TASHKENT UNIVERSITY OF INFORMATION TECHNOLOGIES
NAMED AFTER MUHAMMAD AL-KHWARIZMI

ICISCT 2023

INTERNATIONAL CONFERENCE ON INFORMATION SCIENCE AND COMMUNICATIONS TECHNOLOGIES – APPLICATIONS, TRENDS AND OPPORTUNITIES

28th – 30th September, 2023
Tashkent, Uzbekistan

PREFACE

The 2023 IEEE and IFIP International Conference on Information Science and Communications Technologies ICISCT 2023 invites high-quality recent research results in the areas of Home and Health networking, Electronic commerce, Mobility and Mobile Payment, Broadband access, satellite services, 5G in rural communications, cloud computing, Smart grids, Big data analysis, Cyber security, Internet-of-Things IOT, Mobile and Wireless Communications, optical communications and networking, architectures, protocols, planning and design, management and operation, simulation and performance modeling.

ICISCT2023 conference is the application of the next generation of information and communications technologies on Education, Telemedicine, Finance and Economy, Social Science, Business and Government.

ICISCT 2023 seeks to address and capture highly innovative and state of the art research and work in the area of information and communications technologies including wireless and Optical communications networks. The Authors can present their finding on wireless quality of service, resource management, Ad Hoc and sensor networks. Radio interface design, adaptive antennas and arrays and indoor propagation, measurement and predictions.

ICISCT 2023 is seeking papers in the area: Photonic devices and integration, Optoelectronic integration including devices and materials, Optical networks and transmission systems, Novel fibers and fiber-based devices, Transmission systems and networks, Photonics sensors and sensor networks, Microwave photonics and optical signal processing. Information science papers include knowledge that provides theoretical basis for information technology. It includes computer science, library science, artificial intelligence, mathematical programming, and theory of problem solving.

The main goal of the conference is to bring together scientists and engineers who work and teach in these specialized fields to submit papers and come together in this geographical location. ICISCT 2023 is sponsored and organized by IEEE Uzbekistan Regional Chapter and Tashkent University of Information Technologies TUIT and Technically Sponsored by IEEE Photonics Society https://www.photonicssociety.org

It is technically co-sponsored by Uzbekistan regional IEEE Communications society chapter and Ministry of Digital Technologies of the Republic of Uzbekistan.

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ICIST 2023 Program Sep. 28, 2023 (Day-1)			
Tashkent Time (GMT+5)			**Conference Tracks**
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Conference ID: 425 631 6104 **Pass Code:** RvaMA			
10:00 AM	10:20 AM	**Welcome Words**	**OPENING CEREMONY** **Mr. Sherzod Shermatov,** Minister for Digital Technologies of the Republic of Uzbekistan **Prof. Ibrokhim Abdurakhmonov,** Minister for the Higher Education, Science and Innovations of the Republic of Uzbekistan **Prof. Bakhtiyor Makhkamov,** Rector of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Uzbekistan
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10:40 AM	10:55 AM		**Prof. Han SEUNGHEE,** KOOKMIN University, SEOUL, KOREA TOPIC on "Digital Transformation with a Human Face"
10:55 AM	11:10 AM		**Prof. CHe ZALINA Zulkifli,** University Pendidikan Sultan Idris, TANJUNG MALIM, MALAYSIA TOPIC on "IoT Blended AI Solutions in Green Technology"
11:10 AM	11:25 AM		**PhD. Khabibullo Nosirov,** Tashkent University of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan TOPIC on "Development of a Novel Model for Single Image Super Resolution using Deep Neural Network"
11:25 AM	11:40 AM		**Sheng-Lung Huang,** National Taiwan University. TAIPEI, TAIWAN TOPIC on "Deep learning empowered optical coherence tomography"
11:40 AM	11:55 PM		**Prof. Byoung Joon Kim,** KOOKMIN University, SEOUL, KOREA TOPIC on "Citizens' perception on AI for making better public policies"
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Conference venue address

Building – F, Computer Engineering faculty, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi

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Impact of e-commerce on textile SMEs in Gamarra, La Victoria district - Lima, during the COVID-19 pandemic: an analysis in the Peruvian context

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***Abstract*—This research analyzes the impact of e-commerce on the textile sector of small and medium-sized enterprises (SMEs) located in the La Victoria district of Lima during the COVID-19 pandemic. A survey was conducted with 74 textile SMEs to understand the impact of e-commerce in this sector. Data analysis techniques were used to explore various variables and establish correlations. The results revealed a significant correlation among the variables, supporting the hypotheses proposed. It is concluded that SMEs that manage to adapt and seize technological opportunities have the potential to grow and compete successfully in an increasingly digitized business environment.**

Keywords: E-commerce, SMEs, Textile Sector, Covid-19, Digitalization

I. Introduction

In recent years, there has been a remarkable increase in global e-commerce, which has caused a true revolution in the way organizations interact with consumers and generate revenue. This phenomenon has significantly affected Micro, Small, and Medium Enterprises (SMEs), who have been forced to quickly adapt in order to take advantage of the opportunities offered by e-commerce.

Furthermore, the emergence of the internet and e-commerce has brought about the presence of online competitors and more informed and demanding customers. This highlights the need for all organizations to adopt technology in their internal processes. This action is essential to close the gap that still exists with developed countries and to promote further progress towards a renewed digital economy in developing countries [1].

In the context of technological and digital advancement, the COVID-19 pandemic plays a significant role. It has had a major impact on e-commerce, driving its growth worldwide. Mobility restrictions and social distancing have led to a change in consumer behavior, with more people opting to shop online rather than in physical stores. The convenience of being able to explore and purchase products from home, along with the accessibility provided by the internet, is becoming an increasingly common habit [2].

Gamarra is the largest commercial hub in South America, being the foremost importer and exporter in the textile sector for the region. Textile SMEs play a crucial role in the economy. However, their informality and lack of organization are factors that hinder the implementation of effective strategies [3]. These strategies could mitigate the impacts of the economic recession generated by the pandemic.

E-commerce or online commerce emerges as the response to the new challenges posed in this context, as it has streamlined the adoption process of e-commerce and motivated micro and small businesses (SMEs) to quickly adapt to this new reality.

The main reasons motivating Micro, Small, and Medium Enterprises to adopt e-commerce focus on overall business improvement, with a percentage of 81.7%, and increased sales, with a percentage of 66.8% [4]. Furthermore, this phenomenon has enabled the reduction of operating costs, improved business visibility, and provided a better customer experience.

Therefore, the purpose of this research will focus on Peruvian SMEs in the textile sector, located in the La Victoria district, the commercial center of Gamarra. It will take a case study approach, combining qualitative and quantitative methods to collect and analyze relevant data. In-depth interviews will be conducted with owners and managers of small and medium-sized enterprises (SMEs) in the textile sector. The interest of this research is to analyze the impact of e-commerce on textile SMEs in Gamarra during the COVID-19 pandemic in the La Victoria district, Lima. The findings can contribute to the formulation of effective strategies and supportive policies for textile SMEs in similar situations, as well as expand academic knowledge in the field of e-commerce and its application in the business sector during crisis periods.

II. Theoretical Framework

A. *The pandemic as a catalyst for the rise of e-commerce*

According to recent research, the COVID-19 pandemic has had a significant impact on global e-commerce [5]. The implementation of lockdown and social distancing measures by governments and health authorities has led to a noticeable shift in consumer behavior. Faced with movement restrictions and the closure of physical stores, people have been forced to turn to online shopping as a safe and convenient alternative to acquire goods and services.

The pandemic has accelerated technological adoption in general, and this has been reflected in the increased participation of people who were not familiar with online shopping before [6]. Even older age groups have had to adapt to using online platforms and shopping apps to meet their needs [7].

During a two-day meeting on how to measure e-commerce and the digital economy in retail sales, UNCTAD presented a report highlighting the remarkable growth of online retail sales in several countries, taking a more globalized approach. Global e-commerce sales reached a figure of $26.7 trillion in 2020, representing a 4% increase compared to 2018, according to the most recent available estimates [8].

This increase can be attributed to the likely causes of safety and convenience perceptions [9], as an important factor that has driven the growth of e-commerce during the pandemic. Consumers have preferred to avoid crowds and close contact, opting instead to choose the option of buying online and receiving products directly at their homes.

The need to adapt to the situation and maintain operability has led many businesses, especially small and medium-sized enterprises, to embark on digitalization. These companies have established an online presence by creating e-commerce websites or joining existing online selling platforms to reach their customers. Forced digitization has been a key driver of e-commerce growth during the pandemic [10].

B. General overview of textile SMEs

Micro, Small, and Medium Enterprises (MSMEs) operating in the textile sector play a crucial role in the textile industry of other countries. These companies are engaged in the manufacturing and commercialization of various textile products, such as garments, home textiles, technical fabrics, and industrial textiles [11].

Currently, textile MSMEs face a series of relevant challenges and opportunities. Here are some highlights:

Global competition: Textile MSMEs [12] compete in a globalized market, which means they must face competition from large companies and imported products from countries with cheaper labor. This can make it difficult for them to remain competitive in terms of price and quality.

Innovation and technology: Adopting advanced technologies, such as automation and digitalization [13], can help textile MSMEs improve their efficiency and productivity. Those who manage to adapt and innovate in their processes and products have a better chance of standing out in the market.

Online sales channels: E-commerce has transformed the way textile products are sold. Therefore, textile MSMEs should consider establishing a strong online presence and leverage online selling platforms to reach a wider and more diverse audience.

Despite the mentioned challenges, textile MSMEs also have significant advantages, such as their ability to be agile and flexible, establish close relationships with customers, and develop specialized and niche products. With a strategic focus, innovation, and adaptability, textile MSMEs can achieve success in the current market.

C. Importance of Electronic Commerce for SMEs in the Textile Industry

One of the main reasons why e-commerce is important for these textile MSMEs [14] lies in the greater geographical reach it offers, surpassing the limitations of a physical store and enabling the sale of products anywhere in the world. In this way, MSMEs can access new markets and potential customers that would otherwise be unreachable.

Regarding operational costs, establishing and maintaining a physical store can be expensive for textile MSMEs. However, e-commerce provides a more cost-effective alternative as it significantly reduces expenses associated with renting premises, hiring staff, and overhead costs. Therefore, MSMEs can manage an online store with a tighter budget and allocate additional resources to areas such as marketing and product innovation [15].

E-commerce also offers MSMEs the opportunity to provide a personalized shopping experience to their customers. By using data analysis tools and tracking user behavior, these MSMEs can better understand the needs and preferences of their customers. Using this information, they can offer personalized product recommendations, special promotions, and more efficient customer service, thereby enhancing the overall customer experience and fostering brand loyalty [16].

D. E-commerce boom in Peruvian SMEs

According to the research conducted by CEPAL, there was a significant increase of 87% in e-commerce transactions in the Peruvian territory during the year 2020 [17]. This percentage represents the highest recorded in Latin America, surpassing countries like Brazil with 61%, Colombia with 53%, Mexico with 50%, Chile with 46%, and Argentina with 39%.

Furthermore, it is projected that by the year 2025, e-commerce will achieve a 10% share in the retail market in Peru. This figure is of great importance considering that e-commerce only represented between 2% and 5% of total sales in the country between the years 2019 and 2020 [18].

Lastly, e-commerce provides flexibility and scalability to Peruvian textile MSMEs. These companies can quickly adjust their inventory and product variety according to market demands.

III. METHODOLOGY

Once the research problem has been identified through the description of its elements supported by a scientific literature review, this section is necessary to delimit the selection criteria used to determine the studies that support the research. The research question under discussion is: "What is the impact of e-commerce on textile MSMEs in Gamarra, La Victoria District - Lima, during the COVID-19 pandemic?"

To achieve this purpose, a case study methodology will be employed, allowing for an in-depth analysis using a mixed-methods approach in the research, utilizing both qualitative and quantitative methods. Additionally, it is a descriptive correlational research, as it will investigate the impact of e-commerce on textile MSMEs in Gamarra, La Victoria District - Lima, during the COVID-19 pandemic. This will be demonstrated through data analysis and collection.

In this research, the boundaries of a specific sample were established, and a survey was conducted targeting a group of 74 managers and owners of textile MSMEs located in Gamarra, La Victoria District, Lima. The focus was exclusively on those MSMEs that have adopted an advanced level of e-commerce. During the process, a series of hypotheses corresponding to this topic were formulated, and the relevant variables associated with it were identified and analyzed.

A parametric statistical methodology was employed due to the use of data with qualitative distribution. To evaluate the normality of the sample, the Kolmogorov-Smirnov normality test was applied since the sample size exceeded the threshold of 50 observations ($n > 50$). To carry out the normality test, the following hypotheses were formulated. The null hypothesis (Ho) states that the data followed a normal distribution, while the alternative hypothesis (Ha) suggests that the data did not follow a normal distribution. A significance level of 5% (0.05) was selected, corresponding to a confidence level of 95%. Subsequently, the analysis of the results obtained through the Kolmogorov-Smirnov normality test was conducted.

TABLA I

ASSOCIATED RELATIONSHIP VARIABLE-HYPOTHESIS

VARIABLE	HYPOTHESIS
V1: use of e-commerce in the pandemic	H.A There is a high adoption of e-commerce in the textile SMEs of Gamarra during the COVID-19 pandemic. H.N: There is a low adoption of e-commerce in the textile SMEs of Gamarra during the COVID-19 pandemic.
V2: training of technologies related to e-commerce	H.A: There is a direct relationship between the main barriers to the implementation of e-commerce in the textile SMEs of Gamarra during the COVID-19 pandemic with the lack of financial resources and the lack of training in technology. H.N: There is no direct relationship between the main barriers to the implementation of e-commerce in the textile SMEs of Gamarra during the COVID-19 pandemic with the lack of financial resources and the lack of technology training.
V3: Sales of SMEs	H.A: There is a direct relationship between e-commerce and the increase in sales volume of textile SMEs in Gamarra during the COVID-19 pandemic. H.N: There is no direct relationship between e-commerce and the increase in sales volume of textile SMEs in Gamarra during the COVID-19 pandemic.
V4: Effect of the COVID 19 pandemic	H.A: There is a direct relationship between the impact of the COVID 19 pandemic and the increase in the volume of sales of textile SMEs in Gamarra. H.N: There is no direct relationship between the impact of the COVID 19 pandemic and the increase in the volume of sales of textile SMEs in Gamarra.

Source: Own elaboration

IV. RESULTS

TABLA II KOLMOGOROV-SMIRNOVA TEST OF NORMALITY

	Statistical	gl	p
V1	0.351	74	.000
V2	0.483	74	.000
V3	0.456	74	.000
V4	0.427	74	.000

a. Lilliefors significance correction

Source: Own elaboration from the statistical application SPSS

According to the normality analysis performed using the Kolmogorov-Smirnov test, it was found that none of the variables analyzed follow a normal distribution. This is supported by the fact that the probability value (p) obtained in the test is lower than the established significance level of 5% ($p = 0 < 0.05$). Therefore, it can be inferred that the variables may experience variations over time, including possible long-term increasing trends. Consequently, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted, indicating the need to apply non-parametric statistical methods in the data analysis.

Based on previous research, non-parametric statistical techniques are used to examine the correlation between two variables, referred to as V1 and V3, using the Spearman's rank correlation coefficient. The objective is to test the hypotheses, where the value of the coefficient (ρ) will indicate whether the null hypothesis (Ho) presents no correlation ($\rho = 0$) or if there is a correlation ($p \neq 0$). Based on this value, the null hypothesis can be accepted or rejected.

TABLA III
SPEARMAN´S CORRELATION OF THE USE OF E-COMMERCE IN THIS PANDEMIC WITH COMPANY SALES

		V1	V3
V1	Correlation coefficient *(ρ)*	1	0.708
	Sig. (bilateral)	.	0
	N	74	74
V3	Coefficient correlation *(ρ)*	0.708	1
	Sig. (bilateral)	0	.
	N	74	74

Source: Own elaboration from the statistical application SPSS

According to the study conducted, a significant relationship was found between the use of e-commerce during the pandemic and company sales ($p < 0.05$). This relationship was identified as direct, indicating that as the use of e-commerce increases, company sales also increase. Furthermore, the results obtained through the Spearman's rank correlation coefficient revealed a high and strong correlation (= 0.708) between both variables.

TABLA IV
VARIABLE PEARSON CORRELATION MATRIX V1, V3 AND V4

Control Variables			V1	V4	V3
none - [a]	V1	Correlation	1.00	-0.86	0.60
		gl	0	72.00	72.00
	V4	Correlation	-0.86	1.00	-0.70
		gl	72.0	0	72.0
	V3	Correlation	0.60	-0.70	1.00
		gl	72.0	72.00	0
V3	V1	Correlation	1.00	-0.77	
		gl	0	71.00	
	V4	Correlation	-0.77	1.00	
		gl	71.0	0	

a. The cells contain correlations of order zero (Pearson).

Source: Own elaboration from the statistical application SPSS

Finally, the research results revealed several significant partial correlations between the analyzed variables. Firstly, a significant positive partial correlation of 0.600 ($p < 0.001$, one-tailed) was found between the use of e-commerce during this pandemic and company sales, while controlling for the effect of the COVID-19 pandemic. These findings indicate that there is a positive association between the use of e-commerce and company sales during this health crisis.

On the other hand, a significant negative partial correlation of -0.862 ($p < 0.001$, one-tailed) was identified between the use of e-commerce during this pandemic and the impact of the COVID-19 pandemic. This implies that as the use of e-commerce increases, the negative impact of the COVID-19 pandemic decreases. In other words, e-commerce can mitigate to some extent the detrimental effects of the pandemic on various business activities.

Additionally, a significant negative partial correlation of -0.703 ($p < 0.001$, one-tailed) was observed between company sales and the effect of the COVID-19 pandemic, while controlling for the use of e-commerce during this pandemic. These results suggest that as the impact of the COVID-19 pandemic becomes more pronounced, company sales decrease. Furthermore, the presence of e-commerce appears to attenuate these negative effects of the pandemic on company sales.

V. Conclusions

The findings of this research support the existence of significant links between the use and impact of e-commerce, sales of small and medium-sized textile businesses, and the COVID-19 pandemic. These results highlight the effectiveness of the normality tests conducted, where all alternative hypotheses were accepted in response to the analysis question. It is important to emphasize the relevance of e-commerce as an effective business strategy during the pandemic, as it demonstrates its ability to positively influence sales and mitigate the negative effects of the health crisis.

Regarding the practical applications of the research, it is recommended that managers of small and medium-sized enterprises (SMEs) receive training in technologies associated with e-commerce. Such training is essential to foster greater adoption and mastery of the necessary processes to achieve optimal efficiency in managing online sales.

This study presents several significant contributions; however, it is important to highlight some of its limitations. Firstly, exclusively Peruvian SME data belonging to the textile sector that use e-commerce were used. Therefore, the obtained results should be cautiously extrapolated to other geographical areas. Additionally, due to inherent sampling bias, the results can be more accurately applied to SMEs engaged in commerce and services that show interest in adopting e-commerce as a sales strategy.

Finally, the selected theoretical framework is based on extensive empirical literature that allows for the comparison of the results obtained in this study. E-commerce provides SMEs with numerous opportunities for growth, expansion, and competitiveness in an increasingly digitized business environment. Leveraging the advantages offered by e-commerce can make a significant difference between success and stagnation for these companies.

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Mathematical formalization of the process of drying cotton in a dryer drum

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***Abstract* - The work is devoted to the creation of an adequate mathematical description of the drying process of raw cotton in order to solve the problem of optimization and control of the technological process of cotton processing. The development of a mathematical model of the cotton drying process was based on the application of the heat and mass transfer equation, taking into account the regularity of heat and humidity transfer inside the body, between the surface of the body and the environment. In the developed thermophysical model of the drying process of raw cotton, taking into account the peculiarities of the drying process, heat and mass transfer processes are described, like the components (raw cotton) so the thermal agent (heated air). In drawing up this model of the drying process, the drying unit is considered as a linear deterministic system under conditions of small disturbances, which allowed the use of the method of linearization in research of small deviations from the stationary regime. The developed mathematical model of the process allows you to get its analytical solution and develop algorithms of control that allowing the generation of high-speed control signals. The analytical form of representation of algorithms of control will allow calculating the values of control influences at high speed when using them in real time, unlike the well-known algorithms based on obtaining a solution by a numerical method, and which are now widely used in many control systems.**

Keywords - mathematical model, optimization, thermal agent, thermophysical model, algorithm

I. INTRODUCTION

Currently, one of the most important problems in creating highly efficient automatic control systems by dynamic objects is the development of effective methods of managing technical systems, based on the use of highly efficient algorithms of control, allowing to minimize the cost of raw materials and energy in production. In this regard, at the present time, great attention is paid to the creation of effective algorithms of control that meet the requirements for the creation of automatic control systems for technological processes [1-3].

One of the obstacles to improving most of the existing control systems for technological processes is the lack of adequate models describing real processes and suitable for use as part of systems of optimization and control. Traditionally used models are either difficult to solve the task and, thus, inconvenient in control tasks, or simplified, which does not allow to fully describe the actual processes. To solve this problem, it is necessary to create adequate mathematical models of dynamic objects, with the help of which it would be possible to obtain an analytical solution of the problem. The analytical form of representation of the algorithms of control will allow calculating the values of control influences at high speed when using them in real-time conditions, in contrast to the known algorithms based on obtaining a solution by numerical method, which are currently used in many control systems [4-6].

The application of the proposed mathematical model of the drying process of raw cotton in the automatic control system of drying drums makes it possible to improve the quality of the control process associated with the control algorithm created on the basis of an analytical solution of the mathematical model. This allows you to significantly increase the speed of generation of control signals compared to traditional algorithms based on numerical solution methods. It should be noted that when using the proposed algorithm, the energy costs of the raw cotton drying process are significantly reduced by reducing fuel consumption, which is of great practical importance for modern production.

The intensification of the thermophysical process during the drying of raw cotton is directly related to the object under study, as well as between the surface of the body and the environment. For create a highly efficient control system of the process under consideration, it is necessary to develop a thermophysical model of raw cotton describing heat and mass transfer processes are described, like the components (cotton) so the thermal agent [7-9].

It should be noted that under thermal action, the thermodynamic equilibrium in the agent being dried is disturbed, associated with the transfer of heat and matter (moisture) in the components of raw cotton[4].

It is known that cotton drying units are objects with distributed parameters, since the drying intensity, temperature regime, partial air pressure and other parameters change according to the volume of the dryer.

To build a mathematical model of the drying plant, we will use the heat and mass transfer equations, taking into account the peculiarities of the drying process of raw cotton [2].

When deriving the equation of the relationship of the main parameters of the raw cotton drying process, the temperature of the spent drying agent is assumed to be proportional to the temperature of the raw cotton coming out of the dryer ($t_2=Q_c/c$).

II. Formulation of the Problem

Leave spaces inside the The equation does not take into account transport and transition delays, which are directly related to the design parameters of the drying drum [10,11, 13-15].

Taking into account these assumptions, the equation of heat balance and heat accumulation by raw cotton in the dryer can be presented in the following form [12]:

$$Q_{da}\frac{W_1-W_2}{100-W_1}(C_{da}t_1-C_b\cdot t_2)-G_2\frac{W_1-W_2}{100-W_1}(595+ \\ +0.47t_2-\theta)=G_2\cdot C_c(\theta_2-\theta_1), \quad (1)$$

where: θ_1 – initial temperature of raw cotton; θ_2 – final temperature of raw cotton; W_1 – input humidity of raw cotton; W_2 – humidity of raw cotton after drying; G_2 – weight of dried raw cotton; C_c – heat capacity of raw cotton.

However, equation (1) describes the steady-state (stationary) mode of operation of the dryer and for the study of dynamic modes associated with various perturbations, it should be somewhat transformed.

$$Q_{da}\frac{W_1-W_2}{100-W_1}(C_{da}t_1-C_b\cdot t_2)-G_2\frac{W_1-W_2}{100-W_1}(595+ \\ +0.47t_2-\theta)=G_2\cdot C_c(\theta_2-\theta_1)=\varphi_I(W,\theta,t). \quad (2)$$

In steady state mode

$$\varphi_I(W,\theta,t)=0\ . \quad (3)$$

Any change in the main factors (a change in the initial humidity or the amount of raw cotton received into the dryer) leads to a violation of the normal flow of the cotton drying process, which entails a violation of equality in the expression (3).

With any changes in internal and external influences in the drying drum, a transient process occurs to restore equality (3), as a result of which it becomes necessary to change the temperature of the supplied heat agent t_1, the temperature of the raw cotton heat agent θ_2, the humidity of the raw cotton W_2, as well as the consumption of cotton.

Using the heat balance equation, taking into account the dynamics of the heat generator, we will describe a mathematical model of the cotton drying process using an analytical method.

$$Q_1+Q_2-Q_3-Q_4-Q_5=0\ , \quad (4)$$

where: Q_1 – heat flow coming from the air;
Q_2 – heat flow coming from wet cotton;
Q_3 – the heat flow leaving with the air;
Q_4 – heat flow leaving with dried cotton;
Q_5 – heat flow leaving through the walls of the dryer drum;

It should be noted that in this case, the flows Q_1, Q_2 - are controlling, and Q_5 - is a disturbing effect on the object.

In this case, the main physical law connecting the controlling and disturbing effects is the law of conservation of energy, which can be written for an object in the following form:

$$cm\frac{d\theta}{dt}=\sum_{i=1}^{n}Q_i\ , \quad (5)$$

where c - is the heat capacity of the substance; m - is the mass of the substance in the volume; θ - is the temperature of the substance.

It should be noted that the drying process consists of two parts: a drying drum and a heat generator, where the thermophysical properties of which differ sharply from each other. Then the heat exchange process will be written by a system of equations in deviations:

$$\begin{cases} c_a m_a\dfrac{d\Delta\theta_a}{dt}=\Delta Q_1-\Delta Q_2-\Delta Q_3-\Delta Q_4; \\ c_{fen}m_{fen}\dfrac{d\Delta\theta_{fen}}{dt}=\Delta Q_4-\Delta Q_5, \end{cases} \quad (6)$$

where c_a, m_a – specific heat capacity of air and fencing; m_a, m_{fen} – air mass and fencing; $\Delta\theta_a$, $\Delta\theta_{fen}$ – the deviation of air temperature and fences from the calculated steady state; ΔQ_1, ΔQ_2, ΔQ_3, ΔQ_4, ΔQ_5 – deviations from the steady state temperature respectively with the incoming air, damp cotton, the outgoing air dried cotton and through the wall of the drum.

The temperature deviation can be written as:

$$\begin{aligned} \Delta Q_1&=c_a\Delta m_{s.a}(\theta_{s.a}-\theta_a); \\ \Delta Q_2&=c_a\Delta m_a(\theta_a-\theta_{out}); \\ \Delta Q_3&=c_c\Delta m_c(\theta_c-\theta_{out}); \\ \Delta Q_4&=c_a\Delta m_a(\Delta\theta_a-\Delta\theta_{fen}); \\ \Delta Q_5&=F_{fen}\alpha_{out}(\Delta\theta_a-\Delta\theta_{out}); \end{aligned}$$

where $\Delta m_{s.a}$, Δm_c, Δm_a – are the deviations of the mass, respectively, of the supplied air, the air inside the drum and cotton kg/s; c_a,c_c – are the specific heat capacities of air and cotton, kJ/(kg·°C); F_{fen} – square fence, m^2; α_{out}, α_a – the coefficients of heat transfer on the outer surfaces of the drum and cotton, W/(m^2·°C); $\Delta\theta_a$, $\Delta\theta_{out}$, $\Delta\theta_{fen}$ – deviations from the steady-state temperature of the outside air and walls of the drum, °C; θ_{fen}, θ_a, $\theta_{s.a}$, θ_c, θ_{fen} – air temperature, respectively, outdoor, inside the drum and served air, cotton and walls of the drum, °C.

When drawing up a system of equations (6) which characterizing the dynamics of the drying process, we will make the following assumptions: the drying drum is considered as a linear object with concentrated parameters; the flow rate of the heat agent does not change; the air supply rate inside the drying drum is not taken into account.

In this regard, taking into account the heat flow, the dynamics equations (6) are described as follows: instead of heat flows, we substitute their values expressed in terms of specific heat capacities, masses, temperature differences, heat transfer surface areas and heat transfer coefficient:

$$\begin{cases} c_a m_a\dfrac{d\Delta\theta_a}{dt}=c_a\Delta m_{s.a}(\theta_{s.a}-\theta_a)-c_a\Delta m_a(\theta_a-\theta_{out})- \\ \qquad -c_c\Delta m_c(\theta_c-\theta_{out})-F_{fen}\alpha_a(\Delta\theta_a-\Delta\theta_{fen}); \\ c_{fen}m_{fen}\dfrac{d\Delta\theta_{fen}}{dt}=F_{fen}\alpha_a(\Delta\theta_a-\Delta\theta_{fen})-F_{fen}\alpha_{out}(\Delta\theta_{fen}-\Delta\theta_{out}), \end{cases} \quad (7)$$

where c_{fen} – the specific heat capacity of air, kJ/(kg·°C); m_a, m_{fen}, – the mass of air inside the room and the walls of the drum, kg.

Given that $\Delta m_{s.a} = \Delta m_a$ and $\Delta m_a = 0$, it is possible to somewhat simplify the first equation of the system (7):

$$c_a m_a \frac{d\Delta\theta_a}{dt} = c_a \Delta m_a(\theta_{s.a} - 2\theta_a + \theta_{out}) - F_{fen}\alpha_a\Delta\theta_a + F_{fen}\alpha_a\Delta\theta_{fen}, \quad (8)$$

from which

$$\Delta\theta_{fen} = \frac{c_a\Delta m_a}{F_{fen}\alpha_a}\cdot\frac{d\Delta\theta_a}{dt} - \frac{c_a\Delta m_a}{F_{fen}\alpha_a}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out}) + \Delta\theta_a. \quad (9)$$

The value of $\Delta\theta_{fen}$ is substituted into the second equation of the system (7) and after the transformations we get:

$$\begin{aligned}
&\frac{c_{fen}m_{fen}c_a m_a}{F_{fen}\alpha_a}\cdot\frac{d^2\Delta\theta_a}{dt^2} - \frac{c_{fen}m_{fen}c_a}{F_{fen}\alpha_a}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\frac{d\Delta m_a}{dt} + \\
&+ c_{fen}m_{fen}\cdot\frac{d\Delta\theta_a}{dt} = F_{fen}\alpha_a\Delta\theta_a - c_a m_a\frac{d\Delta\theta_a}{dt} + \\
&+ c_a\Delta m_a(\theta_{s.a} - 2\theta_a + \theta_{out}) - F_{fen}\alpha_a\Delta\theta_a - \frac{c_a m_a\alpha_{out}}{\alpha_a}\cdot\frac{d\Delta\theta_a}{dt} + \\
&+ \frac{c_a m_a\alpha_{out}}{\alpha_a}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out}) - F_{fen}\alpha_{out}\Delta\theta_a + F_{fen}\alpha_{out}\Delta\theta_{out}.
\end{aligned} \quad (10)$$

$$\begin{aligned}
&\frac{c_{fen}m_{fen}c_a m_a}{F_{fen}\alpha_a}\cdot\frac{d^2\Delta\theta_a}{dt^2} + c_{fen}m_{fen}\cdot\frac{d\Delta\theta_a}{dt} + c_a m_a\cdot\frac{d\Delta\theta_a}{dt} + \\
&+ \frac{c_a m_a\alpha_{out}}{\alpha_a}\cdot\frac{d\Delta\theta_a}{dt} + F_{fen}\alpha_{out}\Delta\theta_a = \frac{c_{fen}m_{fen}c_a}{F_{fen}\alpha_a}\cdot \\
&\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\cdot\frac{d\Delta m_a}{dt} + c_a\Delta m_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out}) + \\
&+ \frac{c_a\Delta m_a c_{out}}{\alpha_a}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out}) + F_{fen}\alpha_{out}\Delta\theta_{out}.
\end{aligned} \quad (11)$$

$\Delta\theta_{out}$=0.

$$\begin{aligned}
&\frac{c_{fen}m_{fen}c_a m_a}{F_{fen}\alpha_a}\cdot\frac{d^2\Delta\theta_a}{dt^2} + \left(c_{fen}m_{fen} + c_a m_a\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)\cdot\frac{d\Delta\theta_a}{dt} + \\
&+ F_{fen}\alpha_{out}\Delta\theta_a = \frac{c_{fen}m_{fen}c_a}{F_{fen}\alpha_a}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\cdot\frac{d\Delta m_a}{dt} + \\
&+ \left(c_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)\cdot\Delta m_a.
\end{aligned}$$

$$\begin{aligned}
&\frac{c_{fen}m_{fen}c_a m_a}{F_{fen}\alpha_a\alpha_{out}}\cdot\frac{d^2\Delta\theta_a}{dt^2} + \frac{\left(c_{fen}m_{fen} + c_a m_a\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)}{F_{fen}\alpha_{out}}\cdot\frac{d\Delta\theta_a}{dt} + \\
&+ \Delta\theta_a = \frac{c_{fen}m_{fen}c_a}{F_{fen}\alpha_a\alpha_{out}}\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\cdot\frac{d\Delta m_a}{dt} + \\
&+ \frac{\left(c_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)}{F_{fen}\alpha_{out}}\cdot\Delta m_a.
\end{aligned}$$

In the canonical form, the equation of drum dynamics has the form:

$$T_0^2\cdot\frac{d^2\Delta\theta_a}{dt^2} + T_1\cdot\frac{d\Delta\theta_a}{dt} + \Delta\theta_a = K\cdot\left(T_2\cdot\frac{d\Delta m_a}{dt} + \Delta m_a\right) \quad (12)$$

where $T_0^2 = \frac{c_{fen}m_{fen}c_a m_a}{F_{fen}\alpha_a\alpha_{out}}$;

$$T_1 = \frac{\left(c_{fen}m_{fen} + c_a m_a\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)}{F_{fen}\alpha_{out}};$$

$$T_2 = \frac{c_{fen}m_{fen}c_a F_{fen}\alpha_{out}}{F_{fen}^2\alpha_a\alpha_{out}\left(c_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)} =$$

$$= \frac{c_{fen}m_{fen}c_a}{F_{fen}\alpha_a\left(c_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)\right)};$$

$$K = \frac{F_{fen}\alpha_{out}}{c_a\cdot(\theta_{s.a} - 2\theta_a + \theta_{out})\left(1 + \frac{\alpha_{out}}{\alpha_a}\right)}.$$

III. RESULTS AND DISCUSSIONS.

It is known that the technological and technical parameters of the 2SB–10 drying drum have the following values:

T_a = 104 kg; c_a = 1.005 kJ/(kg·°C); m_{fen} = 8268 kg; c_{fen} = 0.88 kJ/(kg·°C); c_c = 1.71 kJ/(kg·°C); F_{fen} = 106.5 m^2; α_{out} = α_a = 2000 W/(m^2·°C); θ_a = 100 °C; θ_{out} = 25 °C; $\theta_{s.a}$ = 200 °C;θ_c = 60 °C; T_0^2 = 8.82 s^2; T_1 = 6.3 s; T_2 = 0.82 s; K = 0.14 °C · s/kg;

Taking into account these data, the transfer function of the drum for the control action is obtained:

$$W(s) = \frac{\Delta\theta_a(s)}{\Delta m_a(s)} = \frac{K(T_2 s + 1)}{T_0^2 s^2 + T_1 s + 1} = \frac{0.14\cdot(0.82s + 1)}{8.82s^2 + 6.3s + 1}$$

Fig.1. Shows a generalized block diagram of the drying process, presented as a 2-capacity object: the first capacity is the equation of the furnace unit, and the second is the drying drum.

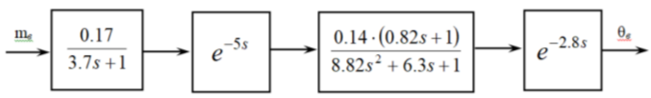

Fig.1. Generalized block diagram of the drying process

The generalized transfer function of the drying drum, taking into account the heat generator and the pipeline, has the following form:

$$\begin{aligned}
W(s) &= \frac{\theta_a}{m_a} = \frac{K\cdot K_{01}\cdot(T_2 s + 1)\cdot e^{-s\cdot(\tau+\tau_0)}}{(T_{01}s + 1)(T_0^2 s^2 + T_1 s + 1)} = \\
&= \frac{0.0238\cdot(0.82s + 1)\cdot e^{-7.8s}}{(3.7s + 1)\cdot(8.82s^2 + 6.3s + 1)}
\end{aligned} \quad (13)$$

The generalized transfer function of the drying drum, taking into account the heat generator and the pipeline, has the following form: The proposed method for constructing mathematical models of drying plants is the basic one for studying the dynamic properties of the drying process and synthesizing algorithms for controlling the 2SB–10 drying drum. It should be noted that the proposed method is universal. Similarly, it is possible to obtain transfer functions for other disturbing effects.

Based on the expression (13), a structural model of a cotton drying unit is constructed (Fig.2).

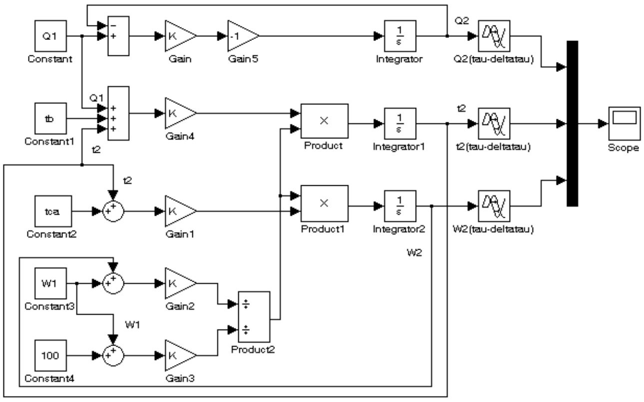

Fig. 2. Structural model of a cotton drying unit

To determine the adequacy of the developed model with a real object, simulation experiments were performed, the results of which are shown in Fig. 3.

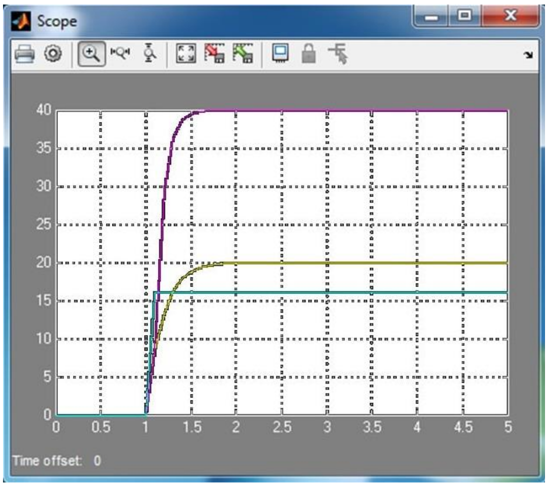

Fig. 3 Transition process graph

The analysis of transients showed that the proposed model coincides with the real process by 98% and this corresponds to the adequacy of the model.

IV. Conclusion

A method for constructing a mathematical model of the drying process of raw cotton is proposed, based on the application of the heat and mass transfer equation, taking into account the regularity of heat and humidity transfer inside the body, between the surface of the body and the environment.

The application of the proposed mathematical model of the cotton drying process in the automatic control system of drying drums improves the quality of the control process and significantly increases the speed of generating control signals compared to traditional systems based on numerical solution methods. It should be noted that when using the proposed algorithm, the energy costs of the cotton drying process are significantly reduced by reducing fuel consumption, which is of great practical importance for modern production.

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A new probabilistic algorithm to check numbers for primality

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***Abstract*— Cryptographic systems are of great importance in protecting confidential information. One of the main parameters in cryptographic systems is the key. The more secure the key, the higher the confidentiality of the data. In public key cryptosystems, in addition to the requirement of key length, the requirement that the key value should be prime is also important. In this paper, a new algorithm for checking numbers for primality is presented and the algorithm is evaluated.**

Keywords — Miller-Rabin test, prime number, recursive function, deterministic algorithms, probabilistic algorithms

I. Introduction

There are various ways or algorithms to check if a number is a prime number. Some algorithms are specific to numbers with certain properties or structures, while others can be applied to any number. The algorithms that work for any number are highly useful both in theory and in practice. Generally, all primality-testing algorithms can be grouped into three major categories [1]:

- One-way error probabilistic algorithms;
- probabilistic runtime algorithms;
- deterministic algorithms.

Although exact tests return, a definite answer about whether a number is prime or not, these types of tests are rarely used in practice because they are slow because of the complexity of the algorithm.

Probabilistic tests - the result of this test is true with a fairly high probability. Repeating them multiple times with different parameters for the same number makes the probability of error quite small.

The methods used to determine whether a number is prime or not can be categorized into different classes based on their execution complexity:

- An algorithm is called continuous if its complexity value does not depend on the size of the initial value, i.e., O(1);
- An algorithm is called linear if its order of complexity is $O(n)$;
- Exponential rank algorithms - an estimate of the complexity level $O(c\hat{}(log\ n))$ for some constant $c > 1$;
- Subexponential level algorithms - complexity level estimate $O(c^{(\log n)^{\gamma}(\log\log n)^{1-\gamma}})$ for any constant $c > 1$ and $0 < \gamma < 1$;
- Polynomial algorithms - complexity estimate $O(log^c n)$ for some constant$c \geq 1$.

Probabilistic algorithms with one-sided error -Historically, the first one-way error probability algorithms were algorithms with polynomial execution complexity.

Algorithms whose execution time is probabilistic - The next important step in the development of primality testing is related to the emergence of algorithms whose execution time is a polynomial time probability. Algorithms belonging to this class are elliptic curve tests (ECC). Algorithms of this type have very high polynomial complexity, due to which they are not used in practice.

Deterministic algorithms - Deterministic algorithms for checking integers for prime numbers have been around for more than two thousand years. One of the earliest algorithms we know is Eratosthenes' algorithm, which determines a prime number by dividing it by the prime numbers preceding it. In general, it is enough to check that $P_i \leq \lfloor\sqrt{n}\rfloor$ is divisible by all prime numbers. This algorithm is also called the trial division algorithm.

Algorithms of this type make an explicit decision as to whether the incoming value is prime or complex. However, such algorithms are impractical because they require large computational registers for very large numbers.

In practical applications, tests that have a higher degree of polynomial complexity are employed.

II. MAIN PART

A. *Fermat primality test*

The tiny Fermat theorem-based algorithm is the first of these class of algorithms. This test procedure is based on the theorem proposed by renowned French mathematician Pierre

Fermat, known as the "little ferme theorem" in the 17^{th} century [2].

If n is a prime, then, according to Fermat's small theorem, the equation $a^{n-1} \equiv 1\ (mod\ n)$ holds, where a is arbitrary and n is not divisible by a. The fulfilment of the equation $a^{n-1} \equiv 1\ (mod\ n)$ is a necessary and sufficient condition for determining the primality of a given number n. That is, if $a^{n-1} \neq 1\ (mod\ n)$ for any a, then n is a complex number, otherwise, it is difficult to say anything definite, but the probability of the number increases. If the comparison $a^{n-1} \equiv 1\ (mod\ n)$ is performed for a complex number n, then the number n is called pseudo-prime based on a.

However, when the number n is complex, a is found such that the comparison $a^{n-1} \equiv 1\ (mod\ n)$ is not performed, such a number a is called evidence of the complexity of the number n, and the previous number a, which made the comparison, is called a "false witness" of primality n.

Consequently, when testing a number for prime according to the Ferm theorem, the number a is chosen. $a^{n-1} \equiv 1\ (mod\ n)$ the larger the number a that satisfies the condition, the more likely that the number n is prime. But there are complex numbers n such that for $a^{n-1} \equiv 1\ (mod\ n)$ the comparison holds in an arbitrary number a, which is prime with n. Such numbers are called Carmichael numbers. The set of Carmichael numbers is an infinite set, the smallest of which is $n = 561 = 3 \cdot 11 \cdot 17$. In spite of this, the Ferma test is effective in determining composite numbers [3]. The Time complexity of this test is $O(k\ logn)^3$.

Input: An odd integer number $n \geq 3$ and hidden parameter $t \geq l$;

Output: "is n prime?" the answer shoul be "prime" or "complex".

1. for $i = 1$ to t do the following:

   1.1. randomly selected the number a, satisfying condition $2 \leq a \leq n - 2$;

   1.2. Calculated $r = a^{n-1}$;

   1.3. If $(r = 1)$, then returns a "complex number";

Returns "prime number" [4].

Fermat's theorem suggests that, when checking for primality, several numbers of a should be selected. The more numbers of a that satisfy the condition $a^{n-1} \equiv 1\ (mod\ n)$, the higher the likelihood that n is a prime number. However, there are n complex numbers for which the comparison $a^{n-1} \equiv 1\ (mod\ n)$ is performed for any prime number a that is coprime with n. These numbers are known as Carmichael numbers. The Carmichael number set is an infinite set, and the smallest known Carmichael number is $n = 561 = 3 \cdot 11 \cdot 17$. Nevertheless, the Fermat test remains an effective way of determining primes.

B. Solovay–Strassen primality test

Another primality-testing algorithm in this category is the Solovay-Strassen test, which always correctly detects prime numbers but may give a wrong answer with a certain probability for composite numbers. The primary advantage of this test is that it can identify Carmichael numbers as composite, which the Fermat test cannot do.

The essence of the test is to test not every number in the entire sequence, but a random set of each random number for k times. This algorithm based on Fermat's little theorem.

If p–simple number, and $a - a_n$ integer that is mutually prime with n, so: $a^{n-1} \equiv 1(mod\ n)$.

In this case, the Jacobi symbol is used to define the Carmichael numbers.

$$\left(\frac{a}{n}\right) \equiv a^{\frac{n-1}{2}}(mod\ n)$$

where $\left(\frac{a}{n}\right)$–Jacobi symbol, called witness of primality n [4].

This test uses the Euler criterion. It is known that according to the Euler criterion, if $a^{(n-1)/2} = \left(\frac{a}{n}\right)\ mod\ n$ condition is satisfied for all witnesses of prime numbers a that do not have the greatest common divisor with n, then n is an odd number of prime numbers.

That is, this algorithm focuses on the elements 1 and -1, which are formed in the column corresponding to the "prime witnesses" a, which are mutually simple with n in the $(n - 1)/2$ row of the table of levels of prime numbers [5].

If at the end of the test witnesses, the prime number n has been discovered as much as iterations k, the number n is probably simple, with a probability $1 - 2^{-k}$. Odd n satisfying the test condition and not being prime is called pseudo-simple Euler numbers at the base a [6c]. The complexity value of this test is $O(log^3\text{p})$.

The Fermat and Solovay-Strassen tests rely on translating a congruence modulus of primes, or Fermat's little theorem, or Euler's congruence into a set of composite numbers and hoping it will fail there.

C. Miller-Rabin primality test

The Rabin-Miller test is one of the probabilistic primality tests based on the strong concept of pseudoprimality.

The test algorithm developed by Michael Rabin, based in part on the ideas of Jerry Miller, is now widely used in the design of public key cryptosystems. This algorithm is recognized as a powerful algorithm for testing pseudo prime numbers. Miller-Rabin is a polynomial-time algorithm with a time complexity of $O(k\ logn)^3$.

As in the Fermat and Solovay–Strassen tests, we are using the term "witness" to mean a number that proves n is composite. An odd prime has no Miller–Rabin witnesses, so when n has a Miller–Rabin witness it must be composite [7].

It is based on the representation of $p - 1$in the representation $2^s * r$. Where s is the number of divisions of

$p-1$ by two, r is an odd number. The Rabin-Miller algorithm is based on the following definition [8].

Definition. Suppose p is an odd composite integer, and $p-1=2^{s}*r$, where r is an odd number. If $a^{r}\neq 1\ (mod\ p)$ and all $j, 0\leq j\leq s-1$, $a^{2^{j}r}\neq -1$, then for p, a is called a "strong witness" (composite). Otherwise, if $a^{r}=1\ (mod\ p)$ or for all $0\leq j\leq s-1$, $a^{2^{j}r}\neq -1$, then p, a is called the number of the "strong pseudo-prime" according to the basis a. An integer a is called a "strong liarwitness" number for p.

The probability of a test error does not exceed 2^{-2} for a single value of x, and if the test is repeated k times for different values of x, the probability of error decreases to 2^{-2k}. Numbers that satisfy this condition but are not prime are called x-based strong pseudoprime numbers. The complexity of this test is $O(log^{3}p)$. In the figure below, the prime number generation time represents the dependence of the number of bits.

D. Lucas primality test

The Lucas test was developed on the Lucas side in 1891, an algorithm for determining the numbers (not just the Mersen and Farm numbers) for the primality, based on the probability used to determine the primality.

According to the algorithm, an input value n is called prime if for any prime q, which is a divisor of $n-1$, there exists a such that $a^{n-1}\equiv 1\ (mod\ n)$ and $a^{(n-1)/q}\neq 1\ (mod\ n)$, if the conditions are satisfied. This algorithm requires that the prime divisors of n-1 are known. At present, there is no known complex number that does not pass a certain number of Rabin-Miller and Lucas tests [9].

E. Proth primality test

Proth theorem is a probabilistic algorithm that is used to test numbers for primality of a certain kind. This test usually tests numbers of the form $k*2^{n}+1$, where k is an odd integer such that $k<2^{n}$. A number p is called a prime number if the condition $a^{(p-1)/2}\equiv -1\ (mod\ p)$ holds for such an integer a. Prime numbers of this type are called Prot prime numbers. Prot's theorem quickly determines whether a number is prime or not. However, it is very slow in determining whether a given number is composite(it is necessary to check every number from 2 to n). This algorithm is recommended for finding prime numbers within a certain range [10]. The time complexity of Proth test is $O((k\ logk\ +\ logn)\ logn)$.

F. Pocklington primality test

The Pocklington test, developed by Pocklington and Lammer, determines whether an incoming prime number can be identified. An input number N is prime if, for any prime number q, which is a divisor of number N-1, there exists an integer a such that $a^{N-1}\equiv 1\ (mod\ N)$ and $\gcd\left(a^{(N-1)/q}-1, N\right)=1$. This algorithm requires that the prime divisors of N-1 are known [11].

Table 1. Below is an analysis of probabilistic algorithms for checking numbers for primality.

Name of test	Advantage	Disadvantage	Complexity
Fermat	- Very simple to implement. - Base for many tests.	-Failure probability may reach 1. -Pseudoprime can pass the test.	$O\ (k\log n)^{3}$
Solovay Strassen	Pseudoprimes are successfully announced as composites.	- an Euler pseudoprime can pass the test. - Computation of Jacobi symbol adds more computation overhead.	$O\ (k\log n)^{3}$
Miller-Rabin	- Fast & efficient. - Euler Pseudoprimes are successfully announced as composites.	Strong pseudoprimes can pass the test.	$O\ (k\log n)^{3}$
Pocklington	Very efficient if there is a factor $q>\sqrt{n-1}$	Prime factors of $n-1$are required to be already known.	$O\ (lnln\ n)$
Lucas	Valid for any generic or special form numbers.	- Prime factors of $n-1$are required to be already known. - Worst case scenario may take long time. (if n is composite, this test may not terminate).	$O\ (p^{2}\ \log_{p} n)$
Proth	Very fast and reliable test to decide about proth number.	Working well only with proth numbers.	$O\ ((k\log k + \log n)\log n)$

G. Releated Work

The authors of [12] conducted an analysis of the Miller-Rabin and Solovay-Strassen tests, which are based on probabilistic testing. They concluded that the Miller-Rabin test is highly effective. This analysis was carried out using a mathematical model.

In reference [13], the authors conducted an analysis of the Miller-Rabin probabilistic test, the deterministic AKS test, and an elliptic curve test. Based on their analysis, they concluded that the Miller-Rabin test is the most effective, while the latter two tests are typically used in practice. They also provided mathematical evidence to demonstrate the superiority of the Miller-Rabin test over the Solovay-Strassen test.

The authors of [14] conducted a study on the correlation between the length of test numbers and the number of Miller-Rabin rounds required to obtain an accurate result. They also provided suggestions for selecting a suitable set of bases that can improve the efficiency of Miller-Rabin. The paper ends with a discussion on several theoretical issues that can enhance the implementation of Miller-Rabin.

In [15], the author discusses the Solovay-Strassen, Miller, and AKS primality tests and presents results from implementing these methods using Maple. The study aimed to determine the number of steps required for numbers of varying sizes (ranging from 4 to 12 digits) and to assess the results obtained.

The article [16] provides C++ implementations of several randomized and deterministic primality tests, including Miller-Rabin, Fermat, Solovay-Strassen, and AKS. The author proves several theorems to help understand these algorithms and provides explanations of the necessary concepts from number theory. While the author provides a brief overview of primality tests, they focus on the AKS test and compare its effectiveness to Fermat's test.

The paper published in [17] describes the implementation of the Lucas probabilistic primality test and focuses on developing a hardware architecture that is suitable for this test. The effectiveness of this algorithm was evaluated for numbers of different sizes.

In [18], the authors conducted a comprehensive study of 14 primality algorithms, including both deterministic and probabilistic tests. They found that deterministic tests were very slow, so probabilistic algorithms were more suitable for real-world applications. However, there is a chance of failure for probabilistic algorithms in certain situations. The authors concluded that the LLR method is the most effective deterministic primality test, while the Miller-Rabin algorithm is the most effective probabilistic primality test.

The authors of [19] provide theoretical and practical justifications for why the Miller-Rabin primality test requires improvements. They present alternative, more effective approaches for testing primality using Miller-Rabin probability error reduction estimations.

In [20], a comprehensive examination of various primality testing methods is presented, along with details on their characteristics, capabilities, limitations, and time complexities. The tests are divided into four subcategories: deterministic, heuristic, monte-carlo randomized, and las vegas randomized. Additionally, eleven of the algorithms are implemented in both Java and Python to assess their effectiveness. The findings reveal that no single primality test is appropriate for all situations and number formats. Thus, it is necessary to choose the appropriate algorithm from among these methods for each instance.

The analysis shows that the Rabin-Milner algorithm is the best probability-based algorithm for checking the numbers for primality. But there will be false witnesses in this method, too.

III. New Probabilistic Algorithm To Check Numbers For Primality

As mentioned above, the Rabin-Milner algorithm treats some complex numbers as prime numbers, which affects the reliability of cryptographic algorithms. Below is an improved Rabin-Milner algorithm that uses a recursive function to solve this problem.

A recursive function (Latin recursio - return) is a numeric function of a numeric argument, which is used in the form of the function itself. That is, $f(n-1), f(n-2), \ldots$ are used to calculate $f(n)$. To complete the calculation for an arbitrary n, it is required that the function value for some n be determined without recursion (for example, for $n = 0, 1$).

An example of a recursive function is the n-counter of the Fibonacci number:

$$F = \begin{cases} F(0) = 1; \\ F(1) = 1; \\ F(n) = F(n-1) + F(n-2), \quad n > 1. \end{cases}$$

Using this formula, you can find the value of $F(n)$ in a finite step for any natural number n. In this case, to find the desired value, it is necessary to calculate the values $F(n-1), F(n-2), \ldots, F(2)$.

For any number n to be prime, the following factorial-recursive function can be expressed for any number a taken in the interval from one to $n-1$:

$$D_k = D_k + (k+a) * (1 + D_k * b) mod\ n,$$

here:

$D_{k=a} = a$;

k is recursion step, from $k = a$ to n;

$a = \{x: x = \overline{1, n-1}\}$, an element of a finite set;

b is the computing base, an integer in the interval $[1, n-1]$;

D_k is the value of the recursive function of the factor in k-steps.

The algorithm of a factorial recursive function is as follows:

Input: a - element and n - module values, k - number of steps.

Output: the value of the recursive function of the D_k-factor in k steps.

1. $j \leftarrow 1,\ D_1 \leftarrow a$.
2. When the condition $(D_k \neq n-1 \,||\, j \neq k)$ is satisfied, do the following:
   2.1. $D1_j \leftarrow D_j + 1, a1 \leftarrow j + a, D2_j \leftarrow D1_j * a1, D_{j+1} \leftarrow D_j + D2_j$;
   2.2. $D_{j+1} \leftarrow D_{j+1} mod\ n$
   2.3. $j++$
3. Return D_j.

In the factorial-recursive function table, since the cells related to factors n occupy a relatively large area when n is a complex number, using such a function in advanced algorithms allows you to speed up the determination of the complexity of the number being checked. Also, when the number being checked is a prime number, it greatly increases the number of witnesses to its prime number, resulting in a lower probability of committing an error.

The Rabin-Miller algorithm can be improved based on this algorithm for computing the recursive function [21].

Input: Choose $n \geq 3$ odd integers, a-random number satisfying the condition $2 \leq a \leq n-2$, and recursion step k.

Чикиш: Is n prime? the answer to the question is "prime" or "complex"..

1. It is written in the form $n-1 = 2^s * r$, where r- is odd number.
2. $y = a^r mod\ n$ is calculated..
3. Go to next iteration if $y = 1$ or $y = n-1$.
4. $s-1$ times $y = y^2\ mod\ n$ is calculated.
   4.1.If $y = 1$, then the answer should be "complex".
   4.2.If $y = n-1$ then:
      4.2.1. Do the following until $(D_j \neq n-1 \parallel j \neq k)$ is satisfied:
      4.2.2. $D_1 = a; j = 1;$
      4.2.3. $D1_j \leftarrow D_j + 1,\ \ a1 \leftarrow j + a,\ \ D2_j \leftarrow D1_j * a1,$
      4.2.4. $D_{j+1} \leftarrow D_j + D2_j mod\ n.$
      4.2.5. $j++.$
      4.2.6. $a = D_j$
5. Return D_j.

The improved algorithm, compared to the existing algorithm, notices earlier when n is a complex number, which significantly reduces the number of "false witnesses".

IV. CONCLUSION

Probabilistic algorithms are more practical for most applications since deterministic tests are very slow. Nonetheless, these algorithms may not always provide accurate results, so it is important to strike a balance between the efficiency of the algorithm and the correctness of the generated results. In fact, the Miller-Rabin algorithm has been identified as the most efficient probabilistic primality test according to reference [6].

When generating prime numbers using algorithms, there is always a probability involved in determining whether a number is prime or not. To determine this, test algorithms are used, which rely on the number of "prime witnesses" that they find. In other words, the more "prime witnesses" a test algorithm finds, the higher the probability that the number being tested (n) is actually prime.

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Overview of The Educational Platform for Predicting and Classifying of Pupils' Knowledge Based on Artificial Intelligence

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Abstract— **In this paper, we will overview the educational platform in order to predict and classify of pupils' knowledge. The platform is designed for middle and high school. However, the platform is flexible. This educational platform is based on machine learning (ML) algorithms that is subpart of artificial intelligence (AI). The architecture of the platform, machine learning algorithms to create the educational platform and other techniques (web frameworks, machine learning frameworks, data base management systems and so on) technologies in order to create the educational platform are overviewed. The architecture of educational platform is composed of three layers, namely: access the platform layer, predicting and classifying of pupils' knowledge layer and results layer. The platform can independently carry out predicting and classifying pupils' knowledge as well as can be assessed pupils' knowledge.**

Keywords— educational data mining, artificial intelligence, machine learning, educational platform, perceptron, ann, k-nn, naïve bayes, decision tree, svm

I. Introduction

Recent years, we have observed some educational platforms based on AI. AI helps effectively in order to solve many problems in education. In particular, we observed that AI is useful in the coronavirus pandemic. Nowadays, the role of AI in education is increasing. For instance, according to research, the role of AI in US education sector could be increased up to 47.77 percent between 2018 and 2022. The role of AI in the education sector is also increasing in other countries. The educations and applications that are based on AI has three main principles, namely learning, self-correction and reasoning. Four forms are presented: assisted intelligence, augmented intelligence, automation and autonomous intelligence. Moreover, we discuss about the role of AI in education in the discussion section.

Educational Data Mining (EDM) [2] is defined the intersection of education and AI. EDM is subpart of AI. EDM could be determined as the technique in order to find the specific types of data that come from the education system. The techniques EDM implements to define pupils' knowledge. EDM is the process of transforming raw data obtained from educational systems into useful data that can be used to make data-driven decisions. The development of data mining and analytics in the education field was relatively late as compared to other fields. Yet due to its specific features on data, it is used to challenge for educational data mining via the Internet. While several types of data have consequential aspects, the distribution of educational information over time has incredible attributes. EDM includes AI (machine learning algorithms, data mining and so on), pedagogical methods to improve pupils' knowledge and information technologies.

One of subparts of computer science is Data mining (DM) [3]. DM is used to discover different factors and patterns in order to make decision. Figure 1 depicts Educational Data Mining. DM could be encouraged Institutional Memory. DM is also known as KDD. KDD stands for Knowledge Discovery in Databases. KDD refers to "Mining" or extracting knowledgeable data from huge data sets. Educational systems have great educational databases. This data is composed of following data. Such as teacher's data, accounts data, pupil's data, alumni data and so on. EDM focuses on the development techniques in order to explore the spectacular types of data that obtain from an educational context. These data obtain from different sources [4]. These data are obtained from the traditional face-to-face classroom environment, online courseware, educational software [16].

DM methods are used to perform on huge data sets to find hidden patterns and relationships, that is useful for lots organizations to make data-driven decisions. Several techniques and algorithms such as Association Rules, Genetic Algorithms, Decision tree, Clustering, Classification, Regression, Neural Networks are used to discover knowledge from databases. EDM includes AI (machine learning algorithms, data mining and so on), pedagogical methods to improve pupils' knowledge and information technologies.

Currently, below educational platforms and applications that is based on AI are using in different stages of education [18].

The platforms based on AI have been indicated to be highly effective at increasing pupils' and pupils' performance and motivation. For instance, Memrise, Kidaptive, Querium, Nuance, Knewton, Cognii, Centry Tech, Carnegie learning, Blippar, Thinkster Math, Volley, Quizlet.

The educational platforms mentioned above and applications aim to teach pupils in which are different ages. Above educational platforms and applications are designed for pupils, undergraduate pupils and graduate pupils. However, we consider the education platform that is designed for 5th to

11th grade pupils in the middle and high education of Uzbekistan [1].

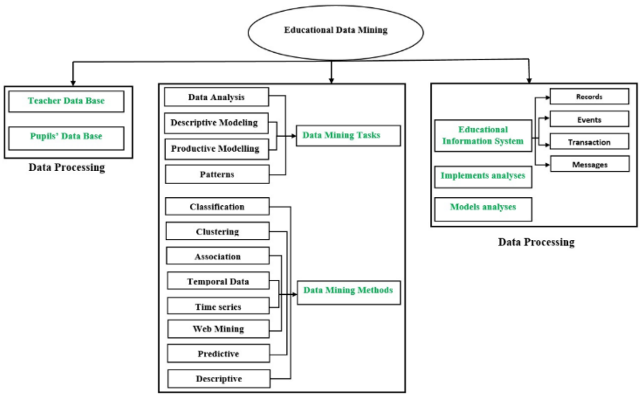

Fig. 1. Educational Data Mining

The purpose [5] of the educational platform is to teach the pupils deeply by predicting and classifying pupils' knowledge. In the sections of this paper, we will overview the architecture of educational platform based on AI that is composed three layers, machine learning algorithms to create each layer, web techniques, use-cases and benefits of the educational platform.

II. Architecture Of Educational Platform

In this section, we overview the architecture of the educational platform. Above mentioned, the platform consists of three layers. Table I fully describes the architecture of the educational platform.

TABLE I. Architecture Of Educational Platform

EDUCATIONAL PLATFORM		
LAYER 1	LAYER 2	LAYER 3
Access the platform	Predicting and classification of pupils' knowledge	Results

We will overview each layer of the architecture and the function [6] of the platform in detail. Layer 1 that illustrates in Figure 2 is called as an access system the platform. In this scenario, when a pupil accesses the platform, pupil's psychological state is determined by test in the first layer [7].

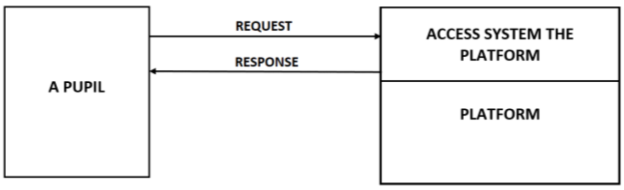

Fig. 2. Layer 1

The pupil that passed successfully from the first layer can be chosen the subjects from the second layer corresponding to the pupil's grade. Before choosing the subject, a pupil has to register in the platform [8]. The second layer of the platform is determined predicting and classifying pupil's knowledge. Figure 3 illustrates Layer 2. The layer 2 is composed of four subparts. First subpart depicts the set of grades between 5th and 11th. Second subpart depicts a set of subjects. Each grade could be able various number of subjects depending on a grade. Each subject has various number of modules that illustrated in the third subpart. Last subpart illustrates each module consists of different complexity levels of tasks, namely: lower, medium, higher. Each level of task has educational materials to study a subject that is composed of recordings, videos, animations, graphic and different types of document (doc, pdf) materials. The pupil has to take an exam to pass the next level. Exam forms could be related to the subject such as: a test, reading, writing, listening, speaking, exercises and etc.

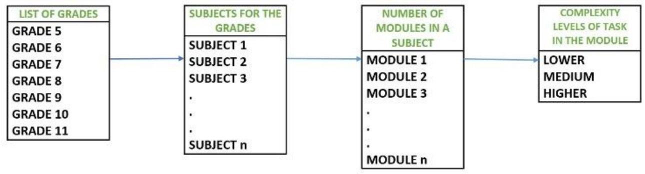

Fig. 3. Layer 2

Last layer is for pupils' results that illustrates in figure 4. After successfully passed the psychological test in the first layer, a pupil can choose the grade. Therefore, a pupil need to finish each subject in the grade. When a pupil chooses the subject, the platform suggests a pupil the test in order to identify pupil's level that a pupil chose from a subject. Depending on a result of the test, a pupil can be started studying educational materials correspond to a pupil in the module/level. In the end of each level of task in the module, a pupil has to take exam to pass next level of task. The result of exam could be poor, average, good, excellent. The result of exam in the complexity level of a module will be poor, the pupil will be back the previous level. if the result will be average, the pupil need to study the level. Otherwise the pupil can pass the next level. after completing all levels, the pupil can pass the next module.

Four categories of score can be able in the platform that poor equals to two, average equals to three, good equals to four, excellent equals to five. If a pupil fails exam, the platform could be allowed a pupil to study the task several times.

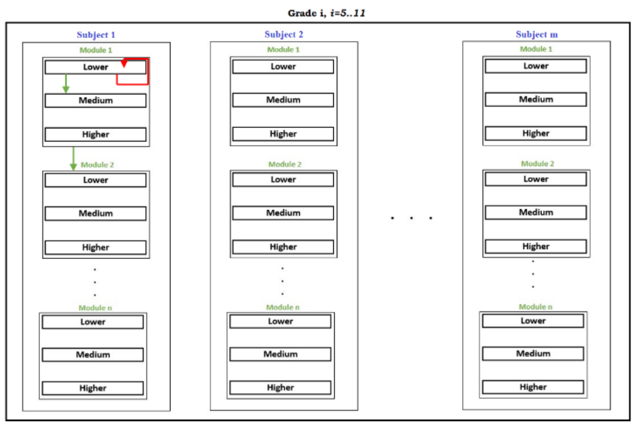

Fig. 4. Layer 3

After a pupil finishes every level of task successfully, a pupil can pass next module.
Finally, after finish every subject in the grade, a pupil can pass next grade. In the end of grade, the platform determines pupil's average score. After completing all the subjects in the grade, the platform allows a pupil to transfer to the next grade [10]. Average score of a pupil is determined in the grade. Thus, at the end of 11th grade, the pupil's total score is determined after completing all grades. Total score of a pupil in the end of 11th grade is related to average score in each grade from 5th grade to 11th grade [11].

III. Creating Methods The Platform

The platform could be created in the form of a mobile app (Android, iOS), a desktop app (Windows, Mac, Linux). However, in this scenario the platform is created in the form of a website. Therefore, Django framework should be used in the back-end side of the web-site, because basic programming language of Django is python. The front-end side should be created by HTML, CSS, JS and Vue.js and Node.js. The database part is created using relational DBMS (PosgreSQL, SQL Server, SQL Developer, MySQL).
In the first layer of the platform, the psychological state of the pupil is determined using a perceptron, a single layer artificial neural network that is illustrated Fig 5. A binary classifier in machine learning is a type of model that is trained to classify data into one of two possible categories, typically represented as binary labels such as 0 or 1, true or false, or positive or negative.

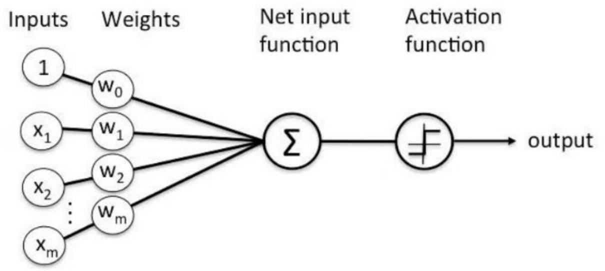

Fig. 5. Single layer artificial network. Perceptron

Psychological test questions are taken as perceptron input values. Input values transmit to the following function.

$$\sum_{i=1}^{n} w_i x_i + b \qquad (1)$$

Formula (1) helps in order to create mathematical model accessing the system, where $n -$ number of psychological tests that given to pupils. The perceptron is identified that a pupil can be accessed the platform [13].
An activation function $g(z)$, where if $g(z)$ is greater than a defined threshold θ we predict 1 and -1 otherwise in Formula (2);

$$g(z) = \begin{cases} 1, & if\ z \geq \theta \\ -1, & otherwise \end{cases} \qquad (2)$$

In this case, the activation function helps to identify pupil's psychological condition. The pupil who successfully passed the psychological test is allowed to register on the platform. when a pupil registers, the pupil inputs personal information into the platform.

Perceptron is simple form of ANN in Fig 6. Unlike Perceptron,can classified more than two classes. ANN is used to determine pupil's knowledge degree from each subject

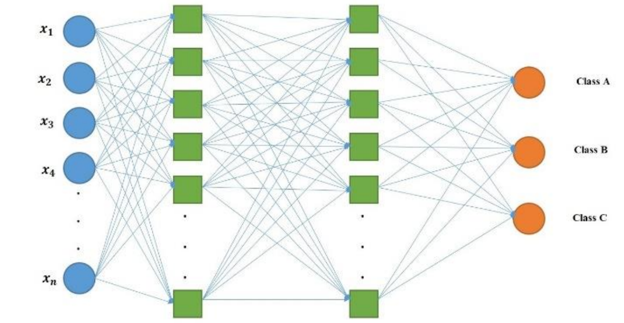

Fig.6. Classification of pupils' knowledge into the classes using ANN

Where $x_i, i = 1..n$ - the number of questions of different complexity for 5th to 11th grades,
Class A- the grade that corresponding to the level of the pupil's knowledge in the chosen subject;
Class B- the module in the selected subject that corresponding to the level of the pupil's knowledge;
Class C- a complexity level of the module;
The educational platform suggests [14] the pupil the grade that the pupil could start studying. Choosing the grade is optional. Afterwards, the pupil can start studying the subjects. Number of subject dependent on the grade. After completing all subjects in the grade, the platform classifies the pupil's knowledge by multi-layer neural network (ANN). ANN classifies the pupil's knowledge depending on the result that the pupil has completed each subject in the grade. As a result, the platform offers the pupil educational materials corresponding to the pupil's knowledge level from each subject. A pupil has to take an exam in the end of each complexity level of task in the module in order to transfer the next level.

Naive Bayes methods are a set of supervised learning algorithms based on applying Bayes' theorem with the "naive" assumption of conditional independence between every pair of features given the value of the class variable. Bayes' theorem states the following relationship, given class variable y and dependent feature vector x_1 through x_n.
A pupil's score is determined using the Naïve Bayes classification machine learning algorithm which expressed in Formula (3).

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \qquad (3)$$

Where:
P(A) is the prior probability of class that reflects background knowledge due to the chance of A to be correct.
P(B) is the probability of B to be observed.
P(B|A) is the probability of observing B given a world in A holds.
P(A|B) is the posterior probability of class (target) given predictor (attribute).

$$P(y|x_1, \ldots, x_n) = \frac{P(y)P(x_1, \ldots, x_n|y)}{P(x_1, \ldots, x_n)}, \qquad (4)$$

Using the Naïve Conditional Hypothesis

$$P(x_i|y, x_1, \ldots x_{n-1}, x_{i+1}, \ldots, x_n) = P(x_i|y), \qquad (5)$$

for each i, this relation simplifies to (6).

$$P(y|x_1,\dots,x_n)=\frac{P(y)\prod_{i=1}^{n}P(x_i|y)}{P(x_1,\dots,x_n)}. \quad (6)$$

$P(x_1,\dots,x_n)$ is constant given the input values, we can use the following classification rule:
And since the denominator remains constant for all values, the posterior probability can be (7):

$$P(y|x_1,x_2,\dots,x_n)\propto P(y)\prod_{i=1}^{n}P(x_i|y). \quad (7)$$

Naive Bayes classifier combines this model with a decision rule. One of the general [13] rules is to choose the most likely high hypothesis as in formula (8);

$$y=argmax_y P(y)\prod_{i=1}^{n}P(x_i|y). \quad (8)$$

and we can use Maximum A Posteriori (MAP) estimation to estimate $P(y)$ and $P(x_i|y)$; the former is then the relative frequency of class y in the training set.
The value of **P(A|B)** could be poor, average, good, excellent. The result of exam classifies by naïve Bayes [12] machine learning algorithm. In this case, naïve Bayes classifies into four classes: namely: poor, average, good and excellent.

Depending on the result of decision tree algorithm [15], the pupil can be transferred the next level (level, module, grade).
If the pupil's score equals to class poor, the platform returns the pupil the previous level. If the pupil's score equals to class average, the platform gives a chance the pupil to study this level again. Otherwise, the pupil can be transferred the next level (Figure 7). After completing each level, the pupil can be transferred the next module (Figure 8).
All modules in the subject must be completed in order for the pupil to finish the subject.
The pupil can be completed each subject in the grade, the platform could be allowed the pupil to transfer the next grade. Thus, in the end of grade 11, the platform determines the pupil's total score. According to the total score, the platform gives the certificate to the pupil (Figure 9).

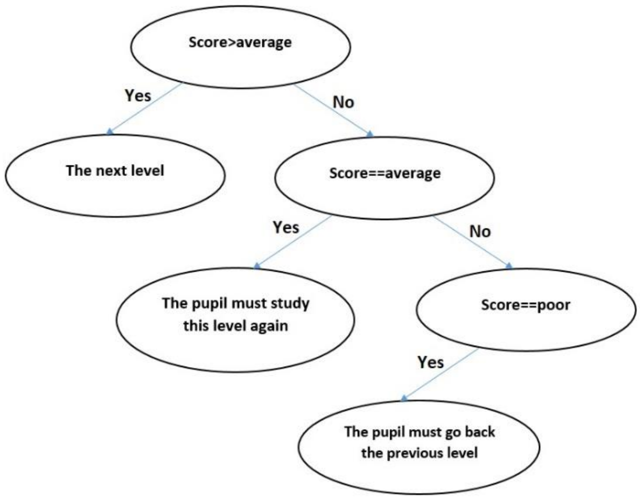

Fig. 7. Determining pupils' level using Decision tree algorithm

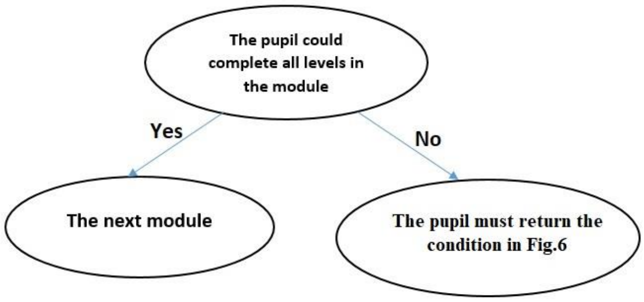

Fig. 8. Determining that whether pupil can pass the next module using Decision tree algorithm

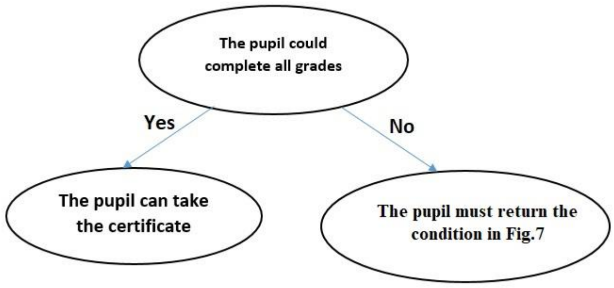

Fig. 9. Determining that whether pupil can finish the school using Decision tree algorithm

IV. USE CASES

Difference of the platform from other educational platforms, the platform is based on machine learning algorithms that is subpart of AI. In other words, the platform is one of the first examples in the new era of educational platforms that is based on AI.

Applying AI in education gives us the following opportunities. The main difference between this platform and others is that the prediction and classification of pupils' knowledge is based on artificial intelligence [17]. The platform can give the pupil following advantages:

- A pupil can study subjects on the platform in a convenient place and at the right time;
- A pupil is allowed to restudy the subjects on the platform;
- The platform concerns individually for each pupil;
- Each pupil's exam is assessed by a system that based on AI, it helps to determine accuracy a pupil's knowledge.

Using the platform in the following cases could be effective:
1. In the education system of poorest countries
2. Lack of teachers
3. Pandemic period

We will overview above mentioned each case in detail.
First case, due to economic problems, many countries in the world cannot spend enough money for education. Educational buildings, educational materials, tools for education, teachers' salaries are required high costs. The platform can help to solve problems in the cases that spend less money for education.
Second case, there may be a shortage of teachers in all regions of the country. This case is not related to money, as the first case. In this case, the shortage teachers can be replaced by the

platform. Third case, due to the coronavirus that emerged in Wuhan in 2019 [9] and spread around the world to pandemic levels, pupils in many countries around the world have not been able to attend classes at school. As a result, the quality of education in schools has fallen. Using the platform is effective in each case mentioned above.

V. CONCLUSION

In this paper, we overviewed the educational platform based on AI that predict and classify pupils' knowledge. We can conclude about the platform as following: low cost, possibility of reusing educational material, the pupils can study subjects on the platform in a convenient place and at the right time, the pupils are allowed to restudy the subjects on the platform, this platform offers an individual approach to each pupil, a pupil's exam in the end of module or in the end of grade is assessed by the system that based an artificial intelligence.

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Development and research of a mathematical model for monitoring the signal points of the railway run

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***Abstract* — As part of a scientific study, devices and their electrical parameters were identified that are of the greatest importance for remote monitoring of signal points of the railways of Uzbekistan. Since the events that occur during the operation of a system created from the sum of these devices, which are random in nature, the theory of Markov chains was used to study them. Based on the theory of Markov chains, a graph of states was constructed, and on its basis Kolmogorov's differential equations were formulated and calculated to find the probability of all states.**

***Keywords* — monitoring, autoblocking, electrical and timing parameters, probability theory, Markov chains, Kolmogorov equations.**

I. Introduction

Most of the railway lines operated in our country use signaling and centralization systems put into operation in the 60s of the last century. The control of railway run devices located between stations is mainly carried out through automatic blocking and frequency dispatch control (FDC) systems [1]. Until now, the devices of the supervisory control system simply do not work or are partially out of order due to the end of the operational period, wear and tear and lack of components to replace the failed device. When upgrading the above systems, in some cases, completely new modern microprocessor systems are used instead of these systems, and in some cases, auto-blocking systems are replaced by semi-automatic ones [2]. The introduction of new modern systems is, of course, a positive factor. But there is another side to the problem. This is a very high price of the above systems. The transition from automatic blocking systems to semi-automatic blocking systems will reduce the capacity of trains. Given this, it is relevant to control and monitor devices located at the railwaw run signal points of the FDC system in local conditions using modern methods. To ensure the foregoing, it is necessary to refine the continuously monitored electrical indicators of signaling devices for automatic blocking and build their mathematical model.

II. Methods

The problem of ensuring the reliability, security and availability of measuring instruments to any system resources is now very relevant. It is difficult to control and predict possible deviations of system parameters due to the complexity of the system, scale, remote location and end of life of devices, wear and tear. Nevertheless, it is necessary to constantly monitor the devices and notify the maintenance personnel in case of deviations from the norm and malfunctions [3-4]. To solve this problem, modeling methods, graph theory, Markov chains and Kolmogorov's mathematical equations were used.

III. Results

Monitoring of automatic blocking signal point devices involves continuous monitoring and monitoring of their technical condition in order to identify malfunctions of the equipment included in it and deviations from the values established in regulatory documents, and notifying technical personnel in case of existing deviations. Monitoring systems help automate equipment checks and collect statistical data on system operation, speed up the detection of problems and reduce the time to fix them [5-8].

Signal point monitoring makes it possible to solve the following tasks:

1) verification and analysis of the state of the controlled object;

2) search for faulty elements and causes of failure;

3) forecasting the technical condition of the controlled object.

For continuous monitoring of the equipment of the automatic blocking signal point and predicting the pre-emergency state of devices, the electrical parameters of the following devices and the variables assigned to them [9] are accepted:

- input voltage of the supply transformer U_{tk};
- output voltage of the supply transformer U_{tch};
- input voltage of the control relay unit section U_{yk};
- control relay block section R_y;
- the relay of control of integrity of a thread of a traffic light R_o;
- Relay for monitoring the integrity of the additional thread of the traffic light R_{od};
- control relay of the main power supply R_a;
- backup power control relay R_{a1};
- relay control by switching direction change R_n;
- green light control relay for traffic light R_z;
- yellow traffic light control relay R_j;
- double voltage drop monitoring relay R_{dsn}.

The monitoring process includes two main steps. The first step is to collect the initial parameters and information about the operation of the nodes in the auto-blocking signal points. Then, the procedure for analyzing the parameters obtained at the first stage is carried out, and then they are compared with the given reference values in order to make a decision about their normal functioning or to find out the causes of the malfunction, unstable or unreliable operation of the system [10-11]. Figure 1 shows the monitoring algorithm for auto-lock signal points.

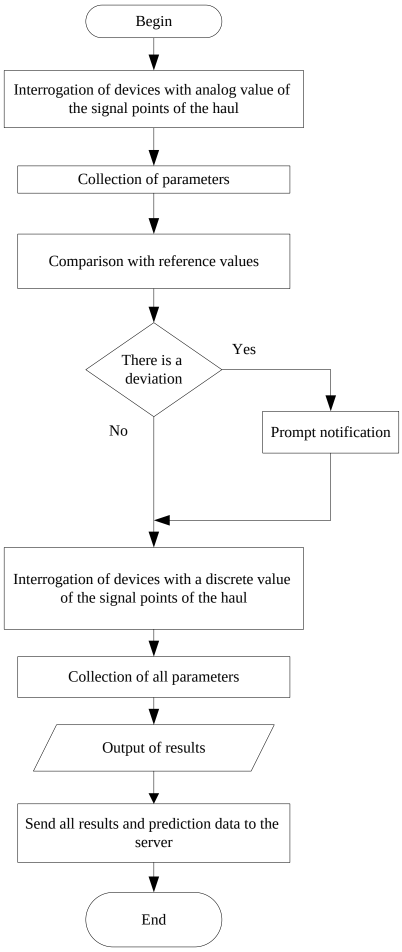

Figure 1. Scheme of the monitoring algorithm

Due to the fact that the phenomena that occur during the operation of devices inside the relay cabinet of the automatic blocking signal point are of a random nature, the most suitable mathematical model for their study is the queuing theory. For the problem under consideration of monitoring the equipment of the signal points of the railway run of the system of numerical coded automatic blocking, aimed at determining the electrical parameters that change their value over time, randomly and building a mathematical model, it is advisable to use the theory of Markov chains [12]. In this case, the circuit can be represented graphically by vertices (system states S_n, where n=0…8) and edges of these states (transition intensities λ_i, where i=1…8). With the help of a structured graph, one can find the probabilities of each state, both under conditions of changing parameters over time, and under conditions of the limiting stationary regime of the system [12-14].

Based on the foregoing, we will describe the situations that may arise when monitoring the parameters of signal points:

- S_0 - no malfunction;
- S_1 - malfunction with any of R_a, R_{a1};
- S_2 - deviation of the value U_{tk} from the nominal value;
- S_3 - deviation of the value U_{tch} from the nominal value;
- S_4 - deviation of the value U_{yk} from the nominal value;
- S_5 - failure with any of R_y, R_o, R_{od}, R_n, R_z, R_j, R_{dsn};
- S_6 - the impossibility of obtaining basic parameters;
- S_7 - the impossibility of obtaining additional parameters;
- S_8 - general system failure.

Now, based on Markov chains, we can describe the situations described above in the form of a state graph. It is shown in Figure 2.

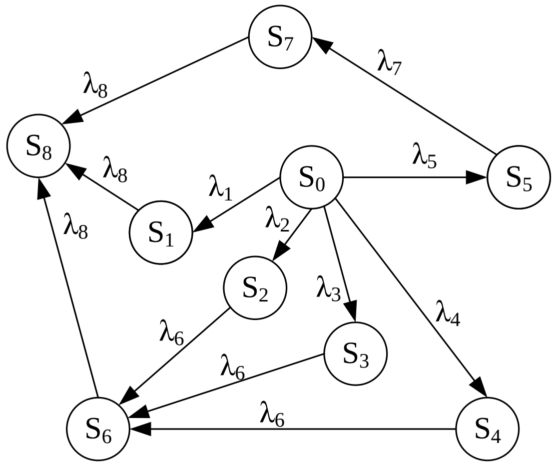

Figure 2. State graph based on Markov chains

After clarifying the situations that may arise when controlling the input parameters of the signal point and the transitional relationships between these situations, we can proceed to the mathematical expression of the results obtained.

Building a model assumes the presence of certain conditions, namely, the detection of faults (regardless of their significance, order and time of occurrence) described by the monitoring system, should be considered as a stochastic process with a fixed number of states. In this case, random events appear one by one (singly), and not in groups (random processes) several at once, which gives reason to assume that the model is ordinary. In addition, the ordinary model does not reflect actions due to the fact that for any two sections that are scattered in time (disjoint), the number of events arriving at one of them does not depend on how many events occur at the other. In this case, the probability of the i-th state is determined by the probability of the system being in the state S_i , that is, the probability of detecting the i-th faulty parameter in the network by the monitoring system. To reflect the possibility of transition from one state to another, it is necessary to reflect the intensity of such a flow of events on the graph, which is tied to the corresponding arrow [14].

Monitoring, designed for continuous control (operational), provides for a procedure (system) of sequential polling. In order to ensure order in the polling system (ranking), the sequence of operations is assigned to the administrator by priority. The higher the priority of the network device parameter, i.e. the significance of this device is so great that a higher intensity of its polling is required. In this case, λ_i is taken as an estimate of the intensity of transitions - the intensity of polling the *i*-th parameter in the monitoring system. Taking into account the above functionality of the monitoring system, it follows that when a failure of any component of the system is detected, it goes from the normal state S_0 to the state of fault detection S_i with intensity λ_i.

If any system S has n possible states $S_0, S_1, S_2, ..., S_n$, then the probability of its being in state Si in some time interval t is defined as $p_i(t)$. It is known from probability theory that the sum of the probabilities of all situations at any given time is equal to 1:

$$\sum_{i=0}^{n} p_i(\mathrm{t}) = 1. \tag{1}$$

The probability of all states P_i (t) can be found based on the state graph. For this, the Kolmogorov equations are compiled and solved. The Kolmogorov equations are a special type of differential equations in which the unknown functions are the probabilities of states [15].

In our specific example, how these equations are compiled. Let the system S have nine states: $S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8$ marked graph, which is shown in Figure 2. Consider one of the state probabilities, for example, $p2(t)$. This is the probability that at time t the system will be in state S_2. Let us give t a small increment Δt and find $p_2(t + \Delta t)$ — the probability that at the moment $t + \Delta t$ the system will be in state S_2. How can this happen? Obviously, in two ways: either 1) at the moment t, the system was already in state S_2, but did not leave it during the time Δt; or 2) at the moment t the system was in the state S_0, and during the time Δt it passed from it to S_2.

Let's find the probability for the first option. The probability that at time t the system was in state S_2 is equal to $p_2(t)$. This probability must be multiplied by the probability that, being at the moment t in the state S_2, the system will not pass from it to S_6 during the time Δt. The The flow of events that brings the system out of state S_2 will also be the simplest, with intensity λ_6. This means that the probability that the system will leave the state S_2in time Δt is equal to $\lambda_6\Delta t$, and the probability that this will not happen is $1 - \lambda_6\Delta t$. Hence, the probability of the first option is $p_2(t)\,[1 - \lambda_6\Delta t]$.

Let's find the probability of the second option. It is equal to the probability that at the moment t the system will be in the state S_0, and during the time Δt it will pass from it to the state S_2, i.e. it is equal to $p_0(t)\lambda_2\Delta t$. Adding the probabilities of both options (according to the rule of addition of probabilities), we get:

$$p_2(t + \Delta t) = p_2(t)[1 - \lambda_6\Delta t] + p_0(t)\lambda_2\Delta t \tag{2}$$

Let's open the square brackets and move $p_2(t)$ to the left side.

$$p_2(t + \Delta t) - p_2(t) = -p_2(t)\lambda_6\Delta t + p_0(t)\lambda_2\Delta t \tag{3}$$

Then we divide both parts by Δt:

$$\frac{p_2(t+\Delta t) - p(t)}{\Delta t} = p_0(t)\lambda_2 - p_2(t)\lambda_6 \tag{4}$$

Let us, as is customary in such cases, let At tend to zero; on the left, we obtain the derivative of the function $p_2(t)$ in the limit. Thus, we write the differential equation for $p_2(t)$:

$$\frac{dp_2(\mathrm{t})}{dt} = p_0 \cdot \lambda_2 - p_2 \cdot \lambda_6 \tag{5}$$

or, in short, by discarding the argument t from the functions p_0, p_2 (now we no longer need it):

$$\frac{dp_2}{dt} = p_0 \cdot \lambda_2 - p_2 \cdot \lambda_6 \tag{6}$$

Arguing similarly for all other states, we write eight more differential equations. Adding equation (6) to them, we obtain a system of differential equations for the state probabilities:

$$\begin{cases} \frac{dp_0}{dt} = -p_0 \cdot (\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5), \\ \frac{dp_1}{dt} = p_0 \cdot \lambda_1 - p_1 \cdot \lambda_8, \\ \frac{dp_2}{dt} = p_0 \cdot \lambda_2 - p_2 \cdot \lambda_6, \\ \frac{dp_3}{dt} = p_0 \cdot \lambda_3 - p_3 \cdot \lambda_6, \\ \frac{dp_4}{dt} = p_0 \cdot \lambda_4 - p_4 \cdot \lambda_6, \\ \frac{dp_5}{dt} = p_0 \cdot \lambda_5 - p_5 \cdot \lambda_7, \\ \frac{dp_6}{dt} = p_2 \cdot \lambda_6 + p_3 \cdot \lambda_6 + p_4 \cdot \lambda_6 - p_6 \cdot \lambda_8, \\ \frac{dp_7}{dt} = p_5 \cdot \lambda_7 - p_7 \cdot \lambda_8, \\ \frac{dp_8}{dt} = p_1 \cdot \lambda_8 + p_6 \cdot \lambda_8 + p_7 \cdot \lambda_8. \end{cases} \tag{7}$$

where: p_0, p_1, p_2, p_3, p_4, p_5, p_6, p_7 and p_8 are the probabilities of occurrence of $S_0, S_1, S_2, S_3, S_4, S_5, S_6, S_7$ and S_8 cases.

This system consists of nine linear differential equations with nine unknown functions $p0, p1, p2, p3, p4, p5, p6, p7, p8$. Note that one of them (any) can be discarded, using the fact that equation (8): express any of the probabilities p_i in terms of others, substitute this expression in (7), and discard the corresponding equation with a derivative.

$$p_0 + p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8 = 1 \tag{8}$$

The solution of the system of differential equations (7) makes it possible to observe the dynamics of the deviation of the measured parameters from the nominal ones when monitoring the equipment of the signal point by determining the probabilities for a specific time interval.

I. CONCLUSIONS

In this article, devoted to the determination of electrical and temporal parameters and the construction of a mathematical model for a device for monitoring the equipment of signaling points of the railway run, an algorithm for continuous polling of devices within a unit of time was created to monitor the indicators of the current state of signaling devices or deviations from the nominal values. On the basis of this algorithm, at the next stage of research, it is planned to create software that allows optimizing the modeling process and controlling the behavior of the system when changing parameters (both temporal and electrical). In addition, the article presents a model showing the process of monitoring signal points and detecting faults. This model is developed on the basis of probability theory. At the same time, the developed model makes it possible to predict the probability of failure of the elements of the signal point of the auto-blocking system that deviate from the nominal value, or the probability of a complete failure of the system, taking into account the probability of previous cases. The direct application of the results of the proposed scientific article creates convenience in maintaining the equipment of automatic blocking signal points remote from the station and leads to economic efficiency.

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Assessing the Influence of AI on Software Development: A Survey Study in Kazakhstan

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***Abstract*—This study explores the effectiveness of AI tools in software development practices among professionals based in Almaty, Kazakhstan. The research encompasses 38 IT professionals specializing in 1C, PHP, HTML/Javascript, database development and system administrators. The research primarily follows a quantitative approach, employing a structured questionnaire with Likert scale items to gauge the perceived usefulness of three AI tools - GPT, Midjourney, and Copilot. Three hypotheses were tested in this study. The first hypothesis posits a positive correlation between the application of Generative pre-training transformer (GPT) models and the efficiency and productivity of software developers. The second hypothesis proposes that adopting Midjourney, an AI-assisted software design and testing tool, enhances design efficiency. Lastly, the third hypothesis asserts that using GitHub's Copilot, an AI-powered code completion tool, increases productivity and creativity among software developers. By testing these hypotheses, the research aims to enhance understanding of the role of AI tools in bolstering software development practices. It provides evidence-based insights that can guide software developers and companies in harnessing the potential of AI tools for improved productivity, efficiency, and innovation.**

Keywords—AI, GPT, MidJourney, Copilot, Software Development, AI-assisted development.

I. Introduction

In an era of rapid technological advancements, Artificial Intelligence (AI) has transformed numerous sectors globally, notably the software development industry. Particularly in Kazakhstan, the industry is undergoing a significant metamorphosis under the influence of AI. The intersection of AI and software development presents many opportunities for efficiency, productivity, and innovation. Recent years have witnessed the widespread introduction of AI-assisted software development tools. A striking example is OpenAI's GPT series models and their AI-powered tool, Codex, which powers tools like GitHub's Copilot.

Similarly, tools like Midjourney, which offer AI-assisted design, have also emerged. These advanced AI-powered tools are pushing the boundaries of software development, revolutionizing traditional programming paradigms, debugging, code generation, and even software project management. These changes driven by AI have fundamentally redefined the software development process, enabling developers to code faster, more efficiently, and with fewer errors. This new dynamic can influence not only the way developers work but also the nature of the software they create, the speed at which they deliver it, and the breadth of problems they can solve.

This paper aims to investigate these implications in detail. By examining the influence of AI on IT professionals, it seeks to determine whether the introduction of AI truly facilitates software development or if its impact is less significant than popularly believed. Through this study, we hope to contribute to understanding the evolving landscape of AI-assisted software development.

The research hypothesizes that such technologies correlate positively with enhanced software development processes. In other words, the paper suggests that as the application of AI tools increases, so does the efficiency and productivity in the software development lifecycle.

However, this correlation may not be uniform across all software development tools. The magnitude of AI's impact could vary significantly based on the nature of the tool and its integration with AI technologies. For some software development tools, the influence of AI might be less significant or negligible. This research seeks to unpack these complex dynamics, providing a more nuanced understanding of the role of AI in software development.

The scope of this research encompasses a diverse range of software developers operating within Kazakhstan. In order to gain a comprehensive perspective, a total of 38 software developers with varied specializations were interviewed. These include but are not limited to PHP developers, MS SQL developers, Front-end developers, 1C Developers, System and Network administrators.

This spectrum of respondents ensures that findings capture the multifaceted effects of AI across different areas of software development. It is considered that the utility and impact of AI-assisted tools can significantly vary across these different roles and specialties. Considering a wide range of professional profiles, this research aims to present a well-rounded analysis of AI's implications for Kazakhstan's IT professionals.

The research hypothesis is that AI technologies have a positive but varied correlation with software development efficiency - will thus be tested across these different specializations, allowing for a more granular understanding of the role of AI in software development.

II. Literature Review

In the paper "Applications of AI in classical software engineering" [1], the researchers conduct a comprehensive analysis through a systematic review of previous research and qualitative interviews with software developers who either use or have shown interest in AI tools in their daily routines. The six-stage software engineering lifecycle model, widely recognized and utilized in academic literature and practical software development, was used as a framework for this investigation. The stages considered include project planning, problem analysis, software design, implementation in software code, software testing and integration, and software support and maintenance. Five software development experts were interviewed, with a good balance in age, gender, and professional experience. Their expertise in AI technologies varied, offering various perspectives on AI tools' applications, opportunities, and limitations. The interviews were semi-structured, allowing the participants to elaborate on the software engineering lifecycle stages and AI's relevance at these stages from their perspective. This approach mitigates the interviewer's bias and offers a more comprehensive understanding of the real-world implications of AI in software development. Findings from this study are expected to illuminate the current status, potential development trajectories, and associated risks of applying AI in software engineering.

In the paper (Battina, 2021), AI tools and DevOps have emerged as significant facilitators in the software development process [2]. These elements are particularly critical in managing complex information technology systems, especially in the U.S., where the scale and complexity of operations are often immense. AI and DevOps are increasingly intertwined in the information technology sphere, working in synergy to boost operational efficiency. This seamless integration of AI tools into the DevOps process contributes to an accelerated and more efficient development cycle. However, it is crucial to note that this symbiotic relationship between AI and DevOps is not just about deploying code rapidly. It is also about creating an environment that promotes continuous learning, integration, and delivery, ultimately improving software quality and customer satisfaction. The study underscores the importance of AI tools and DevOps in software development. The integration of these technologies is changing the dynamics of the development process, accelerating development cycles, enhancing collaboration, and ultimately paving the way for a future where AI and DevOps become even more integral to the software development landscape. As such, embracing these technologies and adapting to their evolution will be essential for developers and companies striving to stay ahead in the fast-paced world of software development.

(Ramchand et al., 2022) focus is on the significant impact AI has on the software testing industry. AI's influence is recognized as transformative, making the testing processes leaner and delivering more accurate results, key components of Quality Assurance (QA). Integrating AI into QA indicates a new era where software testing is made more efficient and delivers sophisticated software development outcomes in less time. With AI's integration, the organizations' efficiency is significantly increased, a game-changing factor in the demanding and rapidly evolving field of software development. The study's findings are based on the responses from 104 participants from various designations within the IT sector. The diversity of the participants, which included Software Quality Assurance Experts (30%), DevOps experts (15%), Data Scientists (25%), and Software Engineers (30%), ensured a comprehensive understanding of AI's role in software testing from various perspectives. Moreover, the experience level of the respondents, which ranged from trainees to senior-level professionals, further diversified the insights. Notably, a substantial number (50%) of respondents had 2-4 years of experience, indicating a relevant and updated understanding of current AI and software testing trends. In summary, this research underscores the growing importance of AI in software QA. It highlights the transformative impact of AI on software testing, making it more efficient, accurate, and sophisticated. As we move forward, the influence of AI on software QA is anticipated to grow, making it an indispensable tool in the software development process.

In the paper "The Programmer's Assistant: Conversational Interaction with a Large Language Model for Software Development", the researchers delve into the applications of Large Language Models (LLMs) in software engineering [4]. These models have been utilized to perform tasks such as translating code between programming languages, generating code from natural language prompts, and auto-completing code during development. The study evaluated the system with 42 participants, featuring a range of programming experiences. It was found that the system could sustain extended, multi-turn conversations and deliver additional knowledge and capabilities beyond mere code generation. This was achieved via the capabilities of the underlying Large Language Model. Initially, participants were skeptical about the practicality of conversational programming assistance. However, after engaging with the system, they admired its wide range of capabilities, the quality of its responses, and its potential to enhance their productivity. The participants in the study spanned various job roles, including Software Engineers, Researchers/Scientists, Software Architects, Data Scientists, Machine Learning Engineers, Systems Test Engineers, Business Analysts, Managers, Marketers, and Consultants. This wide range ensured diverse perspectives on the use and effectiveness of the AI tool. The gender distribution of participants was also diverse, and their experience with Python, a popular programming language, varied significantly. This diversity in Python experience ensured insights from both new and experienced users. In conclusion, the study showcased the remarkable capabilities of Large Language Models in software development, particularly their ability to interact conversationally and assist in programming tasks. Despite initial skepticism, participants recognized the potential of these tools to improve productivity, marking an exciting development in the field of AI-assisted software engineering.

(Wan et al., 2019) in the paper "How does machine learning change software development practices?" investigate the transformative impact of machine learning (ML) on software development practices [5]. It employs qualitative and quantitative research methods involving 14 interviewees and 342 survey respondents from 26 countries spanning four continents. This research aimed to identify significant differences between ML and non-ML systems development processes across various aspects of software engineering requirements, design, testing, and processes. The study also considered work characteristics such as skill variety, problem-solving, and task identity. The first part of the study involved face-to-face interviews with software practitioners experienced in both ML and non-ML development. In the second part, interviewees were asked open-ended questions about perceived differences between ML and non-ML development, enabling them to express themselves freely without interviewer-induced bias. The study emphasizes that software development is not a homogeneous entity but a rich tapestry of diverse practices involving individuals from different backgrounds and domains. It also suggests that distinct differences might exist in distinct ML architectures. In summary, the research underscores the evolving dynamics of software development practices with the integration of machine learning. It highlights how ML has changed the software development landscape, necessitating a diverse range of skills and offering a nuanced perspective on the practice. The integration of ML in software development has resulted in unique challenges and requirements, but it also opens up new possibilities, demonstrating the potential of ML to revolutionize the field.

(Peng et al., 2023) explore the effects of AI-assisted programming on developer productivity through a controlled experiment [6]. The study focused on GitHub Copilot, an AI tool designed to work alongside developers akin to a pair of programmers. In the experiment, software developers were tasked to implement an HTTP server in JavaScript as swiftly as possible. Those developers in the treatment group with access to GitHub Copilot completed the task 55.8% faster than the control group without AI assistance. Notably, the findings indicated heterogeneous effects, suggesting that AI pair programmers like GitHub Copilot have the potential to facilitate career transitions into software development. The study was conducted between May 15, 2022, and June 20, 2022, involving 95 professional programmers recruited through the freelancing platform Upwork. The participants were randomly split into control and treatment groups. This research highlights the significant influence of AI tools like GitHub Copilot on developer productivity. It suggests that AI's assistance in programming tasks not only boosts productivity but also holds promise for those aspiring to embark on careers in software development.

The paper by (Martínez-Fernández et al., 2022) addresses the emerging prominence of AI-based systems - software systems whose functionalities are enabled by AI components such as image and speech recognition and autonomous driving [7]. The increasing advancements in AI have made these systems pervasive in society. However, limited synthesized knowledge of software engineering (SE) approaches for building, operating, and maintaining such systems remains. The authors conducted a systematic mapping study to analyze and compile the state-of-the-art knowledge on SE for AI-based systems, considering 248 studies published between January 2010 and March 2020. This research area is notably emerging, with more than two-thirds of the studies published since 2018. The study reveals that two characteristics primarily mark challenges associated with AI-based systems. Firstly, a significant proportion (25%) of the identified challenges are closely linked to the system domain, making them difficult to classify using the SWEBOK Knowledge Areas and topics. Secondly, these challenges are primarily focused on technical issues, particularly those related to data, and scarcely consider challenges related to other areas, such as economics. In conclusion, the paper identifies the need for more comprehensive research in software engineering for AI-based systems. It emphasizes the significance of AI tools in facilitating software systems' development, operation, and maintenance, despite the emerging challenges and complexities associated with them.

In the paper "CodeNet: A Large-Scale AI for Code Dataset for Learning a Diversity of Coding Tasks", the researchers focus on the emerging area of "AI for Code," inspired by breakthroughs in machine learning and deep learning [8]. This area looks at how AI techniques can be leveraged to enhance software development efficiency, which has generated considerable interest. In the paper, the authors introduce a large-scale dataset named CodeNet, which contains over 14 million code samples and approximately 500 million lines of code in 55 different programming languages. The primary objective of this dataset is to facilitate teaching AI to code. One of the distinctive aspects of CodeNet is its rich set of high-quality annotations. These are designed to benchmark and accelerate research into AI techniques for various essential coding tasks. These tasks include code similarity and classification, code translation across many programming languages, and techniques to improve code performance in runtime and memory. Furthermore, CodeNet offers sample input and output test sets for 98.5% of its code samples. These can be used as an oracle for determining code correctness and potentially guiding reinforcement learning for enhancements in code quality. In conclusion, the paper emphasizes the potential of AI tools in aiding diverse aspects of software development, from coding tasks to code performance enhancement and quality improvements.

(Bedny, 2021) discusses how Systemic-Structural Activity Theory (SSAT), a framework used to analyze and optimize human performance, can be applied to developing AI and BOTs [9]. The SSAT analysis of tasks, their design, and testing can be enhanced by building a human algorithm of task performance. This analysis facilitates the selection of the most efficient method of task performance, which can be integrated into AI or BOT development. The authors present new quantitative analysis methods of human activity development within the SSAT framework in the paper. They present data on task performance measures before and after innovation, covering aspects like task execution time, performance time of perceptual, thinking, and executive components, and time for retaining information in working memory. The authors stress that task complexity assessment is one of the most critical methods of task analysis since complexity is multidimensional and requires multiple measures for evaluation. They recommend that studying human performance at the acquisition stage can pinpoint key points for process improvement and identify ways to reduce human errors and process failures. In conclusion, the paper advocates for using the SSAT framework to enhance the digital customer experience, encompassing both front-end services and back-office process optimization, thereby highlighting the critical role of AI tools in assisting software development.

(Qazi et al., 2022) explore the significant role of AI-based tools in Software Quality Assurance (SQA) [10]. These tools, designed to meet business needs, enable rapid and cost-effective analysis, giving software development professionals a market-oriented approach. According to an international quality report, 64% of organizations employ AI to enhance business processes within their QA strategies. The paper specifically studies the software industry and IT-based approaches in Pakistani software houses specializing in SQA. Modern machine learning models have become integral to SQA over recent years, and the study investigates various AI tools used for this purpose, as well as the latest trends and techniques for improved quality assurance. The researchers propose an approach for SQA based on a survey of AI-based tools, highlighting the efficiency of these tools in software development and quality assurance. However, their results indicate that 70% of software houses in Pakistan have yet to implement AI-based tools to optimize SQA, suggesting considerable potential for AI tools to further assist in software development and quality assurance.

(Bird et al., 2022) in "Taking Flight with Copilot: Early insights and opportunities of AI-powered pair-programming tools" provide insights into the usage and impact of GitHub

Copilot, an AI-assisted programming tool [11]. The researchers conducted three studies: analyzing forum discussions among early Copilot users, a case study of Python developers using Copilot for the first time, and a large-scale survey of Copilot users to understand its effects on productivity. Some key findings were that developers reported spending less time on Stack Overflow but, at the same time, had less understanding of how or why the suggested code worked. There was also a trade-off, with developers accepting Copilot's suggestions for efficiency but relinquishing some control over the code they were writing. The survey analysis of 2047 Copilot users revealed that usage metrics were positively correlated with perceived productivity, with the rate of suggestion acceptance showing the highest positive correlation. These results underline the potential of AI tools like GitHub Copilot in augmenting the software development process, although they also indicate areas for improvement, particularly in enhancing developers' understanding of the AI-generated code.

In the paper by (Borges et al., 2022), the authors investigate the use of AI and Machine Learning techniques by software engineering practitioners and entrepreneurs to support their Software Development Processes (SDP) [12]. The goal is to enable their usage by software startups, particularly in Brazil and Finland. The researchers conducted an online survey and divided it into seven groups with 26 questions. The results were structured based on the concepts of the first ten Knowledge Areas (KA) of SWEBOK, which included Software Requirements, Design, Construction, Testing, Maintenance, Configuration Management, Engineering Management, Engineering Process, Models and Methods of Software Engineering, and Software Quality. The findings indicate that automation is of high interest in areas such as Software Engineering Management (KA7) and Software Engineering Process (KA8), as they aid in the management process for software managers. There is significant interest in Software Maintenance (KA5) as automation could speed up the maintenance process. However, low-quality data presents a challenge. Software Design (KA2) is considered a high priority for automation because of its criticality in the base structure of the software, where any faulty construction can lead to significant problems. Lastly, although many studies focus on tasks linked to Software Testing (KA4), there is still interest and space for solutions supporting processes in this area. These findings provide valuable insights that can guide the automation of the software development process in startups.

(Zhang et al., 2023) offer a comprehensive survey on ChatGPT's role in the era of AI-guided code generation (AIGC) [13]. The study starts by summarizing the underlying technology of ChatGPT, such as the transformer architecture and autoregressive pre-training, as well as the evolution of GPT models. The authors also highlight the broad applications of ChatGPT in various sectors, including scientific writing, educational technology, and medical applications, among others, demonstrating its versatility and ability to assist with complex tasks across different domains. The paper discusses the challenges that ChatGPT faces. These include technical limitations, potential misuse cases, ethical considerations, and regulatory policies that could impact its broader adoption and effectiveness. Finally, the study outlines potential technology roadmaps for ChatGPT's evolution toward General Artificial Intelligence (GAI) and discusses the possible impacts of AGI on humanity. This survey aims to provide readers with a comprehensive understanding of ChatGPT and to stimulate further discussion on AGI and its role in software development.

(Holmberg, n.d.) in the thesis "The Impact of AI-Based Tools on Software Development Work" examines the perception and use of AI-based tools in software development compared to conventional tools [14]. The findings from a case study suggest that developers find AI-based tools less comprehensible and less trustworthy than their traditional counterparts. Even though these AI-based tools appear easier to set up, a significant challenge lies in the lack of understanding of their functioning beyond the results they provide. This lack of comprehension and perceived trustworthiness are critical hurdles to overcome for successfully integrating AI tools in professional software development. The study underscores the need for increased transparency, education, and communication to enhance understanding and trust in AI tools among developers.

(Mashkoor et al., 2022) in "Artificial Intelligence and Software Engineering: Are We Ready?" discuss the potential of AI tools in various stages of software development [15]. Once a system design has been translated into a product, developers often encounter numerous options for tuning. At this stage, AI tools like multiobjective genetic algorithms can assist in configuring the software. Furthermore, these tools can monitor and optimize the running software, minimizing the required cloud resources. Also, the paper explores how AI can support the software development process post-execution. For instance, AI tools can identify and fix buggy code automatically. This demonstrates the potential of AI to make software development more efficient and reliable.

(Weisz et al., 2022) investigate the impact of AI tools on code translation tasks [16]. The findings suggest that when AI-generated code translations aid developers, they produce code with fewer errors than when they work independently. However, the quality and quantity of these translations can influence the process and outcome. The study discovered that providing multiple translations had more impact on the translation process than altering the quality of these translations. Despite the benefits, the paper acknowledges software engineers' challenges while utilizing AI outputs. Hence, there is a need for intelligent user interfaces to help software engineers effectively work with generative code models and understand and evaluate their outputs. The study involved a rigorous selection process, screening 182 technologists and selecting 32 participants who met criteria such as familiarity with Python and Java, recent coding experience, and proficiency with the VSCode IDE. The results indicate that AI-supported code translation could lead to superior outcomes compared to working without AI assistance.

(Meesters et al., 2022) in "What Is an AI Engineer? An Empirical Analysis of Job Ads in The Netherlands" delve into the emerging role of AI Engineers based on an analysis of job advertisements from 2018 to 2021 [17]. The authors identify five core task categories associated with the AI Engineer role: software development, modeling, data engineering, operations, and business understanding. They also highlight the wide diversity of job titles within AI engineering that go beyond AI, Machine Learning, or Deep Learning engineer. Additionally, the paper introduces an extended AI engineering life cycle that includes a business understanding phase. The authors anticipate continued growth in AI engineering-related vacancies, posing a significant challenge to equip future AI Engineers with the necessary skills. They argue for the need for data science and software engineering programs to train professionals with a comprehensive understanding of the entire AI engineering lifecycle. These professionals are expected to work in multidisciplinary teams to develop production-ready machine learning systems.

(Laato et al., 2022) discuss the integration of ML development into established software development lifecycle (SDLC) models [18]. The authors observe that ML system development principles increasingly align with those in traditional software development. Despite the unique aspects of ML, established SDLC models are effective in managing ML system development, though some modifications are needed, as evidenced by the evolution of the DevOps paradigm into MLOps. This finding indicates that while AI tools can support software development, a holistic understanding of the development process and specific adaptations are necessary for effective incorporation.

In the paper by (Becker et al., 2023), the researchers discuss the emergence of AI-driven code-generation tools and their implications for programming education [19]. The authors assert that these tools present considerable opportunities for enhancing programming instruction but also pose challenges that must be addressed. They call for educators to identify, capitalize on, and mitigate these opportunities swiftly. The authors also emphasize the necessity of considering the ethical aspects of using AI code-generation tools and guiding students in understanding these ethical dimensions. The paper signifies that AI tools can greatly assist software development education, but careful consideration is needed to ensure ethical and effective use.

(Becker et al., 2023) explore how online communities influence developers' trust in AI tools and how such community features can be used to foster appropriate levels of trust [19]. The authors conducted two study phases, including interviews with 17 developers, and found that developers often rely on shared experiences and feedback from their online communities when interacting with and evaluating AI tools. This collective sensemaking process enhances understanding of the AI tools and reinforces user trust. The paper underscores the vital role of online communities in shaping trust in AI tools for software development and offers insights into harnessing this to foster a more accurate understanding and appropriate trust in these tools.

In summary, the studies presented provide a profound insight into the transformative role of artificial intelligence and machine learning technologies in software engineering practices. These studies underscore the increasing integration of AI tools into various aspects of software engineering, from project planning to software support and maintenance, their value in enhancing operational efficiency, and their capability to revolutionize software development. Despite initial skepticism, these technologies' practical and substantial benefits have become increasingly apparent, leading to their wider acceptance and adoption. The research also sheds light on the specific impacts of AI on software testing and quality assurance, highlighting its potential to make these processes more efficient and accurate. Notably, the research underscored the remarkable capabilities of Large Language Models and machine learning in software development, pointing to an exciting future for AI-assisted software engineering. The studies also emphasize software development practices' diverse and evolving nature and the unique challenges and opportunities brought by integrating AI and machine learning technologies. The dynamics of the software development landscape are undoubtedly changing, and adapting to these changes will be crucial for future competitiveness and success.

Transitioning to the Research Methodology section, the processes and techniques to investigate the above insights are followed.

III. Methodology

In this research, a Kruskal-Wallis test was utilized. This non-parametric statistical test was used to analyze whether significant differences existed in the dependent variable, GPT Usefulness, Midjourney Usefulness and GitHub Copilot Usefulness across the five independent variable categories.

A. Research Design

This research design applied a quantitative approach to understanding the usefulness of various AI tools such as GPT, Midjourney, and Copilot. The data collection process involved engaging with 38 professionals from Almaty, Kazakhstan, with diverse specialties. The primary tool for data collection was a structured questionnaire designed with Likert scale items. This scale, ranging from 1 (Very Ineffective) to 5 (Very Effective), allowed participants to express their perceptions of the usefulness of the three AI tools - GPT, Midjourney, and Copilot - in their daily tasks. The items in the questionnaire were carefully crafted to capture nuanced insights into the participants' experiences with these tools.

Apart from the Likert scale items, the participants were also allowed to share their thoughts and feedback about these AI tools in an open-ended comment section. Although these comments have not been included in this paper for further analysis and to maintain a quantitative focus. These insights have helped shape the understanding and will inform future qualitative explorations.

B. Data Collection

Data for this research was collected through a dual-method approach - online surveys and telephonic interviews.

For the online survey, a secure platform that allowed participants to provide their responses anonymously and at their own pace was used. The questionnaire was designed to capture relevant aspects of their work, their usage of AI tools such as GPT, Copilot, and Midjourney, and their perception of these tools' impact on productivity and efficiency.

Data confidentiality and privacy of the respondents throughout the data collection process were maintained. Personal data was anonymized and used strictly for research purposes only, following data protection regulations. Participants were informed of their rights, the purpose of the study, and the measures taken to ensure their privacy before beginning the survey or interview. This rigorous data collection process aims to provide a solid empirical foundation for an investigation into the role of AI in software development in Kazakhstan.

IV. Results

This section presents the results obtained from the research. The data collected from the survey responses have been carefully analyzed to test the hypotheses. These results offer insightful observations on the perceived usefulness of the AI tools - GPT, Midjourney, and GitHub Copilot - across the diverse group of software developers participating in the study.

A. GPT Usefulness

To examine the test, let us formulate our hypothesis:

Null hypothesis ($H1_0$)	Alternative hypothesis ($H1_A$)
There is no difference between the five categories of the independent variable in terms of the dependent variable GPT Usefulness.	There is a difference between the five categories of the independent variable in terms of the dependent variable GPT Usefulness.

Table I outlines the summary statistics for the different categories of software developers participating in the study. There were five groups based on their specialization: 1C developers, PHP developers, HTML/Javascript developers, Database developers (working with either MS SQL or MySQL), and System administrators (with expertise in either Windows or Unix shell). The number of participants in each group (N) ranged from 6 to 12.

TABLE I. MEAN RANK OF GPT USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

Groups	N	Mean Rank
1C	6	3.5
PHP	8	29.5
HTML/Javascript	12	18.33
Database developer (MS SQL/MySQL)	6	29.5
System administrator (Windows/Unix shell)	6	14.5
Total	38	

The Mean Rank column provides each group's average responses rank, offering insight into the relative perceptions of AI tools' usefulness among different types of developers. With a mean rank of 29.5, PHP and Database developers reported the highest perceived usefulness, followed by HTML/Javascript developers, with a mean rank of 18.33. System administrators and 1C developers showed lower mean ranks of 14.5 and 3.5, respectively.

TABLE II. KRUSKAL-WALLIS TEST STATISTICS FOR DIFFERENCES IN GPT USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

	Values
Chi^2	29.2
df	4
p	<.001

A Kruskal-Wallis test showed (Table II) a significant difference between the categories of the independent variable for the dependent variable GPT Usefulness , p=<.001. **Thus, the null hypothesis is rejected.**

B. Midjourney Usefulness

To examine the test, let us formulate our hypothesis:

Null hypothesis ($H2_0$)	Alternative hypothesis ($H2_A$)
There is no difference between the five categories of the independent variable in terms of the dependent variable Midjourney Usefulness.	There is a difference between the five categories of the independent variable in terms of the dependent variable Midjourney Usefulness.

Table III outlines the summary statistics of the various software developer groups involved in the study, sorted by their area of specialization.

TABLE III. MEAN RANK OF MIDJOURNEY USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

Groups	N	Mean Rank
1C	6	12
PHP	8	19.13
HTML/Javascript	12	31
Database developer (MS SQL/MySQL)	6	12
System administrator (Windows/Unix shell)	6	12
Total	38	

The Mean Rank column provides the mean ranking of each group's responses. This data offers insight into how each group perceives the usefulness of AI tools in their work. HTML/Javascript developers, with a mean rank of 31, reported the highest perceived usefulness. This is followed by PHP developers, who had a mean rank of 19.13. The 1C developers, Database developers, and System administrators all reported a mean rank of 12, indicating lower perceived usefulness of AI tools within these groups.

TABLE IV. KRUSKAL-WALLIS TEST STATISTICS FOR DIFFERENCES IN GPT USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

	Values
Chi^2	29.36
df	4
p	<.001

A Kruskal-Wallis test (Table IV) showed a significant difference between the categories of the independent variable for the dependent variable Midjourney Usefulness , p=<.001. **Thus, the null hypothesis is rejected.**

C. GitHub Copilot Usefulness

To examine the test, let us formulate our hypothesis:

Null hypothesis ($H3_0$)	Alternative hypothesis ($H3_A$)
There is no difference between the five categories of the independent variable in terms of the dependent variable Copilot Usefulness.	There is a difference between the five categories of the independent variable in terms of the dependent variable Copilot Usefulness.

Table V outlines the summary statistics of the various software developer groups involved in the study, sorted by their area of specialization.

TABLE V. MEAN RANK OF GITHUB COPILOT USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

Groups	N	Mean Rank
1C	6	28.25
PHP	8	28.13
HTML/Javascript	12	9.38
Database developer (MS SQL/MySQL)	6	19.5
System administrator (Windows/Unix shell)	6	19.5
Total	38	

The Mean Rank column provides the mean ranking of each group's perceived usefulness of AI tools in their work. For the 1C and PHP developers, with mean ranks of 28.25 and 28.13 respectively, the perceived usefulness of AI tools was the highest. This contrasts with HTML/Javascript developers, who reported the lowest perceived usefulness with a mean rank of 9.38. Database developers and System administrators reported moderate perceived usefulness, with a mean rank of 19.5.

TABLE VI. KRUSKAL-WALLIS TEST STATISTICS FOR DIFFERENCES IN GPT USEFULNESS ACROSS DIFFERENT SOFTWARE DEVELOPER GROUPS

	Values
Chi^2	20.66
df	4
p	<.001

A Kruskal-Wallis test (Table VI) showed a significant difference between the categories of the independent variable for the dependent variable Copilot Usefulness , p=<.001. **Thus, the null hypothesis is rejected.**

D. Summary

Hypothesis 1 (GPT Usefuless): The application of GPT (Generative Pre-training Transformer) models in software development correlates positively with the efficiency and productivity of software developers in Kazakhstan. This implies that developers who utilize GPT tools in their workflow exhibit increased coding speed, improved code quality, and reduced error rates compared to those who do not use such tools.

Hypothesis 2 (Midjourney Usefulness): The adoption of Midjourney, an AI-assisted software design and testing tool, correlates with improved design quality and more efficient testing processes among software developers in Kazakhstan. This suggests that developers who use Midjourney can design effectively.

Hypothesis 3 (GitHub Copilot Usefulness): The utilization of GitHub's Copilot, an AI-powered code completion tool, has a significant positive relationship with the productivity and creativity of software developers in Kazakhstan. In this context, developers using Copilot are hypothesized to generate more diverse and innovative solutions and benefit from accelerated coding processes compared to their counterparts who do not use this AI tool.

V. CONCLUSION

The application of AI tools in software development has sparked significant interest among researchers and practitioners in recent years. These tools, equipped with advanced algorithms and computational capabilities, promise to transform how software is designed, developed, and maintained. While the global implications of these advancements have been widely discussed, their specific impacts on software developers in Kazakhstan are yet to be comprehensively explored.

In this context, this study aims to investigate the relationship between using specific AI tools and the efficiency, productivity, and creativity of software developers in Kazakhstan. The research hypothesizes that using AI tools, namely Generative Pre-training Transformer (GPT) models, Midjourney, and GitHub's Copilot, positively correlates with improved outcomes in software development tasks.

The first hypothesis (GPT Usefulness) posits that developers who utilize GPT models, known for their proficiency in natural language understanding and generation, exhibit higher productivity and efficiency in their coding activities. The second hypothesis (Midjourney Usefulness) predicts that using Midjourney, an AI-assisted tool designed to improve software design and testing, results in superior software design quality and testing efficiency. Lastly, the third hypothesis (GitHub Copilot Usefulness) proposes that developers employing GitHub's Copilot, an AI-powered code completion tool, are likely to produce more diverse, innovative solutions and enjoy quicker coding processes.

It is essential to consider potential limitations related to the 1C group. The 1C platform, predominantly used in post-Soviet States, is uniquely language-dependent, primarily interfacing in Russian. Consequently, these findings regarding the perceived usefulness of AI tools among 1C developers may be influenced by the nuances of language interaction within the tool and the work environment. The potential language barrier could have affected the developers' ability to fully utilize and understand these AI tools, leading to varied results. Future research could consider these linguistic aspects more closely to understand AI tool applications across different language-dependent programming environments comprehensively.

Through examining these hypotheses, the study aims to shed light on the specific impacts of AI tools on software developers' performance in Kazakhstan, providing valuable insights for the broader software development community.

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Analysis of energy consumption by terminal devices in the ZigBee network

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***Abstract*—At the present stage of telecommunications network development, a new trend focuses on the concept of IoT. To solve these problems, ZigBee technology has been specially created, which was originally developed to create a distributed network of sensors and controls, including home and industrial automation. At the same time, wireless terminal devices that read, transmit over the network and reproduce the collected data for monitoring certain systems are energy dependent.**

***Keywords*—ZigBee, IoT, CSMA/CA, beacons, ZED, SED, MED**

I. Introduction

Zigbee symbolizes the combination of zigzag movement and collective operation of actuators, which are key aspects of this wireless technology.

Zigbee is a wireless network standard designed for low–consumption Internet of Things (IoT) devices. It operates on various frequency bands 2.4GHz, 868 MHz and 915 MHz. Zigbee devices can communicate with each other and exchange data within a network using Zigbee protocols and communication standards. There are also Zigbee coordinators who manage the network and provide communication with other networks or systems.

The paper [1] presents an energy-efficient routing protocol LCF-ZBR (Low Formation of cluster ZigBee Routing). At the same time, if the energy of one particular cluster head node is insufficient, then an alternative cluster head node is used to preserve the residual energy of the original node, which avoids the failure of the cluster head node due to excessive use. Simulation was performed in the NS2 environment. The comparison of the residual energy and the number of idle nodes is carried out. The results showed that the proposed energy-efficient routing protocol was more efficient, which will extend the service life of the entire network.

The authors of the article [2] have developed a wireless sensor for the ZigBee network with standby mode in case of limited power consumption, thus increasing the service life of sensor nodes. In addition, the design of the response mechanism has been improved to ensure effective management of the terminal sensor node by the server to eliminate the problem of transmitting command parameters caused by the silence of wireless communication in the standby mode of the sensor node.

The article [3] is devoted to comparing the energy efficiency of ZigBee and Bluetooth radios, studying their encoding characteristics. The problem was the hidden power consumption of the devices. Firstly, recent advances have changed the power consumption of devices, and secondly, from the point of view of energy efficiency, the gain of systems during encoding has been reduced by determining the signal-to-noise ratio (SNR), where the value of the energy-to-noise ratio (Eb/No) of reception is more significant, providing a direct comparative value for systems. It is concluded that the gain in the diversity of systems is more effective, regardless of which method can provide a gain in diversity compared to the average statistical indicator.

The article [4] proposes an intelligent lighting monitoring and control system based on the Internet of Things, which is created using the ZigBee wireless network for smart homes. The proposed system consists of capacitive touch switches, smartphones and an intelligent integrated control platform. ZigBee is used as a communication bridge that can reduce the power consumption of electrical appliances. Users can monitor the condition of household appliances using an application that eliminates the disadvantages of traditional remote control devices and saves energy.

The work [5] is devoted to the creation of a hardware prototype and implementation on a standard ZigBee, Wi-Fi and FPGA platform. The experimental evaluation demonstrates that backscattering Wi-Fi packets can be decoded by CoTS ZigBee receivers at a distance of 55 meters without line of sight and taking into account human movements. Passive ZigBee can consume as little as 25 MW when transmitting sensor data and relaying ZigBee and Wi-Fi data compared to traditional ZigBee (36 MW).

In [6], an optimization model was developed to maximize the battery life of routers and the coordinator, which was successfully tested with a standard ZigBee data table containing technical data for sensors, routers and coordinators (practical assembly of a wireless sensor network with XBee S2C devices). It is shown that when end devices generate traffic at regular intervals, an increase in the battery life of routers and the coordinator is possible only under certain use cases.

II. FEATURES OF THE ZIGBEE STANDARD

ZigBee technology is special because, despite the fact that the end devices of a wireless network have low power consumption, but at the same time support not only various network topologies ("point-to-point", "tree" and "star"), but this network is self-organizing and self-healing with a mesh mesh topology with retransmission and routing of messages. In addition, the ZigBee standard has:

- the ability to choose a routing algorithm;
- application standardization mechanism – application profiles;
- standard cluster libraries;
- flexible security mechanism and others.

Figure 1 shows the Zigbee protocol stack, where the upper layer is the APS (Application Support Sublayer) application layer, the NWK network layer using lower–level services is the MAC access control layer and the PHY physical layer regulated by the IEEE 802.15.4 standard for low–speed personal radio networks.

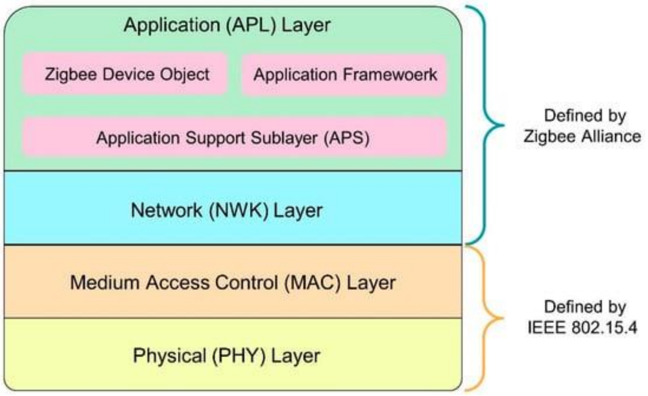

Fig.1. Zigbee standard Protocol Stack

Access to the IEEE 802.15.4 channel is based on Carrier Sense Multiple Access With Collision Avoidance (CSMA/CA).

ZigBee IEEE 802.15.4 devices operate at 2.4 GHz. 16 channels are organized with an interval of 5 MHz. Data transmission can reach up to a base speed of 250 kbit/s over the air, the average transmission rate of useful data, depending on the network load and the number of retransmissions, ranges from 5 to 40 kbit/s. In this case, the distance can be reached up to 100 m if there is no obstacle in the way of signal propagation. IEEE 802.15.4/Zigbee devices are characterized by low power consumption, especially end devices for which a "sleep" mode is provided, which allows these devices to work for up to several years on a single AA or AAA battery. AA batteries are usually used in devices that require more power or longer operating time (from 1.2 Ah to 3 Ah), while AAA batteries are often used in more compact devices where size and weight matter (from 0.5 Ah to 1.5 Ah). The IEEE 802.15.4 standard supports not only standard topologies, but also complex arbitrary ones.

The following devices are components of the IEEE 802.15.4 network:

- a ZC device that forms tree paths with the possibility of interconnection with other networks (coordinator);
- router (ZR);
- ZED (ZigBee End Device) – not sleeping, SED (Sleepy End Device) – sleeping and MED (Mobile End Device) – mobile [7].

Each coordinator or router can support up to 16 or 32 terminal sleepers or mobile devices. The mobile device disappears from the network due to its movement, otherwise it is similar to sleeping. The mobile device disappears from the router's field of view not because of sleep, but because of its movement. Only dormant end modules are introduced into the low-power state, the coordinator and routers maintain the connectivity of such a network (Figure 2). The messages of the end devices are not buffered, they are sent to the network immediately. The end nodes communicate with the entire network through their "parent" node.

The "parent" is selected automatically during the formation of the network. If the "parent" node subsequently stops functioning for some reason, the "child" end node will find another "parent" node. There are four modes (mode 0, 1, 2, 3) of the terminal module activity, with sequence numbers 1, 2, 3, 4. In the initial mode (mode 0), the terminal module does not sleep. The two following modes (1st and 2nd) mean different degrees of energy saving by the processor: semi-awake mode and deep sleep mode 3 (with processor shutdown).

ZigBee's sleeping endpoints can be configured to wake up on a specific schedule or in response to specific events. Typical events may be the receipt of a command from the ZigBee network coordinator or the activation of an internal sensor or sensor.

III. ANALYSIS OF THE PRINCIPLES OF DATA TRANSMISSION BY THE CSMA/CA METHOD

In the 802.15.4 standard, when accessing a radio channel at a frequency of 2.4 GHz, the maximum data transfer rate is 250 kbit/s, in reality it is lower due to the availability of service information. To prevent unwanted interactions, a time separation based on the CSMA/CA protocol (Multiple access protocol to the medium with carrier control and collision prevention) is used.

The ZigBee time division is based on the use of synchronization mode, in which subordinate network devices, which are in a "sleeping" state most of the time, periodically "wake up" to receive a synchronization signal from the network coordinator, which allows devices inside the local network cell to know at what point in time to transmit data. This method, based on determining the state of the communication channel before the start of transmission, reduces (but does not eliminate) collisions caused by multiple devices transmitting data simultaneously. The 802.15.4 standard is based on half–duplex data transmission (the device can either transmit or receive data), which does not allow using the CSMA/CA method to detect collisions - only to prevent them.

ZigBee data transmission technology uses two modes: with and without beacon. In the beacon-free mode, the network works asynchronously, and routers must constantly listen to the air, which does not allow building an ultra-low power consumption network based on this mode.

In the beacon mode, the coordinator and each of the routers with a certain period send frames called beacon to the air, allowing clock synchronization on parent and subordinate nodes. The interval between beacons (BI) includes an active period, called a superframe, and possibly an inactive period (Figure 2).

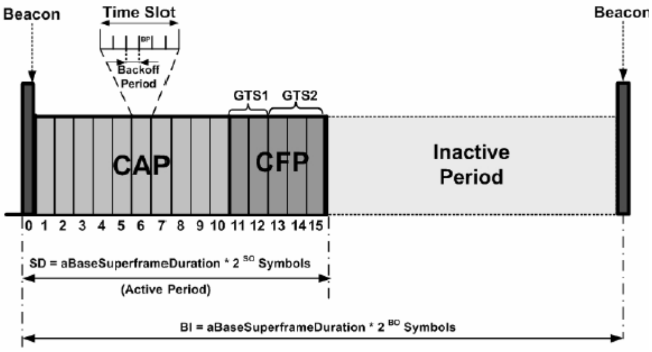

Fig.2. The principle of operation of the network in the mode with a beacon

The superframe is divided into 16 identical time slots, during which data frames can be transmitted. During the inactive period, all nodes can enter sleep mode, thereby saving energy.

The interval between beacons and the duration of the superframe are determined by the parameters BeaconOrder (BO) and Superframe Order (SO), respectively [8, 9]:

$$BI = aBaseSuperframeDuration \cdot 2^{BO}, 0 \leq BO \leq 14 \quad (1)$$

$$SD = aBaseSuperframeDuration \cdot 2^{SO}, 0 \leq SO \leq BO \quad (2)$$

where $aBaseSuperframeDuration$ – minimum duration of a superframe.

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This value is fixed and is equal to 960 characters (a character is 4 bits), which corresponds to 15.36 ms, assuming 250 kbit/s in the 2.4 GHz frequency range.

During the Competitive Access Period (CAP), nodes compete for access to the physical environment using the CSMA-CA slot mechanism.

The IEEE 802.15.4 protocol also provides for a period of non-competitive access to the environment (CFP), during which guaranteed access slots (GTS) can be allocated to nodes.

Figure 3 shows the dependence of BeaconOrder on the intervals between beacons BeaconOrder indicating the number of super frames that must pass between two neighboring beacons.

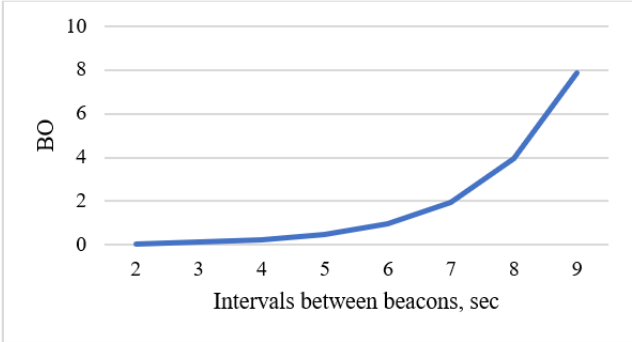

Fig.3. The dependence of the Beacon Order on the intervals between beacons

The average current strength in the Zigbee network does not directly depend on the intervals between beacons. However, the intervals between beacons can affect the power consumption of devices on the network.

On the Zigbee network, devices have the ability to go to sleep during the passive period of the Superframe when no data is transmitted. Longer intervals between beacons allow devices to spend more time in sleep mode, which can reduce the average current in the network.

Figure 4 shows the dependence of the Beacon Order on the average amperage.

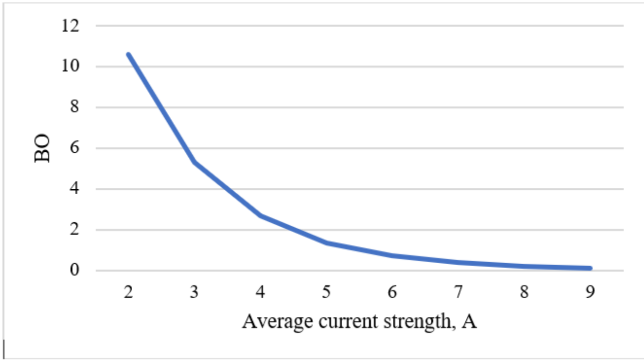

Fig.4. The dependence of the Beacon Order on the average amperage

Figure 5 shows the dependence of the Beacon Order on the lifetime of the AA battery.

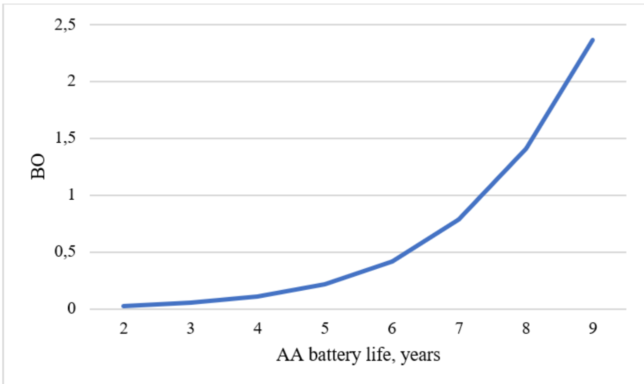

Fig.5. The dependence of the Beacon Order on the lifetime of the AA battery

IV. Conclusion

IEEE 802.15.4/Zigbee is a standardized wireless technology that defines physical (PHY) and channel (MAC) levels for low-speed, low-power wireless networks. It provides a framework for various protocols and technologies, including Zigbee.

The lower the value of the Beacon Order, the more often beacons will be sent, and the more active the network will be, which is important when a quick response to changes in the network is required or when high bandwidth is needed.

A longer interval can also be useful for networks with low bandwidth or when less network activity is required to save energy.

When choosing the intervals between beacons in the Zigbee network, it is necessary to consider the balance between the power consumption of devices and the requirements for data transmission delays in a particular application.

Increasing the intervals between beacons can lead to an increase in battery life due to the sleep of end devices with less energy consumption.

IEEE 802.15.4 and Zigbee standards are widely used in various fields, such as smart home, industrial automation, smart grids, etc. They provide reliable and efficient communication between various devices, such as sensors, actuators and control systems, taking into account the requirements for low power consumption, reliable data transmission and ease of use.

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The role of the patronage mobile application in the evaluation and analysis of the activity of medical information systems

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***Abstract*—Currently, the demand for mobile applications for evaluating and analyzing the performance of medical information systems is increasing due to the need of time for digitization. Medical mobile applications are software products that can be widely used in medicine. In this article, it is shown that the introduction of the use of mobile application service in city multidisciplinary central polyclinics, city and family polyclinics is an important factor in preventing serious diseases, improving the system of quick and accurate diagnosis of diseases, and protecting human welfare. In the evaluation and analysis of the activity of medical information systems, it is shown that mobile applications allow receiving information from several patients at the same time and are the main helper in maintaining human health.**

***Index Terms*—Medical information, diagnosis, disease, mobile application, Soft Computing component, medical information technology, mathematical model.**

I. Introduction

Currently, in many foreign countries, the intervention of information technologies in the field of medicine is moving forward very quickly.

Construction of intelligent systems for control, analysis and decision-making of medical information systems; is the use of modern intellectual information technologies (databases, a component of Soft Computing) to solve the problems of monitoring and decision-making given the initial data, and to develop software tools and analyze the activity of medical information systems in medical institutions and decision-making. Medical information systems (MIS) are comprehensive automation of medical institutions. Development of software modules that meet the modern requirements of the institution for the progress of medical diagnostic processes, elimination of repetitive and unnecessary procedures for diagnosis and medical appointment, control of medical records, analysis and registration of defects in medical processes, quality provides timely improvement [1], [4].

The results of large-scale reforms in the field of health care in our country are not working. In order to widely introduce information technologies in the field of medicine, work is being carried out to consistently study and solve their problems.

Today, the widespread introduction of modern information technologies in medicine serves to improve the quality and efficiency of the provided medical services. Creating a mobile application of the ”Patronage” information system in order to automate the work of documenting in medical institutions, to computerize the patient's medical history and analysis results, to perform diagnostics using the capabilities of information recognition systems based on artificial intelligence, and to visually monitor the stages of the development of the disease is considered an urgent issue [2], [3].

When the world experience was studied in European countries such as Italy, Spain, Greece, Germany, it became known that social patronage service is implemented mainly only for the elderly and mentally ill patients who need the care of others. Brigades equipped with special vehicles have been organized in 46 polyclinics in Russia, where 120 doctors and 264 secondary medical workers work. In Kazakhstan, universal and improved patronage systems have been established experimentally, in which improved patronage services are mainly provided to children and pregnant women.

According to Oljas Abishev and T. Sultangaziev [2], mobile applications are primarily used by patients who have dispensary accounts. More than 6,000 downloads for ”Anti-Stroke”, more than 3,000 downloads for ”Oncoscreen”. He added that the ”Visiting Nurse” mobile program was introduced in the region.

Moscow city scientists A.V.Pogonin and Yu.Khavkina, A.I.Khripun Patronage - a set of planned activities implemented by the district pediatrician, pediatrician (later doctor), district nurse, nurse (later nurse) has been developed [6], [7].

Comparative analysis of the main featu res of existing and developed medical facilities such as health information systems, Center Millennium, IMPAC, INVISION, Integration Patient Information System, Medical Manager System, Med-Series4, mySAP Healthcare, PulsePro Management System, etc., widely used in the USA and Europe, India, Japan, South Korea, China, Russia, Canada show special attention to the following functional capabilities of software systems [2], [5], [8], [9].

If the PATRONAJ mobile application starts working in Uzbekistan, it will save a lot of time, strengthen human health, and create a basis for comprehensive analysis of its capabilities. PATRONAJ mobile application is one of the unique opportunities to understand the problems and make the right decision. If we look at it as a global model, the PATRONAJ mobile application can be called a model that occupies a worthy place in global health [10], [11].

The difference between the new patronage mobile application and traditional models:

1. Effective use of time and not being indifferent to human health;

2. Accurate and qualitative analysis of the problem; ”timely detection and elimination or significant reduction of risk”;

3. The demand for quality, not quantity, is in the first place, ”Everything is for human dignity”;

4. Attention to the medical-social, educational complex is aimed at identifying not only diseases, but also other health problems [7].

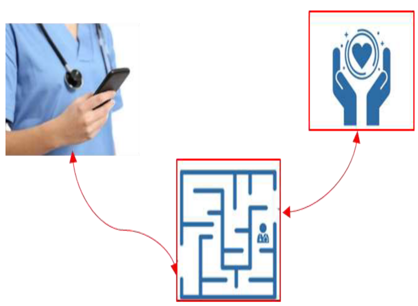

Fig. 1. Mobile application scheme

Open, connected digital platforms can achieve real-time visual management of hospital operations, from patient flow and physician workload to bedside and device utilization. This, in turn, enables hospital management to plan and improve resource utilization and make fully informed decisions based on overall healthcare metrics and outcomes.

Creates an automated workspace for the physician with scheduling, staff, patient, supplier, and resource accounting functions.

The enterprise provides a medical repository with a web interface for exchanging medical messages, sending alarms, accounting for service providers, and collecting data on the results of physiological indicators monitoring.

II. Mathematical Method of Intellectual Analysis of Medical Information

For early detection of diseases in medicine, it is necessary to provide a mathematical description of the problem of forming clinical symptoms. Mathematical methods and algorithms for medical data processing and problem solving and mathematical methods in medicine, criteria for determining the condition of research objects related to health problems, evaluation, analysis and a set of quantitative variables Forming methods and set of algorithms analyzed [4], [6].

In many clinical situations, the patient is affected by several symptoms (signs) at the same time. Therefore, recently, the solution to the problems of forecasting and diagnosis has become related to the methods of information processing. Experts in the field of statistics say that many methods of information processing in this field were created and developed due to the problems posed by medicine and biologists [4], [6], [12].

Linear regression analysis is chosen to determine the effect of disease symptoms on diagnosis. Given the low quality of the initial data, we can use non-linear methods. The analysis shows that linear regression analysis is effective in many areas. The main diagnoses are determined according to the accepted clinical practice. Based on the given data, a list of diagnoses is compiled and we assign a numerical value to each diagnosis (Table 1.1).

TABLE I
TABLE OF DIAGNOSES

No	***Diagnosis***
1	Inflammation of the upper respiratory tract (pharyngitis, asopharyngitis, tracheitis, laryngitis, laryngo-tracheitis)
2	Acute coronary syndrome (ACS)
3	Chronic disorders of the stomach and intestines
4	Acute intestinal infection (OKI, dysentery, salmonellosis, enterichiosis, gastritis, enteritis, gastroenteritis)
5	Headache
6	Heart disease (VPS)
7	Poisoning from medicine, carbon dioxide, alcohol
8	Snake, scorpion, wasp bite
9	Kidney lat eating
10	Rib fractures
11	Diabetes (type 1 and 2)

The specified types of symptoms are listed, in the initial diagnosis of a particular patient, we take into account the following main symptoms of the disease and assign a numerical value to each symptom (Table 1.2). Let M be the

TABLE II
DISEASE SYMPTOM CHART

No	***Symptoms***
1	Sneezing
2	Sputum separation
3	Anxiety
4	Not fully closing the eyes
5	Bruising
6	Blood pressure increase
7	Swelling of the mucous membrane of the mouth
8	Pain
9	Arms and legs
10	Pain in hands and feet
11	Swelling in the legs
12	Lose weight
13	Convulsion
14	Increase in body temperature

number of observations. We take the number of symptoms to be N. From all the observational data we have, we can make a table of symptoms and diagnoses. In this case, we indicate the dependence of the symptoms set on each observation with 0 and 1. As a result, we get a table with values from M to N, 0 and 1. Each row in the table gives the disease symptoms of the diagnosis made as a result of a certain observation. Let's denote table 1.1 as *X*. When compiling the X table, we summarize the symptoms that showed the same relationship in all observations. A table of all observations and diagnoses is made, and we mark this table 1.2 as *Y*. The general purpose of working with regressions is to determine the existence of statistically significant relationships between dependent and independent variables and how they are manifested [3].

In practice, linear regression looks like the following linear function.

$$y = b_0 + b_1x_1 + b_2x - 2 + \ldots + b_nx_n$$

In this formula, y is the diagnosis (dependent variable); x_1, x_2, x_n symbols (independent variables). The value of the dependent variable is given to us in the Y table. A combination of independent values is given in Table X.

This article will analyze mobile applications first. A mobile application is being developed on a very large scale to learn and stay up to date with the latest developments in electronic digital technology and medical mobile applications. Electronicization of medical observations reduces the work of nurses and doctors, provides information about patients remotely. Recently, downloading mobile applications has become very popular among students and medical professionals.

How to create and use the Patronage mobile app

This part of the application consists of an online application and an online patronage part, and it is built on the basis of typical information objects that identify the areas of online patronage activity.

A cross-platform application for monitoring medical care in rural medical centers should perform the following functions:

- registration of citizens (ID, User name (Phone Numb), Password
- Full Name, City, District, Address);
- Submit an online application;
- Information about e-documents;
- Analysis of doctors (F.I.O., time of admission, region of the doctor), nurse (login, password);
- Filtering of information according to the schedule of citizens' examination, filtering: performed by date, region, family polykilinka and village medical centers;
- View the found information, the information is displayed in a short form;
- search for an individual house by the name of the registered representative;
- detailed view of found house information;
- review: ID, Pr-date, End-date, Status, Summary

The goals of creating a medical information system (MIS):

1. Creation of a single information space;
2. Monitoring and managing the quality of medical care through the "Patronaj" mobile application;
3. To increase the transparency of the activities of medical institutions and the effectiveness of management decisions;
4. Analysis of the economic aspects of providing medical care in family polyclinics;
5. Reducing the time of examination and treatment of patients;
6. The introduction of the "Patronage" mobile application into the medical information system will have a positive effect on all participants of the healthcare system.

Benefits for the patient:

Effectiveness of treatment:

- by reducing "paper work", the doctor will have more time to work with patients;
- the efficiency of obtaining diagnostic information increases the speed of appointment and the effectiveness of appropriate treatment;
- collection for any number of years with the possibility of viewing the history of the patient's previous cases;
- reduce the risk of losing patient information;
- Minimize time spent:
- the ability to create an optimal schedule for the patient to go to the diagnostic and treatment rooms in a minimum time interval;
- lack of queues in treatment and diagnostic rooms;
- quick receipt of exam results and conclusions in printed or electronic form;

Privileges for the attending physician:

Effectiveness of treatment:

- the ability to see the previous history of the patient;
- the possibility of obtaining information about the availability of medicines from the pharmacy warehouse of the enterprise;
- the availability of the necessary information from the medical history in real time

Minimizing the time spent:

- reduce the cost of excessive manual labor to rewrite the same data;
- Automatic coding of diagnoses according to ICD-10 codes;
- use of templates (frequently used phrases) when filling out medical history;
- automatic receipt of discharge summary;
- comparison of the activities of different healthcare institutions based on the data obtained from different regions;
- timely adoption of important strategic and tactical decisions based on real-time data analysis;

In Figure 2. program database scheme is presented. The database consists of five tables: "patronage graph", "patronages", "qvp", "districts", "house patronage". The database was implemented based on the embedded SQLite DBMS.

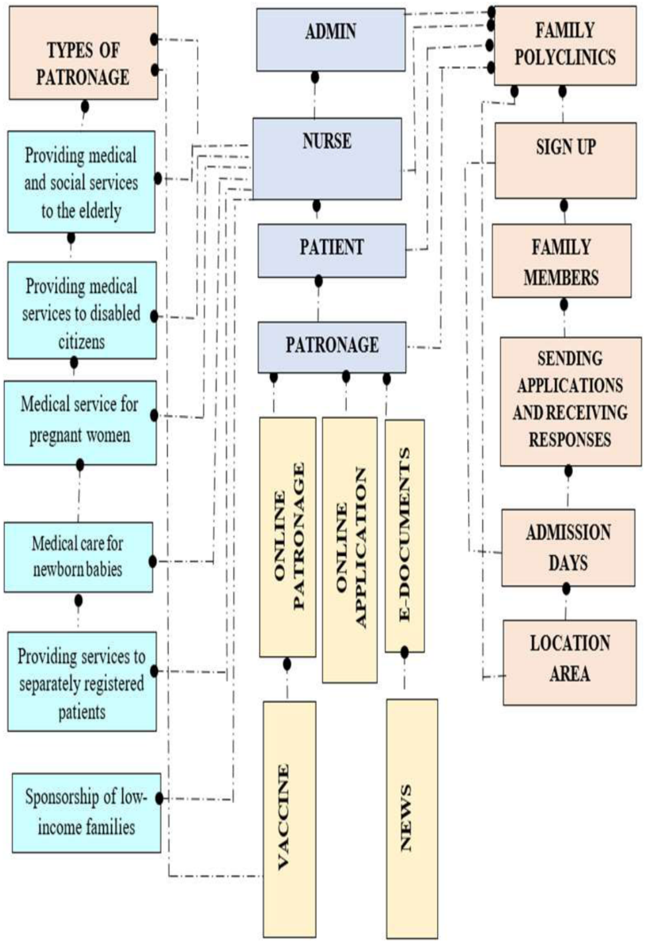

Fig. 2. Functional structure of Potranaj mobile application

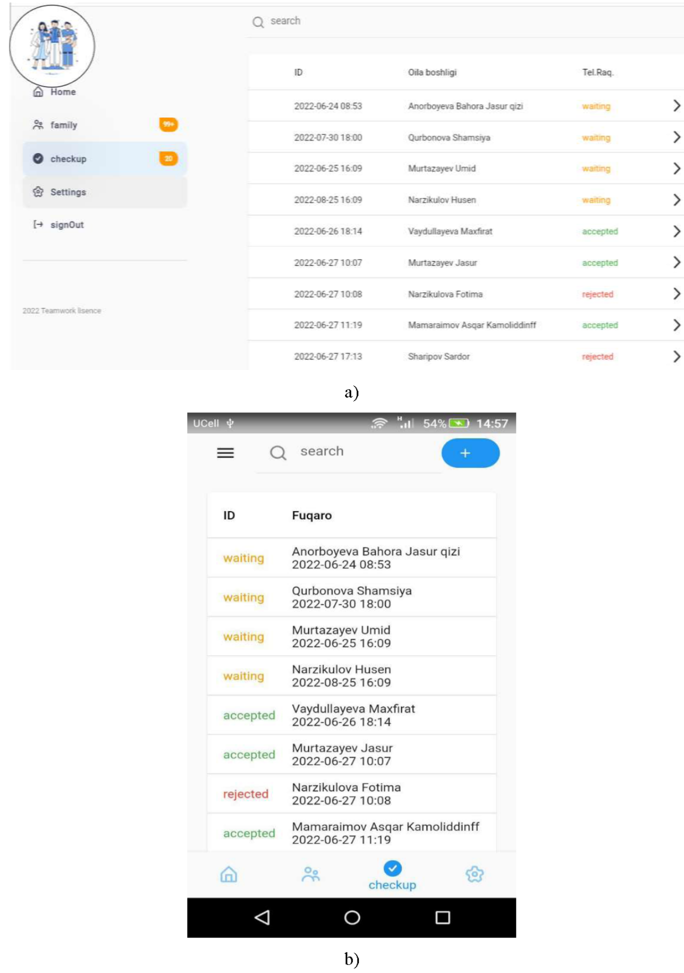

Fig. 3. To enter the system, view the browser in a) web, b) mobile view

Supply lines that provide medical care t o the population are produced at the top level. With the help of patronage nursing brigades, new technologies of comprehensive medical examination of the population and comprehensive medical and social monitoring are being introduced scientifically and into practice.

CONCLUSION

The proposed research work includes the creation of a mobile application for entering, storing and processing information in medical institutions, as well as the development of mathematical methods, algorithms, tools and software to increase the reliability of information in these processes. Determines the mechanisms and ways of implementing the regional target program of organizing medical and sanitary assistance to the population living in remote areas through the primary "patronage" mobile application on the principle of a general practitioner.

Regression analysis allows you to model the situation when making diagnostic decisions.

This part of the application consists of an online application and an online patronage part, and it is built on the basis of typical information objects that define the areas of online patronage activity.

During the construction of the architecture (Clear Architecture), the connection of the Frontend and Backend parts was made on the basis of UML diagrams. This allows the program to connect data, domain, and presentation sections and ensure easy operation of the program.

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A REVIEW: ANALYSIS OF THE PROCESS AND METHODS OF RECOGNITION OF HAND MOVEMENTS BASED ON AN ELECTROMYOGRAPHY SIGNAL

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***Abstract*— This paper presents the optimal processes that can be used in electromyography signal processing in human movement rehabilitation. Here are the best options for EMG signal recording, processing, and classification.**

***Keywords*— electromyography, sensor, electrode, artificial intelligence, data set, muscles, non-invasive, classification.**

I. INTRODUCTION

With the introduction of modern technologies into medicine, the diagnosis of the disease, and rehabilitation of patients with disabilities began.

It also began to be widely used in controlling artificial body organs through biosignals with the help of muscle activity, isolating signal interactions in human and Computer Communication, brain-computer interface systems, and studying human behavior based on exoskeletons.

Currently, people who have lost the limbs of the hands or feet (congenital or increased organ failure) are the majority. They may have been born so or they may have lost their functioning organs due to diabetes, infections of different types, trauma, cancer, or complications of blood vessels. For this reason, several disabled people with circulation in members of the movement is increasing year by year. The use of prosthetics around the world is limited for a while. According to the World Health Organization's reports, 30 million people on Earth need prosthetics [1].

There are several types of prostheses: wooden or iron prostheses, prostheses that work through the body, myoelectric prostheses, and biological prostheses. Currently, myoelectric-robotic prostheses are developing rapidly. The main principles of these prostheses, that is, myoelectric control systems (MCS), consist of the classification and transmission of EMG signals emitted by muscles.

When a person wants to immobilize body organs, such as hands, feet, or neck, a motor contact signal that is part of the brain is produced (Fig.1).

Dressing signal comes to certain skeletal muscles through the spine. Motor neurons are the functional unit of the nerve network. They are connected by muscle. Motor neurons or motor blocks are attached to myofibers. The strength of muscle contraction depends on the number of motor blocks involved [2]. For example, to raise a sheet from the table, several motor blocks are required, but to raise a book with a hardcover, you will need more MU. The volume of the MU population depends on the volume of muscles [3].

In some small muscles, the MU indicator is equal to 1:1. To perform harmonious and delicate movements that require less control, you need large muscles. When increasing strength and strength, these fibers will have to gather [4].

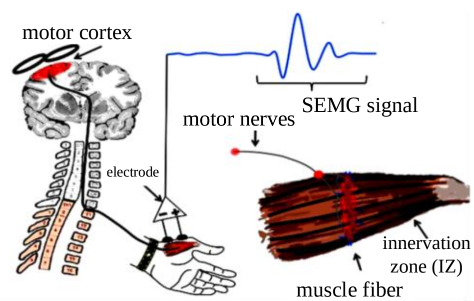

Fig. 1. Control of the muscle through the nervous system.

All muscle fibers relax, shrinking at approximately the same time. Furthermore, if the muscle fibers are faxed to the MU muscle contraction, the fibers will be in a state of maximum contraction. MU is a functional unit of myofibers, which releases muscle contraction [5, 6].

II. ANALYSIS AND DISCUSSION

Nowadays sucks a large number of people with disabilities, amputates with impaired arm or leg movement functions. Rehabilitation of their movement functions as much as possible, and their inclusion in society is one of the essential manners. Amputants are people who have a member of the hand or foot, that is, a member of the movement whose function is impaired, a member of the movement is cut off due to unpleasant phenomena (road traffic officer, diseases, etc.) without a landing.

It is known that as a result of muscle contraction, movement occurs, and the muscle is reduced as a result of the influence of impulses from the brain on muscle fibers. This means that the muscle, which shrinks in amputation, will be damaged, and it will not be able to perform certain movements. However, there will be impulses coming from the brain to the affected muscles that induce it to act, but the impulses will not be able to act, since a certain part of the hand does not exist.

The idea behind this is that if I have an impact on the muscles as a result of the impulses, we will be able to record the signals coming from those muscles and turn them into digital computer commands that trigger the movement in the body. One problem here is that we will have to figure out how many hand movements the residual muscles that are present in the amputee can release. While we know that the movements of the hands are mainly the muscles of the forearm, we need to dress the table of attachment to the forearm muscles or their combination hand movements (TABLE 1).

On the human wrist, six basic muscles provide movement (Fig.2). They are flexor carpi radialis, palmaris longus, pronator teres, flexor digitorum superficial, flexor carpi ulnaris, and flexor policis longus. They are involved in some movements alone, but sometimes several muscle combinations participate in some complex movements. It should be noted that if we correctly determine the connection of the movement to the muscles, and record the signal, we will avoid the fact that the signal data will increase, and as a result, the process of cheating will be more difficult.

TABLE I. TABLE OF THE MUSCLES OF THE FOREARM AND THE MOVEMENTS THAT THEY CAN CAUSE ON THE SURFACE

	Elbow: bending	Palm movement: (palm turn 180 degrees)	Wrist: Bend the palm forward	Wrist: Bend the palm back	Palm movement: making a fist	Palm movement: grip with 1-2-3 fingers	The movement of bending 2-5 fingers from the 2nd bone	2-5 fingers bending back	Palm Movement: Spread the palm
flexor carpi radials	x	x	x		x	x			x
palmaris longus	x	x	x						
pronator trees	x	x							
flexor digitorum superficial			x				x		
flexor carpi ulnaris			x	x					
Flexor pollicis longus								x	

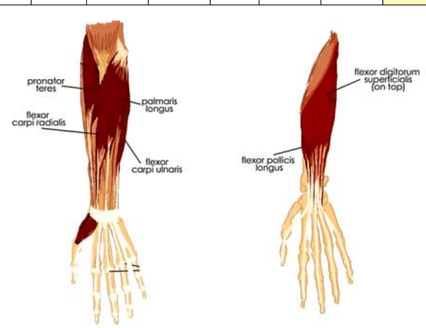

Fig. 2. The structure of the forearm muscles.

Recording an EMG signal is easy, but interpreting it is a difficult process. The analysis of this signal allows you to understand the movements that occur in the body through the strength, and muscles that are characteristic of the muscles. It should be noted that getting the above information correctly will depend on the method of receiving the signal. The traditional method of EMG signal capture consists mainly of three stages: signal capture, signal mining, and signal processing.

Since muscle contraction leads to the appearance of an electric field on the surface of the skin, it is enough to place the electrodes on the surface of the skin.

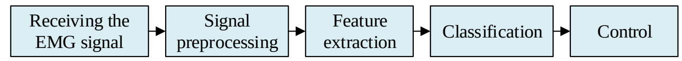

Fig. 3. Signal processing process in EMG signal-based control systems.

It should be noted that, although this is not the case, it may be because it can lead to a deterioration in health. EMG signals that the time spent on trips can be stopped due to the merger (Fig. 3).

The collection and analysis of generalized data, which will be presented below, were carried out in the sequence of processes shown in Fig 3.

The EMG signal recognition will consist of four stages.

1-the stage. At the stage of receiving an EMG signal, the process of recording the EMG signal from the human body is the study of the anatomy of the muscles present in the hand, determining the structure, location, and shape of the muscles, analyzing the possibilities of performing what movements of the hand in the process of studying the muscles, based on recording the signal, the procedures for the correct selection of the location of the electrodes are performed.

2-stage. After receiving the signals from the human body as a result of the necessary actions, the preliminary processing of this signal is carried out. In this case, procedures such as selecting the desired filter, segmentation, and processing of signals in the window, are performed to clean the signal from unnecessary artifacts and noise.

3-stage. At this stage, the separation of the necessary parameters from the cleaned signal is carried out. It will be necessary to determine the most optimal variant of the parameters or the effectiveness of their combinations through certain operations. In subsequent processes, these parameters are obtained and used as a benchmark.

4-stage. The tutorial, dressed through Signal parameters, is taught based on selective algorithms, and the signal is classified based on certain hand movements.

A. *Receiving the EMG signal*

There are various hardware supplies to get the SEMG signal. One of them is the Bitalino device (TABLE 2).

This device is characterized by mobility and productivity. The device can record multiple biosignals at the same time. To get a kind of biosignal, the Har allocated one channel on the device. Currently, BTS FreeEMG analyzers are being used for receiving SEMG signals (TABLE 3). This device is 10-channel, which is used only in obtaining potential from muscles.

B. Signal preprocessing

Processing an unprocessed initial signal (Raw signal) is a necessary step to minimize internal noise and ensure proper analysis of signals. Different types of noise are detected in the recordings of EMG signals. These interactions include noise in data collection equipment, environmental noise caused by electromagnetic radiation, movement artifacts caused by electrode interaction or cable movement, and signal instability caused by changes in the response speed of motor units.

TABLE II. BITALINO DEVICE PHYSICAL PARAMETERS

	Specification
Sample size	1, 10, 100 bath 1000 Hz
Analog ports	4 incomings (10-bit) + 2 incoming (6-bit)
Digital ports	4 incomings (1-bit) + 4 outgoing (1-bit)
Contact information	Class II Bluetooth v2 .0 (up to 10 meters of coverage)
Actuators	LED
Sensors	ECG; EMG; EDA;
Battery	3.7 V LiPo
Weight	30 g
Size	100 × 60 mm

TABLE III. TECHNICAL PARAMETERS OF THE BTS FREEEMG DEVICE

Weight	13 gr
Frequency of use	2.4 GHz (standard IEEE802.15. 4)
Frequency of Information Retrieval	1GHz (16-bit)
Sensitivity	1µV
Connection	USB
USB size	82x44x22, 5mm

The use of low-level conductive filters often eliminates the initial shrinkage on notes that are worn due to movement. In the literature, it has been concluded that the EMG signal is located in the range of 20-500 Hz with the main data [7]. The sliding window method is suitable for myocontrol because it seeks to make a reliable classification decision and reduces the maximum delay time. The choice of the window length is one of the factors that lead to a change in the delay time, and the accounting time. In the studies, 150ms, 250 MS, 50ms, and 100 MS size windows were proposed [7].

C. Feature extraction

Feature extraction - it is understood to obtain the necessary informative parameters from the signal data. Three main categories of features are relevant for EMG signal-based management systems: time (time-domain features - TD), frequency (frequency domain features - FD), and time-frequency domain (time-frequency domain features - TFD) features. Separation of characteristics plays a decisive role in signal processing and classification. This process is carried out by constructing a vector of properties through certain signs of the initial signal. TD properties are distinguished by the signal amplitude. The signal amplitude varies depending on the strength, condition, and types of muscles. Such features do not require changing the signal when allocating. FD is done through the power spectral density of the signal. TFD will be able to accomplish this through a combination of time and frequency fields. The application of the combined form of these features increases a plurality of also precision [8-12]: mean absolute value slope, slope sign changes (SSC), zero crossing (ZC), and waveform length (WL). Although the ZC and SSC features display FD data the signal does not convert to FD. In several studies conducted in the field of manual behavior detection, EMG alarm features such as MAV, ZC, SSC, root mean square (RMS), variance (VAR), and standard deviation (SD) were used. Later, a feature called MAX was introduced, this feature represents the maximum point in WL. Studies have shown that RMS, MAX, and SD feature vectors were the best combinations [8]. Other studies have begun to use features such as Kurtosis (Kurt) skewness (Skew), and approximate entropy (moving ApEn) [9]. These features can classify the EMG signal contraction phases (for example, the beginning, end, and middle of the movement). Studies have shown that the use of ApEn for distinguishing features in clinical processes is effective [10]. The Integrated EMG (IEMG) feature, is used [11]. The FD characteristics of the EMG signal are realized through the properties of its spectrum and frequency fields (Figure 10). Bunda assesses the nature of muscle fatigue [8-12]. The change of signal in FD is due to the median power frequency (MPF), which changes as a result of a relative decrease in the signal strength of the high frequency, and a small increase in the signal strength of the low frequency. In clinical practice, EMG provides data on the mean power frequency (MPF) of signals in the muscle and nervous system changes [12]. This means that EMG signals are reduced as long as they are used as the PSD, MNF, and MNP index on the FD SoC. Scientists have modified mean frequency (MMNF) and modified median frequency (MMDF) to monitor muscle fatigue. They used robust properties of MNF, average frequency (median frequency - MDF), bandwidth (BW), and normalized spectral moments (Normalized spectral moments - NSM) [11].

The third type of SEMG signal characteristic is the characteristics of the signal in the time-frequency field. It should be noted that the Muhim factors in the classification of EMG signal should be high in this accuracy and that the calculations should not be complicated.

D. Classification

There are several artificial intelligence (AI) algorithms based mostly on neural networks to process and differentiate EMG signals (TABLE 4). Below is an analysis of the neural networks used in classifying the EMG signal. In the use of artificial neural networks in the classification of hand movements based on EMG signal, 95% accuracy was achieved when using the AR (autoregressive coefficient) coefficient vector of the signal [13,14,15], but to improve this network, the neural network requires multilayer [16]. This leads to an increase in time consumption in the calculation of signal characteristics and decision-making [17]. The system of computer mouse movement was created through familiar hand movements, and BPNN - (Backpropagation Neural Network) was used in this issue [18]. The mouse cursor worked with 70% accuracy. In such a neural network, hand movements will be limited and you will not be able to use the network in the long term. As an incoming parameter in this neural network, mainly RMS parameters of the signal are used [19]. The Log-Linearized Gaussian Mixture Network (LLGMN) network was used to recognize both EMG signals. Compared to other neural networks, high indicators of discrimination can be achieved, but the accuracy indicator is lower [20]. Not only EMG alarms in space fields can be used in familiar processes but also in such a process, more and more Hidden Markov models (HMM) are used. This network avoids incorrect classification [21], which takes the name of more difficult-to-do accounts than the MLP method.

TABLE IV. COMPARATIVE ANALYSIS OF CLASSIFIERS USED IN EMG SIGNAL CLASSIFICATION.

Classifier	Accuracy	EMG signal parameters	Positive aspects	Negative aspects
ANN [13, 14, 15, 16]	95%	Autoregressive coefficient (AR)	-	A more robust classifier is needed for the disabled. Further improvements require more sophisticated neural networks and better training methods.
	98%	Both the time and frequency domains.	MLP-based model RBF Compared to LVQ, it gave a better result	The computation time was doubled, Features are difficult to differentiate and identify.
	78%	4-level AR	-	There were problems with classification.
BPNN [17, 18, 19]	70%	-	A new type of EMG-controlled mouse has been developed.	Not suitable for long-term use Movement is limited to four directions
	97%	RMS values of the signal	-	Hand movements are limited to 3-6.
LLGMN [20, 22]	86%	-	Higher rates of discrimination can be achieved.	-
Recurrent LLGMN [23]	92%	Time domain parameters	The existing errors in recognition have been significantly improved.	Integration into the device is complex and difficult
PNN [23]	97,9	-	FPGA integration is easy	Out of memory for hardware language. Processing speed needs to be improved.
FMMNN [24]	97%	Difference Absolute Mean Value (DAMV) features	It was possible to classify six wrist movements well	Using more channels when receiving a signal
RBFNN [25]	-	-	RBFNN network, interpolation/extrapolation is performed for real-time recognition of hand movements.	Some parameterization errors were found due to the stochastic nature of the EMG signals.
HMM [21, 22]	95%	-	Averaging signal parameters increases efficiency.	The adaptation and calibration phase require certain adjustments in the model
Bayesian Network [26]	94%	Both the time and frequency domains.	Using an accelerometer together with EMG signal recognition increases the accuracy by 5-10%.	Even the slightest wrong movement can lead to negative results in EMG signal classification, so a special environment is needed for signal acquisition.
RF [27]	99%	Time domain features	Very short reaction time (223ms). The process of integration into the device is easy.	-

Because this requires a phase of flexibility and calibration in the implementation of the process, it requires the implementation of certain corrections in the model [22]. Based on LLGMN, the process of integration with the device in the recognition of a Probabilistic Neural Network (PNN) based EMG signal is improved. However, they experienced a lack of memory for hardware language manners [23]. Here the processing speed is low. EMG uses stochastic parameters of the signal to recognize the signal. Therefore, the use of the Fuzzy Mean Max Neural Network (FMMNN) network makes it possible to increase accuracy, but increasing accuracy requires the selection of the stochastic parameters of the signal with extreme accuracy [24]. In real-time EMG signal recognition, both interpolation/extrapolation methods are used. In this process, the Radial Basis Function Artificial Neural Network (RBFNN) network is often used. However, increasing the familiar accuracy requires an increase in the quantification of the signal and the implementation of the Halda using more sensors [25]. This leads to the fact that as a result of the increase in signal data, the training time of the network increases. Based on the Bayes Network method, it is possible to achieve an accuracy of up to 94% in the signal recognition process, however, a little incorrect behavior can lead to negative results in the signal classification of both EMG, to To avoid this, a separate correspondent will be needed when receiving the signal [26].

In recent scientific studies in this field, the use of neural networks in EMG signal classification has been reduced for some time. The main reason for this is that the EMG signal is a low-frequency and amplitude signal, and the signal values obtained as a result of each motion of the hand are very close to each other. Therefore, in the classification of such value signals, the use of machine learning (ML) algorithms will be sufficient. Since the delay time in myocontrol systems is one of the most important factors, our classification algorithm should be fast. Such a feature is found in Random Forest method (RF) algorithms [27, 28].

When classifying an EMG signal, it will be necessary to pay great attention to the following factors:

•Correct selection of window size and character phase when EMG signal analysis.

•Selection of classification algorithms that are quick and accurate is great.

•Due to the following advantages of RF algorithms, they are being used in the classification of EMG signals and myocontrol systems.

•High training speed compared with neural networks, as well as low training parameters, high integration with the device in the myocontrol systems, and flexibility.

•Superiority of visual recognition. It is easy to classify the previously obtained characters (such as in time or frequency fields) by the classification algorithms of RF.

•Ability to easily classify large amounts of signal values through existing, accurate previously issued signal markers.

III. Conclusion

From the views given in this analytical article, one can draw the following conclusion.

Since the EMG signal is a stochastic signal, when recording the signal, it is necessary to carry out processes such as a special environment, the correct location of the electrodes (in the innervation zone), determining which movements the muscles respond to, and the correct selection of signal parameters based on signal engineering.

In addition, the use of the RF method is effective in classifying the EMG signal and integrating the results into the device. This method is preferred over other methods in terms of reducing reaction time, high accuracy, providing a large number of classification operations, and supporting a small number of channels.

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A NEW APPROACH TO DETERMINING THE ACTIVE POTENTIAL LIMIT OF AN ELECTROMYOGRAPHY SIGNAL

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***Abstract*— In this article presented a new method for determining the active potential of an electromyography signal and compared it with other existing algorithms. The method considered the standard deviation of the electromyography signal. In the future, the creation of Human-Machine Systems provides speed and accuracy with the help of this method.**

***Keywords*— electromyography, bio signals, active limit, frequency, standard deviation, mean error.**

I. Introduction

Currently, a huge number of studies and results have been obtained in areas such as processing biosignals [1][2][3], classification, early detection of diseases in the world with artificial intelligence [4][5][6], the creation of human-machine systems [7].

We comprehend the signals that propagate from the human body by biosignal. They can be a description of natural physiological phenomena that occur in the human body. Biosignals are the main object of Biosystems.

Nowadays, there are many types of biosignals as electrical, magnetic, optical, and chemical, thermo, mechanical [8][9]. These, in turn, divided into such types as endocrine, nervous, cardiovascular, visual, auditory, muscular, respiratory, gastrointestinal system signals according to the system of origin.

Biosignals are much weaker and have very small values like them, with very small values of frequency and amplitude [10]. When it comes to work on human health rehabilitation of patients depending on the physiological data of the patient [10], issues of diagnosis for him also attract attention in the world [11]. For example, we can cite scientific research that is being done on patient health through potentials from human muscles. A signal that measures the electrical potential of the muscles and is the main criterion for movement is an electromyography (EMG) signal. This signal is extremely complex by nature and is distinguished from other signals by its extreme sensitivity to the influence of the external environment. Since it belongs to the category of weak-frequency signals, its processing is a complex process [10].

EMG signal classification is currently being used in the areas of motion recognition, muscle strength analysis, neuromuscular disease detection. The general procedure for classifying an EMG signal is given below (figure 1):

Data collection: signal recording, collection.

Pre-processing of data: initial processing of collected signal data

Parameter extraction: appropriate parameters are obtained to help to class the data [12].

Parameter selection and reduction: select parameters the main objective in this and to calculate them to reduce the time, reducing the amount of information necessary for grading. The choice of appropriate parameters is a very important stage, since functions should provide a high differentiation between categories [13][14][15][16].

Classification model selection: it is necessary to choose the appropriate classification model based on the data. Classifier efficiency may also depends on the type of used.functions [17][18].

Classifier training and testing: the supervisory training is carried out on the Mal using the training sample. At the same time, classification models are tied to a specific training sample, providing a high result in the training of new data.

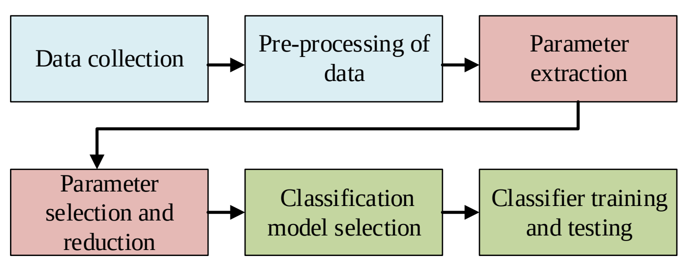

Fig. 1. EMG signal classification steps

II. Materials and Methods

The EMG signal parameters given above are widely used in biomechanics, rehabilitation, clinical diagnostics and other areas of research based on the methods of Character Engineering. Calculation of the given parameters is considered important to distinguish from the signal area at the time of muscle contraction. Therefore, it is necessary to determine the activation part of the signal in the process of classifying the EMG signal. One way to determine the active muscle limit is through visual inspection. Visual inspection can be accurate but complex, while in Real time several algorithms have been developed that detect automatic active potentials because of the low efficiency of this method.

There are algorithms that automatically detect the active potential part of the EMG signal and a comparative analysis of the proposed algorithm in below.

Determination of muscle activity. Research has been done to determine the starting point of muscle activation in the EMG signal. Basically, visual inspection of the signal is carried out using special algorithms. Visual detection cannot be used in real time. Several algorithms that determine the beginning and end of the muscle active potential have been cited [19].

The single limit algorithm. The onset of muscle activation is estimated as a point where the amplitude of the rectified EMG signal exceeds the predetermined threshold. However, the fact that the operation of this method depends on the choice of the boundary creates a tendency to miscalculate.

The two-limit algorithm is an improved representation of the above method by limiting signals with sensitivity. The onset of muscle activation is determined only when a predetermined number exceeds the second limit through sequential experiments.

The character transformation algorithm is reducing the values of a signal by processing it as modular or square values, analyzes important data on how it makes signal records towards the X-axis.

Algorithm 1: Character transformation algorithm.

Step 1. Window sizes are inserted to process the electromyography signal into pieces.

Step 2. A threshold of 0.01 is placed on the signal, and at this threshold the signal is passed through the window.

Step 3. The maximum length of the incoming signal is calculated, and the signal passing through the window is multiplied by 1.5, the modulus of the maximum signal value in the range is determined.

Step 4. The maximum values of the signal are determined by dividing each window into pieces with a ratio such as 2, 4, 6.

Step 5. If the maximum value k is less than the limit the cycle will continue, if the signal value is greater than the specified limit, that point will be the active part of the signal.

A change in sign occurs when the muscle is active. When the muscle is active, it is observed that the voltage values are quite different. The initial signal values determine the location of the change, and this point is considered to be the muscle active point (algorithm 1).

The Komi algorithm is a popular algorithm that can determine the beginning limit of the activity of an EMG signal. Determining the limits of the onset of muscle activity is an important element in the biomechanical analysis of human movement. It was proposed by scientists Komi and Kavanagh in 1979. In the algorithm, the limit value was taken to be 30 MV, since the studies gave it that the voltage produced by the human muscles was considered the lowest limit of diapason [20]. It is calculated as follows.

Algorithm 2: Komi algorithm.

Step 1. A threshold of Onset = 0.03 is placed on the signal, and at this threshold the signal is passed through the window.

Step 2. The Signal length is calculated and the set point is compared with the set limit.

The Teager-Kaiser energy operator (TKEO) algorithm – this algorithm mainly performs calculations along signal wavelengths and is distinguished from others by its extreme sensitivity. It is found as follows:

$$U[i] = \psi(x_i) = x_i^{\,2} - \left(x_{i+1} \cdot x_{i-1}\right)$$

$$U\left[i\right] = \begin{cases} E[i], & if \quad i=0 \ \ or \ \ i=N-1 \\ E[i]^2 - \left(E[i+1]^* E[i-1]\right), & otherwise \end{cases}$$

here, x_i - the i-th value of the EMG signal.

The proposed algorithm.

Step 1. Window size k, mean of EMG signal values – μ, standard deviation of EMG values – σ, h - values such as the variable setting the threshold level are entered.

Step 2. The limit value $threshold=\mu+h\sigma$ is entered and the signal length M is calculated.

Step 3. Signal values equal to M in length are adjusted, that is, those with negative values are discarded.

Step 4. The adjusted signal is the S dispersion between value 1 and window size.

Step 5. The value of the Signal dispersion is 1<S<the offset interval in which the cycle is executed.

Step 6. When the Signal dispersion is less than the S*k value, the sum of the window size with the onset value goes through the cycle.

Step 7. If k exceeds the limit that point marks the beginning of the area of the signal active potential.

The standard deviation of the signal is found as follow:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=0}^{N}(x_i - \bar{x})}$$

here N - is the number of signal values, x_i - signal value, $\bar{x}$- signal average. The total length of the EMG signal is calculated, and the values are adjusted to the absolute value. Is the dispersion of the corrected signal by window size.

It is important to carry out a comparative analysis of these algorithms. Because determining the exact starting point of the active potential and extracting parameters from exactly that point of the EMG signal has a positive effect on speediness on the one hand and accuracy on the other when classifying.

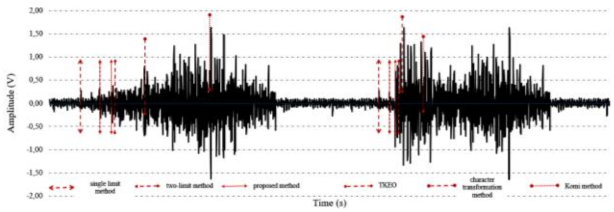

Fig. 2. Comparative graph of results for determining the active limit of the EMG signal

TABLE I
COMPARATIVE ANALYSIS OF ALGORITHMS FOR DETERMINING THE ACTIVE LIMIT OF THE EMG SIGNAL THROUGH VARIOUS ALGORITHMS

Algorithms	**Average error**	**Average deviation**	**Current signal order**
Single limit algorithm	3,1 %	32.2	98
Two-limit algorithm	2,56 %	22.6	156
Proposed algorithm	1,54 %	18.9	352
Character transformation algorithm	2,48 %	25.8	718
Komi algorithm	2,95 %	32.8	956
Teager-Kaiser energy operator (TKEO) algorithm	2,02 %	27.5	402

Table 1. presents the results of these algorithms for determining the active moments of the EMG signal. Analysis shows that the largest mean error was observed in the single threshold (Single threshold) algorithm (Table 1). In the proposed algorithm, the average error was 1.54%, and the average deviation value was 18.9.

III. CONCLUSION

Regarding the studies carried out in this article, we can conclude as:

A new method has been developed to determine the real-time active potential limit of the EMG signal. In the proposed method, the average error was 1.54% and the average deviation value was 18.9. It outperforms other algorithms that determine the active potential by its accuracy, agility, and ease of computation. Since EMG is the most basic mezzanine speed in signal-driven systems or devices, this method is important in future research.

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Student Attention Gauging in an E-learning platform using IoT

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***Abstract*—A live unintrusive attention gauging system using IoT technology is projected in this paper. This structure is carrying through the Blink Sensor which was attached with Arduino Board to classify the state of attention. The classification of a attention state done in three categories are like, Active, Inert and Depart. A blink detection model on eyes is proposed. Assertive and submissive attention gauging experiment is carryout amid a 59 Minutes record streaming lesson as the E-Learning platform material. The results of the experiment are clearly differentiating the attention states of the student join in E-Learning platform.**

Keywords- E-Learning, Attention Gauging, Blink Detection, Attention State

I. INTRODUCTION

The student is attentive when his/her mind is not distracted from the topic which was taught in the class, the same constant attention state will be managed by the educator. In order to maintain the maximum interest and participation of the student the educator plays an important role and adopts topic accordingly, almost every educator goes through the different attention strategies like Breaks Tasks into pieces, Rate Tasks, Play Memory Games, Adjust Time Frames, Remove Visual Distractions, Include Physical Activity and Attention Breaks etc. But all we discussing are possible in traditional classroom where educator and student learning process is indulged.

As we know that now the online education market is boomed with the concept of E-learning platforms where Traditional classroom is shifted to video conferencing without any barrier of specific subject, location, strength infrastructure and time, but gives more flexibility of choosing in terms of time schedule and interested subject. [1] All forms of electronic supported learning and training are included in eLearning. In essence, e learning is a means to transfer skills and knowledge through the use of computers and networks. In the eLearning format, media such as text, images, animation streaming videos and audio may be self paced or instructor led.[2] Proposes two models for how students' attention is to be treated in the current eLearning environment, so as to deliver personalized content and improve their learning experience.

II. LITERATURE SURVEY

[3] The growth of the most recent intelligent machines, which are not alone in being able to process vast amounts of data and therefore must also be self learning and upgrading, is extremely important. In education, much of the world sees Artificial Intelligence as a global competition to develop new and more modern learning platforms and tools quickly. In addition to improving the quality of school, many countries are now providing their young people with an essential understanding of artificial intelligence.[4] A smart drowsiness monitoring system has been put in place. The drowsiness detection generally limits the only detection, the after-effect is never implemented. This system is trying to overcome this limitation. [5] We have identified two main categories of driver inattention, distraction and fatigue, each of which has several subcategories, based on a review of literature. In summary, distraction means that drivers are able to pay attention, but their attention is diverted from the primary driving task to some secondary task, or attracted by an attractive object or event.[6] When users view a video, we analyze how they respond to blinking, saccades, head movements and facial expressions. In order to estimate user's interests on the basis of observing behavior, an attention and emotion model shall be developed. The proposed system consists of a video summary with accompanying music, in which video footage changes as a result of significant music beats, in order to enhance the browsing experience of video summaries. A good performance has been achieved in comparison to the manual editing and content based summarization methods, which show that the resulting summaries are well aligned with user interests.[6] helps students to evaluate the content of the ELearning course and to alert them to inattentiveness during the ELearning course.[1] The IWT eLearning platform will carry out actions designed to improve education for students in response to the level of attention estimated by WiSe.[3] Education, whether it's globalization, internationalization or an enlightened management itself, is the most important thing that needs to be changed by today's world witnesses. The habitual learning which includes teachers, students in a stagnant classroom with a unidirectional way of teaching, reading stagnant text materials, and writing exam assessment to assess the learning skill of all students are being craggy. Fashionable learning directions flock to interactive, personalized learning, student-focused models that assist a single or group of students with improved

intellectual capacity, more rapidly interaction, enhanced engagement, a more extensive coverage of educational outcomes.

III. PROPOSED METHOD

Figure 1 shows a flow chart for the proposed measure of attention..The proposed method gauge the attentiveness of the students while using of the E-learning Platforms. The said model is comprised of a **Blink sensor**, is used to study the student various states or positions of Eye, Duration of predicting the Eye and Eye shutting frequency, moreover the Blink sensor receives and transmits the signals accordingly whenever the eye is open and shut. The **Microcontroller** is used to receive the output signals generated from the Blink sensor, when the eye is shut the sensor will activate automatically and generate the output signals. The **Buzzer** is used to alarm the student to get retentive on E-learning while receiving the output signals at microcontroller. The **Cloud** is used to store the live stream information receiving from the microcontroller which will be monitored by the educators remotely for further process. The AdaFruit cloud is used in the proposed model and the NodeMCU, integrated with microcontroller is used for computing the processing signals, the threshold frequency is assumed as per the individual student to get the accurate results, if the threshold frequency is achieved the signals data will be sending on AdaFruit cloud. Actually the signals are achieved from the ratio of eye which was compared with the threshold value as fixed for detecting the attentiveness, in which if the ratio is found to be more than with fixed threshold value then consider as student eye is opened and focused resulted in **Active** state. If the ratio is found less than fixed threshold value then student said to be in sleepy mode or in attentive mode resulted as **Depart** state. If the ratio is continuously hitting the threshold value and fluctuating then it results to **Inert** state.

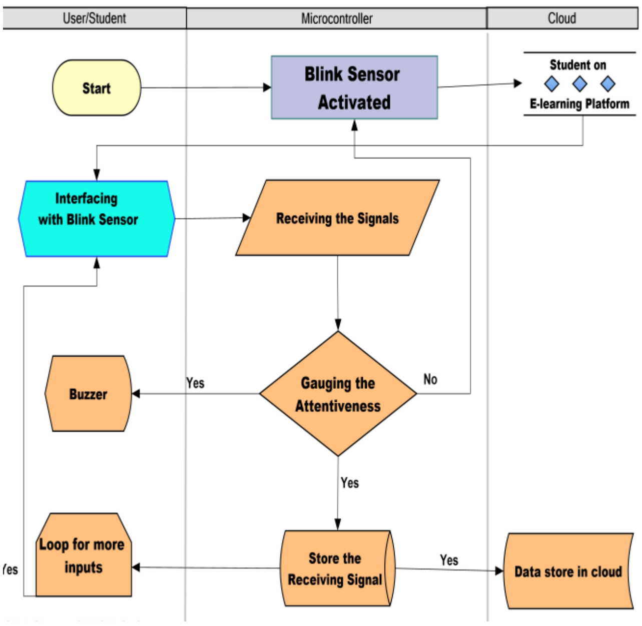

Fig 1: Gauging the attention

IV. COMPONENT DESCRIPTION

The proposed method is comprises of following components:

(a) **NodeMCU Microcontroller:**[7] NodeMCU is a similar microcontroller, which can be connected to the Internet for internet of Things (IoT). NodeMCU is an open source development board of the ESP8266 microcontroller incorporating a wireless transceiver. The NodeMCU hardware and software environment is a complete system for the Internet of Things.

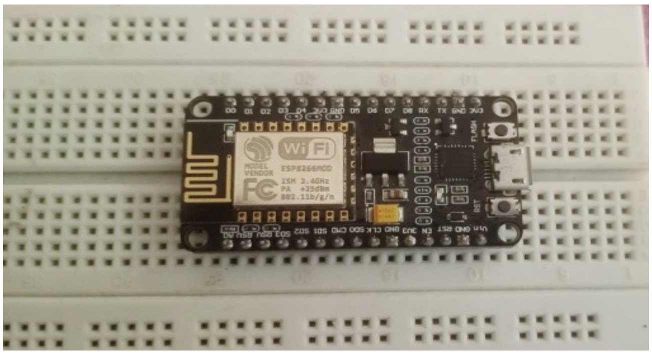

Fig 2: NodeMCU

(b) **Buzzer:** This is a double leg device, and the longer one's positive. If voltage is supplied it generates beep sound. The volume of beep can be controlled via an analogue write. Once the buzzer has been switched on with different time intervals, it generates a melody. This Instructable for NodeMCU is available in the Arduino IDE.

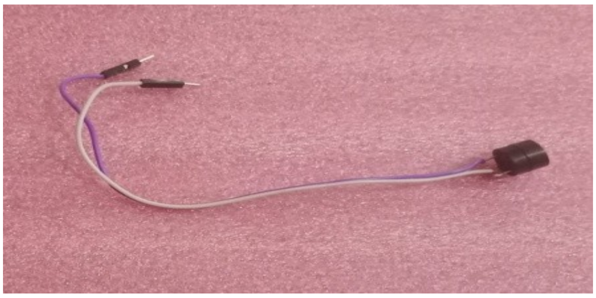

Fig 3: Buzzer

(c) **Eye Blink Sensor with Glasses:**[8] An IR blink sensor with output of 0VngLogic '0' when the eye is open and +5VngLogic '1' if it closes will be used here.

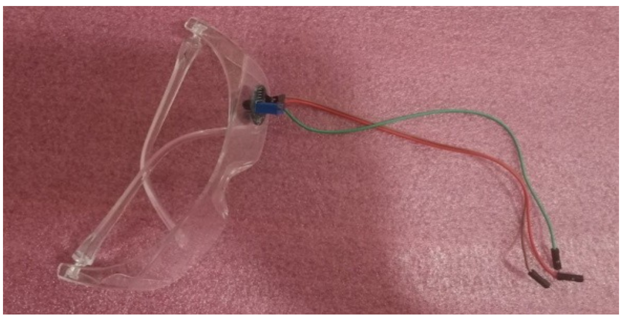

Fig 4: Blink Sensor with Glasses

(d) **Connection Setup**: The blink sensor, buzzer and NodeMCU is connected through the connecting wires using breadboard to perform the initial experiment.

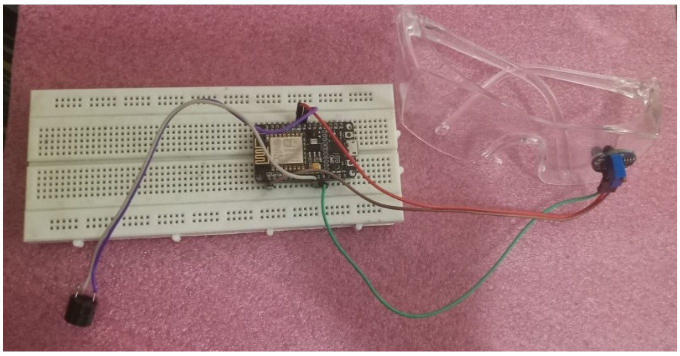

Fig 5: Connection of All Components.

(e) **Installation of Arduino Studio**: [3] Instructions for installing the Arduino SoftwareIDE on Windows are given in this document.

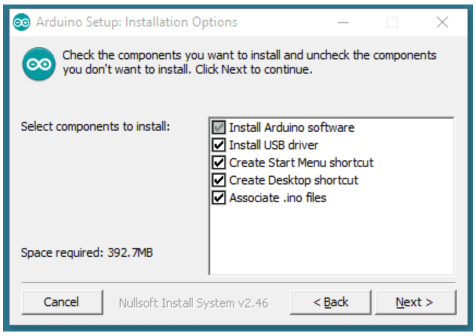

Fig 6: Choose the components to install

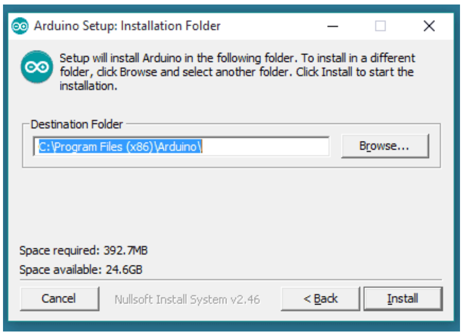

Fig 7: Choose the installation directory.

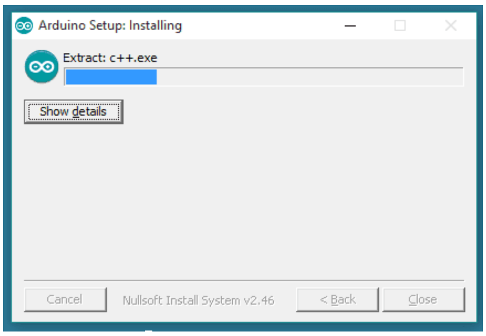

Fig 8: Installation in progress.

(f) **Signup and Login in AdaFruit Cloud**: [9] Explain how to signup and login in AdaFruit IO.

V. EXPERIMENTAL RESULTS

Now, after having the physical setup will perform some of the sophisticated steps to acquire the desire results.

1) User Interaction with E-Learning Platforms:The user interact with any of the E-Learning Platform like Youtube,NPTEL,Courseara,Swayaaam etc.

Fig 9: User Interaction

2) Starting the Setup: Providing the power to the Ardunio board and connected components.

Fig 10: Starting the Setup

3) Collecting the Signals: Input signals will be collecting from the blink sensor through Ardinuo NodeMCU board to the Serial Monitor and AdaFruit Cloud.

A. Active Mode:

If the user is active and concentrating on the E-learning platform then signals will receive as **Active.**

Fig 11: Showing when user is active.

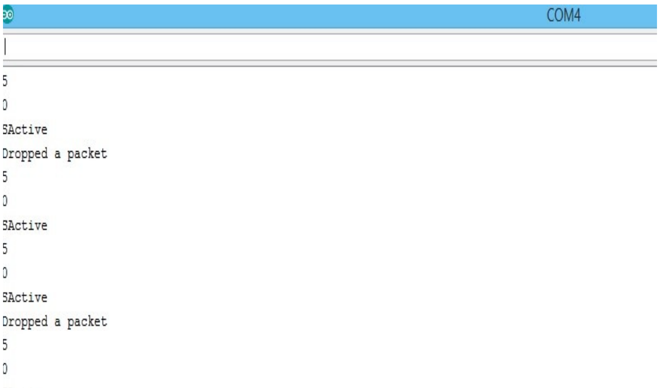

Fig 11: Serial Monitor Output when Active

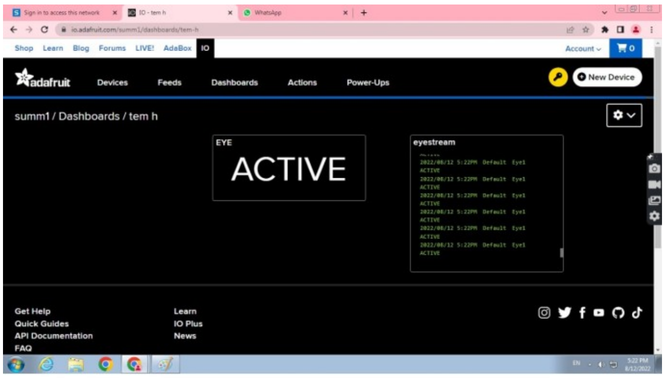

Fig 12: AdaFruit Cloud Output

B. Inert Mode:

If the user is inactive and not concentrating on the E-learning platform then signals will receive as **Inert.**

Fig 13: User Blinks

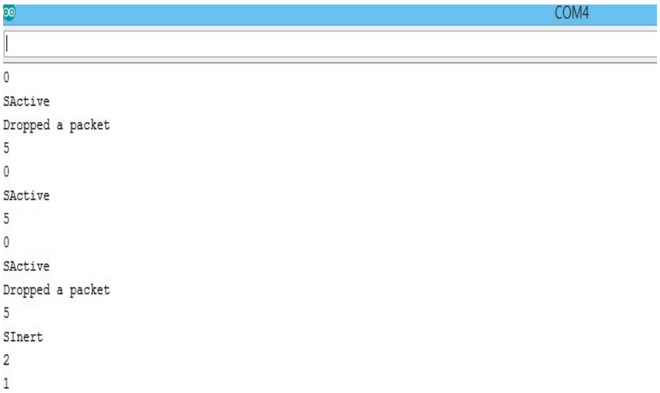

Fig 14: Serial Monitor showing Inert

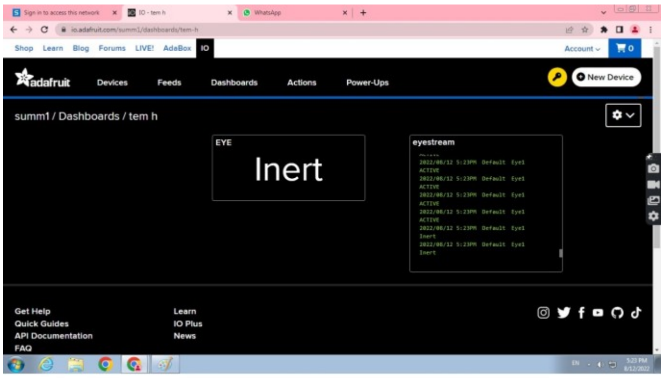

Fig 14: AdaFruit Resulting Inert

C. Depart Mode:

If the user is inactive and not concentrating on the E-learning platform till the threshold reaches then signals will receive as **Depart.**

Fig 15: User crossed fixed Threshold Value

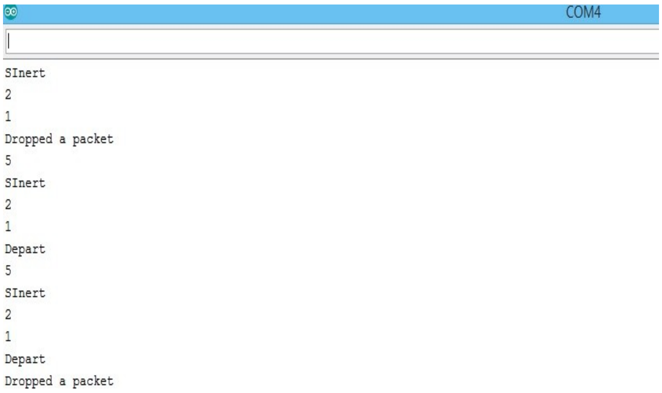

Fig 16: Serial Monitor resulting Depart

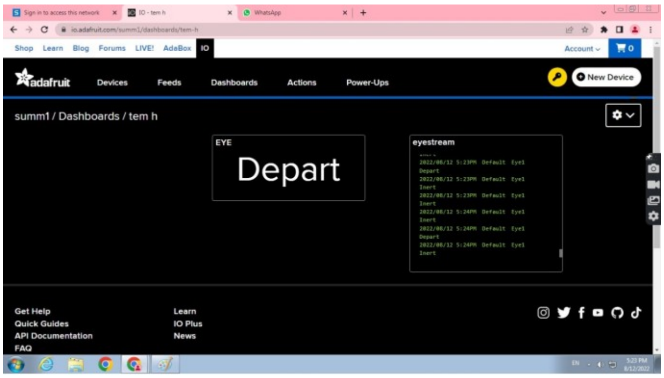

Fig 17: AdaFruit resulting Depart

4) Logical Code :

i. Connecting AdaFruit IO:
Adafruit_MQTT_Client mqtt (&client, AIO_SERVER, AIO_SERVERPORT, AIO_USERNAME, AIO_KEY);
Adafruit_MQTT_Publish Eye1 = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME "/feeds/Eye1");

ii. Resulting Active:
```
if(Read(X))
{
 Serial.println(X);
 Serial.println("SActive");
 //Publish to Adafruit
 Eye1.publish("ACTIVE");}
```

iii.
```
if(X>1)
{
Serial.println(F("SInert"));
 Eye1.publish("Inert");}
```

iv.

v.
```
 if(startTime != 0 && millis() - startTime >= 6000)
 {
 Serial.println("Depart");
 Eye1.publish("Depart");
 }
```

VI. CONCLUSION

The Research provides an automatic method to gauge the attentiveness of the student remotely on an E-learning Platform. The proposed system main components are Blink sensor and Ardunio NodeMCU Microcontroller.

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An optical waveguide as a Refractive Index sensing based on Coupled Cavity using T-stub

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Abstract— **Optical sensor based on the coupled cavity is an interesting topic because these types of sensors have higher sensitivity in comparison to other types of sensors. In this paper, a novel refractive sensor based on a coupled cavity by using T-stub and grating transmission line is suggested. The T-stub interaction with the cavity and coupled line makes two capacitances and the Fano-shape of the transmission appeared. The grating as a slow light structure enhanced the transmission and Q-factor of the proposed coupled waveguide sensor by controlling the phase in the transmission line. The proposed sensor is modified to have dual-band characteristics as a Fano form at 231 and 185 THz respectively and for this aim the T-Stub and the grating structure play the main role. This sensor is used to check the materials with refractive index in the range of 1 to 1.5 and the maximum sensitivity is obtained 1637 nm/RIU. The full wave method of the Finite Integrated Technique as a time domain method is utilized for analyzing this sensor.**

Keywords— coupled cavity; optical sensor; Optical waveguide;Fano shape;

I. INTRODUCTION

The plasmonic characteristic is known as a special behavior of metals in the optical domain [1] and it has been used to develop new optical and subwavelength devices in the nanoscale such as the coupled waveguide [2], absorber, and optical switch [3], nanoantenna [4] and optical gate [5] and these devices have been exerted as an optical sensor [6] for detecting unknown material in the optical spectrum based on the refractive index of materials and the determining the red-shift [7] to calculate the sensitivity [8].

The metal-isolator-metal (MIM) [9] and metal-dielectric-metal (MDM) [10] structures have been utilized enormously in the optical spectrum like the transmission line [11] because the energy can be concentrated between two metal layers and this behavior has been remarked for electric field enhancement to increase absorption in optical absorber [12] or improve the sensitivity in the optical sensors [13].

Recently, the MIM-coupled waveguide has been used in various forms as an optical sensor. The basic models have a simple form with a single stub [14-15], multiple stubs for Fano response [16], and the grating structures as a multi-band filter [17]. For obtaining a sharp Fano response more complicated models have been suggested including a metal-insulator-metal waveguide coupled with a disk and a ring cavity [18], stub and groove resonator coupled [19], multiple-ring shaped [20], the circular cavity optimized by a metallic nanodisk [21], dual T-Shaped cavities side-coupled waveguide [22]. Moreover, the filled cavities with other materials such as DNA [23] and Kerr [24] as reconfigurable structures or filled with silicon for increasing coupling have been presented [25].

In this paper, a MIM cavity coupled waveguide is presented as an optical sensor and T-stub and grating transmission line are used to make dual-band (Fano response) characteristics. The grating works as a slow light structure and controls field distribution and amends the response of the coupling waveguide. This structure is used as an optical sensor and in section II, the background theories about coupled transmission lines and design process are presented and the fabrication process theoretically is discussed. In this section details on the simulation method and boundary condition are given. Section III contains the simulation results and discussions, in this section; the sensing quality of this optical waveguide is examined. The sensitivity of the proposed sensor was calculated and compared with previous structures.

II. BACKGROUND THEORY AND DESIGN PROCESS

The coupled-cavity structures have been studied with various types of stubs to have Fano response based on surface Plasmon Polaritons (SPPs) that are excited in the interface of the waveguide and the air as dielectric [31]. The effective refractive index (n_{eff}) can be described for the SPP mode by Eq. 1:

$$n_{eff} = \beta / k_0 = \varepsilon_m \varepsilon_{in} / (\varepsilon_m + \varepsilon_{in})^2 \quad (1)$$

Here, the β is the propagation constant, and metal and insulator permittivities are denoted by ε_m and ε_{in}, respectively. Typically, the εin for the cavity structure is "1" as the air is filled the gaps of the cavity and k_0 is the free space wavenumber. The dispersion relation of the coupled cavity can be obtained by Eq. 2 [32] :

$$\tanh\left(k_0 \frac{d}{2}\right) = -\frac{k_m \varepsilon_0}{k_0 \varepsilon_m} \quad (2)$$

The km and k0 can be obtained by the $k_m^2 = \beta^2 - k_0^2 \varepsilon_m$ and $k_0^2 = \beta^2 - k_0^2 \varepsilon_m$ .The Transmission lines as stubs play an important role in this type of cavity to provide multi-band and Fano response [2]. The microwave transmission line principles have been considered for developing the coupled cavity waveguide based on the stub techniques. The Z_{MIM} has described the impedance of the basic transmission line and it can be obtained by dividing the electrical in the Y-direction with the magnetic field in the Z-direction as described by Eq.3 the design parameters are: $\beta(h)$ as SPP propagation constant, the η as wave impedance in a vacuum, ε_1 as relative permittivity of the dielectric, and $k = 2\pi / \lambda$ [2] and the h is the height of the transmission line.

$$Z_{MIM}(h) = \frac{E_y}{H_z} = \frac{\beta(h)\,\mathrm{h}\,\eta}{k\varepsilon_1} \quad (3)$$

The Z_S is the impedance of the stubs line as presented by Eq.4.

$$Z_S(w) = \frac{\beta(w)w}{\omega \varepsilon_0 \varepsilon_1} \quad (4)$$

As mentioned above, the MIM waveguide is the same as a microwave transmission line. For the matching circuit, the stub techniques have been suggested and Γ_{in} can obtain by Eq.5 while the Z_L is the required impedance.

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S} \quad (5)$$

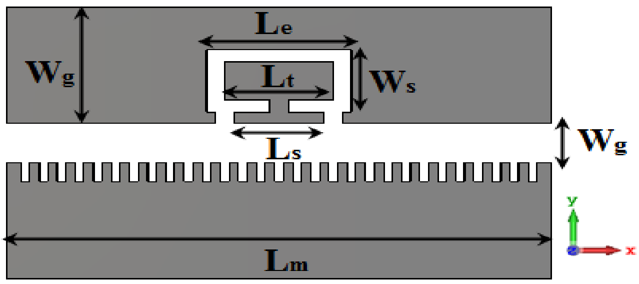
Therefore we can replace the stub line Z_{stub} and we can obtain it by Eq.6 while the Z_S Z_L is achieved from Eq.5 and Eq.6. Finally, based on the transfer matrix [2], it is possible to define the equivalent circuit.

$$Z_{stub} = Z_S \frac{Z_L - iZ_S \tan(\beta l)}{Z_S - iZ_L \tan(\beta l)} \quad (6)$$

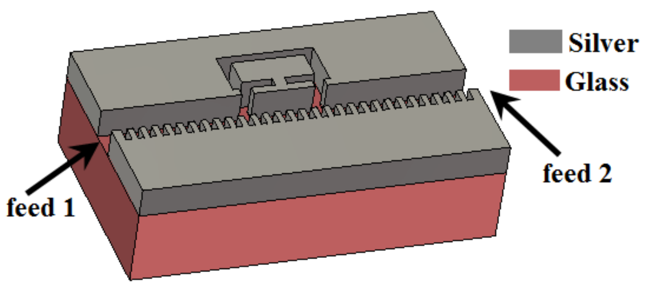
Plus the phase shift can be calculated by Eq. 3 where the k_{spp} ($k_{spp}(\omega) = 2\pi\, n_{eff} / \lambda_0$) is the wavenumber of SPP waves and the effective length of the cavity is l_{eff} [33].

$$\Delta\varphi = k_{spp} \times l_{eff} = 2m\pi \quad (7)$$

The proposed coupled waveguide is presented in Fig.1. The structure contains two main materials of silver Plasmonic material, which is a kind of Nobel metal, and the glass-soda which is transparent material in this wavelength (Fig.1 (b)), photolithography technique can be used for fabrication of this structure. The Palik model is used for the simulation of the silver. The CST microwave studio as commercial full-wave software is used for simulation of the proposed structure and the time domain method of finite integrated technique is applied. The structure contains two main elements for making Fano response. The main element is an H-shape that is placed in the rectangular cavity and this element has two main capacitances as the electric field distribution reveals and these capacitances are making a Fano response of transmission. The second main element is the grating that is added for enhancing the transmission. The grating structure is known at slow light which can impact the phase and group delay and therefore in the waveguide it influences the β. This behavior causes energy to be compressed in the gaps and therefore improves the transmission as our simulation results prove. All dimension of the prototyped sensor are L_m = 1300 nm , W_m = 720 nm , W_g = 700 nm , W_s = 540 nm , L_s = 320 nm , L_t = 125 nm , W_e = 80 nm , t = 80 nm , p = 80 nm .



(a)



(b)

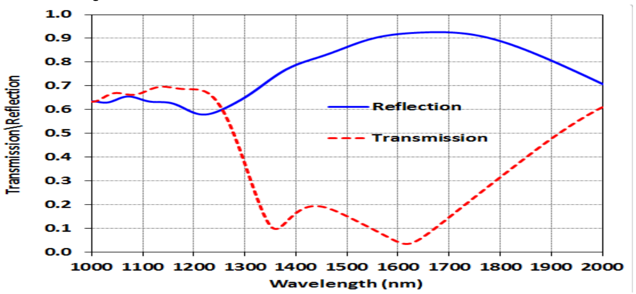
Fig. 1. The geometry of the proposed waveguide (b) The 3D view of the proposed sensor over the transparent substrate and feeding with lasers as feed 1 and feed 2

III. SIMULATION RESULTS AND DISCUSSIONS

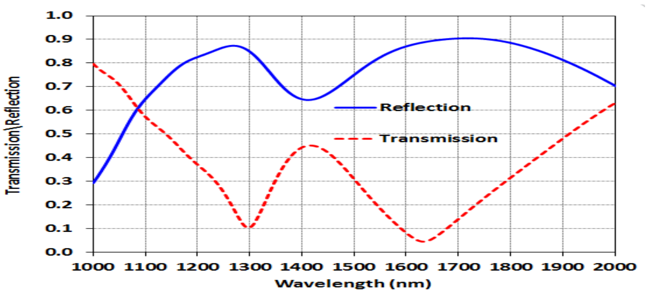
The transmission and reflection of the suggested cavity waveguide are presented in Fig.2. The main element in this cavity is the H-shape element that makes a Fano response as shown in Fig.2 (a), but this response is not too sharp to have higher sensitivity. The sensitivity is a factor based on the dividing of wavelength varying to the refractive index variation. Here the ΔL is the wavelength change for two different materials under test with the refractive index of n_1 and n_2 and Δn is the difference between the refractive index of these two materials. Thus the sensitivity can be shown by Eq.4 :

$$S = \frac{\Delta\lambda}{\Delta n} \tag{8}$$

Thus a grating structure is added to this waveguide as shown in Fig.1 in front of the H-shape element. As shown in Fig.2 (b), the transmission becomes sharp and the value of transmission is reduced which can improve the sensitivity. The basic structure has two resonances at 1360 and 1616 nm with transmission of 0.098 (-20.3 dB) and 0.0338 (-29.4 dB) While for the final structure, the resonances occurred at 1293 and 1632 nm with value of 0.1 (-20 dB) and 0.043 (-27.2 dB). The Q- factor for the resonances can be obtained by $Q-factor = f_0/BW_{3dB}$ and for the basic device, this factor for the first and second resonances are 37.1 and 30.12. By adding the grating to the proposed device, the Q-factor reached 35.6. So, the slow light structure enhanced the Q-factor of the sensor at the second resonance while a reduction in the Q-factor of the first resonance can be seen.



(a)



(b)

Fig. 2. The transmission and reflection of the proposed sensor in the design process (a) For the cavity without grating (b) Adding grating to the transmission line

Therefore, as the phase is changed by adding the grating, the group velocity will be changed or in other words, the β will be changed too. It means that based on Eq.4, the Z_S will have a new value and this behavior provide more matching for the proposed waveguide. The phase response for the proposed sensor with and without grating is presented in Fig.3. The grating influences the phase of the transmission and reduces it between 40º to 120º and in the first resonance, this phase variation is more and made more matching in the proposed sensor.

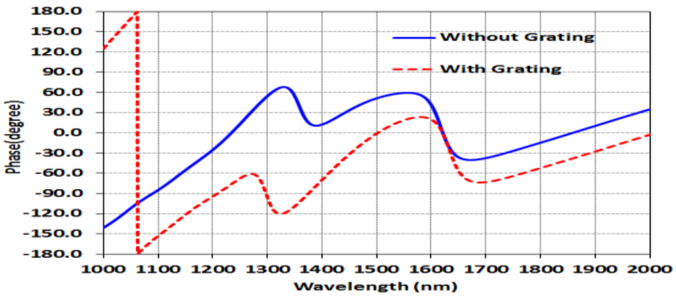
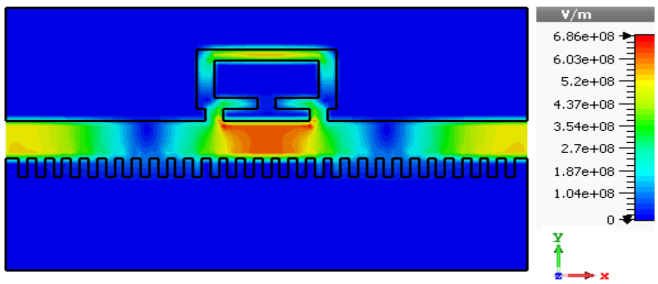


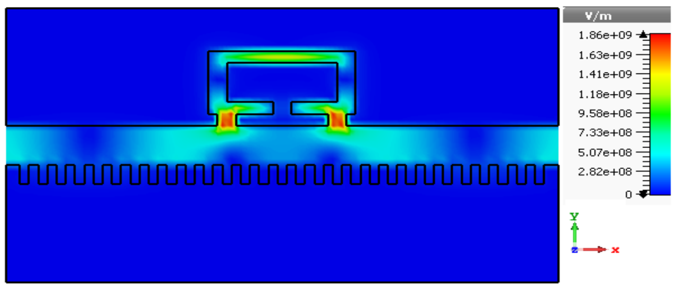
Fig. 3. The phase of transmission for the proposed waveguide with and without grating

The electric field distributions for both resonances are presented in Fig. 4. The electric field distribution proves that the structure has two main capacitances which make the resonances. For the first resonance at 180 THz (1600 nm) as shown in Fig.4 (b), the gaps between stub and grating make the capacitance and the electric field distributed with bright mode and value 6.86e+08 V/m. The second resonance occurs at 230 THz (1300 nm) and the capacitance has appeared

between the stub and the cavity wall with dark mode. The electric field for this resonance is more than the first resonance and it is around 1.86e+09 V/m.



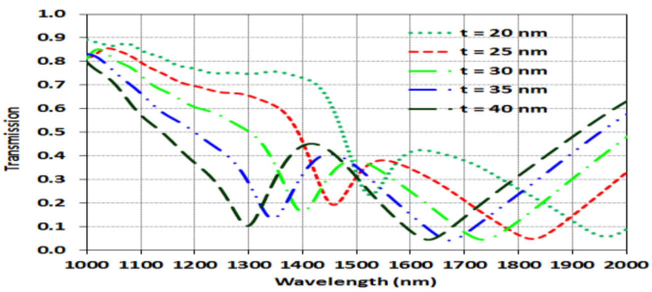
(a)



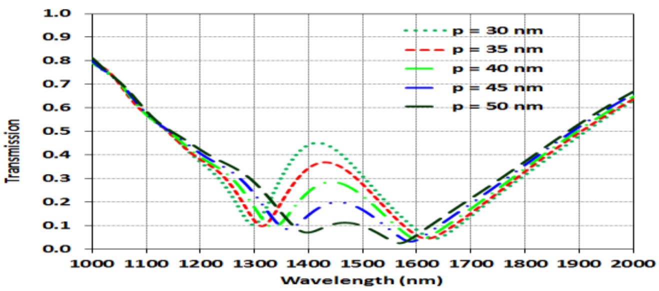
(b)

Fig. 4. The electric field distribution for the proposed sensor (a) The first resonance at 183 THz (1632 nm) (b) The second resonance at 231.5 THz (1297 nm)

As mentioned the gaps are making two capacitances which are important for analyzing the proposed sensor and for realizing the role of these gaps the parametric study is presented in Fig.5. The gaps between the stub and its walls at the edge are checked as the first parameter in Fig.5 (a) is presented. The gaps are checked for the t = 20 to 40 nm. The results show that by increasing these gaps the resonances are shifted to a lower wavelength or in other words it is shifted to a higher frequency. Exactly, the capacitances are reduced by increasing the gap sizes. In addition, the resonances neared to each other, and also for the first resonance transmission value is reduced to 0.1 and the matching is enhanced. The gaps between the stub element and another line can be considered as the second capacitance. This gap is studied as the second parameter in the range of p = 30 nm to 50 nm. This parameter doesn't have any great impact on resonance wavelength but the peak transmission is increased from 0.1 for 50 nm to 0.45 for 30 nm.



(a)



(b)

Fig. 5. The parametric study of the gaps which make capacitances (a) for the gaps of the stub with cavity walls that assigned with "t" for t = 20 nm to 40 nm (a) for the gaps of the stub with the grating that assigned with "p" for p = 30 nm to 50 nm

The sensitivity for both resonances is calculated and presented in Table.1. The sensitivity is obtained based on Eq.3 and the result which are presented in Fig.6 for both f1 and f2. For the first resonance, the wavelength shift is the value of 127.8 to 638.2 and the sensitivity obtained value of 1276 to 1288 nm/RIU and for the second resonance, the wavelength shift is between 163.7 to 806.3 and the sensitivity obtained between 1608 to 1637 nm/RIU. So, the maximum sensitivity of this sensor is 1637 nm/ RIU and it is for the second resonance (f2).

In Table .I, a comparison between this work and some previous studies in this field is presented. The Type of waveguide and technique of design is the main technical design of optical waveguide and the sensitivity to factor for determining the qualification of the sensor.

TABLE I. COMPARISON OF THIS WORK WITH PREVIOUS STRUCTURES

	Type	**Technique of Design**	**Sensitivity (nm/RIU)**
This work	Stub-grating	Slow light	1637
[2]	Stub	Dual stub	1791
[6]	Cavity	Coupled line	6400
[16]	Stub	Dual Stub	1100
[18]	Cavity	Coupled disk	1100
[19]	Stub	Dual stub	1260
[21]	Stub	Cavity -stub	1450

IV. CONCLUSION

In this paper, slow light as a grating is used with the coupled cavity optical waveguide for enhancing the transmission and consequently enhancing the sensitivity of the sensor. As shown in this study, the grating can be used for amending the Fano response by controlling the phase in the transmission line. The main goal of this research is to show the effect of slow wave structure on controlling the resonances and capacitances in a transmission line to enhance the Q-factor. The maximum sensitivity is obtained at 1637 nm/RIU.

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The influence of channel cross-section shape on the self-heating effect of gate-all-around MOSFET

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***Abstract*—In this article, the influence of channel cross-section shape on the self-heating effect of gate-all-around MOSFET has been studied. In this case, the cross-sectional area shape of the channel is rectangular, and the ratio of channel width to channel height T_{Si}/W_{Si} is changed, while the cross-section area of the channel was kept unchanged. It is shown decreasing the channel temperature with increasing the ratio T_{Si}/W_{Si}.**

Keywords—***Self-heating effects, gate-all-around MOSFET, gate oxide, drift-diffusion model, thermal conductivity*.**

I. INTRODUCTION

For the past few decades, the semiconductor industry has been driven by Moore's law [1]. According to Moore's law, the number of transistors, particularly metal-oxide-semiconductor field effect transistors (MOSFET), per chip doubles approximately every two years. This scaling has been dictated by the need for highly-integrated digital circuits to decrease energy consumption. However, the scaling of the device dimensions up to the nanometer scale induces several issues. Among such issues, the impact of the local charges [2, 3, 4], even single charges [5], trapped in gate oxide or at an oxide-semiconductor interface, can considerably change the characteristics of the nanoscale FETs. Variability of the MOSFET geometry also is an important issue that needs to be investigated [6]. The downscaling of device dimensions is achieved at the cost of degraded short channel effects (SCEs) immunity [7-8], which restrains the goal of achieving high performance with smaller power dissipation, especially in Off-state.

Multigate MOS structures provide better control over the channel, among which, Gate-All-Around (GAA) structures are seen as the most competent ones [9 - 11]. They exhibit superb electrostatic control over the channel, are less influenced by short channel effects, and have superior packing density with steep subthreshold characteristics [12-13]. Silicon-nanowire gate-all-around MOSFETs (GAA SNWFETs) have been drawing intensive attention as the MOSFET scaling to the end of the roadmap. Most previously reported GAA SNWFETs have been realized on silicon on an insulator substrate due to their relatively easy realization. Different impacts on the GAA SNWFETs were investigated. Particularly the influence of the doping concentration, nanowire width, and height on electrical and thermal performances was considered [14,15]. Intensive research was done to investigate the short-channel effects of GAA SNWFET [16, 17].

The transistor structure assumes complete surroundings of the channel by an oxide layer, which has small thermal conductivities. Therefore this circumstance can cause a self-heating effect in the channel of the transistor. However, practically there is no research considering the influence of the self-heating effect on the GAA SNWFET, particularly to the transistor with different channel shapes, while it is a very important issue in nanoscale FETs.

In this connection in this work, the self-heating effect of gate-all-around MOSFET with different channel shapes was investigated.

II. SIMULATION CONDITIONS AND TRANSISTOR PARAMETERS

Three-dimensional simulations were carried out based on the Advanced TCAD Sentaurus program package. Drift-diffusion transport model in conjugation with the thermodynamic transport model to account for thermic effects was used in the simulation. In the mobility model, the doping dependence of the mobility, and high field saturation of the carrier velocity were taken into account. To account for quantum effects it is used density gradient quantum correction. 3D structure of the simulated gate-all-around MOSFET is shown in Fig.1.

The gate length L_{gate} of the simulated GAA MOSFETis 22 nm and the gate oxide thickness is 8.46 nm. The thickness of the channel T_{Si} is 11.23 nm. Channel width W_{Si} is 11.3 nm. The doping level of p-Si channel and the source/drain areas was $1\cdot10^{15}$ cm^{-3} and $5\cdot10^{19}$ cm^{-3} respectively The source/drain area length is 30.8 nm. W_{eff} is effective length of channel. W_{eff} is calculated from the following equation

$$W_{eff} = 2(T_{Si}+W_{Si})$$

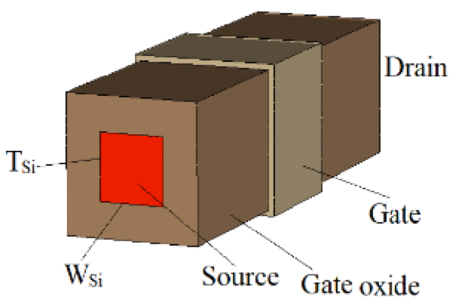

Fig.1. 3D structure of the simulated gate-all-around MOSFET

The parameters used in simulation in this work are listed in Table-1.

TABLE-1. CONSTANT PARAMETER OF DEVICE

Area of device	material	Band gap [eV]	Length [nm]	Width [nm]	Thickness [nm]
Source	Si	1.12	30.8	W_{Si}	T_{Si}
Channel	Si	1.12	22	W_{Si}	T_{Si}
Drain	Si	1.12	30.8	W_{Si}	T_{Si}
Gate oxide	HfO_2	5.9	83.6	W_{Si}+16.92	T_{Si}+16.92
Gate	TiN	-	22	W_{Si}+20.92	T_{Si}+20.92

III. SIMULATION RESULTS AND DISCUSSION

In this work we considered the ratio T_{Si}/W_{Si} as the main parameter which reflects the channel shape of the transistor and we studied transistor characteristics and parameters in dependence on this ratio. In this study it is assumed, that cross-section area of the channel is constant.The results of the simulation of the I_d-V_g dependence on T_{Si}/W_{Si} are shown in Fig. 2. In the figure, it is seen that I_{on} increase with increasing the ratio T_{Si}/W_{Si}. The ratio I_{on}/I_{off} significantly depends on the T_{Si}/W_{Si}: I_{on}/I_{off} is 10^6 and $2.85{\cdot}10^5$ for T_{Si}/W_{Si}=3.85 and 1 respectively.

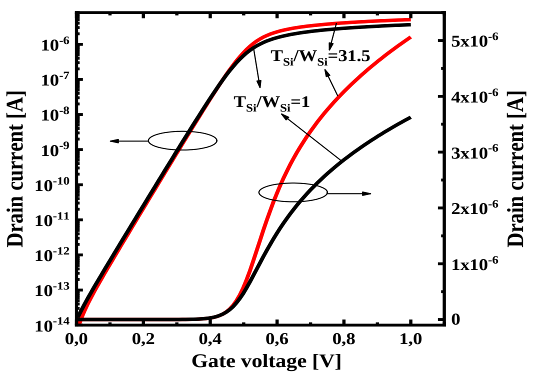

Fig.2. I_d-V_g dependence on T_{Si}/W_{Si}

Increasing the I_{on} is connected with increasing the area under the gate at increasing the T_{Si}/W_{Si} . This mentioned above area can be calculated by multiplying W_{eff} and L_{gate}. In our case. W_{eff} dependence on T_{Si}/W_{Si} ratio is shown in Fig.3. We can see, because of L_{gate} is constant, the mentioned above area is increased with increasing the ratio T_{Si}/W_{Si}.The effect of T_{Si}/W_{Si} ratio on the self-heating effect in the gate-all-around MOSFET was also studied in this work. The obtained results are shown in Fig.4. The Figure shows that the lattice temperature in the center of source area, channel, and drain area of the gate-all-around MOSFET is decreased with increasing the T_{Si} /W_{Si} ratio. This dependence can be explained by the followings: the change of the shape of the cross-sectional surface of the channel, particularly the increasing of the ratio T_{Si} /W_{Si}, leads to an increase in the perimeter under the gate and as a consequence to increasing the area covered by oxide.

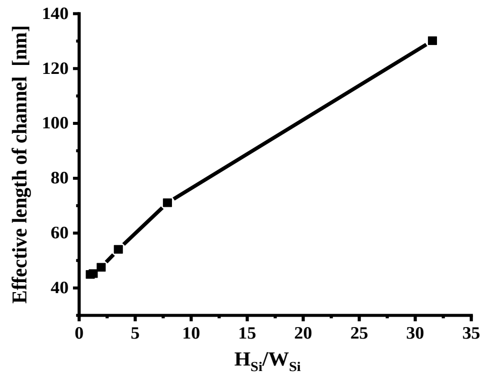

Fig.3. W_{eff} dependence on T_{Si}/W_{Si}

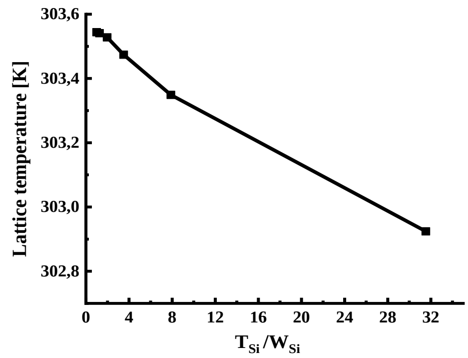

Fig.4. Lattice temperature dependence on T_{Si}/W_{Si}.

This circumstance leads to increasing the heat dissipation rate and decreasing the temperature.

While the drain current is increased with increasing the ratio T/W (Fig.2), the temperature is decreased, obviously, it is connected with a relatively higher heat dissipation rate than the rate of heat generation

IV. CONCLUSION

Results of simulations shows, it is possible to increase the I_{on}/I_{off} ratio and reduce the temperature in the channel of the GAA MOSFET without changing the channel cross-section area by only changing the shape of the cross-section of the channel.

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Research and selection of a cryptosystem algorithm for network protection

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***Abstract*—The publication is devoted to a comparative analysis of existing algorithms of cryptosystems of network protection, where the AES cryptosystem is singled out as the best according to estimates of cryptosystem parameters. A comparative analysis was carried out according to the criteria of cryptosystems. The AES cryptosystem has been studied in the Cryptool 2 environment to determine the cryptographic strength and reliability of its operation. An attack technique has been developed to prove the reliability of the AES cryptosystem. A method for investigating the operation of the AES encryption algorithm using the OpenSSL 1.1.1 program has been developed. In addition, programs have been developed in the C++ and Python programming languages to measure the time of operation of the AES cryptosystem.**

***Keywords*—AES, Cryptool 2, RSA, C++, Python**

I. Introduction

The publication is devoted to a comparative analysis of existing algorithms of cryptosystems of network protection and the choice of the best one according to their characteristics for use in improving network security.

Due to the fact that the development of network technologies is proceeding rapidly, information security specialists should be engaged in finding solutions to protect these technologies. In addition, the protection of data transmitted over networks is also a very important factor.

The publication [1] describes the general concept of network protection of information and that network protection tools exist to protect the confidentiality, integrity and availability of computer networks.

The publication [2] describes how network security and network protection work. Access control helps to limit the movement of intruders inside the network.

The publication [3] is devoted to network security software, such as Firewall (firewall) or network segmentation (that is, network segmentation).

The information in the publication [4] describes the work with cryptographic algorithms, cryptography uses mathematical methods and algorithms to transform messages in such a way that it is difficult to decrypt them.

The publication [5] is devoted to a security model based on confidentiality, integrity and security. The model is the basis of information security, and a recommendation is given that every specialist should familiarize himself with this model.

The publication [6] provides information about what cryptographic algorithms in general are, which is necessary for further work with the choice of a cryptographic algorithm. It is noted that companies engaged in the creation of products are developing cryptographic algorithms and protocols.

The publication [7] provides information about what algorithms exist to ensure information security. According to this publication, there are symmetric and asymmetric cryptosystems.

The publication [8] is devoted to the five most used and most frequently used network protection algorithms, such as DES, TripleDES, RSA, AES and Blowfish, and also provides brief information about what symmetric and asymmetric algorithms are.

The publication [9] contains information about encryption algorithms, their variations, as well as hash functions.

The publication [10] contains information about the comparative analysis between asymmetric and symmetric cryptosystems, as well as how they work.

The publication [11] contains information about which network protection algorithms are used at the present stage, what are their pros and cons.

The publication [12] provides information on the dependence of the protection system against cyber threats and unauthorized access, highlights the following factors: the reliability of keys and the effectiveness of mechanisms, protocols and procedures related to keys.

Based on the results of the analysis of the above works, it can be assumed that the topic: "The choice of a cryptosystem algorithm for network protection and its study" is relevant.

II. Analysis of the Diagram of Symmetric and Asymmetric Encryption Algorithms and Selection of the Criterion of the Best Cryptosystem According to Estimates

The analysis of the values of the criteria of cryptosystems in Figure 1, based on a selection from various sources, shows that the AES cryptosystem is the best according to the criteria, therefore its study is considered in Cryptool 2.

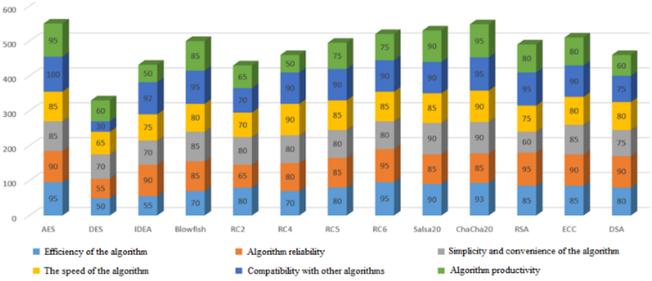

Fig.1. A visual demonstration of the evaluation of cryptosystem criteria

The network was protected on the basis of the OpenSSL program taken from the cryptographic library, which is open source when implementing two protocols: Secure Sockets Layer (SSL) and Transport Layer Security.

OpenSSL is used by almost all network servers to protect the transmitted information. There is an SSL software API (SSLEAY) that allows you to create secure sockets with encryption of transmitted data in your own designs.

SSL uses algorithms to encrypt the transmitted data, which prevents attackers from reading them when transmitting over an encrypted connection. This data includes potentially sensitive information such as names, addresses, credit card numbers and other financial data.

The use of SSL ensures that data transmitted between users and websites or between two systems cannot be read by third parties or systems.

Using the OpenSSL 1.1.1t program, a comparative analysis of the RSA and AES cryptosystems on cryptographic strength was carried out.

III. Evaluation of AES Cryptographic Strength in Comparison with RSA Based on the Cryptool 2 Program

Cryptool is a free and open source software that is designed to implement and analyze cryptographic algorithms.

Using Cryptool, you can create, analyze and test various cryptographic protocols and algorithms, such as ciphers, hash functions, authentications and electronic signatures.

Cryptool is available on various platforms, including Windows, Linux and macOS, and can be used by students, undergraduates, doctoral students and researchers in the field of information security and cryptographic algorithm development.

Figure 3 shows the implementation scheme of the AES cipher using Cryptool 2. To check the security and resistance of the algorithm to attacks, using Cryptool 2, you can attack the AES algorithm.

One of the known attacks is an attack of a known plaintext can be applied to the AES algorithm.

A known plaintext attack is an attack on a cryptographic algorithm in which an attacker gains access to encrypted messages and the corresponding plaintext, i.e. the attacker knows which message corresponds to a specific ciphertext.

Knowing the plaintext and its corresponding ciphertext, an attacker can try to find the encryption key.

To do this, he can use various cryptanalysis methods to extract information from pairs of plaintext and ciphertext and sequentially iterate through the encryption key options until he finds one that gives the ciphertext identical to the target.

To carry out this attack on the AES algorithm, it is necessary to take the text encrypted using the AES algorithm, after which, using the KeySearcher component, try to find the encryption key with which this text was encrypted.

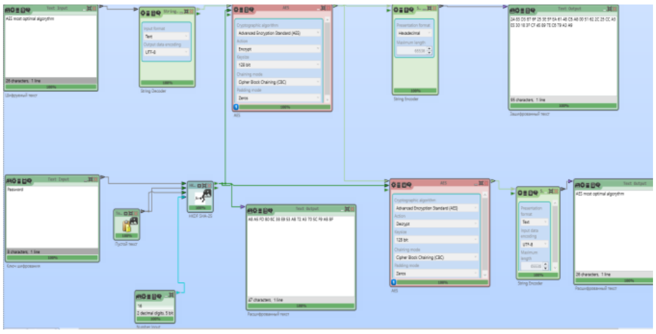

Fig.2. Implementation of the AES encryption algorithm using Cryptool 2

According to the data obtained, shown in Figure 2, the attack on the AES algorithm did not lead to any result. Relying on the KeySearcher data, it can be concluded that the amount of time required to decrypt a message encrypted using the AES algorithm may take a lot of time. This indicates a very high level of security and cryptographic strength of the algorithm.

The AES algorithm has a high level of reliability in comparison with such popular and used algorithms as RSA. If the keys for encryption by the RSA algorithm were chosen incorrectly, that is, without observing all security measures, this algorithm is vulnerable to a common divisor attack.

A common divisor attack on RSA is a cryptanalytic attack that is based on finding a common divisor of two large numbers used in the process of generating RSA keys. If an attacker can find the common divisor of the RSA module and one of the secret keys, then he can use this information to decrypt encrypted messages or to forge signatures.

Fig.3. The developed scheme of the attack on the AES cryptosystem

The implementation of this attack on RSA is shown in Figure 4.

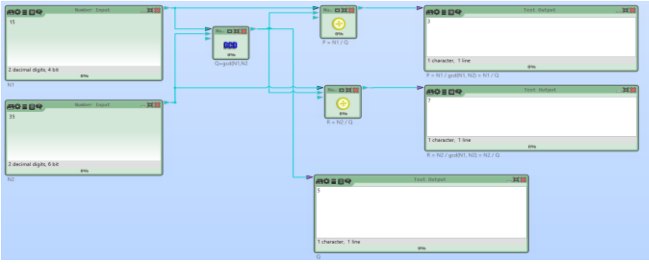

Fig.4. Implementing a common divisor attack on RSA

As a result of this attack, the values used for generating keys and subsequent encryption of messages were obtained. This shows that the cracking of the RSA cipher using Cryptool was carried out successfully.

However, it is worth noting that with the right selection of keys and the choice of large values for key generation, it will be almost impossible to crack the RSA algorithm. Hacking RSA with proper implementation can take longer than hacking AES.

The possibility of implementing and visually demonstrating the capabilities of the AES algorithm using the Cryptool 2 utility without serious requirements for computer computing systems indicates that the AES algorithm is simple and easy to implement and resistant to attacks compared to RSA.

IV. Comparative Analysis of the Operating Time of the Developed Software Implementations in C++ and Python Languages

To prove the speed of the AES cryptosystem, software implementations of the encryption algorithm were developed in two programming languages – in C++ and Python to determine the programming language that solves the problem faster. In addition to encryption and decryption, the time spent on encryption and decryption was calculated in software implementations. The code is written in two different programming languages in order to conduct a comparative analysis of the implementations of the AES algorithm. According to the results of the tests, the result was obtained that the software implementation of the AES cryptosystem in C++ turned out to be faster than the software implementation in Python. The execution time of encryption and decryption using the C++ implementation was 1600 nanoseconds, the execution time of the Python code was 1001.6 microseconds, which is 100 101 nanoseconds. Code written in C++ works faster for the reason that C++ is a compiled language, that is, accessing directly to the processor, and Python is interpreted, that is, before the code is executed, the interpreter must access the processor, which takes extra time.

V. Conclusion

1. The implementation of the AES cryptosystem algorithm in the Cryptool 2 environment has been developed to demonstrate its capabilities, as well as to prove that the choice of AES and the evaluation of its criteria is justified. The reliability of the AES algorithm was proved by conducting an attack on it, which did not lead to any results, that is, the attack failed to capture packets.

2. To prove the high speed, efficiency and performance of the AES algorithm, as well as compatibility with other systems, work was carried out with the OpenSSL cryptographic library version 1.1.1t.

3. The AES algorithm was compared with algorithms such as RSA and during the comparison on cryptographic strength, AES turned out to be better than RSA

4. It should be noted that AES is not the best algorithm for reliability, but at the same time it provides a fairly high level of data protection. The most reliable algorithm is RSA, but it loses to AES in terms of speed.

5. According to the results of the tests, the result was obtained that the software implementation of the AES cryptosystem in C++ turned out to be faster than the software implementation in Python. The execution time of encryption and decryption using the C++ implementation was 1600 nanoseconds, the execution time of the Python code was 1001.6 microseconds, which is 100 101 nanoseconds. Code written in C++ works faster for the reason that C++ is a compiled language, that is, accessing directly to the processor, and Python is interpreted, that is, before the code is executed, the interpreter must access the processor, which takes extra time.

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Stationarity identification using unit root tests

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***Abstract*—Functioning packet trunks are experiencing an ever-increasing load from wired access networks, which in turn are being transformed and becoming more and more optical for connecting terminal devices in the future to one degree or another with built-in artificial intelligence. Numerous studies of the actual measured data in the multiservice network confirm that they are not stationary. The article is devoted to the study of traffic in the network between LAN with IP-PBX Asterisk and ISP using unit root tests.**

Keywords—unit root, traffic, autoregression, non-stationary, single root

I. Introduction

Access networks with the transport core of digital infrastructure, in the future, will allow creating a fully digital, automated and programmable world of interconnected people, machines, things and places [1]. All this leads to heterogeneity of the network traffic structure of the access network, which is in constant development with a wide range of terminal devices and with an increasing number of applications that use the access network to reach the NGN/IMS network backbone through the ISP provider in order to use the exchange of messages, audio, video services.

Review of some foreign articles on this topic:

In [2] "Statistical methods for studying network traffic" it is described that the integration of voice, data and multimedia transmission aroused interest in studying the nature of network traffic and the results of the study showed the presence of a self-similar structure in it, which requires a revision of the results of modeling infocommunication networks under the assumption of a Poisson data flow.

The work [3] "Traffic Measurement and Analysis of a Broadband Wireless Internet Access" presents the results of measurements of Internet traffic in a commercial broadband wireless network for home users. It is noticed that daily traffic fluctuations differ from the corresponding data taken on the highway. It is noted that the total throughput increases in the evening hours, unlike the trunk. At the same time, the increase is mainly caused by web traffic and streaming traffic, which are often used in the evening, and P2P file sharing traffic is used around the clock.

The paper [4] "Towards Fully-Shared Access: Designing ISP Service Plans Leveraging Excess Bandwidth Allocation" discusses the problems in the modern practice of generating Internet provider traffic and corresponding fixed-rate tariff plans in the public access network. Generating subscriber traffic based on a bucket of tokens ISP filtering leads to losses of network resources in public access when there are few active subscribers and therefore cannot allocate extra bandwidth in the long run. Based on new traffic management schemes related to bandwidth, a hybrid ISP traffic management scheme is proposed with the gradual introduction of excess bandwidth in collective access.

In [5] "The Effect of ISP Traffic Shaping on User-Perceived Performances in Broadband Shared Access Networks", Internet provider traffic is considered using models based on user behavior and application/session level metrics that provide quantitative measurements of user-perceived performance for HTTP, FTP and streaming video traffic. The results of the ongoing work can provide ISPs with valuable information about the design, deployment and operation of next-generation access networks from the end-user perspective, especially to control peak speeds and spikes to improve the user-perceived performance of their access services.

The publication [6] "Testing time series data for stationarity" discusses the SAS programming method for analyzing time series data. The Dickey-Fuller criterion is applied in order to check the time series for stationarity. Next, the statistical method of forecasting ARIMA time series is applied.

The main purpose of the article [7] was the application of some statistical tests for the study of hydrological time series. A modified Mann-Kendall model was used. An autocorrelated data test was used to identify the trend. After removing the trend, the authors used "unit root tests" based on both the DF test and the KPSS test. For the completeness of the research, the analysis of residues was carried out, the information criterion Akaike AIC and others were calculated.

In this article [8], the results of KPSS tests and generalized GFL fluctuation tests for the absence of stationarity are considered. The simulation results show that KPSS and GFL tests have the same dimensions and energy characteristics. At the same time, it is concluded that KPSS tests have a greater ability to detect structural changes, and also that a more reliable conclusion about zero stationarity can be obtained by combining information from KPSS and GFL tests.

The article [9] investigated the effect of trend elimination on the properties of the KPSS seasonal test in finite samples. In addition, a Monte Carlo study was conducted to analyze the behavior of the test for a monthly time series. The author managed to identify a number of seasonal roots in the time series.

In [10], various unit root tests are presented, including those that take into account structural gaps in the intersection and/or trend. Threshold tests for a single root have been introduced. Modeling is used to compare unit root tests in different scenarios. The case when the analyzed time series can have stationary and non-stationary segments is also considered.

The study of the appearance of a diverse type and volume of traffic, leading to the appearance of a heterogeneous traffic structure, is an urgent task.

The study of the appearance of a diverse type and volume of traffic, leading to the appearance of a heterogeneous traffic structure is an urgent task. In probability theory and statistics, the unit root is a characteristic of some stochastic processes (for example, random walks).

The unit root test checks whether a time series is stationary and whether it consists of a unit root in time series analysis. A time series has stationarity if a time shift does not cause a change in the shape of the distribution; unit roots are one of the reasons for non-stationarity.

In this paper, three unit root tests will be applied to the time series:

- Augmented Dickey-Fuller Test (ADF-test), which was developed in 1979 by American scientists David Alan Dickey and Wayne Arthur Fuller.
- Kwiatkowski–Phillips–Schmidt–Shin (KPSS-test), developed in 1992 and designed to complement unit root tests such as Dickey-Fuller tests.
- Phillips-Perron Test (PP-test), developed in 1988.

II. STATIONARITY ASSESSMENT USING UNIT ROOT TEST

The empirical data (packet intensity) shown in Figure 1 in the form of a time series were obtained using the Wireshark sniffer program playing the role of capturing packets passing through the network on the subscriber access network segment between the LAN with the installed IP–PBX Asterisk and the ISP provider network, which were investigated in the Matlab Econometrics Toolbox Version 5.7 software environment (R2021b). In just five hours, 7655 packages were tracked. Visually, the uneven arrival of the number of packets is visible. There are places with discharged areas where there are few incoming packets [11].

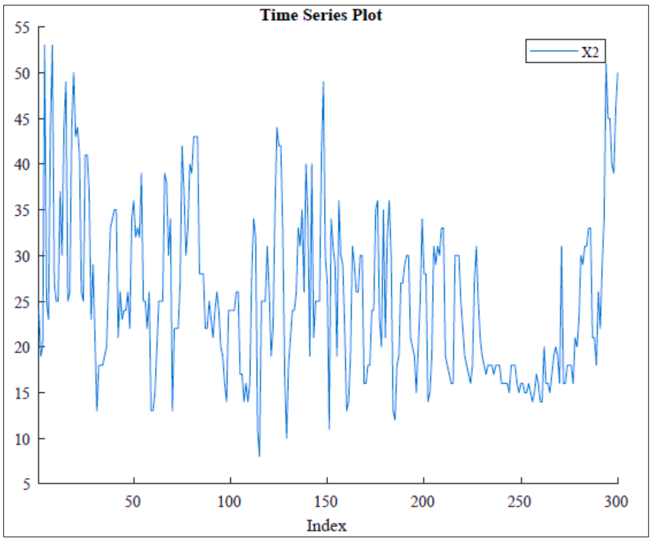

Fig. 1. The intensity of packet arrival on the high-speed backbone of the multiservice network

The concept of a "single root" determines the nature of fluctuations in the system. The system of linear difference equations of the nth order has N roots. If the absolute value of any of them is greater than 1, the system is approaching an "explosion", at least until it meets some restrictions, due to which it will cease to be linear. If all the roots are less than 1 in absolute value, the system will inevitably tend to its initial equilibrium after any temporary deviations. A root equal to 1 in absolute magnitude, or a single root, will cause a steady shift of the system, and a series of violations can cause an infinite deviation from the original position. A large number of methods for statistical verification of the presence of a single root have been developed. An analytical test for a single root can be represented as:

$$y_t = D_t + z_t + \varepsilon_t \tag{1}$$

where y_t – the level of the series at time t.

D_t – deterministic component.

z_t – stochastic component.

ε_t – stationary error process.

The basic concept of the unit root test is to determine whether z_t (stochastic component) consists of a unit root or not.

ADF-test is an extension of the Dickey-Fuller test, which removes autocorrelation from a series and then performs tests similar to the Dickey-Fuller procedure. This test checks the presence of a single root in the time series under study in order to identify the type of stationary or non-stationary series using an auto regression model. At the same time, the null hypothesis H0 corresponds to a series of type DS (Difference Stationary), and the alternative hypothesis corresponds to a series of type TS (Trend Stationary). Both types of series differ by a random part. A trend-stationary process is a stochastic process from which you can remove the underlying trend (a function of time only), leaving the stationary process. In the TS-series, the influence of previous shocks fades over time, and in the DS-series, the accumulated disturbances from all previous shocks do not fade so much and each individual shock affects all subsequent values of the series with the same force.

To explain the Dickey-Fuller test, it is necessary to describe a simple AR (AutoRegression) model [12]:

$$y_t = \rho y_t + u_t \tag{2}$$

where ρ – the coefficient determining the unit root.

u_t – is noise or can be considered as an error.

If ρ = 1, there is a single root in the time series, and the time series is not stationary.

The regression model can be represented as:

$$\Delta y_t = (\rho - 1)y_t + u_t = \delta y_{t-1} + u_t \tag{3}$$

where Δ – difference operator.

$\delta = -\rho - 1$.

Thus, if the time series is non-stationary, it will tend to return an error term or a deterministic trend with time values. If the series is stationary, then it will tend to return only the error term or a deterministic trend. In a stationary time series, a large value is usually followed by a small value, and a small value is usually followed by a large value. And in a non-stationary time series, large and small values will add up with probabilities that do not depend on the current value of the time series.

The ADF test is a statistical significance test, which means that the test will give results in hypothesis tests with null and alternative hypotheses. As a result, we will have a value of p, from which we will need to draw conclusions about the time series, whether it is stationary or not.

In this case, the hypothesis is used:

- H_0: $\phi=1$ – the series is non-stationary: it contains a unit root and is described by a random walk process.
- H_1: $\phi<1$ – defines a time series as a stationary series.

As a result, Matlab gave the information "Null Hypothesis: X2 contains a unit root" (Null hypothesis: X2 contains a unit root), test parameters (Figure 2) and test results (Figure 3).

	Lags	Model	Test Statistic	Significance Level
1	0	AR	t1	0.05

Fig. 2. Test parameters

	Null Rejected	P-Value	Test Statistic	Critical Value
1	true	0.026439	-2.2109	-1.9417

Fig. 3. Test results

To confirm or refute a hypothesis, the lowest value of the significance level (that is, the probability of rejection of a fair hypothesis) is used, the value of p-values. If p–values are greater than 5%, then the null hypothesis is rejected, and, consequently, the series is stationary [13]. Based on the above, it can be seen that the p-value is 0.026439, and the critical value is 0.05. Since the p-value is less than the critical value, it is impossible to reject the hypothesis that the time series under study has the character of a random walk, that is, the series under study is not stationary.

It is described in [14] that for the reliability of the results when analyzing time series for belonging to the class of stationary or non-stationary, it is customary to use not one, but several tests.

To confirm the non-stationarity of the original time series, we will additionally use the KPSS test, which can detect the presence of a random walk in the process, which will lead to systematic deviations from the trend in some parts of the series.

KPSS-test determines whether a time series is stationary relative to an average or linear (deterministic) trend or non-stationary due to a single root [15], and in [16] it is described, KPSS-test differs from ADF-test and PP-test in that it considers the belonging of a time series as a null H0 hypothesis. the trend-stationary TS-series and the alternative hypothesis H1 belonging of the time series to the non-stationary DS-series. The authors of the KPSS test use the statistics of the Lagrange multiplier test (LM statistics).

The following steps are performed:

- regression is evaluated $y_t = \delta + \varphi t + \varepsilon_t$.
- the residuals are calculated $e_1, e_2, ... e_T$.
- auxiliary sums (T pieces) are calculated $S_t = \sum_{m=1}^{T} e_m$.
- calculated value of statistics is calculated $KPSS = \sum_{t=1}^{T} \frac{S_t^2}{\hat{\sigma}^2}$, where $\hat{\sigma}^2$ – estimation of the variance of a random error.
- if the calculated statistic value is less than the critical value equal to 0.146, then the null hypothesis is accepted. It can be concluded that the non-stationarity of the series.

Figures 4 and 5 show the data of the results of checking the Matlab time series using the KPSS test – test parameters and test results.

	Lags	Include Trend	Significance Level
1	0	true	0.05

Fig. 4. Test parameters

	Null Rejected	P-Value	Test Statistic	Critical Value
1	true	0.01	0.35798	0.146

Fig. 5. Test results

In this test, the test-statistical value is 0.35798, which is greater than the critical value of 0.146, that is, under the assumption that the sequence is stationary, an event occurred with a low probability with a probability of 0.01. So, the null hypothesis is incorrect. Thus, it is concluded that the initial sequence is a non-stationary sequence.

The null hypothesis of PP-test is that the variable contains a single root, and the alternative indicates that the variable was generated by a stationary process. At the same time, PP-test uses standard Newey-West errors to account for sequential correlation. PP-test, unlike ADF-test, is based on t-statistics adjusted for possible autocorrelation and heteroscedasticity [17].

Figures 6 and 7 show the data of the test result by the Matlab program of the PP-test time series - test parameters and test results.

	Lags	Model	Test Statistic	Significance Level
1	0	AR	t1	0.05

Fig. 6. Test parameters

	Null Rejected	P-Value	Test Statistic	Critical Value
1	true	0.026439	-2.2109	-1.9417

Fig. 7. Test results

If the p-value is higher than the critical size value, then the zero value cannot be rejected, and the series looks like a single root.

III. Conclusion

The empirical data were tested by three Unit root tests, which rejected the hypothesis that the series is stationary. The evaluation of the stationarity of the ADF test showed that the p-value is 0.026439, and the critical value is 0.05. If the p-value is less than the critical value, then it is impossible to reject the hypothesis that the series under study has the character of a random walk, that is, it is not stationary. As for the KPSS test, the test-statistical value is 0.35798, which is greater than the critical value of 0.146, that is, assuming that the sequence is stationary, an event occurred with a low probability of 0.01. PP-test output the p-value above the critical size value, which indicates the presence of a single root.

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This article was prepared as part of the government contract as requested by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan on the subject formulated as «Development of a method for improving the security of a telecommunications network based on IP-PBX Asterisk» (project No. AP14871745).

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Self-heating effect and subthreshold slope at different oxide materials in 2D MoS_2-based MOSFET

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Abstract- **In this paper self-heating effect (SHE) and subthreshold slope (SS) at different gate and back oxide materials in 2D MoS2-based MOSFET were considered through simulation. In this study, the Al_2O_3 and HfO_2 oxides were selected as gate oxide materials and SiO_2 and HfO_2 as back oxide (BOX) materials. The lattice temperature in the channel center and SS dependences on the gate length were considered at different gate oxide, BOX materials, and their combinations. It is shown that using Al_2O_3 as gate oxide material and SiO_2 as BOX material result in relatively low SS, and using HfO_2 as gate oxide as well as BOX material results in high immune against SHE**

Keywords—2D MoS_2, self-heating effect, subthreshold slope, MOSFET, lattice temperature.

I. Introduction

Decreasing the sizes of metal-oxide-semiconductor field effect transistors (MOSFET) up to the nanoscale induces different degradation effects such as the impact of variability [1], the effect of injection of the local charges to the oxide layer and at the interface [2, 3, 4], short channel effects [5, 6, 7]. It considerably restricts the continuation of the scaling of MOSFETs. Therefore different ways to avoid this restriction are suggested. One of the popular suggestions is the use of two-dimensional materials as a channel material in MOSFET. Two-dimensional molybdenum disulfide (MoS_2) is well known as a transition metal dichalcogenide which is suggested to using in MOSFET [8, 9, 10]. A two-dimensional channel in 2D MOSFET is surrounded by oxide materials: top by gate oxide and bottom by back oxide. Oxide materials have low thermal conductivity, therefore it results in arising SHE in 2D MoS_2-based MOSFET. SHE has an essential effect on nanoscale tri-gate SOI FinFETs [11, 12, 13], as well as on the drain current of 2D material-based MOSFET [14, 15].

It is known, SHE mainly is defined by thermal conductivity, while SS is defined by the dielectric constant of oxide materials surrounding the channel [16]. The thermal conductivity and dielectric constant are not connected to each other directly, therefore it needs to define an optimal combination of gate oxide and BOX material which results in low SHE as well as SS.

From this point of view, in this work, the SHE and SS dependence on oxide materials such as Al_2O_3, HfO_2, and SiO_2 and their combinations are studied by simulation. SiO_2 material as gate oxide is not considered in this study because it has a small dielectric constant.

II. SIMULATION CONDITIONS AND TRANSISTOR PARAMETERS

TCAD Sentaurus program was used in the simulation. MoS_2 material is not included in the list of materials in this program, therefore the method for simulation developed in the [9] and applied in [14, 15] is used in this work. For consideration of the self-heating effect, the thermodynamic transport model is included in conjugation with the drift-diffusion transport model.

The structure of the considered 2D MOSFET is shown in Figure 1. The thickness of the transistor channel is 0.65nm. Transistor length L depending on gate length Lg is in the range from 60nm to 300nm and the ratio L/Lg =3. The thickness of the aluminum gate is 2nm and the considered lengths is 20nm, 30nm, 50nm, and 100nm. The carrier mobility in the channel depends on the gate oxide material, therefore the used mobility in the case of Al_2O_3 as gate oxide is 125 cm^2/Vs [9] and in the case of HfO_2 is 320 cm^2/Vs [17].

Four different combinations of using the oxide materials as a gate oxide and back oxide were considered (Table 1). In this combination, the equivalent thickness of gate oxide is 1nm. Using SiO_2 with a thickness of 1nm as gate oxide results in arising a leakage current between the gate and channel. Therefore SiO_2 is not considered as a gate oxide material in the mentioned above combinations.

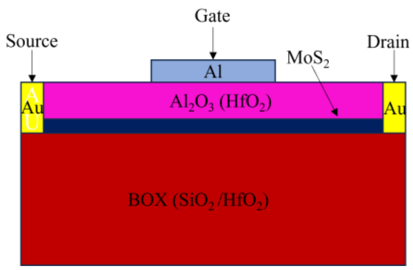

Fig.1. The structure of the simulated 2D MoS_2-based MOSFET.

Besides analysis of the literature show that Al_2O_3 is not used as a back oxide material, therefore we also have not considered this oxide as BOX material.

The thickness of BOX considerably influences the temperature in the channel [18]. Increasing the thickness of the BOX results in increasing the temperature. The thickness of BOX considerably influences the temperature in the channel [18]. Increasing the thickness of the BOX results in increasing the temperature. Therefore we have chosen the BOX thickness t_{box}=80nm as in the [19].

TABLE I. COMBINATIONS OF THE MATERIALS FOR GATE OXIDE AND BACK OXIDE

The number of combination	**Gate oxide material**	**BOX material**
1	Al_2O_3	SiO_2
2	HfO_2	SiO_2
3	Al_2O_3	HfO_2
4	HfO_2	HfO_2

III. RESULTS OF SIMULATIONS AND DISCUSSION

A. *SHE at different combinations of the gate oxide and the back oxide materials*

SHE is defined by the temperature in the channel. The temperature in the channel depends on the heat generation as well as the heat dissipation rates. For providing the same heat generation rates, in all considered cases, the applied voltages and geometries of the transistor structures were the same. Therefore the difference in the channel temperature for the different oxide materials combinations is defined only by the heat dissipation rate

The dependence of the temperature in the middle of the channel on the gate length for the different combinations of the oxide materials in 2D MoS_2-based MOSFET is shown in Figure 2. The temperatures are defined for gate and drain voltage V_g=0,1V and V_d=0,4V respectively. It is seen in the figure, that the temperature is increased with decreasing the gate length. At the same drain voltages for the longer channel transistors drain current is lower because of higher channel resistance. Therefore for the transistors with shorter channels, the temperature in the channel middle is higher.

Besides it is also seen the lattice temperature dependence on the oxide materials. For the transistor with a gate length 20nm, the temperature is higher for the 1st and 2nd combinations with respect to the 3-rd and 4-th combinations. It can be explained by using as BOX material SiO_2, with relatively low thermal conductivity, in the 1-st and 2-nd combinations, and HfO_2, with higher thermal conductivity (1.5 times higher), in the 3-rd and 4-th combinations.

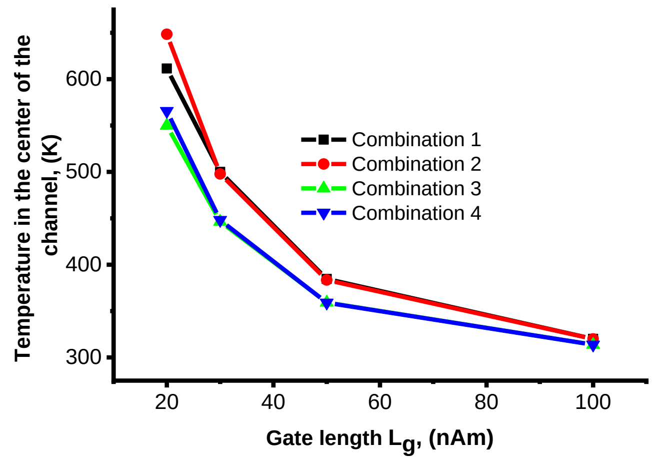

Fig. 2. The dependence of the temperature in the middle of the channel on the gate length for the different combinations of the oxide materials.

The thermal conductivities used in the simulation are shown in Table 2. Obviously, BOX material with respect to the gate oxide material, has the main influence on the lattice temperature. For the first group (1-st and 2-nd combinations) as well as for the second group (3-rd and 4-th combinations) the lattice temperature is higher for 2-nd and 4-th combinations where HfO_2 is used as gate oxide (Fig. 2). Thermal conductivity of HfO_2 less by 5 times in comparing to the thermal conductivity of Al_2O_3 which is used as gate oxide material in 1-st and 3-rd combinations 4125(Table 2). Thermal conductivity for Al_2O_3 and HfO_2 depending on sizes and temperature is in the range 6–30 $W/m \cdot K$ [20–23] and 0,27–4,3 $W/m \cdot K$ [24, 25] respectively.

TABLE II. DIELECTRIC CONSTANTS AND THERMAL CONDUCTIVITIES USED IN THE SIMULATIONS.

Oxide materials	**The thickness of oxide layers (nm)**	**Dielectric constants**	**Thermal conductivities, $W/m \cdot K$**
SiO_2	80	3.9	1.4
Al_2O_3	2.385	9.3	12
HfO_2 (gate oxide)	5.641	25	2.3
HfO_2 (Box)	80	25	2.3

B. *SS at different combinations of the gate oxide and the back oxide materials*

For comparing the effects of the oxides combinations on SHE and SS, the simulation of SS dependence on the gate length has been carried out for all 4 oxide combinations. The influence of the gate and back oxide materials on SS is the result of the dependence of the carrier distribution in the transistor channel on the dielectric constant of oxide materials. The Change of the carrier distribution results in changing of I-V and therefore of the value of SS.

Results of the simulation show a more significant dependence SS on the gate length for the second combinations group (3-rd and 4-th combinations) rather than for the first group (1-st and 2-nd combinations) (Fig. 3). SS is higher for the second group in all range of the gate length. In this group, the dielectric constant of the BOX materials is higher. BOX material HfO_2 is used as BOX material and the dielectric constant for this is $\varepsilon_{HfO_2} = 25$. In the first group, the SiO_2 is used as BOX material, it has a relatively low dielectric constant ($\varepsilon_{SiO_2} = 3.9$) and appropriate low SS. Therefore SS more significantly depends on the dielectric constant of the back oxide material and is higher for the higher dielectric constant of the BOX material. While in the second group, SS dependence on the dielectric constant of the gate oxide is reverse, that is at the same dielectric constant of the back oxides, SS is lower for transistors with gate oxide with a higher dielectric constant. The same dependence is also seen for the first group (1-st and 2-nd combinations) at gate length 30nm and higher.

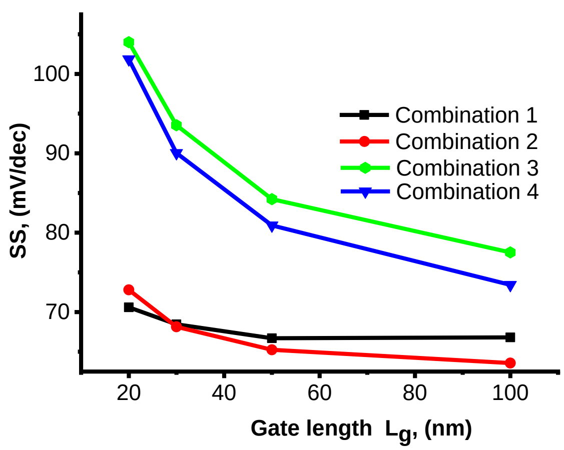

Fig. 3. SS dependence on the gate length for different oxide materials combinations in 2D MoS_2-based MOSFET.

C. Choice of the optimal combination of oxides to increase the immunity against both SS and SHE degradation effects

SHE as well as SS is more significant in short channel transistors, therefore SHE and SS dependences on the combination number are presented in Fig. 4 for the transistor with a gate length of 20 nm. This figure is constructed using the data from the Fig.2 and Fig. 3. It is seen in Fig. 4, that the dependences of the SHE and SS on the number of combinations are different, even is opposite. For the first group of combinations, SHE is high and SS is low, while for the second group SS is high and SHE is low.

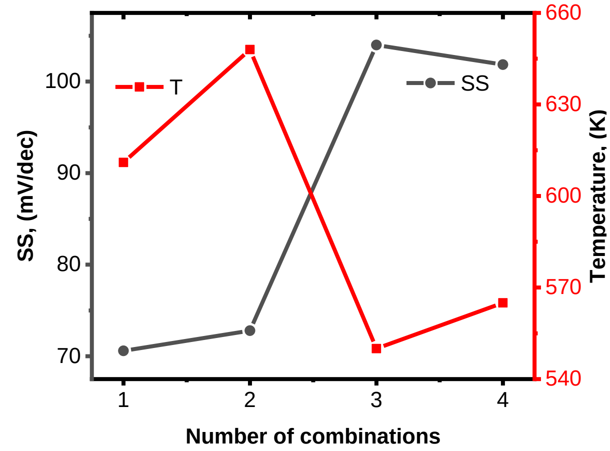

Fig.4.SHE and SS dependence on the combination number oxide materials for 2D MoS2-based MOSFET.

In the Fig. 4 it is seen, for providing possible low SHE as well as SS in 2D MoS_2-based MOSFET it is expediently to use BOX material with dielectric constant in the range from 3.9 to 25 and with thermal conductivity in the range from 1.4 to $2.3 W/m{\cdot}K$.

IV. CONCLUSION

Simulation results show in 2D MoS_2-based MOSFETs the SHE and SS are mainly defined by electrical and thermal properties of the BOX material rather than gate oxide material. Increasing the immunity against SHE as well as SS degradation by choosing the gate oxide and back oxide materials is a problem of optimization

For providing higher immunity against SHE it is expediently to use the second group of combinations of oxide materials and for reaching high immunity against SS degradation is better to use the first group of combinations of oxide materials.

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Analysis of the possibilities of using reflected radiation of ground-based radioelectronic devices from low-orbit Earth satellites

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Abstract—High-speed communication lines are one of the priorities of the developed countries of the world today. The scale of the territory, the cost of construction, the remoteness of many objects and other factors prevents the laying of this type of communication everywhere and create prerequisites for the importance of further development of radio communication systems, both terrestrial and satellite. This article discusses an extensive analysis of the possibilities of building passive radar and space communication systems based on the re-reflection of signals from space objects in near-Earth orbit. The objectives of the article are to conduct a point analysis to derive a preference for the use of reflected radiation of ground-based radio-electronic means from low-orbit Earth satellites.

Keywords—Low-orbit satellites, ground-based electronic means, passive radar, space debris.

I. Introduction

Large territories, diverse landscape, low population density, high cost of construction and operation, as well as many critically important natural and man-made facilities scattered throughout our country, prevent the laying of high-speed fiber-optic communication lines. Considering the above reasons, it is of interest to study the possibility of using space objects located in low Earth orbits as passive repeaters of the radiation of unauthorized ground-based electronic means for subsequent reception of reflected radiation.

The development of space communications today has predetermined a new stage of information transmission. Thanks to the use of satellites, remote and hard-to-reach areas can be connected, and the Earth's surface can be monitored.

It is known that during the period of space exploration, the amount of space debris in near-Earth orbit is also increasing. To date, there are more than 600 thousand objects of space debris larger than 1 cm in the near-Earth space [1].

Unfortunately, there are no effective measures to eliminate and protect spacecraft from space debris. However, objects of non-functioning satellites and their fragments in low orbit can serve as a repeater of the signal of ground-based electronic means.

II. Analysis of the Distribution of Space Objects in Near-Earth Orbits

Reflecting objects of electromagnetic waves emitted by the transmitter are artificial space objects in near-Earth orbit that are capable of scattering or directionally reflecting electromagnetic radiation of the operating frequency range of the communication line.

65 years have passed since the launch of the first spacecraft. More than 7500 space objects have been successfully launched in the world during this time.

Currently, the largest database of space objects contains a catalog of American NORAD services. The NORAD catalog contains the following information: NORAD Number, COSPAR Number, Name, Source, Period, Inclination (in degrees), Apogee (in km), Perigee (in km), Eccentricity, etc.

About 6% of tracked objects are active. About 22% of the facilities have ceased functioning, 17% are spent upper stages and upper stages of launch vehicles, and about 55% are waste, technological elements accompanying launches, and fragments of explosions and fragmentation.

The Union of Concerned Scientists database consists of the following data for active satellites: satellite name, country of operator/owner, operator/owner, users, destination, orbit class, type of orbit, longitude of the geostationary orbit (in degrees), perigee (km), apogee (km), eccentricity, inclination (in degrees), period (in minutes), launch mass (kg), dry mass (kg), power (Watts), launch date, expected service life, contractor (designer), contractor's country, launch pad, launch vehicle, COSPAR number, NORAD number, etc.

According to the American non–governmental organization Union of Concerned Scientists, among 4,852 active satellites in Earth orbit, 2,944 satellites for various purposes belong to the United States, 169 – to Russia, 499 - to China, 1,240 – to the rest of the world.

The distribution of active spacecraft in near–Earth space as of December 12, 2021, was as follows: the number of satellites in low–Earth orbit (LEO), with altitudes from 160 km to 2000 km above the Earth's surface - 4,078, medium-orbital (MEO) satellites, from 2000 km to 35786 km - 141, geostationary (GEO) satellites, the altitude of about 35786 km is 574, the satellite in an elliptical orbit is 59.

To analyze the space objects listed in the NORAD database, it is necessary to determine the height of the large semi-axis, which determines the average distance from the center of the Earth.

By the distribution of space objects by height, it can be found out that the most clogged areas of orbits around the Earth, which are most often used for spacecraft operation. These are Low Earth Orbit (LEO), Medium Earth orbit (MEO), geostationary orbit (GEO). Thus, 90% of near-Earth orbit space objects are located at an altitude of up to 2500 km. The largest number of low-Earth orbit space objects are located at 3 base altitudes: 300 km, 800 km, 1500 km.

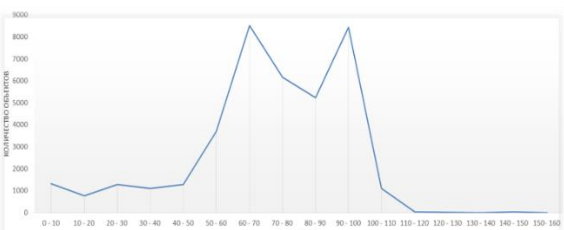


Fig. 1. Distribution of space objects by inclination angle

The orientation of the orbital plane in outer space is determined by the angle of inclination. The inclination of the orbit of a celestial body. According to the results of the analysis of the NORAD catalog, it was found that the inclination angle of 82.2% of space objects in the range of values from 50° to 100° (Fig.1).

One of the 6 Kepler elements of the orbit is the eccentricity, which determines the shape of the orbit. Depending on the magnitude of the eccentricity e, the orbit has the shape of a circle ($e=0$), an ellipse ($0<e<1$) and a parabola ($e>1$). Analysis of the NORAD database showed that the eccentricity of 92.4% of space objects in the range of values from 0 to 0.1.

The reflectivity of space objects is determined by the effective scattering area (ESA). ESA is the area σ of some fictitious flat surface located normally to the direction of the incident plane wave and is an ideal and isotropic re–emitter, which, when placed at the point of the object, creates the same power flux density at the antenna of the radio-electronic means (REM) as the real object. According to the results of the analysis of the Space Track catalog [3], it was revealed that the ESA of more than 33 thousand space objects is less than 0.1 m^2, the ESA of about 6,135 space objects is between 0.1 m^2 and 1 m^2, the ESA of 12,500 space objects is more than 1 m^2.

Analysis of the distribution of artificial space objects in near-Earth orbits, given in the NORAD catalog, shows that more than 35,000 space objects, whose dimensions exceed 10 cm, are located at an altitude of up to 2500 km from the Earth's surface. As reflectors of electromagnetic waves, it is advisable to use space objects at an altitude of 100 km, the number of which is about 7000. The values of the range of reflecting objects can be used 300, 800 and 1500 km as the heights with the largest accumulation of objects. Since most space objects are in orbits with a high inclination from 50° to 100°, the planes of which intersect, the average relative speed of their mutual passage is about 10 km/s.

According to the results of the analysis of the NORAD and Space Track catalogs and the calculations carried out, it was determined that at any given time at least 251 space objects fly over the territory of the Republic of Kazakhstan at an altitude of up to 1500 km. At the same time, more than 60 space objects have an ESA of more than 1 m^2 and of these, more than 30 space objects are located at an altitude of about 300 km. These space objects will be used as reflecting radiation objects in the communication system.

III. Analysis of the Possibilities of Using Reflected Radiation of Ground-Based Radio-Electronic Means from Low-Orbit Earth Satellites

In world practice, there are several projects in the organization of space radio communications using space objects as passive communication repeaters. Early analogues of the proposed passive radio communication system are American projects of the 60s, such as the Echo program, the Westford program and passive radar.

Echo-1 (1960-1968) was developed for research in the use of satellite space repeaters. Due to its considerable size and large windage, it was quickly slowed down in the upper layers of the Earth's atmosphere. Echo-2 (1964-1969) was used in the joint research program on satellite communications of the USSR and the USA.

Project West Ford is an experiment carried out in 1961-1963 by the Lincoln Laboratory of the Massachusetts Institute of Technology commissioned by the US Armed Forces. The belt of needles is an artificial space formation created in near–

Earth orbit from many short pieces of thin metal wire thrown out of the container of an artificial Earth satellite.

The main application is to serve as a passive repeater with non—directional scattering. Two belts of needles at an altitude of about 4000 km, in the equatorial and polar planes, provide communication between any ground points. Each of the needles was a dipole micro antenna and had 1.78 cm in length and 25.4 microns (1961 launch) and 17.8 microns (1963 launch) in diameter. The needles were placed in near-Earth orbit at an altitude between 3,500 and 3,800 kilometers. The first radio communication session via an artificial copper cloud took place on the fourth day after the launch — between the transmitting antenna installed in California and the receiving antenna in Massachusetts.

Spaced radio measuring systems are spaced transmitting and receiving devices. The main elements of the system are the transmitter subsystem, the receiver subsystem, and the observed area of space.

Taking into account the previous experiences of foreign countries, it is proposed to modernize the organization of the space communication system using passive communication repeaters, which currently are a large amount of space debris in near-Earth space. The proposed space communication system will be built based on advanced computing and electronic digital technology, modern methods of encoding, modulating, and processing information will be used. Countries with a large territory, such as Kazakhstan, Russia, and China, do not need expensive communications throughout the country, low-speed communication is allowed in a number of tasks.

IV. Analysis of the Reflectivity of Spase Objects

The primary radio wave induces conduction currents (in a conductor) or displacement currents (in a dielectric) on the surface of objects. These currents are a source of secondary radiation in different directions, i.e., radio waves are scattered. For a limited number of bodies of a relatively simple shape (a half-wave vibrator, a ball, a metal sheet, etc.), an electrodynamic calculation of the secondary radiation field is possible. However, most real space objects have a more complex shape. It is advisable to describe their secondary radiation statistically.

Complex objects can be divided into concentrated and distributed. Concentrated objects include objects whose dimensions are noticeably smaller than the size of the allowed volume of the REM. Examples of such objects are aircraft, spacecraft and ships at long distances from the REM. Note that concentrated objects, in turn, can be divided into single and group objects, consisting of a number of independent single objects (for example, a group of spacecrafts within one allowed volume). Single concentrated objects will be called point objects. Distributed objects include the earth and water surface (surface objects), clouds, rain, snow, fog (volumetric objects), for which the specified ratio of dimensions and resolution elements is not met. They can occupy several allowed volumes.

The reflective properties of objects depend on its size (usually there is a strong dependence on the projection area of the body on a plane perpendicular to the direction of the REM), the configuration, the surface material, the wavelength of the REM, its polarization, the direction of irradiation.

Effective reflecting area of objects (ERA)—this is the area σ_o of some fictitious flat surface located normally to the direction of the incident plane wave and being an ideal and isotropic re-emitter, which, when placed at the point of the object, creates the same power flux density at the REM antenna as the real object. a common expression for ERA:

$$\sigma_o = 4\pi D^2 \left(\frac{E_p^2}{E_o^2}\right). \qquad (1.1)$$

The lobe scattering diagram (SD) of the shadow contour can be interpreted as the radiation pattern of an equivalent flat antenna (Fig.2) oriented normally to the beam axis of the transmitting antenna. The maximum of the main lobe of the shadow field is oriented exactly in the direction of propagation of the plane incident wave emitted by the transmitting antenna.

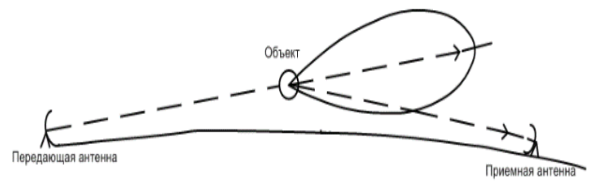
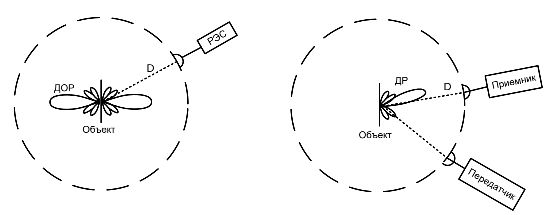


Fig. 2. The main lobe of the shadow contour scattering diagram

The peak of the main lobe of the SD along the direction of propagation of the incident wave can be immense. An essential feature of bistatic forward scattering is that an intense reflected signal can arrive at the receiver even in cases when the "object-receiver" direction corresponds to the side lobes of the shadow field diagram.

The ESA value when the directions from the diffuser coincide with the source of the probing signal and the observation point is called a backscattering diagram (BSD). For experimental determination, the BSD REM is moved around objects and at the same time the field strength of the E_{px} is measured (Fig.3, a). Then the tested object is replaced with a reference (usually shaped like a ball) with a known ERA value of $\sigma_{oэ}$ and the $E_{oэ}$ field strength is determined.



a) b)

Fig. 3. Conditions for the experimental determination of BSD and SD.

In contrast to the considered case of single-position (monostatic) REM, the term ESA (effective scattering area) is more applicable for two-position (bistatic) REM. To remove the SD, you can, for example, fix the transmitter and move the receiver around the circle around the object (Fig.3, b).

The possibility of comparing SD and BSD in some cases is of interest. So, for simple ideally conducting bodies of sufficient smoothness at a small wavelength (strictly speaking, tending to zero) and the transmitter—object—receiver angle β <180°, the SD is equal to the BSD in the direction of the angle bisector β. It follows that the SD does not change if you swap the transmitter and receiver. This theorem is clearly incorrect at angles β ≈ 180° i.e., near the so-called forward scattering (or shadow scattering).

ERA of two-point objects. Several point objects located within the allowed volume form a group object. The simplest model of group objects is two-point.

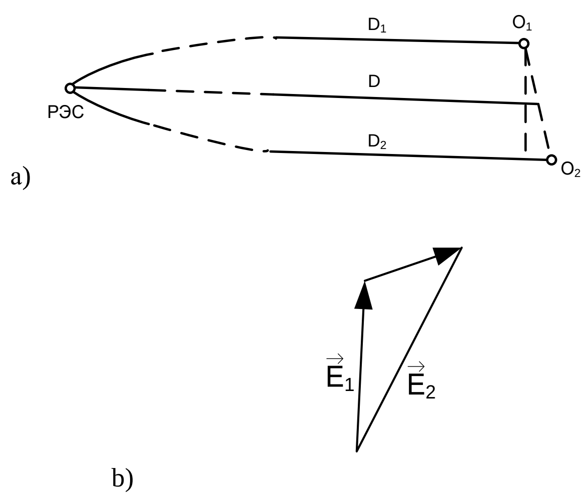


Fig. 4. Determining the ERA of two point objects

It consists of two isotropic reflectors, the distance between which is L, and the distance to the REM is D_1 and D_2 (Fig. 4, a). Such a model correctly describes complex objects containing at least two shiny points. Real objects contain many brilliant points, however, using the example of a two-point model, it is possible to trace the most important patterns that occur when the REM signal is reflected from complex objects.

The secondary radiation fields of each of the reflectors O_1 and O_2 at the REM are characterized in a complex form by the following expressions:

$$E_1 e^{j\omega(t-t_{31})} = E_1 e^{-j\varphi_1} e^{j\omega t},$$
$$E_2 e^{j\omega(t-t_{32})} = E_2 e^{-j\varphi_2} e^{j\omega t}, \qquad (1.2)$$

The fields of individual reflectors at the REM are summed up. The total field is represented as $\dot{E}_p e^{j\omega t}$, where the complex amplitude

$$\dot{E}_p = E_1 e^{-j\varphi_1} + E_2 e^{-j\varphi_2}. \qquad (1.3)$$

Accordingly, the amplitude

$$E_p = \left|E_1 e^{-j\varphi_1} + E_2 e^{-j\varphi_2}\right| = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\varphi_{1,2}} \qquad (1.4)$$

where is the phase difference of the oscillations from the individual reflectors:

$$\varphi_{1,2} = \varphi_1 - \varphi_2 = \frac{2\pi}{\lambda}2(D_2 - D_1) = \frac{4\pi}{\lambda}L\sin\theta \qquad (1.5)$$

A similar result for E_p can be obtained using the formula of an oblique triangle when adding two vectors (Fig. 4, b).

Applying formula (1.1) and assuming that its primary field E_o is the same for both objects, we obtain the ERA of two-point objects

$$\sigma_o = 4\pi D^2 \frac{E_p^2}{E_o^2} = 4\pi D^2\left(\frac{E_1^2}{E_o^2} + \frac{E_2^2}{E_o^2} + 2\frac{E_1}{E_o}\frac{E_2}{E_o}\cos\varphi_{1,2}\right) =$$
$$= \sigma_{o1} + \sigma_{o2} + 2\sqrt{\sigma_{o1}\sigma_{o2}}\cos\varphi_{1,2} \qquad (1.6)$$

In particular, for identical objects, when $\sigma_{o1} = \sigma_{o2} = \sigma_{o0}$, we obtain the following expression for BSD:

$$\sigma_o(\theta) = 2\sigma_{o0}\left[1 + \cos\left(\frac{4\pi L}{\lambda}\sin\theta\right)\right] = 4\sigma_{o0}\,cos^2\left(\frac{2\pi L}{\lambda}\sin\theta\right) \qquad (1.7)$$

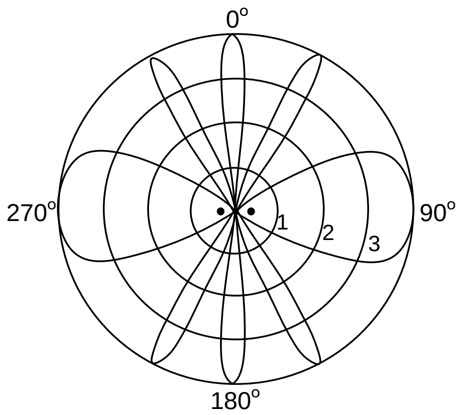
The analysis of the dependence $\sigma_o(\theta)$ shows that it is multi-petal (Fig.5). The zeros of the function $\sigma_o(\theta)$ correspond to the directions where the secondary oscillations of two objects are in antiphase and cancel each other out, and the maximum to the directions of in—phase addition, and the resulting ERA exceeds four times the ERA of each object. The greater the ratio L/λ, the stronger the interference nature of the dependence $\sigma_o(\theta)$ is manifested.

If group objects consist of n reflectors, then the resulting field

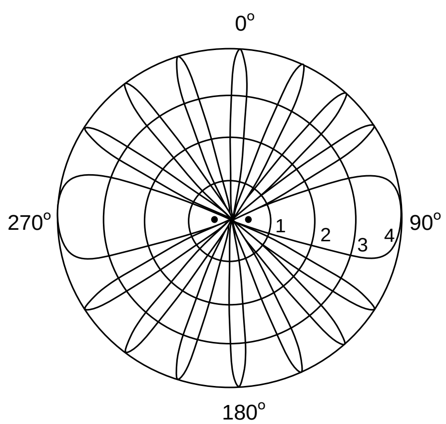
$$E_p = \left|\sum_{k=1}^{n} E_k e^{j\varphi_k}\right|. \qquad (1.8)$$

Small random movements of objects lead to random changes in the phase difference $\varphi_{i,k}$ and, as a result, to significant fluctuations in the amplitudes of the reflected signals. If the phase difference $\varphi_{i,k}$ is equally probable in the range 0–π, then the average value of the cosine $\cos\varphi_{i,k}=0$. Therefore, the average value of the ERA

$$\overline{\sigma_{ц}} = \sum_{i=1}^{n} \sigma_{цi}. \qquad (1.9)$$



a)



b)

Fig. 5. BSD of two-point objects

For n=2, this directly follows from the fact that, for $\varphi_{1,2} = \pi$,:

$$\overline{\sigma_o} = (\sigma_{o\,max} + \sigma_{o\,min}). \quad (1.10)$$

The power of reflected radiation depends on the ESA σ of objects, which depends on the main reflective properties of objects, such as the size of the object (the projection area of the body on a plane perpendicular to the direction of the REM), configuration, surface material, the wavelength of the REM, its polarization, the direction of irradiation. The power of the reflected signal in the receiving antenna is given by the equation:

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 {R_t}^2 {R_r}^2 L} \qquad (1.11)$$

This equation establishes the relationship between the received signal power P_r and the radiation power P_t. From the formula (1.11) it can be seen that with increasing distance to objects, the power of the received signal decreases very quickly-inversely proportional to the 4th degree of range. In this regard, the power of the received signal will be small, and the signal itself is random. The low power of the reflected signal is explained by the large distance to objects in near-Earth orbits and the absorption of signal energy during its propagation.

Using the MATLAB Radar Equation Calculator application, it is possible to determine the required signal strength of the transmitter according to the formula (1.11) (Fig.6). It is necessary to enter data such as wavelength, pulse width, system losses in dB, noise temperature and effective scattering area of objects, gain of transmitting and receiving antennas, signal/interference ratio on the receiving antenna (probability of detection, probability of false alarm, number of pulses) and distance to objects. When performing the calculation for the radio communication system under consideration, the parameters given in Table 1 were used.

TABLE I. SYSTEM PARAMETERS

Parameter	**Value**
Wavelength λ, m	0,9
Pulse width, ms	2,66
System losses L, dB	6
Noise temperature, К	290
ESA of objects $S_{эфо}$, m^2	1,0
Transmitter Amplifier G_t, dB	30
Receiver Amplifier G_r, dB	32
Distance from the transmitter to the objects R_1, km	424
Distance from receiver to objects R_2, km	424
Signal-to-noise ratio at the receiver:	
Probability of detection	0,1
The probability of a false alarm	0,05
Number of impulses	30
Maximum power of the transmitter, W	20

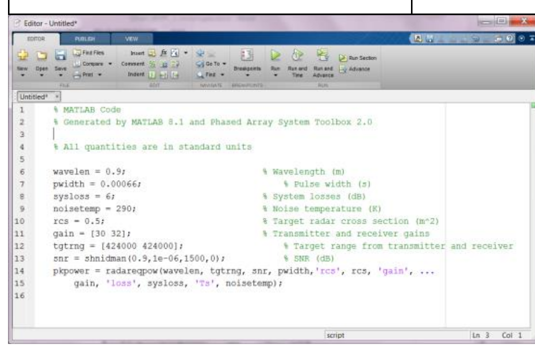


Fig. 6. M-file of the Radar Equation Calculator application

Using the Radar Waveform Analyzer signal analyzer application in MATLAB, it is possible to visualize the real and imaginary parts, magnitude and phase graphs, signal autocorrelation, spectral analysis of the signal, etc. It can also get a calculation of the minimum and maximum range, range resolution, etc. To do this, it needs to specify the following parameters: sampling rate, number of pulses, pulse width, system losses, bandwidth, etc. Figures 7 and 8 show the analyzer of the real and imaginary parts of the signal and the spectral analysis of the signal.

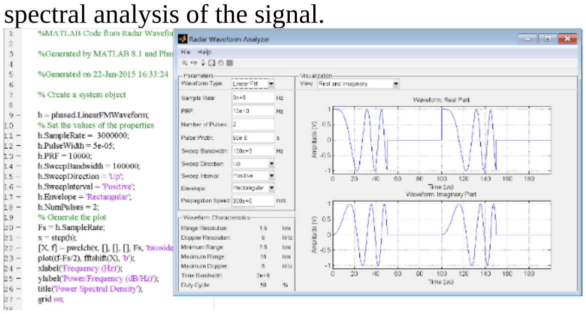


Fig. 7. M-file and analyzer of the real and imaginary part of the signal

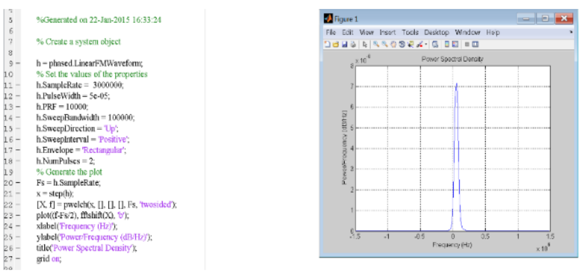


Fig. 8. M-file and signal spectral analysis

To detect and restore a useful signal on the terminal device at a distance of 600 km from the receiver to the transmitter, the power on the transmitter must be large. To reduce the power of the transmitter, one solution is to increase the number of pulse signals. The calculation results are obtained by increasing the number of pulses from 1 to 30. When 30 pulses with a maximum power of 20 watts are accumulated on the receiver, it is possible to receive a useful signal re-reflected from a group of space objects in low Earth orbit at 424 km from the receiver and transmitter. In the example given, the information is transmitted at a speed of 8 bit/s, while the signal level at the receiver will be -17.7 dB.

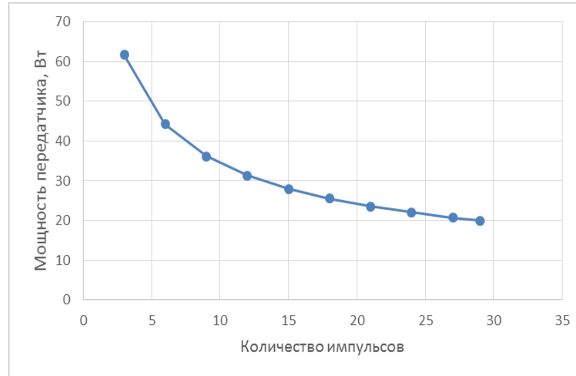


Fig. 9. Graph of the dependence of the transmitter power on the number of pulses

CONCLUSION

As a conclusion, we can say that the use of reflected radiation of ground-based radio-electronic communications from low-orbit idle satellites and their fragments of the Earth has good prospects, since the number of satellite data and its fragments continues to grow. As the study showed, when 30 pulses with a maximum power of 20 watts accumulate on the receiver, it is possible to receive a useful signal re-reflected from a group of space objects in low Earth orbit at 424 km from the receiver and transmitter. In the example given, the information is transmitted at a speed of 8 bit/s, while the signal level at the receiver will be -17.7 dB. It is necessary to evaluate the characteristics of the reflected radiation of radio-electronic means and build a mathematical model on this in order to better derive the expected results from the actual use of these systems.

V. SOURCE OF FINANCING. GRATITUDES

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Synthesis of an optimal control system based on the minimum root-mean-square error criterion

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Abstract—The paper proposes a method and algorithms for the synthesis of discrete controls for continuous linear dynamic objects based on a hybrid application of the topological interpolation approach and the calculusof variations. During the development, the goal was to obtain such a form of a microprocessor controller in order, on the one hand, to take into account the dynamics of the controlled system and, on the other hand, to eliminate the need to include a so-called "observer" in the controller, which restores unobservable variables using the model.

Keywords— regulator, square deviation6, managed systems, microprocessor controller, interpolation approach

INTRODUCTION

The presence of microprocessor-based tools in the control loop requires the development of a highly efficient method and algorithm for synthesizing the controller for optimal control of complexmulti-dimensional dynamic systems. Optimization criteria are formulated taking into account thesampling and control signals and the properties of the control delay. To take into account the dynamics of the controlledмsystem in the development of controlled actions, it is proposed to use deviations of the output variables from the set values and the values of previous control actions. If the minimum square deviation criterion is met, it ensures the existence of a unique solution under nonzero initial conditions. In addition, the goal was to develop the most algorithmic method possible and eliminate the need to enter any formulas during the synthesis of a specific controller.

The solution method

Let there be a dynamical system with m_{t1} inputs and m_{m2} outputs, described by the vector difference equation

$$\vec{X}_{k+1} = C \cdot \vec{X}_k + D \cdot \vec{U}_k , \tag{1}$$

where $\vec{X}_k$ – is the state vector of the system at time k, the dimension of the vector is determined by the structure and complexity of the system; $\vec{U}_k$ – is the control vector, with dimension m; C and D *are* coupling matrices. Control actions are applied to the input of the system with a control period T_u. It is required to find such a sequence of optimal control actions $\vec{U}$,in order to minimize the total squares of deviations of the output processes $\vec{Y}$ from the target over a certain time interval $\overline{Y^{зад}}$. As an optimization interval, we take the time of the transient process of a dynamic system. The criterion includes all squared deviations of the output variables, taken with their own weights at times that are multiples of the control period T_u. Taking into account that in the general case, this value can be relatively large, for better optimization, we will also include in the criterion the squares of deviations of the output variables at intermediate N time intervals at multiples of moments T_u / N.

Thus, taking into account the cost of management as well, we write the optimization criterion in the form:

$$F = \sum_{j_1=1}^{k-1} \left(\sum_{i=1}^{m_2} q_i \sum_{n=1}^{N} \left(Y_{in_1}^{зад} - Y_{in_1} \right)^2 + \sum_{j=1}^{m_1} r_j \cdot U_{jj_1}^2 \right), \tag{2}$$

where $i = \overline{1, m_1}$ – is the input number; $j = \overline{1,(k-1)}$ – the moment when the action is applied; N – the number of points taken into account on the control period; *k is* the number of control intervals T_u on the system transition time; $U_{ij} = U_i(t_0 + (j-1)T)$ – the control action on *the i*–th input; t_0 – the initial moment for which the object state is set; $Y_{in_1} = Y_i(t_0 + (n_1 - 1)T / N)$ – the variable on *the i*-th output of the object; $Y_{in_1}^{зад}$ – the set values of output functions; time *point* n_1 it is determined by the formula $n_1 = N(j_1 - 1) + n + 1$, $n = \overline{1, N}$, $j_1 = \overline{1,(k-1)}$; $(k-1)T$ – optimization period; $T = T_u / N$ – period of accounting for output variables; q_i – weight or significance *of the i*–th output variable; r_j – weight or relative cost *of the j*-th output variable. administrative divisions [1].

Output processes in the system are functions of control actions. The optimal control condition for minimizing criterion (2) is that the following requirements are met::

$$\frac{\partial F}{\partial U_{ij}} = 0; \tag{3}$$

$$\frac{\partial^2 F}{\partial U_{ij}^2} > 0, \quad i = \overline{1, m_1}, \quad j = \overline{1, (k-1)}$$

if boundedin the form of linear equations (1).

To solve this problem, we will use the values of the transition function obtained on the basis of the topological interpolation method [2] of each transmission channel:

$$Y_{in_1} = \sum_{j_2=1}^{m_1} \sum_{i_1=1}^{j_1} h_{i_3}^{ij_2} \cdot U_{j_2 i_2}, \tag{4}$$

where $i = \overline{1, m_2}$ – output number; $i_2 = j_1 - i_1 + 1$ – time instant; j_2 – input number; $h_{i_3}^{ij_2} = h^{ij_2}(t_{i3})$ – value of the transition function over the transmission channel from j_2 input to i output at time $i_3 = N(i_1 - 1) + n$, $t_{i_3} = i_3 \cdot T / N$.

The second partial derivatives of (3) will always be positive, which is ensured by the positivity of the values of the weights q_i, $i = \overline{1, m_2}$ and r_j, and $j = \overline{1, m_1}$. Substituting equation (4) into expression (2), we perform operations of partial differentiation of the criterion *F* with respect to the desired *U* (3.20). After reducing such terms, we obtain a system $m_1(k-1)$ of equations with $m_1(k-1)$ unknowns. *In* matrix form

$$A \cdot U = B, \tag{5}$$

where U – is the vector of all dimension controls $m_1(k-1)$, A – is the matrix of the left-hand side of the system of equations, whose elements are obtained by the formula:

$$\left.\begin{array}{l}
a_{i3j3} = \sum_{i=1}^{m_2} q_i \sum_{j=j_4}^{k-n_1} \sum_{n_2=1}^{N} h_{j_5}^{ij_2} \cdot h_{j_6}^{ij_1}, \text{ где } n = \overline{1, (k-1)},\ n_1 = \overline{1, n},\ j_1 = \overline{1, m_1};\\
j_2 = \begin{cases} \overline{1, m_1}, & \text{при } n \neq n_1; \\ \overline{1, j_1}, & \text{при } n = n_1; \end{cases}\\
i_3 = m_1(n_1 - 1) + j_2; \qquad j_3 = m_1(n-1) + j_1;\\
j_4 = 1 + n - n_1; \quad j_5 = N(j-1) + n_2; \quad j_6 = N(j - n + n_1 - 1) + n_2;\\
a_{ij} = a_{ji}; \quad i = \overline{1, (m_1(k-1) - 1)}; \quad j = \overline{1, (i-1)};\\
a_{ii} = a_{ii} + r_j; \quad i = m_1(i_1 - 1) + j; \quad j = \overline{1, m_1}; \ i_1 = \overline{1, (k-1)}.
\end{array}\right\} \tag{6}$$

In the formation of the symmetric matrix A, discrete values of the object's transition functions h_l^{ij} obtained at a time l multiple T_u/N, $l = \overline{1, N(k-1)}$ for the transmission channels from j – the input, $j = \overline{1, m_1}$, to i – the output, participate $i = \overline{1, m_2}$. The object's transmission channels may have delays greater than the value T_u / N, so the first values of the transition functions will be zero. In order not to obtain a zero determinant from the matrix of coefficients of the left-hand side of the system of equations, it is necessary to analyze all the transition functions and, if necessary, discard the same number $\Delta k \cdot N$ of first moments of the transition functions of each transmission channel so that at least one element of all transmissions in the control interval is not equal to zero. The value will also decrease accordingly *To*. If the system is in zero initial conditions, then the values of the output variables must be adjusted by the required controls for the value of the task $Y_i^{зад}$, $i = \overline{1, m_2}$.

If the system has a non-zero state, then the elements of the right-hand side of the system of equations are determined in accordance with the functions $Y_{i_1}^{kop}$ that need to be corrected *for the i–* output process of free motion $Y_{ij}^{св}$ in the optimized time interval $[t_0, t_0 + j \cdot T_u / N]$ in order to obtain the specified output processes $Y_{ij}^{зад}$:

$$Y_{ij}^{kop} = Y_{ij}^{зад} - Y_{ij}^{св}, \quad i = \overline{1, m_2}, \quad j = \overline{1, N(k-1)}. \tag{7}$$

Output processes are set to discrete values in increments T_u/N $Y_{ij}^{зад} = Y_i^{зад}(t_0 + j \cdot T_u / N)$. Free processes $Y_{ij}^{св} = Y_i^{св}(t_0 + j \cdot T_u / N)$ are defined using transition functions.

Let us express the output processes $Y_{ij}^{св}$ of free motion of the system with self-alignment in terms of the current values of the output variables at the first moment of time Y_{i1} at each output $i = \overline{1, m_2}$

$$Y_{ij}^{св} = Y_{i_1} + \sum_{n_1=1}^{m_1} \sum_{n=1}^{z} \left(h_{j-1+n}^{in_1} - h_n^{in_1}\right) \cdot U_{n_1 n}^{П}, \tag{8}$$

where $U_{n_1 n}^{П}$ – is the control effect stored by the controller on n_1 the output at a time $(-nT_u)$ point relative to the current time point for developing optimal controls; z – the number of control intervals on the transition z = time is an integer (t_{nn}/T_u).

We definethe direct part of the system of equations (5) formed for the synthesis of a controller that generates optimal control as a function of deviations of output variables from the set and previous control actions applied to the controlled system at a given time interval

$$\overline{U_k^0} = E \cdot \overline{e_k} + \sum_{i=1}^{z} G_i \cdot \overline{U_{k-i}}, \tag{9}$$

where $\overline{U_k^0}$ – is the vector of optimal control actions at time *k*; $\overline{e_k}$ – is the vector of deviations of output variables from the set point at the *k* – moment; $\overline{U_{k-1}}$ – is the vector of control actions applied to the system at the elapsed moment $(-jT_u)$ relative to the *k* moment of determining controls; *E* is the *G* –matrix of coefficients of the optimal controller; z – is the number of control parameters taken into account in the controller [3].

This form of controller allows you to fully take into account the dynamics of the controlled system when developing optimal controls and at the same time is very convenient for a micro-machine implementation.

Given the expressions (7-8–8) for obtaining the regulator in the form (9), we obtain the equations for obtaining matrix elements B.

$$B_{i3}=\sum_{i=1}^{m_2}\left(q_i\sum_{j=1+\Delta k}^{k-n_1+\Delta k}\sum_{n_2=1}^{N}h_{j_5}^{ij_2}\left(Y_{ij_6}^{зад}-Y_{i_1}\right)\right)- \qquad (10)$$

$$-\sum_{n_3=1}^{z}\sum_{j_1=1}^{m_1}\left(\sum_{i=1}^{m_2}q_i\sum_{j=1+\Delta k}^{k-n_1+\Delta k}h_{j_5}^{ij_2}\left(h_{n_5}^{ij_2}-h_{n_4}^{ij_1}\right)\cdot U_{j_1 n_3}^{\Pi}\right);\ \ n_1=\overline{1,(k-1)};$$

$$j_2=\overline{1,m_1};\ i_3=m_1(n_1-1)+j_2;\ j_5=N(j-1)+n_2;\ n_4=N\cdot n_3;$$
$$j_6=N(j+n_1-2+n_3)+n_1+1;\ \ n_5=N(j+n_1-2+n_3)+n_2.$$

The controls satisfying the system of $m_1(k-1)$ linear equations obtained in this way are optimal in the sense of minimizing criterion (2). You need to find the first m_1 unknowns that correspond to the controls $U_{ij},\ i=\overline{1,m_1}$. To do this, we will get rid of all variables in the system of equations, except for the first one, by one exception in succession, starting from the last one. As a result, we obtain the first control for the first input of the system in the left part of the system of equations and the expression in the right part in accordance with the form (10). Then, moving in reverse order, we pass to the system with the first two unknowns, substitute the found expression for the first input control into one of the equations, and find the second one [4] [5]. And so on, until all m_1 the input controls for the first time point are known. The program implementation of formulas (6), (10) is difficult and difficult to implement, since they involve a three-dimensional matrix *h*. To facilitate the solution of this problem, we propose the following form of matrix representation *A* and vector *B:*

$$A(i,j)=\begin{cases} i-k_1=j-k_2; & \sum_{s=1}^{m_5k-j+1}h_{m_3,s}h_{d^2,s};\\ i-k_1>j-k_2\ \text{ и }\ j>k_2; & \sum_{s=1}^{k-i+1+k_1}h_{d^2,s}h_{m_3,s+m_4};\\ \sum_{s=1}^{m_5k-j+1}h_{m_3,s}h_{d^2,s+m_4}, & \end{cases}$$

$$B(i,j)=\sum_{s=1}^{k-i+1}Yd_{s+1}h_{d^2,s},$$

where

$$k_1=k(d-1);\ \ k_2=k(m_5-1);\ \ m_4=\left|j-i+k_1-k_2\right|;\ \ d=1,m_1$$
$$m_5=h_9+1;m_3=d+m_1h_9;h_9=(j-1)/k;i=1,k\cdot m_1;j=1,k\cdot m_1.$$

The analysis of the obtained results showed the adequacy of solutions, but the latter differs in convenience and speed [6].

The proposed method is also applicable for one-dimensional objects. In this case, the problem statement is formulated as follows:

it is required to determine piecewise constant control actions *U* applied to the input of an object with a constant specified period *T*, in order to minimize the total quadratic quality criterion:

$$F=\sum_{s=1}^{k}(Y_i-Y^{зад})^2\rightarrow\min, \qquad (11)$$

where $U_i=U((i-1)T)$ are the desired discrete values of the control step actions;

$Y_i=Y((i-1)T)$ discrete values of the controlled variable of the object; $Y^{зад}$ – set value of the output variable; k – the number of control periods in the optimization interval. The optimization interval is sufficient to take no more than the time of the transition process of the t_m control object.

Let's consider the processes at zero initial states of an object. In this case, the output variable is defined by the formula

$$Y_i=\sum_{j=1}^{i-1}h_jU_{i-j}, \qquad (12)$$

where $h_j=h(jT)$ – is the moment of the object's transition function.

Let's solve the problem using the least squares method. In the optimization interval, we have unknown values of the control actions $U_i.(k-1)$ неизвестных значений управляющих воздействий U_i Accordingly, differentiating the quality functional *F* with respect to each of the unknowns, we obtain a system of equations:

$$\frac{dF}{dU_i}=0,\ \ i=1,\ (k-1) \qquad (13)$$

This condition is met:

$$\frac{d^2F}{dU_i^2}>0, i=1,(k-1) \qquad (14)$$

Substituting equation (3.29) into (3.31) and expanding it, we obtain:

$$F=(h_1U_1-Y^{зад})^2+(h_1U_2+h_2U_1-Y^{зад})^2+.....+\left(\sum_{j=1}^{k-1}h_jU_{k-j}-Y^{зад}\right)^2 \qquad (15)$$

Performing the operations of difference the criterion *F* by the initial variables U_t – after reducing such terms , we obtain the following system of equations:

$$\left.\begin{aligned} &U_1\sum_1^{k-1}h_i^2+U_2\sum_1^{k-2}h_ih_{i+1}+U_3\sum_1^{k-3}h_ih_{i+2}+.....+U_{k-3}\sum_1^{3}h_ih_{i+k-4}+\\ &+U_{k-2}\sum_1^{2}h_ih_{i+k-3}+U_{k-1}h_ih_{k-1}=Y^{зад}\sum_1^{k-1}h_i;\\ &U_1\sum_1^{k-1}h_ih_{i=1}+U_2\sum_1^{k-2}h_i^2+U_3\sum_1^{k-3}h_ih_{i=1}+U_4\sum_1^{3}h_ih_{i=2}+......=Y^{зад}\sum_1^{k-2}h_i\\ &U_1\sum_1^{2}h_ih_{i=k-3}+U_2\sum_1^{2}h_ih_{i=k-4}+......+U_{k-3}\sum_1^{k-3}h_ih_{i=1}+....\\ &.....+U_{k-2}\sum_1^{2}h_i^2+U_{k-1}h_ih_2=Y^{зад}\sum_1^{2}h_2;\\ &U_1h_ih_{k-1}+U_2h_ih_{k-2}+.......+U_{k-2}h_1h_2+U_{k-1}h_1^2=Y^{зад}h_1. \end{aligned}\right\} \qquad (16)$$

The analysis of this system shows that the quadraticity of criterion (3) ensures the existence of a unique solution for nonzero initial moments of the transition function.

Having solved the system of equations (16), we obtain stepwise control actions $U_i, i=1,(k-1)$, which are applied with an interval of *If T* is the input of an object with zero initial conditions, we optimize the output process in the sense of criterion (11).

The described approach to control synthesis is convenient because it is enough to have a model of an object in the form of a transition function, which is relatively easy to obtain as a result of conducting active or pseudo-active experiments on the object, or as a result of statistical processing of data collected in a passive way. The developed algorithm is easy to implement in microprocessor-based tools [7].

Example of a solution. The applicability of the proposed algorithm for solving the problem of synthesis of a dynamic object control system with a microcontroller is considered. (fig.1.)

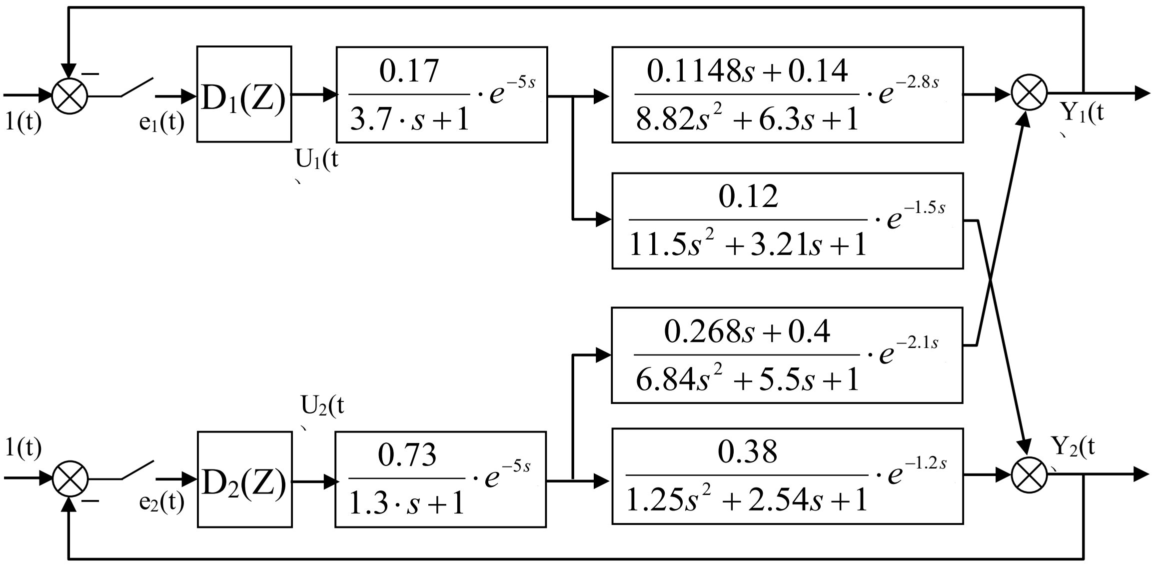


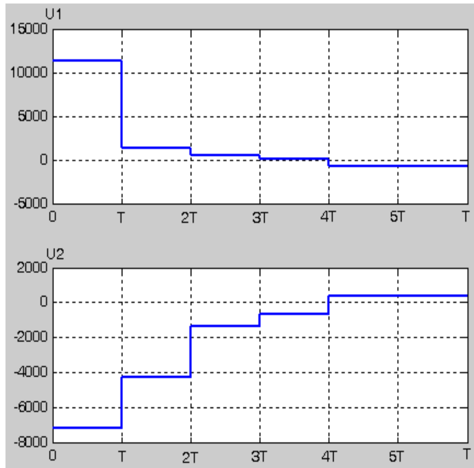
Figure 1. Block diagram of the control system

The block diagram shows that the total order of the transfer function of the transmission channels is 12, which means that the process ends in 6 cycles. In this case, T = 5 seconds [8]. Using the proposed approach, we determine the values of the control signal for each control channel (Table 3.2):

Table 3.2.

Values of the transient process at each control cycle.

	Step number					
	1	2	3	4	5	6
U_1	11300.17	1275.96	482.68	36.88	–773.5	–773.5
Y_1	0	0.0273	0.5308	0.9181	1.0022	0.9999
U_{2}-	–7171.63	– 4318.08	– 1398.82	–658.34	348.57	348.57
Y_2	0	0.7342	1.1962	1.1093	0.9956	1.0001



Based on these data, the transfer functions of the microprocessor controller for each channel are obtained:

$$D_1(Z)=\frac{10.456-2.993z^{-1}}{1+0.00543z^{-1}};$$

$$D_2(Z)=\frac{1.058-0.048z^{-1}}{1+0.007738z^{-1}}.$$

To verify the reliability of the obtained results, a simulation experiment was conducted, the simulation results of which are shown in Fig.2.

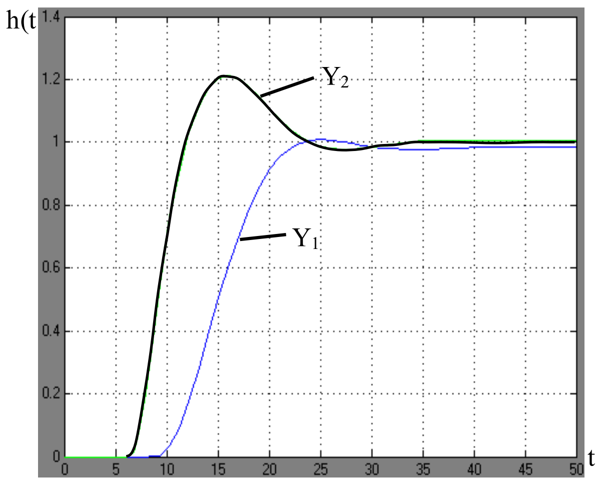


Figure 2. Transient characteristics of the synthesized automatic control system.

The graphs show that the proposed synthesis algorithm gives positive results and ensures high accuracy of controlling amultidimensional object.

Conclusion

A method for synthesizing multidimensional discrete control systems based on the hybrid application of the structural method and the calculus of variations method is proposed. Optimization criteria are formulated taking into account the sampling of control signals and the state delay properties. When developing control actions, it is proposed to use the deviation of output variables from the set values and the values of previously defined control values, taking into account the dynamics of controlled systems. Simulations of the synthesized system have shown a high efficiency of the developedmethod in determining the optimal parameters of a multidimensional discrete controller.

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Comparative study of the self-heating effect in the accumulation and inversion mode FinFETs

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***Abstract*- In this work, the self-heating effect in inversion mode FinFET and Junctionless (accumulation mode) FinFET is compared and the influence of the different electrical and geometric parameters on the self-heating effect is considered. It is shown, that the lattice temperature in the channel center is higher in junctionless (JL), accumulation mode FinFET than in inversion mode FinFET with the same parameters. The difference in the temperature is explained by the difference in the structure, particularly by the difference in the doping level of the channel for these transistors. The dependence of the self-heating effect on the doping depth and doping profile of the source and drain areas along the channel were considered.**

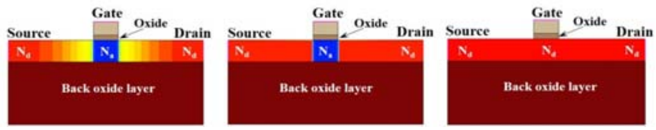
Keywords— FinFET, JLFinFET, self-heating effect, doping level.

I. Introduction

The main trends of nanoelectronics are decreasing transistor sizes to provide decreasing energy consumption and increasing the integrity level of integral circuits (IC) [1,2,3]. Metal-oxide-semiconductor field effect transistors (MOSFET) are one of the main elements of the IC. Decreasing the MOSFET sizes leads to arising different types of degradation effects, particularly short channel effects [4, 5], and self-heating effects [6, 7, 8].

Short channel effects is significant for planar MOSFET at nanometer sizes. To increase immunity against short channel effects, fin field effect transistors (FinFET) [9] instead of planar MOSFET were suggested. FinFET works in inversion mode as well as MOSFET.

For simplification of the FinFET technology it was suggested new, junctionless FinFET transistor structure, which works in accumulation mode [10, 11] (Fig.1). In this new transistor technology thermic process which is used to form the source and drain areas by diffusion is absent. This thermic process in nanosized areas can lead to degradation of some parameters of the transistor. Therefore this technology is preferable and is more simple. Besides it, JL FinFET also shows high immunity against short-channel effects.



a) b) c)

Fig. 1. The structures of the FinFET with analytical (a) and constant (b) doping profile in source and drain areas, and JL FinFET (c)

One of the features of the FinFET and JL FinFET is the fabrication of them on the basis of silicon-on-insulator (SOI) structures. It means the bottom of the channel of the transistors has contact with back oxide. Because the oxide materials have small thermal conductivity, in the channel the self-heating effect (SHE) can take place [12, 13]. The self-heating effect is an important problem in providing reliability of ICs. Therefore studying the self-heating effect in FinFET is very important problem. Separately this effect in FinFET and JL FinFET [6, 7, 8] was considered, however, comparison of this effect in such transistors with the same parameters is not carried out yet. In this work, the comparison of the self-heating effect in such transistors with the same parameters is considered.

II. SIMULATION CONDITIONS AND TRANSISTOR PARAMETERS

FinFET differs from JL FinFET by the high doping level of the channel in JL FinFET and by the presence the source and drain areas which is doped with high concentrations in FinFET. Therefore it is expedience to investigate the influence of the parameters of these areas on SHE. In this work, it was simulated the dependence of the temperature in the center of the channel on the doping profile and on the depth of the doping along the channel in FinFET. It was considered the analytical and constant doping profile of the source and drain areas.

TCAD Sentaurus program was used in the simulation. The transistor parameters indicated in Table 1 were used. To account for thermic effects the thermodynamic transport model with quantum correction is used. In the mobility model, the doping dependence and velocity saturation at the high field were accounted. For calibration, the used physical models the I-V curves carried out in the simulation and experiment [14] were compared (Fig.2).

TABLE I. PARAMETERS OF THE FINFET AND JL FINFET USED IN THE SIMULATION

Parameter	Designation	JLFinFET	FinFET
Dopin level in the channel	N	$5\cdot10^{18}$ cm^{-3} (n-tip)	10^{16} cm^{-3} (p-tip)
Doping level in source and drain areas	N_d	$5\cdot10^{18}$ cm^{-3} (n-tip)	$5\cdot10^{18}$ cm^{-3} (n-tip)
Gate oxide (HfO_2) layer thickness	t_{ox}	6,7 nm (t_{eff} = 1,2 nm)	6,7 nm (t_{eff} = 1,2 nm)
Channel thickness	T_{si}	9 nm	9 nm
Channel width	W_b	22 nm	22 nm
Back oxide layer thickness	T_{box}	145 nm	145 nm
Gate length	L_{gate}	10 nm	10 nm

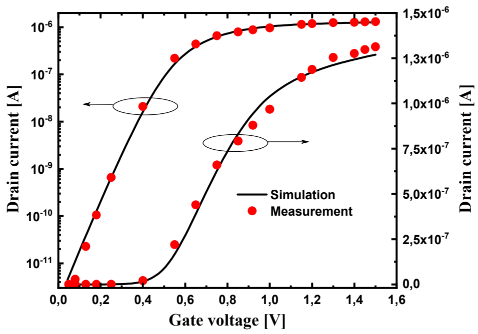


Fig.2. Comparing of the Id-Vg characteristics for SOI JL FinFET carried out in simulation and experiment.

III. RESULTS OF SIMULATIONS AND DISCUSSION

The doping level of the channels for the considered JL FinFET and FinFET is $5\cdot10^{18}$ cm^{-3} va 10^{16} cm^{-3} respectively, which is typical for such transistors. The maximal Doping level at an analytical profile of doping the source and drain areas of FinFET is $5\cdot10^{18}$ cm^{-3}. The results of the simulation of Id-Vg dependence for FinFET as well as for JL FinFET is shown in Fig.3.

It is seen in the figure, in the saturation region a drain current in JL FinFET is higher than in FinFET. It results in a higher lattice temperature in the channel center of JL FinFET (Fig.4). The resulting temperature in the channel is defined by the heat generation as well as by the heat dissipation rates. The heat generation rate depends on the drain current, while the heat dissipation rate depends on the thermal properties of the materials surrounding the channel. In our consideration, the materials and geometry surrounding the channel is the same for both transistors and therefore the heat dissipation rate is also should be the same. Therefore in our case difference in the channel lattice temperature for considered transistors is defined only by the difference in the heat generation rate which is defined by the difference in a drain current in the transistors.

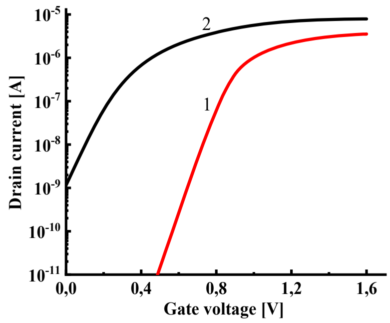


Fig.3. Id-Vg characteristics of inversion mode FinFET (1) and accumulation mode JL FinFET (2) with the same geometric parameters.

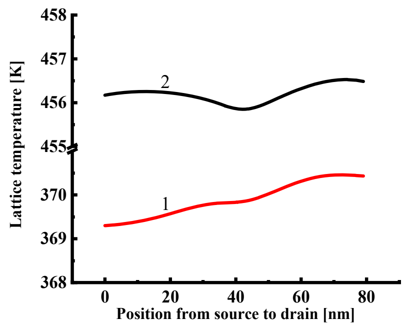


Fig. 4. Distribution of the lattice temperature along the channel of inversion mode FinFET (1) and accumulation mode JL FinFET (2) with the same geometric parameters. Vd=0.75V Vg=1.6V

Drain currents can be influenced by the parameters of the source and drain areas. We simulated the influence of the doping profile and doping depth L (Fig.5) of the source and drain areas to the lattice temperature in the center of the channel.

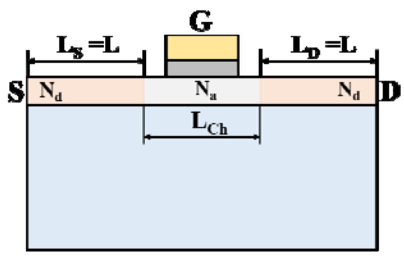


Fig. 5. The structure of the simulated inversion mode FinFET. L is the doping depth of the source and drain areas.

From the simulation results it is seen that with increasing the doping depth of the source and drain areas the lattice temperature is increased for analytical as well as for constant doping profile (Fig.6). With increasing the doping depth up to contacting of the source area with the drain area and when the channel will become homogeneous the lattice temperature of the inversion mode FinFET aspires to the temperature of the JL FinFET.

In Fig.6 we can also see, that the lattice temperature sufficiently depends on the doping profile. In the case of a constant doping profile, the lattice temperature in the channel center is higher by 75-85 K than in the analytical doping profile, depending on the doping depth. This difference is explained by the difference in the current density. In Fig.7 it is seen, that the current density in the channel center in the case of the constant doping profile is higher than in the case of the analytical doping profile. The doping level of the channel in JL FinFET ($5\cdot10^{18}$ cm^{-3}) is higher than in FinFET by 3 orders and therefore drain current density is higher respectively.

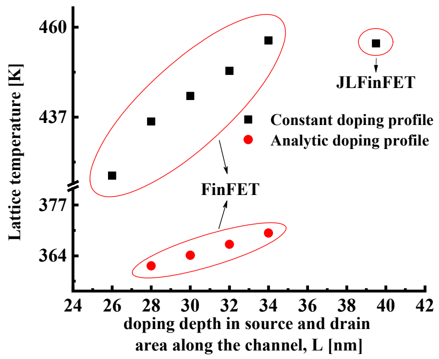


Fig.6. Dependence of the lattice temperature in the center of the channel on the doping depth along the channel.

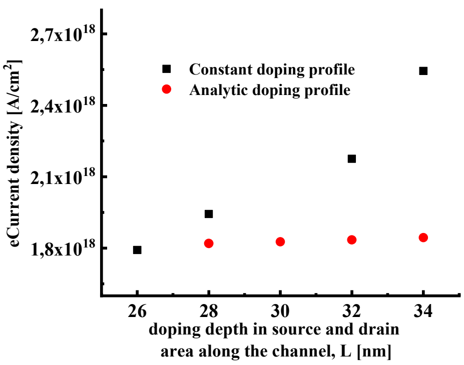


Fig.7. Dependence of the current density in the center of the channel on the doping depth along the channel in FinFET.

IV. CONCLUSION

Thus SHE is more significant in SOI JL FinFET than in SOI FinFET with the same geometrical parameters. It is explained by differences in the structures and in some electrical parameters. Particularly it is connected with a relatively high doping level in the channel (on several orders) in JL FinFET.

The lattice temperature in the channel center of the inversion mode FinFET depends on the doping profile and doping depth of the source and drain areas. At the constant doping profile the temperature is higher than at the analytical doping profile. With increasing the doping depth along the channel the temperature aspires to the value which corresponds to the temperature of JL FinFET with the same geometry.

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Design of a Dynamic Document Circulation System and its Structure

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***Abstract*—This article examines the design of a new approach document circulation system in order to improve the efficiency of electronic document circulation systems (EDCs) used in the activities of organizations of various scales. In this, the proposed DFIT system development tasks, design and system organizers are given. This system creates new document templates, edits document data, manages user roles, and controls information flow based on existing databases of various formats.**

Keywords—formatting, EDCs, DFIT, database, document template, information flow

I. Introduction

It is known that in the activities of any enterprise and organization, the task of creating various reports and organizational-administrative documents is often performed. It is no exaggeration to say that the preparation and formation of data takes a lot of time of employees. Forming new documents using existing databases is one of the urgent issues of automating the process and putting it into practice. Almost most of the information circulating in electronic document circulation systems (EDCs) is repetitive. At the same time, these data are stored in databases of internal or external systems. Increasing the effectiveness of the EDCs through the effective use of this available information is one of the current issues. Literally, a typical EDCs is mainly aimed at central management of the exchange of internal and external electronic resources. That is, operations such as network and inter-user management and control of their flow are carried out in the space of files. What we want to say is that the information world, in particular, there is a great need for modern dynamic document exchange systems that work with new information units using information in the databases of various systems, and this is a very problematic issue. Because the first issue is the integration of the new system in place of EDCs with other permitted systems, the second issue is the creation of a dynamic template document with a new approach to efficient use of external system resources with the information resources in its information space, and then the created document editing and management of information units in the internal-external environment is the third issue..

II. MATERIALS AND METHODS

1) *Materials*

Fundamentals, requirements, architectures, analysis of international and national systems, management and control systems of electronic documents and their internal-external network circulation are presented in works [1-2]. Methods and algorithms for creating document templates based on the information base, software for exporting/importing data to template files have been sufficiently studied in the work [3,4]. In educational institutions, scientific researches were conducted on the technology of processing information flows of electronic documents and their control systems, the use of available information resources in the formation of necessary documents [6]. The development features of EDCs and the advantages of client-server architecture for it, as well as the development of updates for document management systems, are presented in [8,9]. The analysis shows that the integration of software in both directions, i.e., the construction of document circulation systems based on the database of information, is almost not done.

2) *Methods*

The idea of this scientific-practical work is to create a "dynamic document circulation system" that will create new document templates based on existing data bases, edit time-dependent document information, manage user roles and control information flow. This system is called DFIT (Dynamic Formation of Information Templates). In this case, the incoming document is transferred to a template document on the basis of information bases for the internal system, and the flow of information between nodes at the executive level is optimally controlled. A mathematical model for DFIT was proposed in [5], and this research work is literally its successor. In order to make the model understandable, the document circulation activity of the Higher Education Institution was taken as an example, and the algorithms for transferring the document to the internal network and resummarization processes were described in detail. In the development of this DFIT system, the following sequence of tasks should be solved:

- System infrastructure formation;
- Designing a database of dynamically expanding and integrating information;
- Integration with external system information base;
- Formation of template documents based on the database of informants;
- Management of documents, resources and information flow based on regulations;
- Document circulation monitoring;
- Creation and implementation of a system based on functional modules.

It is clear from the sequence of tasks that the system to be created has a separate information space, which is connected to other systems through separate gateways. The difference with the usual EDCs is that it does not only manage the flow of files, but manages file information through a single dynamic database.

III. RESULTS

As a result of the system database creating a separate table for each document and expanding with the information in it, the number of information required in a new incoming document decreases. Because the information in the documents is repetitive and the form or structure of the requested information may change without changing its essence. Now the methods of performing the given tasks will be studied in detail.

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1) System infrastructure

For this, first of all, it is necessary to identify the objects that make up the system and form information relations between them. The main organizers of the DFIT system under consideration include:

- system information space. It includes a database of dynamic data, static data, and templates for tables and data records responding to incoming documents;
- information bases of external information systems;
- system administrator, moderator and users.

Information relations include:

- algorithmic maintenance of creating and editing a new standard document suitable for the incoming document based on the database of informants;
- management of the flow of information in the transfer and retrieval of the standard document in the internal system between executive nodes, establishing the principles of copyright information security;
- a parametric set of APIs that integrate with external databases;
- an interface that provides time-dependent information exchange of user roles and authorities in relation to the current document;
- algorithms and software of information flow and document management.

The infrastructure of the new DFIT system based on the mentioned objects and their relationships is proposed as shown in Fig. 1.

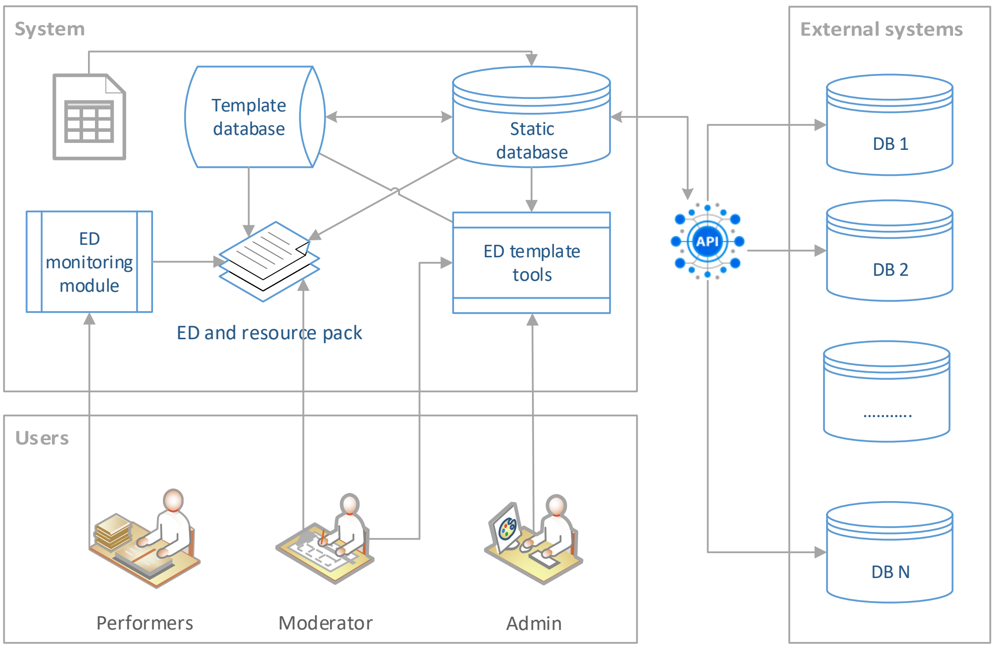

Figure 1. Dynamic document circulation system infrastructure

2) Database

Optimum design of DB with dynamic characteristics in the system being created is an important task. In the system information space, DB is divided into the following classes: static relational DB, DB for dynamically expanding document records, templates bases, resources, parametric set of APIs that provide communication with external information systems. Now these organizers will be detailed.

A) **Static database.** Static database. Usually, the content of the incoming documents asks for information about the organization's activities, and most of the documents repeat this information. Repetitive information is based on the organization's structural objects, employees, activity indicators, etc. In particular, at the level of higher education institutions, these include reports on education (attendance, mastering, students of certain parameters), employees (teachers, staff), departments and departments, scientific activities and indicators, material support, etc. . Therefore, in the DFIT system, frequently requested and immutable data are stored in a separate static database.

B) Database of document templates. In this, information such as document creation, naming, attached files, requisites, document notes are placed. The table describing document attributes is as follows:

$$Temp\_doc, Temp\_file \text{ and } Temp\_role.$$

$Temp\_doc$ – dynamic document name, author, text indicating the essence of the document, its creation and validity periods, the name of the internal unique table reserved for the document;

$$Temp\_doc\begin{pmatrix} idT, name, id_{avtor}, text, \\ data_{create}, data_{activ}, data_{end}, table_{name} \end{pmatrix}$$

$Temp\_file$ – resources included in the document (files, multimedia, url links);

$$Temp\_file(idF, idT, url\_file, file\_name)$$

$Temp\_role$ – assign permissions to users based on roles;

$$Temp\_role\ (idR, idT, id\_rule, type\_edit)$$

T_data – database of document record information formation. This database consists of 3 parts: information units obtained from the external DB, obtained from the internal DB and newly inserted into the document.

$$T\_data = \{T^{External}, T^{Internal}, T^{New}\}$$

Each part is organized separately:

$T^{External}$- information obtained from external information system DB ;

$$T^{External}\begin{pmatrix} idE, idT, id_{system}, id_{table}, id_{collumb}, \\ where, order, group, type, name \end{pmatrix}$$

$T^{Internal}$– internal DB is static and performed according to pre-created templates;

$$T^{Internal}\begin{pmatrix} idI, idT, idT_{old}, id_{collumb}, \\ where, order, group, type, name \end{pmatrix}$$

T^{New}– categories of attributes and information that are newly added to the template.

$$T^{New}(idN, idT, type, name, interval)$$

C) database of document records. The internals of the above T_data database are created when creating templates. However, after the template is created, all the specified columns will be transferred to a newly created single unique table. That is, the resulting dynamic table name is reflected in the table ($Temp\_doc$) representing the dynamic document. Templates are created separately for each document, and although previous templates can be used in this process, the tables attached to it are new in terms of writing. So, the T_data parameters can be expressed as:

$$T_{DATA} = T_{data}^{idT}\begin{pmatrix} T_1^{ext}, \dots, T_{Next_{idT}}^{ext}, \\ T_1^{int}, \dots, T_{Nint_{idT}}^{int}, \\ T_1^{new}, \dots, T_{Nnew_{idT}}^{new} \end{pmatrix},$$

where $Next_{idT} \geq 0$, $Nint_{idT} \geq 0$, $Nnew_{idT} \geq 1$ conditions are satisfied. Because the current document may not use external and/or internal DB. However, it is required to enter at least one new information in the new document. In particular, let's imagine that the system is not connected to an external DB. In this case, only an empty table with new column(s) is presented in the very first document, and the template from the first document and the tables created for it can be used when creating the second document. This is the extensibility and dynamic nature of DB, where the number of different T_data tables increases.

As a result of dynamic T_data construction, the data obtained from internal/external DB is selected based on certain conditions and recorded in the T_data table. As a result, a semi-finished table appears. That is, the table fields selected as initial data will contain relevant entries, but the newly entered field elements will be empty. The main one is editing (insert, update, delete - a new entry, updating and deleting) on these initial records within the system user roles..

D) API parameter set. A software base that describes receiving the necessary data from external information systems (servers) and their authorized DB sectors to the internal system (client). Simply put, there are many types of external information receiving systems and information obtained from them. Information about the API (system name, address, API parameters) is stored in this database. API parameters are not in the form of a relational table, but rather an ordered set of code that stores the formats for requesting and receiving responses from authorized servers.

3) Integration with external system DB

This is mainly done in one of two ways: API and parsing. When creating new template documents in the DFIT system, if the attribute information necessary for the initial incoming document is available in internal and/or external systems, then it is necessary to contact the external system. It should not be overlooked that the parsing or API features and structures that provide information for sending requests to external systems are different. It uses the request-response principle for the API. For parsing, the url address of the system with an external web interface has open data and the principle of information structures (fragmentation, use of symbols) is used. In both these principles, the attributes are reflected in the local DB. The parsing algorithm consists in the fact that data with a structure or pattern in a certain url address is scanned using special algorithms and the results are recorded in the DB after processing.

An API can generally be thought of as enabling the exchange of information between two systems. An API is a set of routines, protocols, and tools for building web and mobile-based applications. The API defines how to authenticate (optionally), request and receive data from the API server. When used in the context of web development, an API is typically a defined set of HTTP protocol request messages, along with a definition of the response message structure. Web API allows multiple services to be combined into new applications known as hybrid applications.

Currently, many information systems offer a special API list for other information systems to freely use their open data. For example, the HEMIS platform, which is widely implemented in HEIs of the Republic of Uzbekistan, has an API for integration with other information systems (https://student.karsu.uz/rest/docs#).

Tool for creating templates. This program, which is important in the DFIT system, performs the task of converting incoming documents into a template document form for internal document circulation through visual observation. A separate relational table is automatically created for each template document. This table stores the information requested in the content of the incoming document in attributes. Executors edit the entries in this table based on their permissions. The business process of creating a template document is given in BPMN notation (Fig. 2). The flow chart mainly consists of three sections: database, template editing and toolbar. The process of creating template documents consists of four stages: initial and prepared document, templates, static data, API parameters. In the process, actions are carried out in the following sequence:

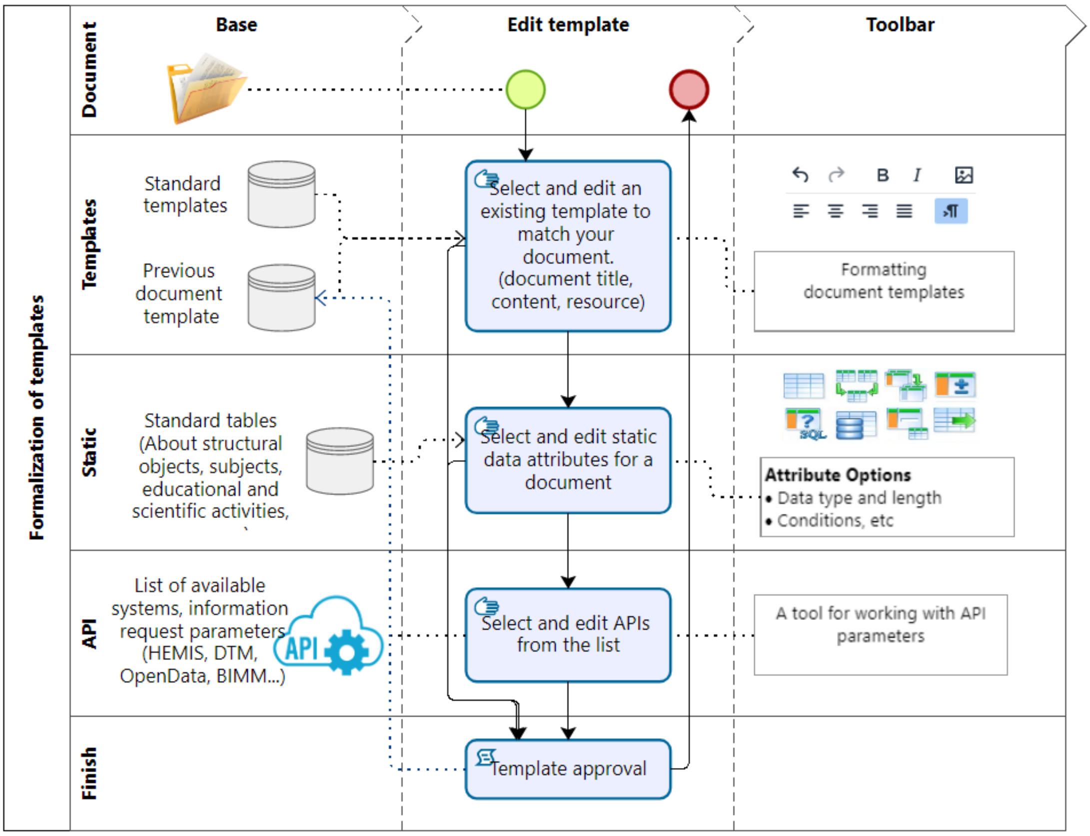

Figure 2. Scheme of the process of forming standard documents

Template. The authorized person gets acquainted with the content of the incoming document. He chooses one of the standard templates or previous document templates that are suitable for him. Re-edits the selected template through the tools panel. Here, templates are linked to separate tables in the system DB. The user can temporarily save and edit the template.

Static DB. Appropriate attributes from tables in static DB can be attached to the selected template. In this case, if more than one table data is used, the system automatically creates an INNER JOIN SQL query through the appropriate key attributes. If the key attributes don't match, it puts the responsibility of linking the tables on the moderator and calls a convenient interface for the SQL query on it. Usually, all tables in a static DB are interconnected. A new attribute for the template is created through the toolbar, and data classifications are defined and boundary conditions are entered. Also, given that there is a lot of information in the attributes selected from the static DB, this stage interface has the ability to sort the ones that are needed for this document.

API. As mentioned earlier, API parameters are placed here in the form of a separate list for integration with other systems. In this case, the user selects the necessary system and an API that receives a set of data from it. There are several attributes in the API request, and just like static DB, their selection and sorting operations are performed from the toolbar.

Finish. At this stage, the created template is approved and written to the template database. The table attached to the approved template document is filled with initial information. This information comes from; 1) select a previous document template for the current template (since previous template documents will be connected to separate tables), 2) static DB and/or 3) API. According to the request of the moderator, the data of the formed template table can be deleted. The approved template document is sent to the next module to define regulations and executors in the internal system.

Internal document circulation unit. First of all, a regulation is established for the template document. This stage is mainly performed by the office and sent through the system to the person responsible for whistleblowing. The process and algorithms of transferring the document to executives in the internal structure of the organization and summarizing the finished document are studied in detail in [5]. BPMN notation was used to form a business jaroon for internal document circulation (Fig. 3). The scheme consists of two blocks: EDCs (external) and DFIT (internal).

If the EDCs block describes the arrival of the initial document and the exit of the finished document, the DHAT block consists of actions from converting the initial document into a template to its internal document circulation system. The endorsement section begins with the analysis of the administrative document's content. With the help of a specially developed software module, the document is modeled on the basis of databases and it is approved and transferred to the internal EDCs system. This section contains information about the database of pre-formed templates, the static database that is often used in the system, and the API parameters that provide integration for obtaining data from external systems via API during modeling.

The internal EDCs department consists of the actions of the regulated transmission of the document to the internal nodes and their generalization and transfer to the external EDCs block. These actions, in turn, are based on the database of objects and subjects, users and their roles of influence on this document in the system.

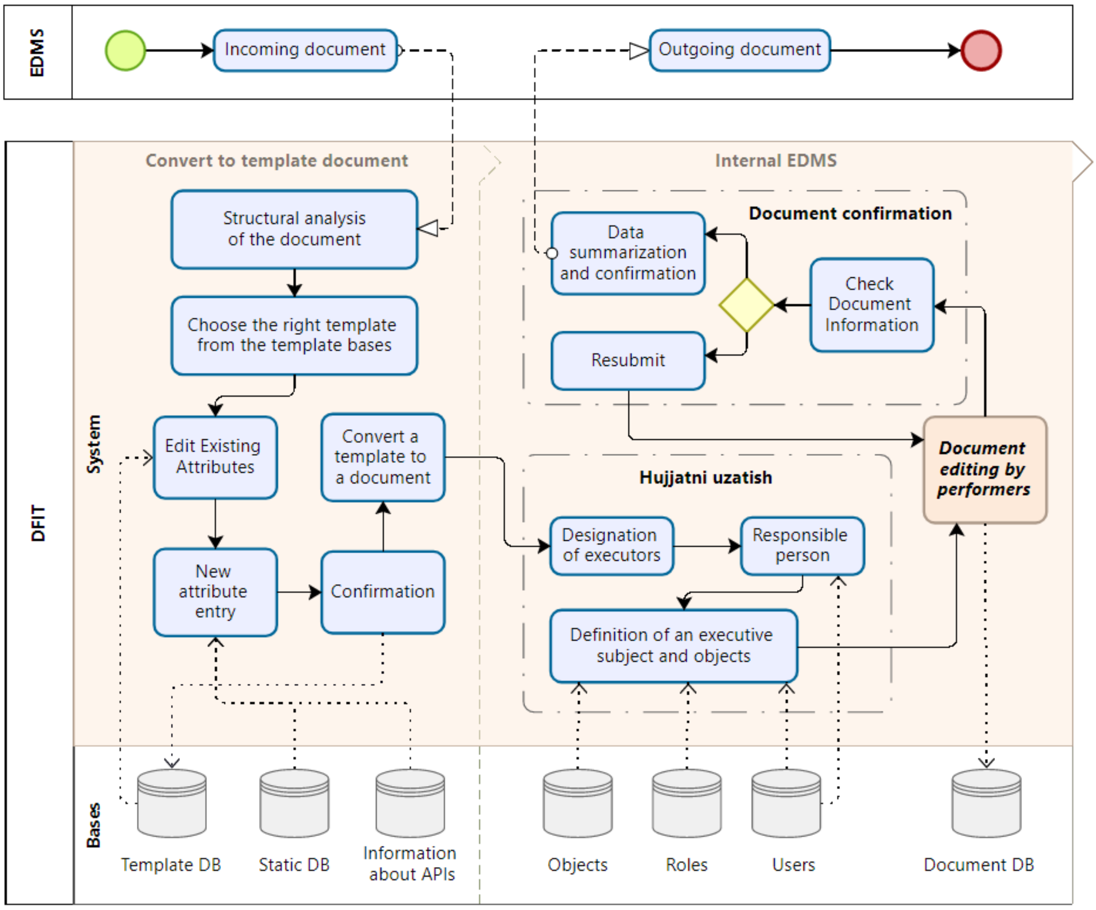

Figure 3. The scheme of the process of documents and systems

IV. CONCLUSION

Thus, EDCs is the "blood circulation system" of the entire business process. This significantly saves time and positively affects the work of the organization. Work efficiency can be increased in two ways: reducing costs or increasing results. EDCs documents allow achieving two goals at the same time. That is, the implementation of the system allows the organization to spend less money and achieve more productivity. Cost reduction is carried out by reducing paper costs, avoiding excessive time, speeding up the process of information exchange, and changing the corporate culture. Above, the tasks in the organization of the DFIT system were performed according to the sequence. As a result, the infrastructure of the system, multi-disciplinary DB, means of integration with external systems, the tool for creating standard documents and the processes of movement of the document in the internal system were studied in detail.

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Algorithms For Formation Of Features Of Speech Signals

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***Abstract*— The formation of features of speech signals is the most important aspect of speech recognition and person identification by voice. Speech signals are complex waveforms that convey information through changes in acoustic properties such as frequency, amplitude, and duration. These features are essential for both human perception and machine speech processing.**

This article describes the stage of forming features of a speech signal, which is considered one of the important stages of processing and analysis of speech signals. In addition, based on experimental studies, a feature generation algorithm has been proposed for use in recognizing speech commands in the Uzbek language and a comparative analysis of recognition speed has been carried out.

Keywords— speech signal, feature, Mel-frequency cepstral coefficients (MFCC), discrete cosine transform (DCT), Fourier transform (FT), amplitude, frequency, normalization, filter, spectrum.

I. INTRODUCTION

The process of understanding human speech is a complex and multifaceted endeavor that lies at the heart of various technological applications, from voice assistants and automated transcription services to linguistic research and communication systems. At the core of this intricate process is the formation of features within speech signals, a crucial stage that enables us to decode spoken language effectively. This article explores this pivotal aspect of speech signal processing, shedding light on its significance in the broader context of speech analysis.

The formation of features within speech signals is a fundamental step that involves the extraction of key information from the raw acoustic data. These features serve as the foundation for numerous applications, including speech recognition systems, emotion detection, and dialect identification. They allow us to decode the nuances of spoken language, discerning phonetic patterns, prosody, and speaker-specific characteristics.

One of the notable contributions presented in this work is the development of a feature formation algorithm tailored for the recognition of speech commands in the Uzbek language. As languages differ in their phonetic structures and acoustic characteristics, the creation of language-specific algorithms becomes essential for accurate and efficient speech recognition. Furthermore, the article offers a comparative analysis of this algorithm's performance, focusing on recognition speed, based on rigorous experimental studies.

This research not only highlights the importance of feature formation in the broader realm of speech signal processing but also demonstrates its practical application in a specific linguistic context. By delving into the intricacies of speech signal formation and showcasing the results of empirical investigations, this article provides valuable insights into the ever-evolving field of speech analysis and its real-world implications. It underscores the continuous pursuit of improving our ability to understand and interact with spoken language, transcending linguistic boundaries and enhancing communication across diverse cultures and languages.

Speech signal processing is important for automatic speech recognition, speech recognition and other speech systems. Mel-frequency cepstral coefficients have been widely used in speech system design for many years, but Mel-filter banks have been increasingly used in recent years.

II. LITERATURE REVIEW

The research paper [1] analyzes of the methods of linear predictive coefficient - LPC and MFCC, perceptual linear prediction - PLP, wavelet transform - WT, relative spectral PLP - RASTA-PLP and considers the strengths and weaknesses of each method. Among them, it is stated that FFT, LPC and MFCC methods have high computational complexity, and Wavelet-based methods show high efficiency.

In the article [2], MFCC, LPC, LPCC, LCF, PLP, and DWT six feature extraction methods are analyzed, and their relationship with time calculation speed and noise exposure level is described. It shows that MFCC, LPCC and PLP methods are effective in speech recognition in terms of computational time.

The article [3] proposed an approach based on machine learning at the feature extraction stage, which is important in speech recognition processes, which enables real-time operation in the smart city project. In this approach, the MFCC method was also used, as a result of which the calculation time was relatively reduced.

In [4], the accuracy of speech recognition of English and Punjabi words was increased using the Markov model. At first part of the research, the MFCC method was used for feature extraction and the k-folded method and Baum-Welch algorithm were used for signal training in the second part.

In the article [6], the issue of recognizing Chinese words in speech was studied, the fusion speech feature extraction method was used by reducing the size of Mel features, and as a result, it was shown that this method gives better results than the MFCC method.

Many researchers have studied the issue of voice recognition and analyzed the methods of feature extraction [5,7-9]. Among these methods, the MFCC method is more cited and shown to be effective.

III. Algorithms for Extracting Feature from a Speech Signal

These algorithms for extracting feature from a speech signal consist of similar steps in which Mel filter banks are considered in both cases. Additional steps are taken to calculate the MFCC.

The signal is passed through a pre-processing filter, then split into partially overlapping frames, a windowing function is applied to each frame, and a short-time Fourier transform is performed on these frames [10-12]. The power spectrum and filter bank are then calculated.

Applies DCT to the Mel filter bank to determine the MFCC feature vector. In this case, the obtained coefficients are discarded. At the last step, the vector is normalized according to the mathematical expectation [13-15]. These steps are standard on almost all ASR systems [16].

To perform the sequence of steps described above, a single-channel 16-bit speech signal with a frequency of 16000 Hz was received in wav format. The duration of the signal is 3.5 seconds and the phrase "Time is the Great Trainer" is pronounced in it. The file name is "8_57931. wav", where the first part of the file name corresponds to the identification number of the corresponding text in the text base. The raw speech signal is shown in Fig.1.

One of the stages of speech signal analysis is pre-processing, in which high-frequency amplification is performed. Performing this action is useful because it solves the following problems:

- balancing the frequency spectrum because higher frequencies have less amplitude than lower frequencies;

- to avoid problems with the numerical value that can occur with the Fourier transform;

- can increase the signal-to-noise ratio.

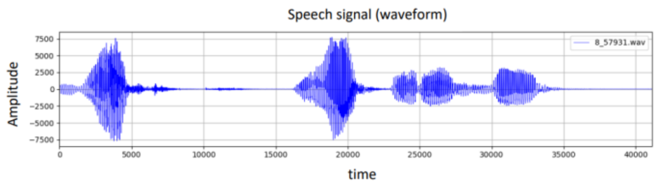

Fig. 1. Samples of the speech signal

A first order pre-processing filter is applied to signal $x(t)$ as follows:

$$y(t)=x(t)-\alpha x(t-1), \quad (1)$$

where α is the filtration coefficient, usually taken equal to 0.95 or 0.97. Despite the simplicity of this expression and software implementation, the above factors have a positive effect on system performance.

The representation of the preprocessed speech signal in the time domain is as follows:

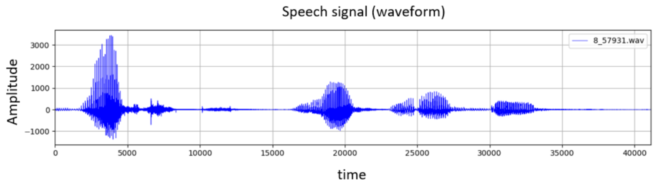

Fig. 2. Processed speech samples

The preprocessed speech signal is divided into short time frames. The purpose of this step is to treat the signal as stationary without taking into account the change in frequency over time by dividing it into short-term fragments. If the FT is performed for the entire signal, the frequency contours may disappear [17]. In such short-term frames, can get a good approximation of the signal frequency contours.

The result of the Fourier transform for the total signal is generated by combining the results for these frames. Typically, in speech processing, frames in the range of 20ms to 40ms are captured with an overlap of 50% (+/-10%). The most common settings are a frame duration of 25 ms and a frame shift of 10 ms (15 ms frame overlap). The window image function is then applied to the frame. Examples of such functions include Blackman, Kaiser, Hann, Hamming and other functions. The Hamming function is usually widely used and its form is expressed as follows:

$$w[n]=0.54-0.46\cos\left(\frac{2\pi n}{N-1}\right), \quad (2)$$

where $0\leq n\leq N-1$, N window length. The graph of the above expression looks like this:

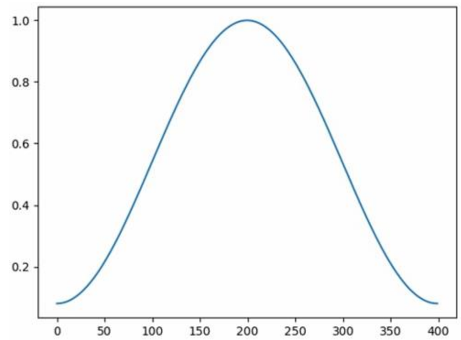

Fig. 3. Hamming window

FT and power spectrum. In this case, a short-time Fourier transform is performed on the samples in each flipped frame, and the power spectrum (periodogram) is calculated using (3). Typically, the value of N is taken to be 256 or 512. In Fig.4 shows the power spectrum.

$$P=\frac{\left|\sum_{i=1}^{N}(x_i)w(i)e^{\frac{-j2\pi ki}{N}}\right|^2}{N}, \qquad (3)$$

where x_i – i – frame of the x signal.

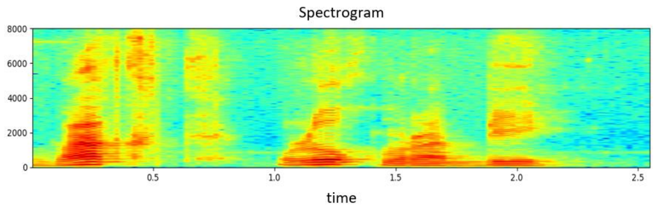

Fig. 4. Power spectrum (periodogram)

Bank of filters. The last step in the filter bank calculation is the application of triangular filters, in which the number of filters is 40. These filters are used to separate the frequency bands from the power spectrum on the Mel scale.

The Mel scale reflects the non-linearity associated with the fact that the human ear is better at distinguishing low frequencies and harder at high frequencies. In this case, the transition from frequency to mel-scale is carried out by the following expressions:

$$m=2595\log\left(1+\frac{f}{700}\right)$$
$$f=700\left(10^{m/2595}-1\right) \qquad (4)$$

Each filter has a triangular in shape and is equal to 1 at the center frequency of the filter, as shown in the figure below.

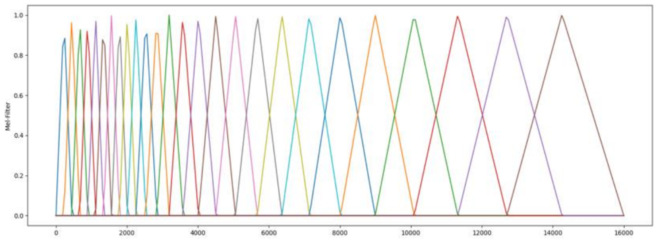

Fig. 5. Mel filter bank

The filter bank can be modeled using (5).

$$H_m(k)=\begin{cases}0 & k<f(m-1)\\ \frac{k-f(m-1)}{f(m)-f(m-1)} & f(m-1)\le k<f(m)\ldots\\ \ldots 1 & k=f(m)\\ \frac{f(m+1)-k}{f(m+1)-f(m)} & f(m)<k\le f(m+1)\\ 0 & k>f(m+1)\end{cases} \qquad (5)$$

The spectrum obtained by applying a bank of filters to the power spectrum (periodogram) is shown in Fig.6.

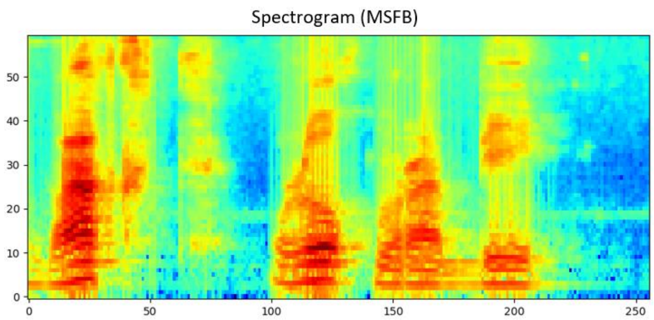

Fig. 6. Mel-scaled filter banks

If Mel-scaled filter banks are used for recognition, then these features can be normalized.

MFCCs-Mel-frequency Cepstral Coefficients. There is a strong correlation between the filter bank coefficients calculated in the previous step, which can cause various problems for some machine learning algorithms. Therefore, the DCT is used to decorrelate the filterbank coefficients and to obtain a compressed description of the filterbank. Usually, for automatic speech recognition (ASR), cepstral coefficients from 2 to 13 are kept, and the rest are discarded, and their number is 12. The remaining coefficients are discarded because they reflect rapid changes in the filter bank coefficients. These coefficients do not improve recognition accuracy, but reduce the speed of calculations.

Sinusoidal signal amplification is applied to MFCC to improve recognition accuracy in dynamic speech signals. In Fig.7 shows a spectrogram of the MFCC features.

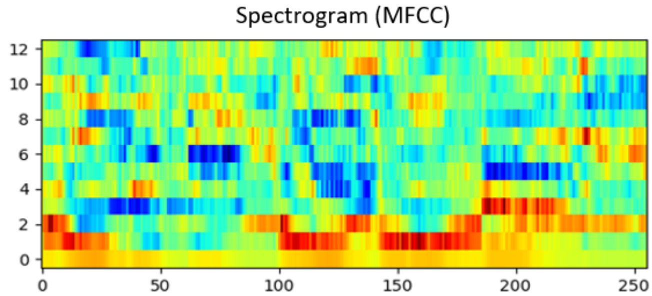

Fig. 7. Mel-frequency cepstral coefficients

Normalization. To increase the signal-to-noise ratio and balance the spectrum, it is necessary to calculate the mathematical expectation of the obtained coefficients for each frame and normalize them. Figure 8 and Figure 9 show the normalized Mel-scale filter banks and spectrograms of MFCC.

To improve the signal-to-noise ratio and spectrum balancing, it is necessary to calculate the mathematical expectation of the obtained coefficients for each frame and normalize by this value. In Fig.8 and Fig.9 show normalized Mel-scaled filter banks and normalized MFCC feature spectrograms.

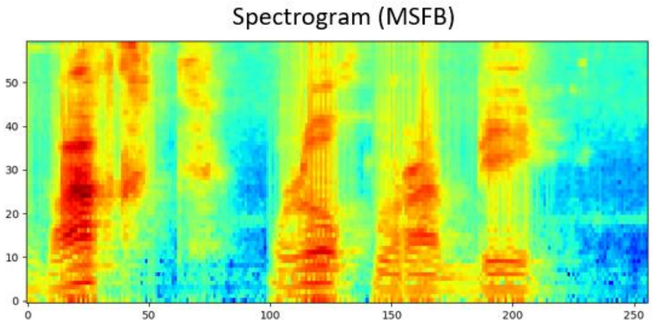

Fig. 8. Normalized Mel-scaled filter banks

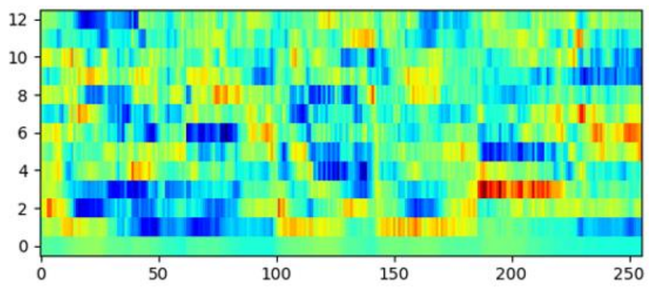

Fig. 9. Normalized MFCCs

The proposed algorithm A1 for extracting speech features and identifying informative features includes the following steps:

1-step. The speech signal is pre-processed.

$$y(t)=x(t)-\alpha x(t-1), \tag{6}$$

where $x(t)$ - speech signal, α - is the filter coefficient, which is usually taken as 0.95 or 0.97.

2-step. Window processing is performed using the Hamming function:

$$w[n]=0.54-0.46\cos\left(\frac{2\pi n}{N-1}\right), \tag{7}$$

where $0 \le n \le N-1$, N window length, typically 400 samples for a speech signal with a sampling frequency of 16 kHz.

3-step. FT and power spectrum calculations are (8):

$$P=\frac{\left|\sum_{i=1}^{N}(x_i)w(i)e^{\frac{-j2\pi ki}{N}}\right|^2}{N}, \tag{8}$$

where x_i – i–frame of the x signal. In this case, the value of N is usually taken as 256 or 512. N=256 were obtained in the work.

4-step. A transition from frequency to mel scale is performed. In this case, the transition from the frequency to the mel scale is carried out by the following expression

$$m=2595\log\left(1+\frac{f}{700}\right),\ f=700\left(10^{m/2595}-1\right). \tag{9}$$

5-step. The trained neural network encoder is fed filter bank features, i.e. the neural network input is given Mel-scaled filter banks of 60 feature vectors per frame.

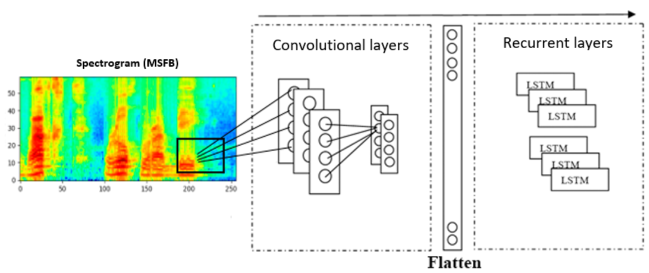

Fig. 10. Layers separating speech features

6-step. The process of identifying informative features is performed [28-37].

7-step. Recognition is in progress. In this case, the resulting set of informative features is transferred to the classification algorithms of a fully connected neural network or machine learning.

With the help of this algorithm, a significant increase in the speed of recognition of speech commands has been achieved by distinguishing features and identifying informative features. This is based on the fact that the number of features used in recognition decreases, and the number of parameters in the fully connected layer of the neural network decreases by an average of 1.7 times. This is reflected in the table below.

TABLE I. COMPARATIVE ANALYSIS OF FEATURE EXTRACTION ALGORITHMS

Feature Extraction Algorithm	Recognition accuracy	Recognition Time (ms)	The number of parameters in the recognition layer
MSFB	82	3.21	27 648
MFCC	79	4.63	27 648
A1	82	2.06	16 262

IV. CONCLUSION

In this article, the calculation steps of filter banks and MFCC coefficients have been discussed on their motivation and implementation. All calculation steps of filter banks are based on the nature of the speech signal and human perception of them. Conversely, since some machine learning algorithms have limited capabilities, additional steps are required to calculate the MFCC. The filter bank coefficients are generated based on the DCT. In particular, Markov models with Gaussian hidden mixture models (GMM-HMM) were very popular when MFCC was widely used, and MFCC and GMM-HMM developed in parallel, and became a standard method for automatic speech recognition (ASR). After applying deep learning to automatic speech recognition systems, the question arises whether MFCC is still the right choice, since deep neural networks are not very sensitive to highly related input data, so the step of applying a DCT is optional. It is important to note that the DCT is a linear transform and is therefore undesirable because it removes some highly nonlinear information in the speech signals. Here another important question arises: is the Fourier transform a necessary operation? Since this transformation is linear, it can be omitted and it is advantageous to train directly from the time domain signal. Currently, in some works this has already given positive results. However, Fourier transform has a complex training operation and increases the amount of data required to achieve the expected result and complexity of the model. In addition, when performing the short-time Fourier transform (STFT), the signal is assumed to be stationary for a short time, and therefore the linearity of the Fourier transform does not pose a serious problem. Mel-scaled filterbanks and MFCC computation procedures are reviewed. If machine learning algorithms are not sensitive to highly related inputs, then it is appropriate to use Mel-scale filter banks, otherwise using MFCC can provide higher speed and accuracy.

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Development of a National Scientific and Technical Information Analytical System

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***Abstract*— An important element of the national innovation system is the scientific and technical information system (STIS). The innovative path of state development directly depends on the level and variety of forms of development of STIS, in particular, on the development of important components such as information flow and resource management in scientific and technical directions. The state scientific and technical information system is an interconnected system of organizations that carry out scientific and information activities based on a certain agreed division of tasks. Innovative processes in countries must rely on a reliable and solid scientific and technical base based on a unified national scientific and technical information system. It is required that national information systems integrate both state and commercial scientific and information structures. This article is devoted to the development of the national scientific and technical information system, it contains information on the general structure of the system, the principles and departments of the information system, and their use.**

Keywords*— scientific sphere, automation, innovative development, region, monitoring, assessment, information and analytical system, intellectual analysis of data.

I. Introduction

An important element of the national innovation system is the scientific and technical information system (STIS). The innovative path of state development directly depends on the level and variety of forms of development of STIS, in particular, on the development of important components such as information flow and resource management in scientific and technical directions. The state scientific and technical information system is an interconnected system of organizations that carry out scientific and information activities based on a certain agreed division of tasks.

In recent years, the Ministry of Innovative Development has been leading in the formation of scientific and technical information sources in Uzbekistan. Scientific and technical information sources are usually embodied in STIS and they include scientific and technical libraries, institutions, enterprises and organizations. Scientific and technical information is important in the general information flow of the society, and it serves the development of the state economy. Therefore, in many countries, great attention is paid to the creation and development of the scientific and technical information system, that is, to the development of automated systems that store, process, analyze, and conveniently present information to users.

Information-analytical systems (IAS) allow to improve management procedures and increase management efficiency in the organization. IAS collects data from various sources, processes it, and compiles it into reports for the user to make quick decisions.

The innovative development of organizations and enterprises, regions and other economic entities occupies one of the most important places in the economic and technological development of the state. A developing society and economy requires the introduction of new approaches to various aspects of human activity. The rapid development of innovative processes shows the level of development of the country's entire economy, including the readiness of regions, enterprises and organizations to create new technologies and products.

Today, the concept of the development of science and innovative ideas has been successfully adopted and implemented in many countries, including Uzbekistan. For the successful implementation of scientific and innovative ideas, it is necessary not only to promptly intensify the scientific and innovative activities of research institutes and higher educational institutions, but also to constantly monitor such activities, evaluate their results and predict their effectiveness.

The Ministry of Innovative Development carries out annual monitoring of enterprises and organizations on the implementation of the state scientific-technical and innovation policy. It must be based on the application of systematic analysis and targeted analytical research based on statistical data collected over the years to evaluate innovative development. Monitoring is used for these purposes. The information required for monitoring is often not primary, but is calculated through other indicators that take into account the current state of the organization.

If you look at it from the point of view of fully automating the process of collecting and analyzing report data, you can see many gaps. In some cases, it is required to re-enter the information manually in the automated systems of information recording and storage. This problem is solved in modern information-analysis systems [1, 2].

The legal regulation of the relationship between scientific or scientific-technical subjects, authorities and public administration and consumers of scientific and technical products, including works and services, has been strengthened by the law introduced in our country.

At the same time, the Ministry of Innovative Development is working to increase state spending on promising fields and priority scientific and practical research, and to bring national science to the global level.

Innovative processes in countries must rely on a reliable and solid scientific and technical base based on a unified national scientific and technical information system. It is required that national information systems integrate both state and commercial scientific and information structures.

II. IAS STRUCTURE

Effective data storage in modern IAS is provided by the availability of various data sources in IAS. The task of processing and combining information is solved by means of data acquisition, transformation and loading.

In modern information and analysis systems, it is required to divide the steps of data collection, preprocessing, data retrieval, exchange, loading, data storage, data presentation, data analysis, and web portal [3].

The main stages of the scientific IAS are considered below, and the national IAS was developed based on them (Fig. 1).

Fig. 1. Login window

Data collection and primary preprocessing. The first stage of ATT consists of information oriented to the collection and processing of primary data used in the organization's daily activities. Nowadays, many organizations have created ATTs that demonstrate their scientific activity. However, not all organizations make full use of them or do not have ATT. The set of transactional data sources for the socio-economic development of the scientific field forms the lower link of the ATT structure.

Get, change and load data. Modern IASs use special tools to retrieve, transform, and load data. In the preprocessing step, all necessary calculations are performed and the data is cleaned.

Data storage. The third phase of the IAS architecture includes the "data warehouse". In this, a data warehouse stores data sources for storage and analysis. The analysis is carried out using modern hardware and software tools of data analysis.

Distinctive features of data storage are: relatively small and partial adjustments to a lot of data, periodic and frequent updating of data, a single and common approach to naming and storing data, regardless of how they were originally generated.

The data storage is one of the main parts of the IAS architecture, which is an integral source of data for a complete analysis of all data.

Providing information. This stage is the fourth stage of the IAS architecture, in which targeted information analysis is performed. Here the presentation is compiled using data from the storage.

Data analysis. The next stage of the IAS architecture includes modern hardware and software, which makes it possible for the highest authorities of the state to fully analyze information in real time. These tools improve efficiency in managing and analyzing big data; based on the analysis, optimal conclusions and informed decisions are formed, more accurate forecasts are made and the number of erroneous decisions is minimized.

Data mining tools are used by analysts to access data, display it, perform multidimensional analysis, and generate reports. It should be noted separately that IAS is the only system of socio-economic development of the scientific field, which allows effective management of the development of the scientific field. In this case, data analysis must be carried out using modern analysis technologies and tools [4] . During the creation of this system, the information in Uzbek language was eliminated from errors, noises and interferences using the program developed by the authors [5-13], and then placed in the system.

Web portal. The development of the IAS architecture led to the widespread use of Internet technologies. Currently, the Website and web portals are playing an important role in the IAS architecture. The use of a web portal makes it possible to quickly provide data to users or analysts anywhere in the world in real time.

To monitor an organization, a well-designed and formed web portal is required. By registering, the user has the opportunity to easily and simply enter data into the system, and after that he will immediately receive the results of the analysis of the input data. Fig. 2 shows the registration matrix of the national IAS created.

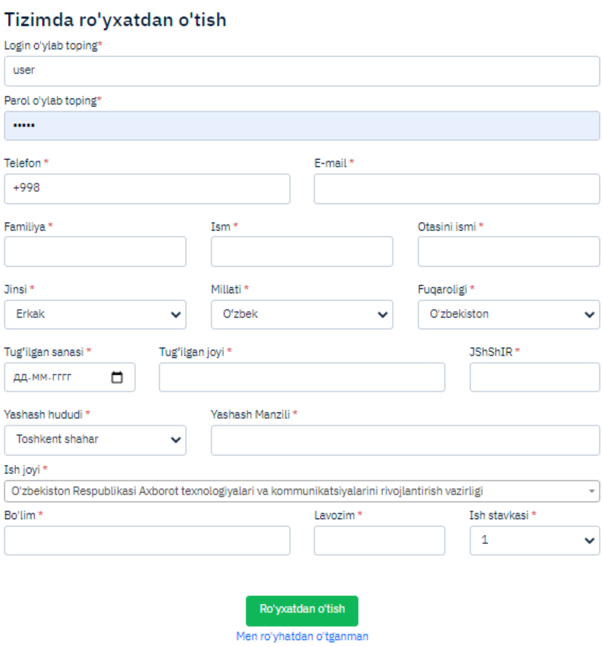
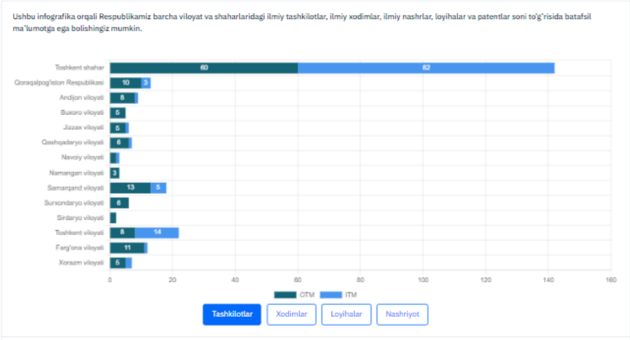


Fig. 2. Registration window

After providing the official results, you can immediately see the results of the information analysis on the portal. But any registered user will not be able to see the analysis results. An example of the result of information analysis, which was obtained using an opaque web portal, is shown in Fig 3.



HUDUD	TASHKILOTLAR	XODIMLAR	LOYIHALAR	NASHRIYOT
Toshkent shahar	142	375	981	140
Qoraqalpog'iston Respublikasi	13	5	18	0
Andijon viloyati	9	1	31	0
Buxoro viloyati	5	0	16	0
Jizzax viloyati	6	0	3	0
Qashqadaryo viloyati	7	0	15	0
Navoiy viloyati	3	14	11	9
Namangan viloyati	3	0	16	0
Samarqand viloyati	18	0	55	0
Surxondaryo viloyati	6	3	5	2
Sirdaryo viloyati	2	0	9	0
Toshkent viloyati	22	18	225	8
Farg'ona viloyati	12	2	19	0
Xorazm viloyati	7	1	24	0

Fig. 3. Information on regions

First of all, IAS is a means of scientific substantiation of management decisions. Decisions should be formed on the basis of a comprehensive analysis of the development of science, trends, and scientific field.

It is known that the tasks of data analysis, modeling and forecasting are quite complex. Sometimes it is required that the data stored in a data warehouse should be open to registered users and the necessary tools should be developed by the scientific community in accordance with the principle of open systems.

III. The Principle of Information System Operation

The "scientific-technical" information system has a user-friendly interface, and access to the system is carried out through a password-login or OneID (Fig. 1).

If the user is not registered in the system, he will register by entering the information shown in Fig. 2.

The user interface is a set of communication tools, which provides a joint action between the user and the system. That is why it is an element of the information system and gives an idea about the system.

The following problems may arise when developing a user interface:

- absence of specific requirements for the user interface in the technical assignment. This requires a system reset many times;

- the absence of a clear structure of the user interface. It does not allow you to schedule work when creating a system;

- change of system elements and its development. This requires adapting the user interface, but it is not always possible.

In order to overcome the above problems, it is necessary to apply adequate methodological approaches.

During the development of the user interface, the following very important and big issues should be solved:

-definition, analysis and research of general requirements for the user interface;

- definition of user model and scenarios of the interface;

- introduction of user interface;

- testing and quality assessment.

Depending on the chosen model, these steps can be repeated many times during the system life cycle. During the implementation of the first two stages, the system structure must be perfectly created and the basic requirements defined. When building a prototype of the user interface, the main functional aspects of the information system and the initial approaches of the user interface must be shown. The created prototype allows to obtain solutions up to the stage of system creation.

And in testing, it is possible to evaluate the system together with testing by involving different users. This allows you to properly organize the user interface. This process is carried out iteratively, which allows to eliminate errors in iterations.

The home page provides information on:

1. Organizations. On this page of the scientific and technical information analysis system, you can get a brief description of the scientific organizations operating in Uzbekistan and their structure and management, departments, employees, the number of projects implemented by the organization, patents, scientific laboratory equipment, and information about the degree programs in the organization. You can also get acquainted with short statistical information.

2. Scientific staff. This page of the scientific and technical information analysis system is devoted to basic information about researchers working in scientific organizations, their information about their place of work, academic degree and title, publishing, patent and scientific activities, participation in state and foreign projects, as well as work experience employees, h-index and brief statistical information about employees.

3. Projects. This page contains information about current and implemented projects and their detailed processes, executive organization, name of the project, scientific direction of the project, project manager, announced type of the project, project code, project start and completion date, and the amount of funding. It is also possible to get acquainted with the thematic topic of the project, project application, technical expertise report, scientific expertise report, scientific and technical council report, ministerial board report, Minister's decision, project contract, monitoring result and project report documents.

4. Publishing activity. This page is devoted to information about scientific articles, monographs, educational methodical manuals and theses published in national and foreign countries by scientists working in scientific organizations.

The database structure for these sections of the home page is fully formed and they have interconnections (Fig. 4-5).

"Organizations" section. The section includes a list of scientific organizations and universities with a filtering and search module based on specified necessary parameters, which contains more than 60 indicators.

Through this page of the scientific and technical information analysis system, you can get acquainted with a brief description and structure of scientific organizations operating in Uzbekistan, management, departments, employees, patents, scientific laboratory equipment, fellows, as well as projects implemented in the organization and brief statistical information about the organization (Fig. 4-5).

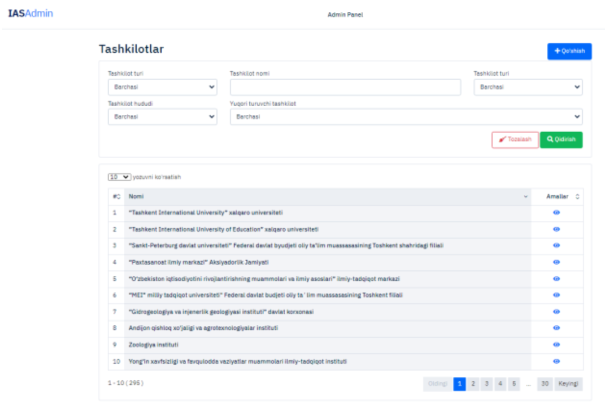


Fig. 4. Scientific organizations page

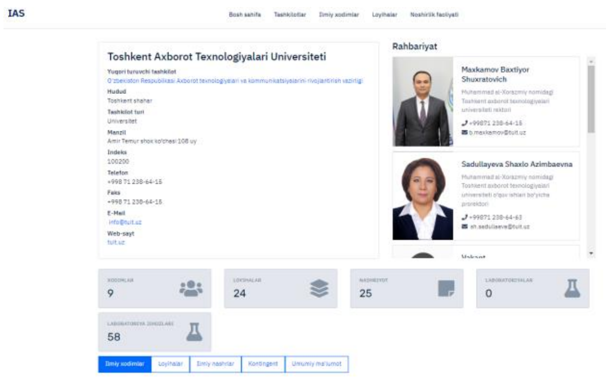


Fig. 5. Management page of scientific organizations

Through the infographic located at the bottom of the page, the scientific staff working in the organization (Fig. 6), the ongoing projects, available scientific publications, the contingent of the organization and general information about the organization are placed in it (Fig. 7).

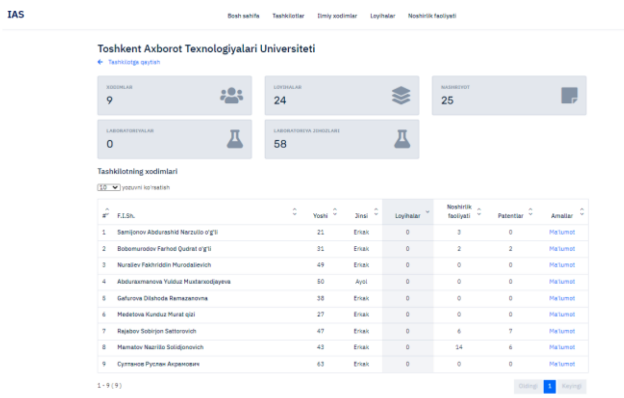


Fig. 6. Information about employees of the organization

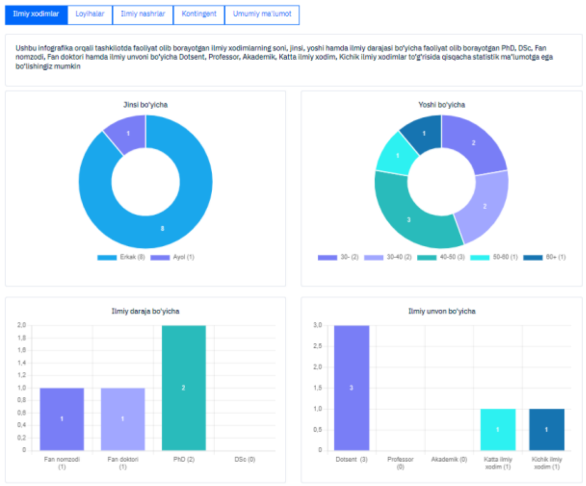


Fig. 7. Diagrams of scientific organizations page

"Scientific staff" section. This section consists of 15 parameters, it will consist of a list of academic staff with filtering and search function according to the required parameters.

Contact information is displayed as a separate section where the section is visible and consists of the following fields: address, index, phone number, alternate phone number, fax, e-mail address, website.

Buttons (recordable actions):

- "List of projects" button goes to the list of all projects where this researcher is named as an author or co-author;

- The "Print Data" button sends the displayed data to the connected printer for printing. You can also use the download function in the form of a PDF document.

"Publishing activity" section. From this section of the scientific and technical information analysis system, information about the scientific articles, monographs, educational manuals and theses published in national and foreign countries by scientific staff working in scientific organizations in Uzbekistan can be obtained based on the principles presented in the work.

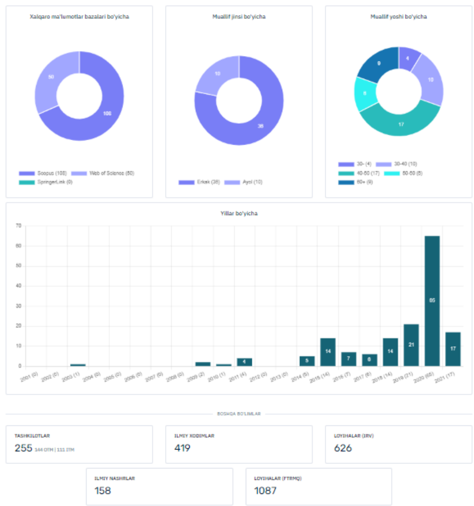


Fig. 8. Publishing activity window statistics section

IV. ACKNOWLEDGEMENTS

The work was carried out within the framework of the innovative project No. I-2021-76 on the topic "Development of the electronic platform of the scientific and technical information system" presented by the Ministry of Innovative Development of the Republic of Uzbekistan.

Conclusion

The results of the research and analysis carried out by the authors of the article revealed that the IAS created for each ministry has the main features characteristic of modern information and analysis systems, but the following shortcomings exist in the existing IAS.

The completed formalization and the defined requisite composition of information objects in the main areas of activity of scientific organizations laid the groundwork for the development of their information model and the National scientific and technical intellectual information system of the Republic of Uzbekistan. This system provided the following:

- rapid acquisition and analysis of integrated statistical information about the types of products received, storage documents and publications:

- in different time periods;

- in the section of individual organizations;

- in the field of science;

- in terms of priorities of the innovative development strategy;

- by types of scientific research (fundamental, applied, innovative);

- on the implementation of scientific and technical programs;

- preparation of analytical data on the effectiveness of scientific researches for state administration bodies, as well as the entire scientific community. All this allows for the centralization of scientific and technical data collection, monitoring and analysis, as well as helps to make timely and accurate decisions based on complete and reliable information, simplifies the coordination of research organizations and the optimization of the use of resources allocated to science and innovation. In addition, it allows to identify development trends and growth points, as well as commercially attractive results of the research.

The introduction of this information-analytical system into the regional management system allows to increase the quality of information-methodical supply in the study and analysis of innovative development. This serves to make adequate, effective management decisions. The developed system includes several important aspects, i.e. statistical and analytical data collection, storage, and processing stages. This system allows to monitor and evaluate the innovative development of the region by implementing effective technologies, management mechanisms in the specific field under study, i.e. state regulatory measures in this field.

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Methods For Detecting Voice Activity In Speech Signals

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***Abstract*— Speech is a method of information exchange between people, produced by a speech apparatus and transmitted in natural conditions through sound waves. In voice communication, the space where the speech information is located in the signal is called the speech active area. Intervals that do not contain speech information, regardless of the presence or absence of background noise, are called intermediate stops.**

Speech recognition and speech-to-text stoppages present many challenges. In particular, it reduces the speed and efficiency of the algorithm. In order to eliminate these problems as much as possible, methods and algorithms for determining the active area of speech are used.

Most of the algorithms for extracting the active part of speech are commercial and closed. The main problems of the existing VAD-algorithms are their unreliable performance in the presence of background interference and the need for large computing resources. The article analyzes the methods and algorithms of voice activity detection and proposes a neural network model based on deep learning. Based on them, software was developed and tested in experimental studies.

***Keywords*— speech signal, amplitude, energy, field, recognition, background, noise, threshold, voice activity detection, VAD, deep neural network, identification, feature, model.**

I. INTRODUCTION

In recent years, a lot of attention has been paid to the implementation of artificial intelligence technologies all over the world. One of the main areas of artificial intelligence is the area of person and speech recognition based on the speech signal. At the moment, voice recognition systems are developing rapidly in motion pictures. The main reason for the development of these systems is the increasing demand in areas such as biometric search, voice verification of passengers and drivers, restriction of access to information using voice biometrics.

Voice-based speaker recognition systems are less expensive than other biometric recognition systems. They do not lag behind other recognition systems in terms of reliability, and are higher in some indicators. For example, in relation to systems for recognizing a person based on his image.

Speech is a method of information exchange between people, produced by a speech apparatus and transmitted in natural conditions through sound waves. In voice communication, the space where the speech information is located in the signal is called the speech active area. Intervals that do not contain speech information, regardless of the presence or absence of background noise, are called intermediate stops.

Speech recognition and speech-to-text stoppages present many challenges. In particular, it reduces the speed and efficiency of the algorithm. In order to eliminate these problems as much as possible, methods and algorithms for determining the active area of speech are used.

In the literature, the algorithm for determining speech activity time limits is called VAD (Voice Activity Detection). Usually, the VAD algorithm is used to divide the signal into two active A (activity) and S (silence) segments (Fig. 1).

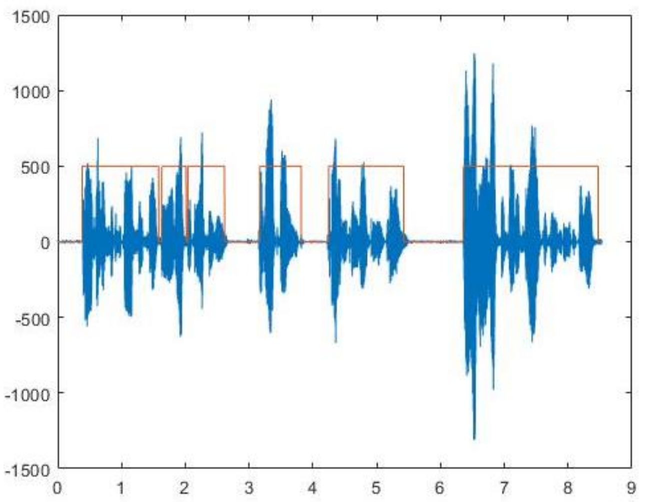

Fig. 1. The result of determining the limits of speech activity

The VAD algorithm was one of the first to be successfully used in the GSM (Global System for Mobile Communications) standard cellular radio communication system [1]. In this case, speech processing according to the principle of discrete transmission DTX (Discontinuous

Transmission) allows to connect the transmitter during the duration of the user's active speech and to turn it off when it is stopped or when the conversation ends. DTX is driven by a VAD detector, which is used to detect and separate speech and non-speech intervals even when the signal-to-noise ratio is below 0 dB. In GSM systems, the VAD detector plays an important role in reducing consumption, because the speech activity of the speaker in a monologue is less than 50% on average, and in a dialogue, it allows to reduce the active conversation period of the participant to 30% [1].

VAD algorithms face many problems in the presence of significant background noise, in such situations it is recommended to use more sophisticated approaches, for example, the methods proposed in works [8-11]. The authors of [2] proposed an adaptive threshold VAD algorithm. It has also been proven to perform well in time-varying signal-to-noise ratio.

Most of the algorithms for extracting the active part of speech are commercial and closed. The main problems of the existing VAD-algorithms are their unreliable performance in the presence of background interference and the need for large computing resources.

VAD is widely used in many speech-related applications, including coding, recognition, speech enhancement, and audio indexing. Its anti-noise power is also very important for automatic speech recognition (ASR). A powerful detector can improve the accuracy and speed of any ASR in a noisy environment. Voice activity detection is the first step in speech preprocessing, and is also typically used to remove any non-speech segments from the speech signal. This helps to save the speech to be made available for further processing steps.

Fig. 2. General scheme of the speaker's speech processing algorithm

The necessary features for an ideal detector of voice activity detection are presented in [3], which are features such as reliability, stability, accuracy, flexibility, simplicity, and real-time use without noise information. Ensuring stability against noise is a very complex process. Under conditions of high SNR (Signal-to-noise ratio), the simplest VAD algorithms perform relatively well, but under conditions of low SNR, almost all VAD algorithms give somewhat poor results. In order to fulfill the requirement of real-time application, the VAD algorithm should be as simple as possible. Therefore, its simplicity and noise tolerance are two important features of practical speech activity detectors.

Since evaluating the performance of VAD is very complex [4], it is desirable to fully evaluate the algorithm by applying it to solving problems such as coding or speech recognition. Some issues, including speaker segmentation, can be handled quickly by separating non-speech segments in an audio file as separate speakers. For example, in segmentation, it is common to use music, overlapping speech, and silence as separate speakers. However, VAD remains an open research problem as it has not been perfected to date [5].

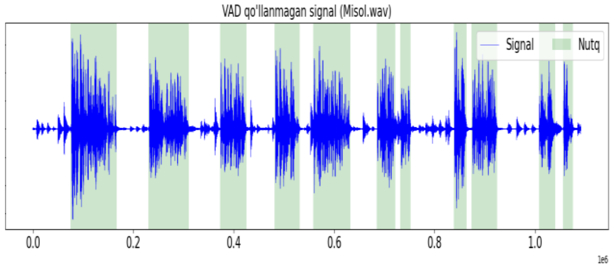

Fig. 3. Speech signal without VAD applied (Example.wav)

II. FORMULATION OF THE PROBLEM

Determining whether each input signal x is speech or non-speech is a generalization of the VAD problem. This algorithm can be expressed as a function of $y = VAD(x)$ where y is the desired result, i.e.:

$$\bar{y} = \begin{cases} 0, x - no\ speech \\ 1, x - speech \end{cases} \quad (1)$$

The probability that x is speech is the probability that speech exists, where $S(x) = P(x)$. In this case, the VAD can be expressed as:

$$VAD(x) = \begin{cases} 0, & S(x) < \theta \\ 1, & S(x) \geq \theta \end{cases} \quad (2)$$

where θ - scalar threshold.

III. THE MAIN PART

Energy-based VAD method. In this method, non-speech areas are considered to have less energy than speech areas. Speech is not a stationary signal, and a person sometimes speaks loudly and sometimes not. Therefore, signal energy can be used as an indicator of the presence of speech. Since speech adds energy to the signal, areas of it with higher energy are more likely to be speech areas. For example, by setting the threshold θ_{speech}, if the signal energy $\sigma^2(x)$ is greater than the threshold, then the VAD takes it as the speech active area, that is:

$$VAD(x) = \begin{cases} 0, & \sigma^2(x) < \theta_{speech} \\ 1, & \sigma^2(x) \geq \theta_{speech} \end{cases} \quad (3)$$

To implement this method, a 25 ms window and 10 ms offset windows are initially applied to the input signal. The signal energy in each window is calculated by the following formula:

$$\sigma^2(x) = \|x\|^2 = \sum_{k=0}^{M-1} x_k^2 \quad (4)$$

The window is moved along the stream and the energy is calculated for each window separately, or a threshold value of energy is given to make the decision, or if the entire stream of speech is known a priori, then the windows are ordered in descending order of energy. In this case, those with a higher percentage of sorted windows are taken as speech areas, thus the speech areas are retained, and the rest of the windows are discarded as non-speech areas.

This method is parametric and requires a threshold parameter value to be specified in advance. The results of the application of energy-based VAD in the time domain are presented, where the threshold value is taken as 0.6 (Fig. 4).

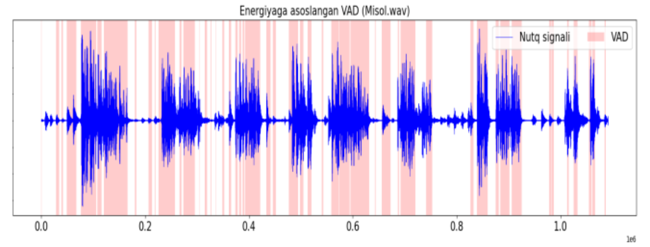

Fig. 4. Time series and energy-based VAD results

VAD method based on zero crossing frequency and energy. This method is a simple and fast way to divide the given speech signal into vocalized and non-vocalized classes [6]. This method is based on zero-crossing rate and energy calculation, where the zero-crossing rate is determined by the number of cases where successive samples of the speech signal have different signs, or the number of signal amplitude zero-crossings. This can be expressed as follows:

$$Z_m = \sum_{k=-\infty}^{\infty} \left| sign\left[x(k)\right] - \left| sign\left[x(k-1)\right] \right| w(m-k) \right., \quad (5)$$

where

$$sign\left[x(k)\right] = \begin{cases} 1, & x(k) \geq 0 \\ -1, & x(k) < 0 \end{cases} \quad (6)$$

$$w(m) = \begin{cases} \dfrac{1}{2M}, & 0 \leq m \leq M-1 \\ 0, & else \end{cases} \quad (7)$$

M – window length.

The zero-crossing frequency makes it possible to determine the presence or absence of speech in the incoming speech signal. If the number of zero crossings is large, the window is considered speechless, otherwise speech. An example of the result obtained based on this method is shown in Fig. 5.

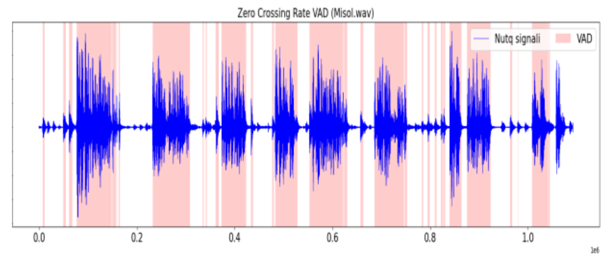

Fig. 5. Time series and VAD results based on Zero crossing rate and energy

A deep neural network VAD method. In many cases, the real speech signal is recorded under interference conditions. In such cases, the use of deep neural networks is effective. Because deep neural networks have been proven to be more robust to noise than traditional statistical methods.

A deep neural network (DNN) is a general nonlinear classifier that can be trained to collect speech and non-speech frames and easily distinguish between speech and non-speech signals as a binary classification problem. Training the VAD-DNN model requires specifying the speech and non-speech regions separately for each frame, which is a mandatory task and is considered a non-trial issue.

DNN models are successfully used in ASR systems and are trained on large speech corpora. And DNN models trained on speech corpora labeled with words or phonemes are highly effective at recognizing phonemes. This can be used to create a powerful VAD method. The output values corresponding to all speech (noise) phonemes from ASR-DNN and VAD-DNN must be combined to obtain the a posteriori information that the incoming frame is speech (noise). The result obtained using DNN as VAD is shown in Fig. 6 [7].

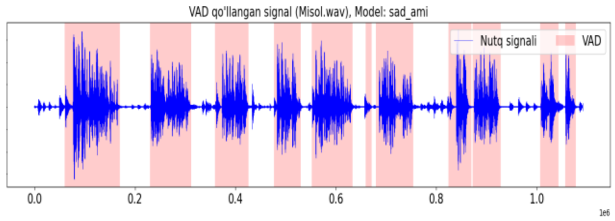

Fig. 6. Time series and VAD results based on DNN

In order to evaluate the effectiveness of the above-mentioned speech activity detection methods, experimental studies were conducted on recognizing a person based on his voice [12] and converting speech to text [13-15]. A total of 250 speech audio files consisting of 3 to 10 words were used. The obtained results are presented in the table below.

TABLE I. THE RESULTS OF METHODS

Method	Voice recognition (accuracy level, %)	Speech to text (accuracy level, %)
Energy-based	86,3%	80,9%
Zero crossing rate	89,5%	82,2%
Deep neural network	96,8%	91,2%

IV. Conclusion

VAD is important as a pre-processing step in speech or person recognition. However, the more noise in the speech stream, the stronger the VAD. Applying VAD to identity recognition allows you to get more results with less effort. Because using a simple energy-based VAD in training and testing is strict and discards multi-speech parts as non-speech parts. However, if the streams are long, the remaining parts of speech are sufficient to correctly form or recognize the person models. This leads to a reduction in overspending. The experimental results showed that VAD methods based on neural networks are more effective than other methods in identifying speech parts of speech signals.

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Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP) for Mobile Ad Hoc Networks.

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***Abstract*— Mobile ad hoc networks (MANETs) are collaborative networks formed by mobile nodes without a centralized infrastructure. They find applications in various domains, including military and security-sensitive operations. However, securing the routing process in MANETs is challenging due to the absence of a central authority and dynamic network characteristics. Existing routing protocols have limitations in terms of bandwidth consumption and route request delays. To address these challenges, this paper proposes a Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP) for MANETs. SEZMRP combines proactive and reactive approaches and incorporates digital signatures and encryption techniques to ensure message integrity, data confidentiality, and end-to-end authentication at the IP layer. The paper presents a comprehensive design of SEZMRP, evaluates its resilience against security attacks, and measures its performance through simulations. The findings demonstrate the robustness of SEZMRP against various security attacks, its efficient security performance with an acceptable overhead, and its suitability for securing MANETs in military and security-sensitive operations. SEZMRP, when combined with existing security measures, provides a solid foundation for ensuring secure operations in ad hoc networks. Future improvements can focus on optimizing performance, scalability, energy efficiency, and considering quality of service requirements to further enhance the protocol.**

Keywords*— *Zone-based Routing, security, energy efficiency, MANETs etc.

I. Introduction

MANETs are decentralized networks enabling communication without infrastructure. They serve various applications but face challenges due to mobility, limited resources, and lack of central control, impacting secure and efficient routing.

As the nodes in MANETs are autonomous and dynamically organize themselves into a network, traditional security mechanisms designed for wired networks are often ineffective. Moreover, MANETs operate in open and hostile environments, making them more vulnerable to various security attacks, including eavesdropping, tampering, and denial-of-service attacks[2].

To address these security challenges, researchers have proposed numerous routing protocols for MANETs. However, existing protocols suffer from limitations in terms of bandwidth consumption, route request delays, and vulnerability to security threats[3]. Therefore, there is a need for a routing protocol that not only ensures secure and reliable communication but also optimizes energy efficiency to prolong the network's operational lifespan.

The paper introduces SEZMRP, a novel routing protocol for secure MANETs with energy efficiency. It details proactive and reactive components, advanced security mechanisms, and robustness against attacks. Simulations assess its performance, highlighting routing overhead, packet delivery, and energy use. Future work includes optimizing performance, scalability, energy efficiency, and QoS integration.

The rest of the paper is organized as follows. Section II provides an overview of the related work in the field of secure routing protocols for MANETs. Section III presents the detailed design and architecture of the proposed SEZMRP protocol. Section IV evaluates the security resilience and performance of SEZMRP through extensive simulations. And discusses the implications of the findings. Finally, Section V concludes the paper, summarizing the contributions and outlining future research directions.

II. Literature Review

The paper[4] EEZRP optimizes energy and communication in zones via Zone Coordinators, multi-path routing, and efficient route maintenance. Simulations show better energy efficiency, network life, and packet delivery than traditional protocols

The paper[5] protocol suggests a collaborative method for secure routing in MANETs, focusing on node cooperation, encryption, authentication, and key management to ensure safe data transmission, thus minimizing vulnerabilities and improving overall reliability..

The paper[6] protocol proposes a clustering-based, fault-tolerant routing for MANETs. It clusters nodes for efficiency, employs secure error reporting, and ensures reliable data transmission in dynamic, resource-constrained scenarios.

The paper[7] presents a security-aware routing protocol for Wireless Ad hoc Networks (WAHNs). It emphasizes security with encryption, authentication, and key management for safe data transmission and protection against threats. This approach enhances routing resilience and reliability in dynamic, self-configuring networks, ideal for security-sensitive applications."

The paper[8] Introducing "SEAL" (Security-Aware List-Based Routing Protocol) for Mobile Ad hoc Networks (MANETs), prioritizing security. Using a list-based approach, it ensures secure data transmission against threats. SEAL integrates encryption, authentication, and secure key management for protection, enhancing communication resilience and reliability in dynamic, resource-constrained MANETs.

The paper[9] proposes Presenting "SARP-HWNs," a security-aware routing protocol for Hybrid Wireless Networks (HWNs) with trust-based features. It emphasizes secure routes using node trust levels for reliable data transmission. The protocol includes encryption, authentication, and secure key management for protection, offering a strong and secure routing solution for HWNs with diverse wireless technologies.

The paper[10] introduces a "Blockchain-assisted Secure Routing Protocol" for Cluster-based Mobile ad hoc Networks (MANETs). The protocol leverages blockchain technology to enhance security in cluster-based MANETs. By utilizing distributed ledger and cryptographic techniques, it ensures secure and trustworthy data routing. The blockchain-assisted approach offers resilience against attacks and tampering, making it suitable for dynamic and self-organizing MANETs.

The paper[11] This paper offers an extensive survey of 'Trust-Based Secure Routing Protocols' in MANETs. It examines protocols using trust mechanisms for improved data routing security. Through evaluation and comparison, the survey offers insights into strengths, limitations, and trends. It aids researchers and practitioners in choosing suitable solutions for securing MANETs in dynamic environments.

The paper[12] Introducing a 'Hierarchical Energy Efficient Secure Routing Protocol' for Wireless Body Area Networks (WBANs). This protocol employs hierarchy for energy optimization and network efficiency. It integrates security measures like encryption and authentication for secure data transmission. The paper offers a thorough analysis, showcasing the protocol's real-world effectiveness and benefits.

The paper[13] Introducing an 'Enhanced Energy Efficient Secure Routing Protocol' for MANETs. This protocol targets energy optimization and secure data transmission among nodes. The paper offers a detailed performance analysis, showcasing how the protocol effectively balances energy efficiency and security goals in dynamic, resource-limited MANETs.

III. Design and Architecture of the Proposed SEZMRP Protocol

To address limitations in existing approaches to securing ad hoc routing [14-18], we propose SEZMRP as a comprehensive and practical solution for ensuring secure routing in diverse ad hoc network applications.

A. Protocol Overview:

SEZMRP is an advanced MANET routing protocol emphasizing secure communication and energy efficiency. It's inspired by Zone Base Multipath Routing AOMDV, enhancing security and resource use. The protocol combines security with energy-saving methods, dividing the network into zones for localized security. RSA signatures ensure authentication and data integrity, using symmetric and asymmetric encryption for privacy. A certification process verifies nodes for secure channels. SEZMRP optimizes resource use and energy, dynamically choosing efficient paths and managing routes effectively. Overall, SEZMRP offers energy-efficient secure routing for MANETs, boosting security while optimizing resources. Nodes undergo certification for communication, as explained in the next section.

B. Certification Process:

The SEZMRP includes a certification process for secure communication within the network. Trusted certification authorities (CAs) act as reliable servers and CNs act as common nodes. CAs' public keys are known to all valid nodes[19]. The certification process is shown in Figure 1. SEZMRP operates as a two-phase protocol. In the initial phase, known as the preliminary certification process, each CN obtains the necessary keys from its nearest CA. Subsequently, the secure routing phase utilizes these keys to facilitate secure intra-zone or inter-zone routing, employing digital signatures and message encryption for enhanced security.

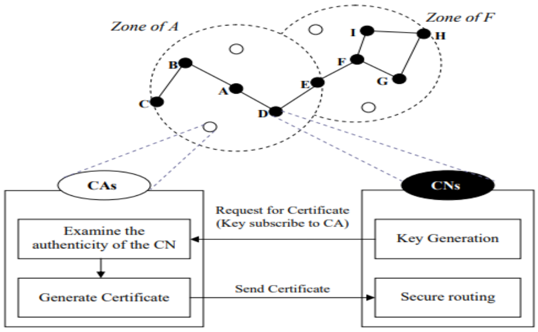

Fig. 1. Certification Process in SEZMRP

- **Algorithm for the certification process in the Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP):**

1. Input: Node X requesting a certificate from its nearest CA.
2. Output: Certificate (certX) issued by the CA.

Algorithm:

1. Node X sends a certificate request message to its nearest CA: X → CA: certX_request.
2. The CA receives the certificate request from Node X.
3. The CA generates a certificate for Node X with the following information:
   - Node X's IP address
   - Public key for verification (VKX)
   - Public key for encryption (EKX)
   - Creation timestamp (t)
   - Expiration time (e)
4. The CA securely signs the certificate using its private key (SKCA): CA → X: certX = [IPX, VKX, EKX, t, e] | signCA.
5. Node X receives the certificate (certX) from the CA.
6. The certificate (certX) contains the necessary credentials for secure communication within the SEZMRP network, including Node X's IP address, verification public key (VKX), encryption public key (EKX), creation timestamp (t), and expiration time (e).
7. The certificate is appended with the CA's digital signature (signCA), ensuring its authenticity and integrity.

8. Node X now possesses a valid certificate (certX) issued by the CA, allowing secure communication within the SEZMRP network.

It is essential for all nodes in the SEZMRP network to maintain up-to-date certificates issued by their respective CAs to establish secure communication channels and facilitate secure routing within the network.

C. Design of Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP):

This section provides a detailed explanation of the architectural design of the SEZMRP protocol, outlining its components and their functionalities.

- **Components of SEZMRP Architecture**

The architecture of SEZMRP is a modified version of the Zone Based Routing Protocol AOMDV. The functionality and interrelationship of each component are explained below in figure 2.

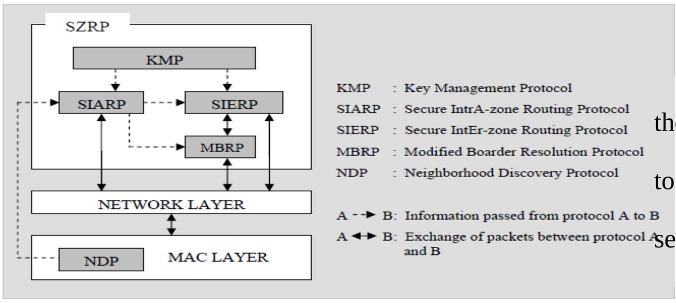

Fig. 2. Architecture of SEZMRP

Components of SEZMRP Architecture are described below:

1. Key Management Protocol (KMP): Responsible for public key certification process.
2. Secure Intrazone Routing Protocol (SIARP): Performs proactive link-state routing within a zone.
3. Secure Interzone Routing Protocol (SIERP): Offers reactive secure route discovery and maintenance between zones.
4. Neighborhood Discovery Protocol (NDP): Detects neighbor nodes and monitors link failures.
5. Modified Border Resolution Protocol (MBRP): Implements bordercasting technique for interzone route discovery.

- **Secure Routing Algorithm**

The following section explains intrazone and interzone routing processes within SEZMRP using network diagram shown in Figure 3 and the algorithms for both are described in the following sections:

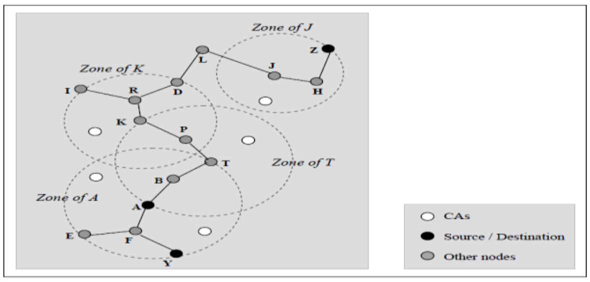

Fig. 3. Intrazone and Interzone destinations of node A (zone radius β = 2)

- **Algorithm for Secure Intra-Zone Routing:**

Input: Source node A, destination node Y within the same zone

Output: Secure communication channel between A and Y using session key KAY

1. A selects a route to Y within the same zone from its SIARP routing table.
2. A sends a Session Key Request (SKREQ) packet to Y:
   - Construct SKREQ packet: [SKREQ, IPY, certA] | signA
   - Send SKREQ packet to Y: A → Y
3. Y receives the SKREQ packet:
   - Verify the packet's signature using A's public key.
   - Authenticate the packet.
   - Generate a session key KAY.
4. Y sends a Session Key Reply (SKREP) packet to A:
   - Construct SKREP packet: [SKREP, IPA, certY, (KAY)EKA] | signY
   - Send SKREP packet to A: Y → A
5. A receives the SKREP packet:
   - Verify the packet's signature using Y's public key.
   - Decrypt the packet using A's private key to obtain the session key KAY.
6. A encrypts the data packet with KAY and sends it to Y along the same route (A-F-Y).
7. Subsequent communication between A and Y is secured using the session key KAY.

- **Algorithm for Secure Inter-Zone Routing:**

Input: Source node A, destination node Z in a different zone

Output: Secure communication channel between A and Z using session key KAZ

1. A initiates secure route discovery by bordercasting an SRD packet to peripheral nodes (T, E, and Y) with MBRP's assistance:
   - Construct SRD packet: [SRD, IPZ, certA, β, NA, t] | signA
   - Bordercast SRD packet: A → Bordercast
2. Peripheral nodes validate the SRD packet, set up a reverse path to A, sign and append their certificates, and rebordercast the packet if they lack a route to Z.
3. Rebordercasting continues until a node with a valid route to Z is reached. At that node, the SRD is forwarded to Z:
   - Construct and forward SRD packet: [[SRD, IPZ, certA, β, NA, t] | signA] | signT, certT → K → J → Z
4. Z verifies J's signature, extracts the encrypted session key KAZ, and creates an SRR packet:
   - Construct SRR packet: [SRR, IPA, certZ, NA, t, (KAZ)EKA] | signZ

   - Send SRR packet to H: Z → H

5. As the SRR packet travels along the reverse path, each node validates the previous hop's signature, removes the certificate and signature, signs the packet, appends its certificate, and forwards it to the next hop.

6. A receives the SRR packet from J, validates J's signature, extracts the session key KAZ, and encrypts the data packet using KAZ.

7. A sends the encrypted packet to Z along the same route (A-F-J-Z).

8. Subsequent communication between A and Z is secured using the session key KAZ.

These algorithms ensure secure intra-zone and inter-zone routing in SEZMRP, enabling nodes within the same zone and different zones to establish secure communication channels using session keys.

D. Route Maintenance:

Route maintenance in the Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP) ensures reliable and energy-efficient communication in ad hoc networks. It involves the following steps:

PROTOCOLS	NUMBER OF NODES VS THROUGHPUT		
	50	75	100
AODV	6718.66	8708.63	9249.71
AOMDV	6852.44	8979.59	15186.84
SEZMRP	12666.85	22366.39	26055.05

1. Link Failure Detection: SEZMRP detects link failures through periodic hello messages or signal monitoring.
2. Route Error Signaling: Upon link failure, nodes generate digitally signed Route Error (RE) messages to notify neighbors and the source node.
3. Route Repair or Redirection: Neighboring nodes and the source node take action to repair or redirect routes based on available alternatives.
4. Multipath Utilization: SEZMRP utilizes multiple paths to mitigate link failures, improve load balancing, and enhance network resilience.
5. Energy Efficiency Considerations: SEZMRP optimizes energy consumption by selecting energy-efficient paths and distributing traffic load evenly.

These mechanisms ensure reliable and energy-efficient routing, enabling secure communication while preserving network resources in SEZMRP.

In the realm of energy efficiency, SEZMRP employs multipath routing for traffic distribution, resource optimization, and node load reduction. It dynamically chooses energy-efficient paths using residual energy and link quality. The protocol backs route maintenance, avoids needless updates, and integrates power-conscious node scheduling and sleep modes.

To conclude, SEZMRP merges security and energy optimization effectively, making it reliable for routing in wireless ad hoc networks. It guards against security threats while minimizing energy use, suitable for resource-constrained settings.

IV. Results and Discussion

This section shows the results of Simulation. After implementing protocols in NS2.35 simulator [21] some screenshot of network topology is shown in Figure 4.

A. *Simulation Parameters*

The performance evaluation of the protocol developed by the event-driven ns2.34[21] simulator is implemented. A random mobility model has been selected for this simulation. A rectangular area 1500 m x 1000 m has been used to randomly distribute nodes in the simulation area. To simulate this protocol, some parameters have been set for evaluation in the TCL script of the network, which is shown with the help of Table 1.

The following table shows the simulation parameters used in simulations.

TABLE 1: SIMULATION PARAMETERS

PARAMETERS	VALUE
Simulator	NS2.35
Simulation Area	1500 m x 1000 m
Number of nodes	50, 75 and 100 nodes
Node Speed	20 Meter/second
Queue size	50 packets
Studies Routing Protocols	AODV, AOMDV & SEZMRP
Data Payload	512 bytes/packet
Initial energy	50 joule
Idle Power	0.100 J/bit
Sense Power	0.0175 J/bit
Energy consumption of transmitting data	0.035 J/bit
Energy consumption of receiving data	0.035 J/bit
Traffic Type	CBR
Simulation Time	200 Seconds
Channel Type	Wireless channel
MAC type	802.11
Mobility	Random Way point
Antenna model	Omni

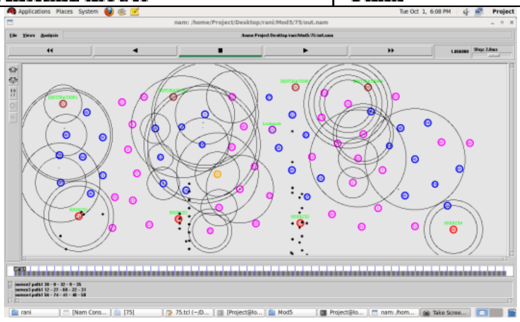

Fig. 4. Network Simulator Windows

The SEZMRP zone-based strategy is evaluated using the metrics throughput, end to end Delay, Packet delivery ratio, Energy Consumption and Network Lifetime. Their analysis on different number of nodes is provided in the following section.

1) **Average Throughput:**

Throughput is the total number of bits successfully transmitted from the sender to the receiver per unit of time, measured in bytes per second (bytes/sec). It represents the overall performance of the system.

- **Analysis of Throughput on Varied Number of Nodes**

The study evaluated SEZMRP's throughput on networks with 50-100 nodes moving at 3 m/s, using 512-byte packets. SEZMRP blends proactive and reactive routing to boost data delivery speed. With digital signatures and encryption, it ensures secure communication, preventing tampering and unauthorized access, resulting in smoother data transmission and enhanced overall throughput.

Table II. Throughput of AODV, AOMDV and SEZMRP with different Number of Nodes.

PROTOCOLS	NUMBER OF NODES VS THROUGHPUT		
	50	75	100
AODV	6718.66	8708.63	9249.71
AOMDV	6852.44	8979.59	15186.84
SEZMRP	12666.85	22366.39	26055.05

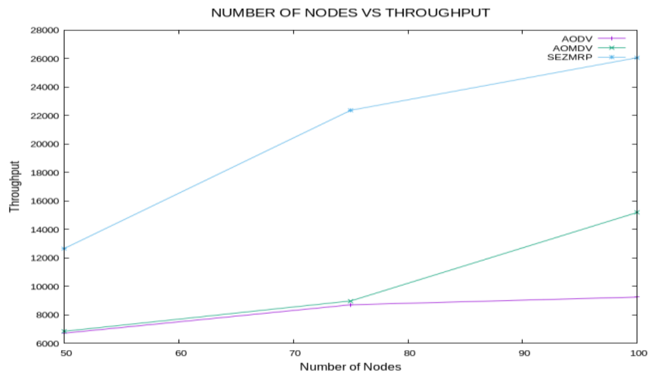

Figure 5 Throughput comparison based on Scenario 4

Table 3 compares the throughput of SEZMRP with that of AODV and AOMDV for different packet sizes (50, 75, and 100 bytes). The results demonstrate that SEZMRP consistently outperforms both AODV and AOMDV, achieving higher throughput percentages for all packet sizes.

Table 3 Throughput comparison of SEZMRP with AODV and AOMDV

PACKET SIZE	50	75	100	AVERAGE/ OVERALL
SEZMRP **compared to AODV**	46.95%	61.06%	64.49%	59.60%
SEZMRP **compared to AOMDV**	45.90%	59.85%	41.71%	49.22%

SEZMRP's throughput analysis on different node counts demonstrates its efficiency and robustness. It provides superior throughput even with more nodes, making it an ideal choice for secure and energy-efficient routing in mobile ad hoc networks.

2)End to End Delay

End-to-end network delay includes queuing delay, transmission delay, processing delay, and propagation delay. Average Delay is a very important performance metric of any network. Minimum is the delay better is the performance of the network.

- **Analysis of End-to-End Delay on Varied Number of Nodes**

SEZMRP's delay analysis on networks with different node counts shows its efficiency. It consistently outperforms AODV and AOMDV in terms of lower delays, even with more nodes.

Table 4 End to End Delay of AODV, AOMDV and SEZMRP with different Number of Nodes

PROTOCOLS	NUMBER OF NODES VS END TO END DELAY		
	50	75	100
AODV	479.44	757.079	907.463
AOMDV	451.778	841.936	962.646
SEZMRP	295.526	301.801	395.19

Table 5 shows that SEZMRP outperforms AODV and AOMDV in terms of end-to-end delay for different node counts.

Table 5 End to End Delay comparison of SEZMRP with AODV and AOMDV

NUMBER OF NODES	50	75	100	AVERAGE
SEZMRP **compared to AODV**	38.36%	60.13%	56.45%	53.70%
SEZMRP **compared to AOMDV**	34.58%	64.15%	58.94%	56.01%

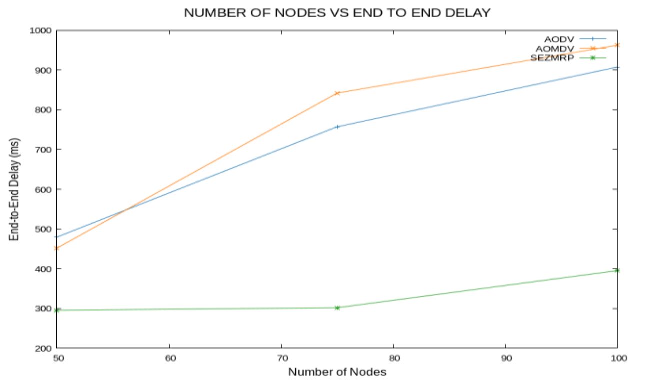

Figure 6 End to End Delay comparison based on Scenario 4

In conclusion, the analysis of end-to-end delay demonstrates that SEZMRP effectively maintains low delays even with increasing nodes. Its proactive and reactive routing, zone-based optimization, and energy-efficient mechanisms contribute to favourable end-to-end delay values.

3)Packet Delivery Ratio

It is the ratio of a number of packets that got at the destination and packets sent by a sender.

- **Analysis of Packet Delivery Ratio (PDR) on Varied Number of Nodes**

In this section, the Packet Delivery Ratio (PDR) of SEZMRP is evaluated on networks with different node counts. SEZMRP promptly detects link failures and adapts to network changes, maintaining reliable data delivery. The security mechanisms do not compromise PDR, ensuring data integrity and confidentiality.

Table 6 PDR of AODV, AOMDV and SEZMRP with different Number of Nodes

PROTOCOLS	NUMBER OF NODES VS PACKET DELIVERY RATIO		
	50	75	100
AODV	49.5544	50.2045	54.3859
AOMDV	48.9817	52.7977	60.9714
SEZMRP	60.5352	75.82134	78.4531

Table 7 shows that SEZMRP outperforms AODV and AOMDV in terms of PDR for different node counts. SEZMRP consistently achieves higher PDR percentages across all scenarios.

Table 7 PDR comparison of SEZMRP with AODV and AOMDV

PACKET SIZE	50	75	100	AVERAGE
SEZMRP compared to AODV	18.13%	33.78%	30.67%	28.24%
SEZMRP compared to AOMDV	19.08%	30.36%	22.28%	24.23%

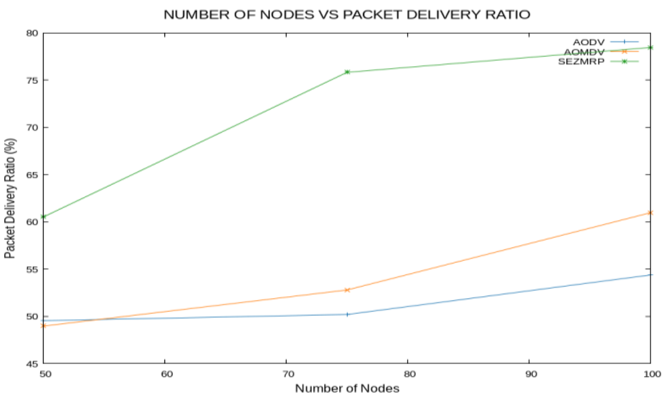

Figure 7 Packet Delivery Ratio comparison based on Scenario 4

In conclusion, SEZMRP exhibits a high Packet Delivery Ratio (PDR) on networks with varying node counts. Its proactive and reactive routing, zone-based optimization, and multipath routing contribute to the superior PDR. SEZMRP's ability to handle security requirements while ensuring reliable data delivery makes it suitable for various applications, including military and security-sensitive operations.

4)**Energy Consumption**

Energy Consumption in a network refers to the amount of energy consumed by each node during the simulation time. It is calculated by measuring the energy level of each node at the end of the simulation.

- **Analysis of Energy Consumption on Varied Number of Nodes**

This section evaluates SEZMRP's Energy Consumption performance in various node-count networks in mobile ad hoc setups. SEZMRP maintains energy efficiency as node numbers increase. Its zone-based and multipath routing lowers energy use. Dynamic path selection, node scheduling, and sleep modes further save energy.

Table 8 Energy Consumption of AODV, AOMDV and SEZMRP with different Number of Node

PROTOCOLS	NUMBER OF NODES VS ENERGY CONSUMPTION		
	50	75	100
AODV	95.4259	157.634	196.709
AOMDV	95.6652	157.991	196.558
SEZMRP	72.7573	153.871	173.805

Table 9 shows that SEZMRP outperforms AODV and AOMDV in terms of energy efficiency for different node counts. SEZMRP consistently achieves lower energy consumption percentages across all scenarios, indicating its superior performance in optimizing energy usage compared to the other two protocols.

Table 9 Energy Consumption comparison of SEZMRP with AODV and AOMDV

PACKET SIZE	50	75	100	AVERAGE
SEZMRP compared to AODV	23.75%	2.38%	11.64%	10.96%
SEZMRP compared to AOMDV	23.94%	2.60%	11.57%	11.057%

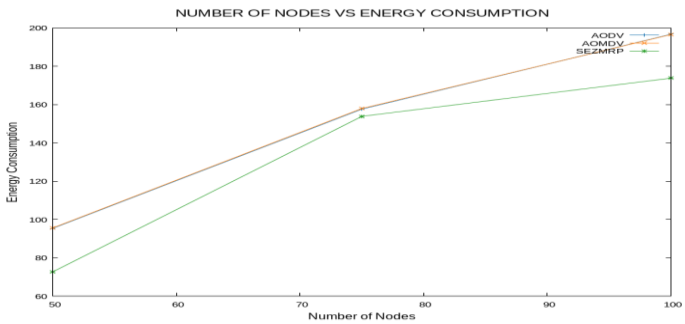

Figure 8 Energy Consumption comparison based on Scenario 4

In conclusion, the analysis of Energy Consumption on networks with varying node counts confirms that SEZMRP is an energy-efficient routing protocol. Its zone-based approach, multipath routing optimization, power-aware node scheduling, and sleep modes contribute to reduced energy consumption and prolonged network lifespan.

5)Network Lifetime

Network Lifetime shows how long nodes in the network continue active. The unit of Network Lifetime is a sec. It is a highly powerful metric since it shows the operational time of the network.

Analysis of Network Lifetime on Varied Number of Nodes

The analysis of Network Lifetime shows that the Secure and Energy-efficient Zone-based Multipath Routing Protocol (SEZMRP) effectively manages energy resources, leading to a prolonged Network Lifetime. SEZMRP's zone-based approach, multipath routing optimization, and adaptive strategies contribute to its energy efficiency without compromising security.

Table 10 Network Lifetime of AODV, AOMDV and SEZMRP with different Number of Node

PROTOCOLS	**NUMBER OF NODES VS NETWORK LIFETIME**		
	50	**75**	**100**
AODV	42.2749	42.3658	22.2908
AOMDV	42.2929	42.0088	22.4415
SEZMRP	52.5456	46.2503	36.5234

SEZMRP outperforms AODV and AOMDV in Network Lifetime, demonstrating its superior energy management and efficiency for mobile ad hoc networks. It prolongs the network's operational lifespan and is suitable for various applications, including military and security-sensitive operations.

Table 11 Network Lifetime comparison of SEZMRP with AODV and AOMDV

NUMBER OF NODES	**50**	**75**	**100**	**AVERAGE**
SEZMRP compared to AODV	19.54%	8.39%	38.96%	20.97%
SEZMRP compared to AOMDV	19.51%	9.17%	38.55%	21.11%

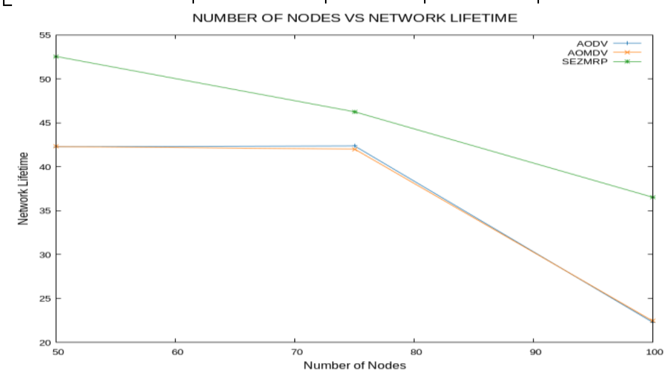

Figure 9 Network Lifetime comparison based on Scenario 4

SEZMRP efficiently manages energy, leading to a prolonged Network Lifetime. Its zone-based approach, multipath routing, and security measures contribute to reliability. Suitable for resource-constrained environments and security-sensitive scenarios. Robust and efficient routing protocol.

V Conclusion

The paper introduces SEZMRP as a comprehensive solution for secure routing in MANETs. It combines proactive and reactive methods, using signatures and encryption for data security. Simulations demonstrate its efficacy against attacks and its efficiency in various aspects. SEZMRP excels in energy efficiency, network longevity, and secure communication, outperforming AODV and AOMDV. It suits military and security scenarios and offers reliability and efficiency. Future work can enhance performance, scalability, and energy efficiency. SEZMRP is a robust, efficient routing solution for secure ad hoc network communication.

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MODEL AND ALGORITHM FOR CONTROLLING CHANNELS OF CONFIDENTIAL DATA LEAKAGE IN COMPUTER SYSTEMS

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***Abstract*—Sensitive and confidential data are a requisite for most companies, so protection for this data takes great attention by company's top management, administrators and IT managers. Data leakage causes negative impact on companies. The traditional security approaches, such as firewalls, can't protect data from leakage. Data leakage/loss prevention (DLP) systems are solutions that protect sensitive data from being in non-trusted hands. This article covers DLP system architecture construction and algorithm. In addition, a system model consisting of several modules was built.**

***Keywords*—Confidential data, DLP, Monitoring, Controlling channels, Decision, Block.**

I. INTRODUCTION

Cryptographic information security methods ensure confidentiality, integrity, authentication and availability of data. These methods are used to protect information from unauthorized access, changes and other types of cyber threats [1-9]. However, over the past ten years, there have been frequent leaks of confidential information from various organizations. The reasons for information leakage can be different. In this situation, controlling the channels for leaking confidential information is very important to prevent data leakage. For example, a June 2022 survey by Technavio DLP found that between 2022 and 2026, companies will spend \$6.03 billion on data breach prevention programs. This means an average increase of 23.78 percent in the amount spent on data leakage prevention every year [10]. Through these types of attacks, valuable or confidential information of the organization is given by insiders to outsiders or sold for a certain amount. Data Leak Prevention (DLP) security systems are currently being used in the information environment to prevent this type of incidents. The demand for this system is growing year by year, and it is installed not only in commercial organizations, but also in state institutions. These types of security systems are mainly provided by western countries. Currently, such organizations as Symantec, McAffee, TrendMicro, WebSense offer their products worldwide [11]. Scientists are also proposing new algorithms and modules of this system, for example, the behavior of information leakage by insiders is analyzed by analyzing previous studies and implementing the in-depth interview method. Statistical analysis of the analyzed data leakage behavior is carried out to determine the validity and level of leakage risk for each behavior [12] or high regulation of access to personal data and, in addition, which parts of the system are external construction of a DLP system architecture designed to determine the possibility of hacking or internal attacks, [13] as well as construction of a system that prevents data leakage through network channels [14], analysis of data from web browsers through a proxy server and methods of finding confidential information from them, [15] the work done by such scientists and their results can be seen in the article prepared by Isabel Herrera, Jose Javier Garca Aranda. [16] Recent research shows that government organizations allocate hundreds of millions of dollars a year to DLP systems from their budgets, and this type of indicator is growing year by year. This issue requires the organization to create its own DLP system [17]. In this article the issues of monitoring confidential data leakage channels in computer systems have been studied, the proposed algorithm and modules can be used in the creation of a DLP system or can be added as an additional module to the created system.

II. DLP AGENTS

DLP agents consist of 10 main modules. These are: *"Monitoring file system", "Monitoring the printer", "Monitoring external storage devices", "Monitoring clipboard", "Monitoring screen", "Monitoring keylogger", "Monitoring network", "Analysis and decision making", "Decision implementation"* and *"Updating the database"* modules.

Agents monitor user behavior and processes through "Monitoring" modules. "Monitoring" modules include such modules as "Monitoring file system", "Monitoring the printer", "Monitoring external storage devices", "Monitoring clipboard", "Monitoring screen", "Monitoring keylogger", "Monitoring network"

Monitoring file system monitors all file-related events on workstations. Controls operations such as reading, writing, deleting a file. To process file-related events, the following file event attributes are read and used for analysis: *file path, file content, file size, file type, event time, attributes of the storage device, the operation performed on the file, the program performing the operation, the name of the user who launched the program* [18-24].

Monitoring file system captures and processes file related events. During processing, it performs the following actions:

1) Checks if the file contains text or image data.
2) If there is a file with image data, the text in the image will be recognized.
3) Textual data and event information are passed to the next step.

Files are continuously accessed by various programs in the operating system. Events such as creating, reading, writing, deleting a file, and changing a file attribute occur. In this case, classifying all files increases the load on computer resources. File classification is performed to determine the confidentiality of the contents of the file [25-31]. The classification is based on the complete content of the file. Therefore, when referring to a file, it must first be determined whether the file is a text file. For this, the following steps are taken:

1) The extension of the file is checked if it corresponds to the extension of files with text content, for example: txt, docx, doc, xls, xlsx, ppt, pptx, rtf, jpg, png, pdf, etc.
2) If the extension of the file does not correspond to the extension of files with textual content, then a certain number of bytes are read from the beginning of the content of the file, and based on these bytes, the file type is determined.

Monitoring the printer keeps track of the user's access to the printer device and the data given to this device to print. The following printer event attributes are read and used for analyzing: *printer name, the data transferred to the printer, the time of the event, the program executing the action, the name of the user who started the program.*

Monitoring the printer captures and processes printer events. During processing, it performs the following actions:

1) Recognizes data sent to the printer.
2) Textual data and event information are passed to the next step.

Monitoring external storage devices monitors external devices connected to the workstation by users. If the external storage device connected to the computer is in the list of trusted devices (white list), it allows to copy data from the computer. If the external storage device is on the list of untrusted devices (blacklist), it will be blocked when connected to the system. The list of trusted devices is created by the administrator based on the organization's security policy.

The following attributes of the external storage devices event are read: *device ID, event time, username and other attributes* [32-26].

Monitoring the clipboard monitors the data in the clipboard. If the user writes data to the clipboard, the *Monitoring the clipboard* will catch this event and process it. Monitoring the clipboard performs the following actions during event processing:

1) Checks whether the data in the buffer is text or image.
2) If there is image data, the text in the image will be recognized.
3) Textual data and event information are passed to the next step.

Monitoring screen takes a screenshot of the workstation screen at specified times or situations. The time interval and conditions can be configured by the system administrator. This monitoring is more used to find traces of illegal activities. A screenshot is taken while the employee is working with certain programs at the workplace.

Monitoring keylogger records the keys pressed on the keyboard. This monitoring serves to monitor logins and passwords, as well as to monitor users' accounts on resources considered "important". In addition, it allows to monitor the employee's messages in instant messaging systems. Identifies users who entered passwords from the keyboard on encrypted data.

Monitoring network monitors outgoing data through the computer's network interfaces. It intercepts the data and sends it for analysis.

One of the main requirements for DLP systems is to identify confidential information from large volumes of data. There are different approaches to solving this. For example, it is possible to identify confidential information through keywords, statistical and linguistic analysis, and search for confidential information by content using intellectual methods [37-41]. Recent research shows that these methods are more effective when implemented through intellectual methods than other methods [42-48].

In the **"Analysis and decision making"** module, information received from monitoring modules is classified by content and attributes. For example, the classification of information based on its content can be done by analyzing the similarity

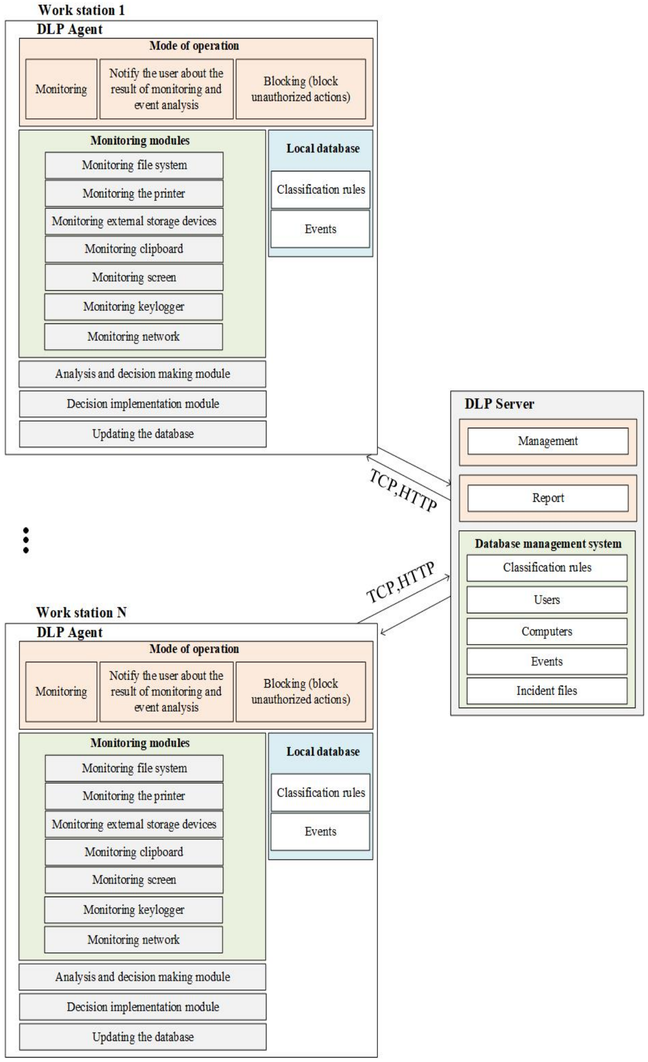

Fig. 1. A model of control of confidential data leakage channels in computer systems.

of open texts using the method of frequency analysis [19]. Information related to the incident is classified according to confidentiality through intellectual analysis [17]. Based on the result of information classification, a decision is made regarding the action in the event.

After the decision is made, the decision result is sent to the **"Decision implementation"** module. This module checks the mode before making a decision. Agents on workstations work in the following modes:

1) Monitor.
2) Notification.
3) Block.

Monitor mode. The agent monitors the system through modules in the "Monitor" mode. Sends information to the central server when an event occurs. In this mode, the agent does not affect the user's work, does not issue any warning messages, and does not block user actions.

Notification mode. In this mode, the agent collects event data through modules and sends it to the server. However, unlike the mode described above, the organization will warn the user about this situation if an event occurs that is contrary to the information security policy. Limited to user notification, event action is not blocked.

Block mode. In this mode, the agent will issue a warning message and block the action, and then report the event to the server.

The **"Updating database"** module is to update the local database based on the database on the server. That is, if, for example, a new law, regulation or information security policy is changed in the organization, the agents will learn about the change through this module.

III. DLP Server

As shown in Figure 1, the model for controlling confidential data leakage channels in computer systems works on the basis of client-server technology. That is, several clients send event information to a central server. DLP server part consists of "Management" and "Report" modules and database management system (DMS).

The DLP agents located at the workstations are managed through the management module. For each user, his rights are determined based on the information security policy or the organization's internal legal regulations, a white list of external memory devices is formed, and DLP agents are configured.

Various reports are created in the reporting module. Reports can be obtained by time interval as well as by individual agent. Reports are presented through various dashboards. In addition, it is possible to obtain a list of risks and the most important events, detailed information about users, data analysis and reports about the locations of files. The database management system is divided into sections such as classification rules, users, computers, events, and incident files.

The classification rules section lists the values used in the methods of analyzing the content of information.

In the *Users* section, information about all users available in the system is stored. Also, information such as when they entered the system, what rights they have, what programs they launched, what files they worked with, what actions they performed on files, what data they copied to an external device or computer.

In the *Computers* section, the name of the computer on which the agents are installed, its IP address, where it is located, (that is, which department and room number of the organization), which users used it, which domain it belongs to are given.

The *Events* section is the largest section in the database because it stores all the events in the computer systems. Using this information, the normal state of each user can be constructed. As a result, it will be possible to determine the abnormal state of the user or process in the system. This allows to identify new threats.

In the section of incident files related to the event, mainly files are saved, that is, an action is performed on a file, this file is automatically copied and saved to the database. Along with the file, its hash value is stored together. If any changes are made on this file and saved, the changed file will be saved separately. A file tree can be viewed through the reporting module.

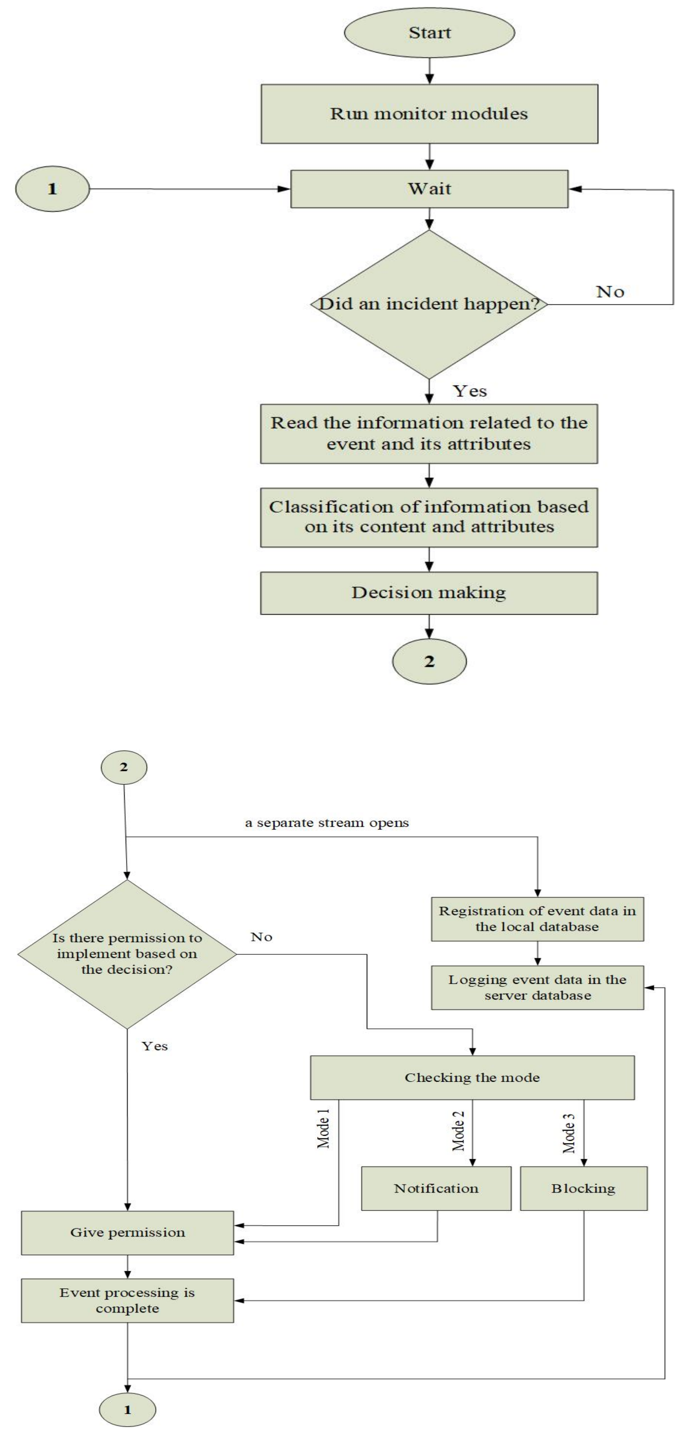

Fig. 2. Leakage of confidential information in computer systems channel control algorithm

An algorithm for controlling the channels of leakage of confidential information in computer systems works in the following order (Fig. 2). When the workstation is started, the DLP agent is also started. As soon as the agent starts, the monitoring modules are activated and start monitoring user behavior. If any action is performed by the user, immediately the information related to this event and its attributes are read. As mentioned above, information is classified and decided on the basis of its content and attributes. After the decision is made, it is determined whether there is permission to perform an action based on this decision. Before that, a separate thread is created in the process, and through this thread, event data is recorded in the agent's local database. After some time, this information from the local database is transferred to the central server and stored in the database on the server. The transmitted data is deleted from the agent's local database. If the action is allowed based on the decision, then the agent allows the action to take place and terminates the event processing process, waiting for the next event to occur. If the action is not allowed based, then the agent checks the operation mode. If there is a ”Monitor” mode, then the information about the event is written to the database and the action is allowed to be performed. In the ”Notification” mode, the user is informed about the decision made as a result of the analysis of the event, and the action is allowed to be performed. In blocking mode, the action is completely blocked. Then result of action of agent are stored in a database on a central server.

Server and client send and receive data via TCP or HTTPS protocols. Agents transmit the event and information about it to the server via the HTTPS protocol. All data must be transmitted in encrypted form. Cryptographic providers that support national cryptographic providers or standard Windows cryptographic providers can be used to provide cryptographic protection [5-6]. In addition, the TCP protocol is also used. The TCP protocol is used to notify about the addition of new classification rules and deliver the newly added rules to the agents, as well as to transfer the data sent from the agent for reporting, to add trusted external settings by the administrator.

IV. CONCLUSION

The proposed national DLP system provides the following opportunities:

- Helps prevent leakage of confidential data
- Eliminates unauthorized sharing of documents
- Protects against fraud
- Monitoring employee behavior
- Security incident investigation

The following results were obtained through the proposed DLP system algorithm and module:

- DLP system algorithm was created.
- DLP system modules were built.

The obtained result was tested in a special laboratory. For this purpose, information was leaked to one computer through the non-network information leakage channels specified in the information security policy. Then the efficiency of this algorithm and module was 76%. That is, 76 out of 100 possible exit paths from the agent were prevented.

Public institutions or private organizations can add additional changes or new modules to the DLP system proposed above, depending on their needs. Military vehicles in particular deal with confidential information on a daily basis, and the use of this security system developed by private companies can lead to significant risks. The reason is that the DLP security system is not disclosed on the basis of which algorithm is built and what code is written in it, because this information is a trade secret of the organization. The proposed algorithm and model can be useful in building national DLP systems. In addition, additional modules can be added in the future to increase the efficiency of this DLP system. For example, control of confidential information through social networks, identification of potential insiders through user actions, prevention of leakage of confidential information through e-mail channels, etc.

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Correction of Distortions in Signal Characteristics of Technological Parameters Based on Wavelet Analysis

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***Abstract*—The methodological foundations for optimal identification of images of production parameters based on filtering and fast Fourier, shift - transformations and wavelet analysis have been developed. Models for using statistical, dynamic and specific characteristics of image information are proposed. The principles of filtering, as well as two- and three-dimensional transformations, correction of distorted points and identification algorithms with sliding wavelet analysis have been modified. The signal delay times during their restoration, determination of decomposition coefficients, optimal sampling frequency, wavelet decomposition level, segment boundaries and image identification interval are determined. Combined operations of thinning out non-informative points and modeling signal characteristics based on a damped sine, bell-shaped function and rectangular pulse have been implemented. A method for determining the maximum and average error in image identification is proposed. A software package for visualization, recognition and classification of objects has been developed and implemented, which has been tested using real data on the conditional parameters of the technological process.**

Keywords—production, parameters, signal characteristics, images, identification

I. Introduction

In control systems of production and technological complexes, monitoring of ecology and environmental protection, medicine, mining, etc., methods are being implemented, models, information processing algorithms for identification, visualization, recognition and classification of images of micro-objects of non-stationary nature [1, 2, 3].

As objects of the subject area of research, the signal characteristics of technological parameters, images of pollen grains, unicellular microorganisms, useful minerals, fingerprints, etc. [4, 5, 6].

Signal characteristics of objects subject to restoration, filtering, transformation, identification, contain distorted points, the appearance of which is due to errors in the stages of input, transmission, storage and processing of information. Low-quality identifications are made, as well as incorrect recognition of objects as a result of the negative influence of various types of interference, smearing of image points and other defects [7, 8, 9].

The study of the problem of object identification on the basis of tracking mechanisms, detection and correction of distorted points, optimization of identification and computer vision of images is considered topical and highly demanded. [10, 11, 12].

This study is devoted to the development of methods, models, algorithms, software complex for detecting and correcting distorted points based on the use of structural components of the image for identification, recognition and classification in conditions of a priori insufficiency, parametric uncertainty, low reliability of data processing [13, 14, 15].

II. Main Part

A. Identification of micro-objects using image characteristics based on wavelet analysis

A mechanism based on the traditional principles of applying filtering methods, two-dimensional and three-dimensional transformation, tracking, detection and correction of distorted points based on models and algorithms of wavelet analysis for the identification, recognition and classification of images of micro-objects is proposed [16, 17, 18].

The basic function of image identification based on wavelet analysis when detecting and correcting distorted points requires considering the time parameters for the beginning and implementation of the convolution of samples, determining and adjusting the values of the expansion coefficients until the required information reliability is achieved. The products of the signal delay time, tracking, detection and correction of distorted samples are determined t_i images [19, 20, 21]

$$t_i = \left\lfloor (2^j - 1)n_w - 2^j + 2) \right\rfloor \cdot \Delta t \,, \tag{1}$$

where n_w – wavelet length - analysis; j – signal decomposition level.

The mechanism is based on a sliding wavelet - analysis, the implementation of which allows you to determine the signal delay time.

The methods of processing the original image (filtering, transformation, segmentation, correction of distorted points, identification) are associated with the execution of operations that use the signal delay parameter per samples. Sliding discrete wavelet analysis (DWA) algorithm introduces a time delay in image reconstruction based on the determination of the decomposition coefficients of the DWA model [22, 23, 24]. The decomposition coefficients of DWA are divided into segments. The beginning of the first segment and the end of the last one cannot be restored. And its recovery is associated with obtaining additional readings at current times. The values of the minimum time delay are determined depending on the level of decomposition j and the number of samples n_w. Table 1 shows the results of calculating the time delay of the generalized mechanism based on the DWA model [25, 26, 27].

TABLE I. CALCULATION OF THE TIME DELAY OF THE IMAGE IDENTIFICATION MECHANISM

Models DWA	Degradation levels		
	1	2	3
Daubechies 2	$2\Delta t$	$4(2\cdot 2+2-2)\Delta t$	$8(4\cdot 2+2-2)\Delta t$
Daubechies 4	$4\Delta t$	$10(4\cdot 2+4-2)\Delta t$	$22(10\cdot 2+4-2)\Delta t$
Daubechies 6	$6\Delta t$	$16(6\cdot 2+6-2)\Delta t$	$36(16\cdot 2+6-2)\Delta t$
Daubechies 8	$8\Delta t$	$22(8\cdot 2+8-2)\Delta t$	$50(22\cdot 2+8-2)\Delta t$

It was determined that due to the change in the length parameter wavelet function has the following advantages:

- the increase in the time delay is linear;
- an increase in the level of signal decomposition becomes quadratic;
- with an increase in the level of decomposition, the delay time becomes long;
- it is advisable to restrict ourselves to the first levels of decomposition, and pay more attention to the shape and length of the applicable DWA;
- to reconstruct the image, half the number of samples is required, which are used for decomposition without the use of the DWA algorithm.

The inverse DWA algorithm uses the additional time delay required to determine the top-level expansion coefficients. The even indexes of the coefficients and odd ones are filled with zeros. The result of the convolution is the values of the coefficients [28, 29, 30].

The algorithm of the DWA model with a sliding mechanism for image identification, in addition to calculating the expansion coefficients, also requires the determination of the recovery coefficients of the original image.

When it is implemented, an additional delay is determined at the beginning, coefficients of lower levels, the procedure for decimating image points is applied. It was determined that with this approach, the number of coefficients at the level j will be in 2^j times less than the required number of samples of the image signal.

Additional time delay based on segment size s_n, which, in turn, is selected according to the depth of decomposition j and wavelet order - functions n_w, as $s_n = 2^{j-2}\cdot n_w$.

When determining low-level image restoration coefficients, the previous $n-n_w$, …, $n-n_w-1$ samples $\Delta t\cdot n$ are used, where n is the countdown of time Δt.

B. A mechanism for detecting and correcting distorted points based on wavelet image filters

A mechanism is proposed that is aimed at identifying time intervals (boundaries) of the object of interest, detecting and correcting distorted image points based on filtering the wavelet function $W\{S\}$ without applying reverse recovery $W^{-1}\{L,H\}$.

Wavelet - function $W\{S\}$ allows you to get a length of time ΔT in which an identifiable object with signal characteristics is considered.

Let the selected object be specified by the discretization function f_d c specified frequency and zero amplitude, which is indicated by the symbol $(\circ)$. Counting an object at a point in time t_0 denoted by the symbol $(\bullet)$. Wavelet Decomposition Mechanism $W\{S\}$ includes procedures for decimating the filter of the Daubechies model of order 4, which selects two significant nonzero coefficients on $j=1$ level. As a result of the implementation of the model and testing of the mechanism, it was found that in the transition from high-frequency, detailing coefficients to low-frequency coefficients, the number of coefficients increases almost three times.

To represent the characteristics of time-varying image points, it is very important to determine the sampling step $S(t)$, which is a prerequisite for optimizing the reliability of image information against the background of distorted points and additive noise [31, 32, 33].

The selected object is represented by a sequence of discrete samples taken with an interval $\Delta T - s(i\Delta T)$ at sampling rate $f_d = 1/\Delta T$. Discrete readings S_i are represented by the product of the function $S(t)$ per pulse train $\delta(t)$ as

$$S_i = S(t)\sum_{i=-\infty}^{\infty}\delta(T-i\cdot\Delta T) = \sum_{i=-\infty}^{\infty}S(i\Delta T)\cdot\delta(T-i\cdot\Delta T). \quad (2)$$

The optimal sampling rate is selected based on the wavelet decomposition level j, the time interval is calculated ΔT, segmentation boundaries are defined and image identification is performed [34, 35, 36].

As a result, the effectiveness of the mechanism depends on a set of factors such as the number of counts n_s, filter type n_w, decomposition rate j and etc. In general, the interval of the estimated time of image identification is defined as

$$\Delta T \le 2^j\,\Delta T\cdot\left[M(j,n_w,n_s)+k\right], \quad (3)$$

where M – number of nonzero coefficients; j - decomposition rate; n_w - the number of samples used by the wavelet function; k – pixel distortion factor.

A combined decimation operation is implemented. It was found that at the level of decomposition j, interval ΔT, the number of nonzero coefficients $M(j,n_w,n_s)\rightarrow(N_w-1)$ the value of the coefficient of distorted points k decreases to zero.

Coefficient $k_{\max}$ also reflects the result of thinning out points of the identified object. In real time, the considered mechanism is executed in the following calculated time interval $\Delta T \approx 2^j \Delta T \cdot n_w$.

Interval value ΔT a variable whose value is determined by the properties of the parameters of the wavelet function. Its calculation is performed upon receipt of each discrete sample of the previous level of decomposition. It is also important to determine the beginning, end, location of the maximum of time points while minimizing the identification error.

A computational scheme for determining the approximation error based on the wavelet function with the following tasks is investigated:

- simulation of local signals of three different forms: damped sine, bell-shaped, rectangular pulse;
- calculation of the maximum and average error in image identification with different sampling rates;
- selection of the optimal ratio of the sampling step and the magnitude of the error;
- establish the requirements for the sampling rate required for the subsequent implementation of the DWA.

C. *Analysis of the effectiveness of identification error control mechanisms*

The analog sampling function is displayed f_d, produced at a certain frequency per unit of time. The sampling error function is set Δf_d, as the difference of instantaneous discrete values between the calculated and true analog value of the function f_d.

The amount of sampling error between intervals ΔT depends on the sampling rate, as it tends to infinity, its value tends to zero. The more will be taken the number of samples of the image in the time interval, the more accurately its image is represented in the digital model. The greater the number of image samples taken over a time interval, the more accurately its image is represented in the digital model. Reducing the number of samples converted into a digital image leads to its distortion to such an extent. In this case, it is impossible to restore its original appearance. Two types of error were studied: the average value of error Δ_{av} and the maximum value of $\Delta_{\max}$ over the entire time interval. The average error value Δ_{av} represents the average difference between the analog and discrete models at intervals t_0 and t_1.

The detailing coefficients of wavelet expansions, taken modulo depending on the sampling frequency, have been studied. Significant coefficients with non-zero amplitude were obtained. The following characteristic points of the study were noted:

- high sampling frequency, in the least possible way, distorts the shape of the image of the selected object. In this case, the error value remains minimal, except for the case with a rectangular pulse, in which the maximum and average error does not change;
- when distorted points of an object image are detected, it is not necessary to perform a full wavelet decomposition, in which only one or several significant coefficients are considered at the output;
- it is sufficient to use a mechanism with a lower sampling rate when detecting distorted points. At the same time, the computational complexity of the wavelet decomposition is reduced, and a smaller number of significant coefficients are used;
- with a strong noise component, the implemented image filter based on the wavelet function is able to smooth out high-frequency noise at higher levels of decomposition. This minimizes the likelihood of errors such as false alarms;
- the greatest probability of detecting distorted points is ensured when the time and frequency characteristics
- wavelet functions are best comparable to the signal characteristics of the object image.

The results of testing model implementations made it possible to establish the following points: the generating frequency of image sampling depends on the order of the DWA model used; as the number of expansion coefficients increases, the period increases, which is inversely proportional to the frequency value; the value of the generating frequency of wavelet filter f_{rev} depends on the speed of the sampling step ΔT, which at step $2\cdot 10^{-4}$ is calculated as $f_{rev} \approx (\Delta t_w \cdot 2w)^{-1}$. Table 2 shows the values of the parameters of the DWA Daubechies 4 model.

TABLE II. RATIONAL VALUES OF THE PARAMETERS OF THE DAUBECHIES DWA MODEL 4

n_w	w	n_w / w	f_{rev}
4	3	≈ 0.75	≈ 833
12	4	≈ 0.33	≈ 625
20	5	≈ 0.25	≈ 500
28	6	≈ 0.21	≈ 417
36	7	≈ 0.19	≈ 357
44	8	≈ 0.18	≈ 312

D. *Mechanism for correcting distorted image points based on the Daubechies 4 model*

It was determined that the DWA model with the generating frequency f_{rev} with a correction mechanism and a procedure for decimating distorted points, the value of the image identification error is halved.

And an increase in the order of the filter, the number of expansion coefficients leads to a decrease in the value of the generating frequency [37, 38, 39].

To analyze the properties of the parameters of the DWA Daubechies 4 model, an experimental study was carried out.

Conditional technological parameters with the following specified image parameters are considered: signal carriers f_{ls} in an interval with a constant sampling step $\Delta T_w = 2 \cdot 10^{-4}$ mks; the number of discrete samples is $I = 500$; the generating frequency is calculated as $f_w \approx (\Delta T_w \cdot w)^{-1}$.

The maximum number of expansion coefficients is found. For everyone with a frequency f_{ls} five-level decomposition is carried out. At each level, the maximum absolute value of the detailing and approximating coefficients is determined [40, 41].

The results obtained represent the amplitude-frequency characteristics of various levels of decomposition of discrete wavelet transform (DWT).

Table 3 shows the results of testing the DWA Daubechies 4 model.

TABLE III. BASIC PROPERTIES OF TIME-FREQUENCY EXPANSIONS

Level	CF r AC	Cf r DC
2	$f_{L2} \approx f_{w/2} \approx 312$	$f_{H2} \approx 3f_{L2} \approx 936$
3	$f_{L3} \approx f_{w/4} \approx 156$	$f_{H3} \approx 3f_{L3} \approx 468$
4	$f_{L4} \approx f_{w/8} \approx 78$	$f_{H4} \approx 3f_{L4} \approx 234$
r	$f_{Lr} = f_{w/(2^{r-1})}$	$f_{Hr} = 3f_{Lr}$
Level	**LFDCF**	**HFDCF**
2	$f_{G22} \approx 2f_{L2} \approx 625$	$f_{G21} \approx 4f_{L2} \approx 1248$
3	$f_{G33} \approx 2f_{L3} \approx 312$	$f_{G32} \approx 4f_{L3} \approx 624$
4	$f_{G44} \approx 2f_{L4} \approx 156$	$f_{G43} \approx 4f_{L4} \approx 312$
r	$f_{Grr} = 2f_{Lr}$	$f_{Grr-1} = 4f_{Lr}$

In fig. 1 a) reflects the values of the detailing coefficients at levels 1 - 5. In fig. 1 b) the values of the approximating coefficients for the decaying cosine signal are reflected.

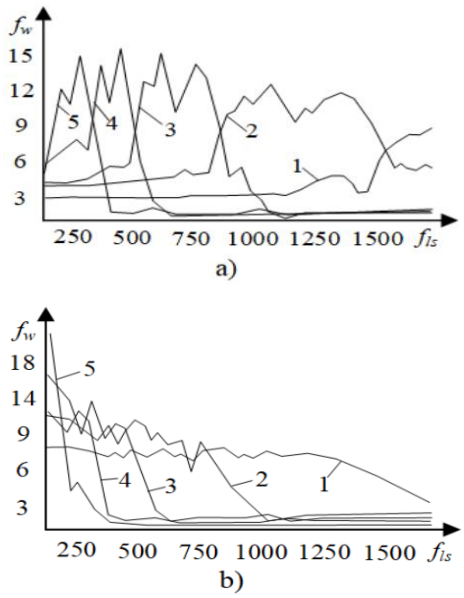

Fig. 1. Maximum amplitudes detailing a) and approximating b) the coefficients for the damped cosine signal.

The following parameters were used during testing: f_0 - sampling frequency; $\Delta t = 1/f_0$ - sampling step; $\Delta t = \Delta t_{ls} = \Delta t_w = 2 \cdot 10^{-4}$ mks;

generating frequency (GF) $f_w \approx 1/(T_w) = 1/(\Delta t \cdot w)$, where T_w – "period" approximating basis function, w – the number of samples per "period" of the approximating basis function;

GF of the local signal – $f_w \approx 1/(T_w) = 1/(\Delta t \cdot w)$, where T_{ls} – "period", I_{ls} – number of samples per period; r - center frequency (CF r) decomposition DWT; $f_{Lr} = f_{w/(2r-1)}$ - approximating coefficients (AC), $f_{Hr} = 3f_{Lr}$ - detailing coefficients (DC); $f_{Grr} = 2f_{Lr}$ - lower frequency of DC filter (LFDCF) DWT; $f_{Grr-1} = 4 \cdot f_{Lr}$ - high frequency DC filter (HFDCF) DWT.

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Development of a hardware-software complex based on machine learning for primary diagnostics

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***Abstract*— This research article focuses on the development of an advanced hardware-software complex dedicated to primary diagnostics of gastroenterological diseases. The complex integrates cutting-edge neural network algorithms to enhance diagnostic accuracy and efficiency. A meticulously curated dataset, collaboratively prepared by domain experts and gastroenterologists, was employed for the algorithm's training process. The study was conducted in close partnership with the Gastroenterology Department of Tashkent Medical Academy, ensuring a rigorous scientific approach and fostering valuable clinical insights.**

***Keywords*— algorithm, primary diagnosis, machine learning, gastroenterology, gastroenterologists, hardware-software complex.**

I. Introduction

Currently, the development of artificial intelligence (AI) is progressing rapidly and cautiously worldwide. The President of the Republic of Uzbekistan, Sh. Mirziyoyev, has issued a resolution titled "Measures to Create Conditions for the Accelerated Adoption of Artificial Intelligence Technologies," aligning with the "Digital Uzbekistan - 2030" strategy [1].

In the field of medicine, digital technologies have the potential to be extensively utilized for diagnosing and treating various diseases of varying severity. These technologies can facilitate healthcare professionals' work, reduce human error, shorten examination time, and enhance overall efficiency.

Digital technologies employ artificial intelligence, neural networks, machine learning, and modern programming languages like Python [8,9,10]. In light of these advancements, a hardware-software complex was developed utilizing state-of-the-art hardware technologies, such as microcontrollers, regulators, analog-to-digital converters, etc.

Furthermore, an algorithm based on neural networks was developed to train a dataset for primary diagnosis of gastroenterological diseases. Human saliva samples were obtained for a scientific study, as saliva has the potential to predict such diseases. Significant changes occur in the saliva composition during illness, and its parameters correspond to the disease status [20].

By manipulating the saliva composition, it is possible to create a dataset for training AI algorithms. Table 1 presents the composition of saliva in a healthy individual [14,15,16].

TABLE 1. COMPOSITION OF THE SALIVA OF A HEALTHY PERSON

№	*The composition of saliva*	*Qty. (% and g/l)*
1	Water	99.4-99.5%
2	Organic and inorganic components	0.5-0.6%
3	Proteins	1.4-6.4 g/l
4	Mucin	0.8-6.0 g/l
5	cholesterol	0.02-0.5 g/l
6	Glucose	0.1-0.3 g/l
7	Ammonium	0.01-0.12 g/l
8	Uric acid	0.005-0.03 g/l

II. Hardware Development

The Saliva device comprises essential components, including a sensor, analog-to-digital converter (ADC), microcontroller, universal asynchronous receiver-transmitter (UART), regulator, and Bluetooth module. Emphasis was placed on achieving cost-effectiveness and portability during the development process.

Accurate and efficient diagnosis of gastrointestinal tract diseases necessitates the utilization of specialized devices. This study introduces the "Saliva" device, specifically designed for primary diagnosis within this domain. Notably, the development process emphasized the device's affordability and ease of portability, enhancing its accessibility and practicality.

The Saliva device integrates multiple components critical for disease diagnosis. A sensor is incorporated to detect relevant biomarkers in saliva samples, enabling disease identification. Acquired signals undergo conversion through an analog-to-digital converter (ADC) to facilitate subsequent analysis. A microcontroller manages data processing and control functions, while a universal asynchronous receiver-transmitter (UART) facilitates seamless communication between the microcontroller and external devices. Furthermore, a regulator ensures a stable power supply, and the inclusion of a Bluetooth module allows for wireless data transmission.

The architecture of the Saliva system is structured into distinct functional blocks, each assigned specific tasks (as depicted in Figure 1). The Saliva system is composed of five main modules, which collectively constitute a comprehensive hardware-software complex designed for efficient disease diagnosis.

The development of the Saliva device marks a significant advancement in the primary diagnosis of gastrointestinal tract diseases. By integrating crucial hardware components and software modules, while considering cost-effectiveness and portability, the Saliva device demonstrates promise as a valuable tool for accurate and accessible disease diagnosis. Further research endeavors will focus on validating its performance through extensive clinical trials and refining its capabilities.

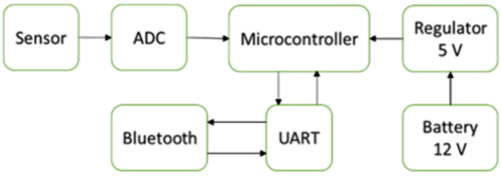

Fig 1. Functional module of the “Saliva” device

Sensors: A set of protein, glucose, mucin, cholesterol, ammonium, and uric acid sensors was assembled based on the selected parameters of the dataset.

ADS1298: The ADS1298 is a low-power, multi-channel 24-bit delta-sigma analog-to-digital converter (ADC) developed by Texas Instruments. It simultaneously samples all channels. The gain parameters of the ADS1298 can be controlled using the programmable gain amplifier (PGA). This chip enables measurement of patient's saliva based on the selected parameters and can utilize the right leg drive (RLD) scheme. The chip's data transmission speed can reach up to 500-32 kbps (with a discrete frequency transmission rate of 103 seconds). The connection between the "Saliva" device and the computer is established through the UART interface [14].

The specifications of the ADS1298 ADC are as follows:

- 8 low-noise programmable gain amplifiers (PGA) and 8 high-precision analog reference channels (ARC)
- Channel power: 0.75 mW per channel
- Noise level: 4 mVpp (at a bandwidth of 150 Hz and gain of 6)
- Bias current: 200 Pa
- Data rate: 250 SPS - 32 kSPS
- Common mode rejection: -115 dB
- Programmable gain options: 1, 2, 3, 4, 6, 8, or 12
- Compliance with ADC AAMI EC11, EC13, IEC60601-1, IEC60601-2-27, and IEC60601-2-51 standards

Provides single polarity and bipolarity:

- AVDD: 2.7V - 5.25V
- DVDD: 1.65V - 3.6V
- Built-in features: RLD amplifier, trigger detection, WST terminal, speed detection, and test signals
- Built-in breathing impedance measurement capability
- Digital speed measurement capability
- Built-in oscillator
- SPI interface

Atmega328 Microcontroller: The Atmega328 microcontroller plays a crucial role in the Saliva device by receiving primary processed signals from the ADS1298 microcircuits and performing secondary processing.

It then transmits the processed signals to the Bluetooth module via the SPI interface. Additionally, the microcontroller controls the ADS1298 module, which is a 12-channel converter for discrete and analog-to-digital conversion of saliva sample signals, along with other peripheral devices.

The communication between the Atmega328 microcontroller and these peripherals is established using the SPI module. The block diagram of the Atmega328 microcontroller is shown in Figure 2.

The Atmega328 microcontroller is equipped with two SPI interfaces that support high-speed communication with the ADS1298 and NS-05 devices.

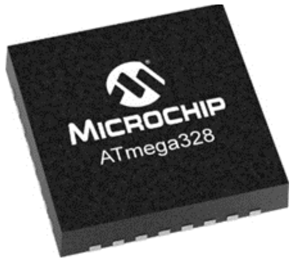

Fig 2. Atmega328 microcontroller

The ADS1298 module provides a serial communication timing system, and synchronization in all communication processes should be maintained at the minimum level. The Atmega328 microcontroller is characterized by its low power consumption, high efficiency, and the following features.

Specifications of the Atmega328 microcontroller:

- Operates with precise short commands
- AVR architecture with 40 pins
- 32 kB of flash memory
- 1 kB of EEPROM
- 2 kB of RAM
- 23 input/output pins
- Timer: 2 8-bit and 1 16-bit timers
- 10-bit 6-channel analog-to-digital converter
- 6-channel wide pulse modulator
- Separate oscillator
- Supports SPI master-slave and I²C modes
- External oscillator frequency: 20 MHz
- Universal synchronous-asynchronous receiver and transmitter (USART)

Bluetooth HC-05: The Bluetooth HC-05 module serves as one of the primary power supply modules for the "Saliva" device. It enables wireless data exchange between the device and a computer via the UART interface.

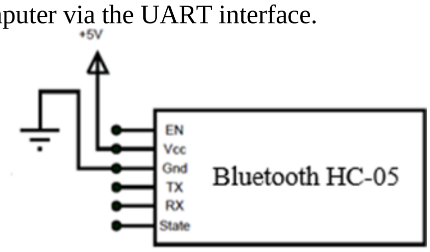

Fig 3. Block diagram of Bluetooth module HC-05

The HC-05 module operates within the ISM frequency range of 2.4 GHz, which is an internationally designated radio frequency range as per the regulations of the International Telecommunication Union.

The block diagram of the Bluetooth HC-05 module is depicted in Figure 3.

The total information size from the 8 channels of the ADS1298 is 224x8 = 224x23 = 227, equivalent to 227x50/8 = 838,860,800 or 838,860,800/1024 = 819,200 Kbps or 800 Mbps. In the hexadecimal number system, this value is 800/216 = 0.0122 MB. The selected NS05 Bluetooth device for the ECG design has a total bandwidth of 2.1 Mbps, which is approximately 10 times higher than the digital data (0.0122 Mbps) generated by the ADC device, thus satisfying the current requirements.

Bluetooth HC-05 operates in two distinct modes: command state and transmit/receive state, with data rates of 38,400 bps and 9,600 bps, respectively.

The NS05 Bluetooth device has the following technical specifications:

- Bluetooth chip: HC-05 (BC417143)
- Radio frequency range: 2.4-2.48 GHz
- Transmission power: 0.25 - 2.5 mW
- Signal sensitivity: -80 dBm (0.1% BER)
- Supply voltage: 3.3-5V
- Current requirement: 50 mA
- Range: up to 10 meters
- Interface: serial port (UART)
- Modes: master, slave, master/slave
- Operating temperature: -25...75 °C
- Dimensions: 27 x 13 x 2.2 mm
- Standard: IEEE 802.15.1
- FHSS (Frequency Hopping Spread Spectrum) transmission method with modulation type
- Default baud rate: 38,400 bps, but supports 9,600, 19,200, 38,400, 57,600, 115,200, 230,400, and 460,800 bps.

Universal Asynchronous Transceiver (UART): UART is a simple protocol that uses only two wires for bidirectional data transmission between a transmitter and receiver.

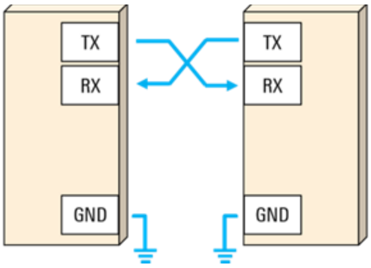

Fig 4. Data in the UART is transmitted in the form of frames

Communication in a UART can be simplex, half-duplex, or full-duplex. The UART protocol operates asynchronously, meaning the transmitter and receiver do not share a common clock signal. To ensure proper communication, both ends must transmit at the same predetermined rate and use the same frame structure and parameters.

The UART frame structure is illustrated in Figure 4. It consists of a start bit, data bits (typically 8 bits), optional parity bit, and stop bit(s).

LM2596 Regulator: The LM2596 series regulators are monolithic integrated circuits (ICs) that encompass all active functions necessary for a buck switching regulator capable of controlling a 3-A load with excellent line and load regulation. These regulators are offered in fixed output voltages of 3.3V, 5V, 12V, as well as an adjustable output voltage option.

Designed to require minimal external components, the LM2596 regulators are user-friendly and feature internal frequency compensation and a fixed frequency oscillator. Operating at a switching frequency of 150 kHz, these regulators allow for the use of smaller filter components compared to low-frequency switching regulators.

The LM2596 regulators are available in a standard 5-pin TO-220 package, with various lead bending options, as well as a 5-pin TO-263 surface mount package.

III. MATHEMATICAL MODEL FOR THE RANDOM FOREST MACHINE LEARNING ALGORITHM

The Machine Learning Algorithm Random Forest Can Be Adapted to the Developed Mathematical Model. The Random Forest algorithm has been chosen for the hardware-software system 'Saliva'. Let's assume there is a dataset consisting of N observations, where each observation has the following parameters:

TABLE 2. X_1, X_2, X_3, X_4, X_5, X_6 - PARAMETERS

X	The dataset parameters are as follows	Saliva Composition Components
x1	Parameter_1	Protein
x2	Parameter_2	Mucin
x3	Parameter_3	Cholesterol
x4	Parameter_4	Glucose
x5	Parameter_5	Ammonium
x6	Parameter_6	Uric Acid

Each parameter has its own value for each observation. Suppose it is possible to predict the target variable Y based on these parameters.

Random Forest creates an ensemble of decision trees, each of which is trained on a random subset of the data and a random subset of parameters. Each tree will provide its prediction, and then the prediction results of the trees are combined to obtain the final prediction.

The mathematical model for Random Forest can be represented as follows: $Y = f(X_1, X_2, X_3, X_4, X_5, X_6)$ where f is the function representing the combined prediction obtained using Random Forest.

To solve the mathematical model based on Random Forest, you will need to perform the following steps:

Step 1 is shown in Table 3-4.

TABLE 3-4. DATA PREPROCESSING

Y1	Class 1 (Healthy Patient)
Y2	Class 2 (Patient with Suspicion)
Y3	Class 3 (Patient with Disease)

№	Saliva Composition	Healthy Individual Amount (% and g/L)	Suspected Gastrointestinal Tract Disorder Amount (% and g/L)	Gastrointestinal Tract Disorders Amount (% and g/L)
1	Water	99,4-99,5 %	≥90 %	≥85-89 %
2	Organic and inorganic components	0,5-0,6 %	≥0,5 %	≤ 0,3 %
3	Proteins	1,4-6,4 g/L	≥ 5 g/L	≤ 6,6 g/L
4	Mucin	0,8-6,0 g/L	≥ 5 g/L	≤ 6,5 g/L
5	cholesterol	0,02-0,5 g/L	≥ 0,3 g/L	≤ 0,6 g/L
6	Glucose	0,1-0,3 g/L	≥ 0,2 g/L	≤0,35 g/L
7	Ammonium	0,01-0,12 g/L	≥ 0,10 g/L	≤0,13 g/L
8	Uric acid	0,005-0,03 g/L	≥ 0,02 g/L	≤0,035 g/L

Step 2. Model Evaluation. After training the model, assess its performance on the test dataset. Utilize evaluation metrics such as accuracy, recall, F1-score, and others to gauge how effectively the model predicts the target variable.

Certainly, here's the translation of the formula for calculating the precision, recall, and F1-score metrics:

$$precision = \frac{TP}{TP+FP} \quad (1)$$

$$recall = \frac{TP}{TP+FN} \quad (2)$$

$$F1 - score = 2 * \frac{precision*recall}{precision+recall} \quad (3)$$

Precision, also known as accuracy, indicates the proportion of objects classified as positive that truly belong to the positive class. Recall, or sensitivity, signifies the fraction of positive class objects that were correctly identified by the algorithm. The F1-score represents the harmonic mean between precision and recall. Both precision and recall metrics enable an evaluation of the model's quality with respect to each individual class, while the F1-score amalgamates these assessments into a single metric.

The formula for calculating the accuracy metric is as follows:

$$accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (4)$$

Accuracy, or precision, reveals the proportion of objects that were correctly classified. This metric takes into account both correctly classified positive and correctly classified negative examples.

The formula for calculating the precision metric is:

$$precision = \frac{TP}{TP+FP} \quad (5)$$

Precision, or accuracy, illustrates the fraction of objects classified by the model as positive that truly belong to the positive class. In other words, this metric considers the number of false positive responses generated by the model.

The formula for calculating the recall (sensitivity) metric is:

$$recall = \frac{TP}{TP+FN} \quad (6)$$

Recall, or sensitivity, demonstrates the fraction of positive objects that were correctly classified by the model. In essence, this metric takes into account the number of false negative responses generated by the model.

The formula for calculating the F1-score metric is:

$$F1 - score = 2 * \frac{precision * recall}{precision+recall} \quad (7)$$

The F1-score, also known as the F1-measure, represents the harmonic mean between the precision and recall metrics. It demonstrates the balance between these two metrics and can be utilized to evaluate the model's performance, particularly in cases with imbalanced classes. A high value of this metric indicates that the model achieves both high precision and recall simultaneously.

Step 3. Fine-tuning the model (optional): If necessary, you can engage in model fine-tuning by adjusting parameters and performing cross-validation to achieve optimal performance.

Cross-validation formula:

$$CV(B) = \frac{1}{K}\sum_{k=1}^{K} Err_k \quad (8)$$

Where, $CV(B)$ - an evaluation of classification quality using cross-validation with B trees,

K - the number of folds in cross-validation,

Err_k - classification error on the k-th fold.

Cross-validation provides a more reliable estimate of classification quality since the assessment is conducted on multiple partitions of the dataset. Typically, 5-fold or 10-fold cross-validation is commonly used.

Step 4. Application of the Model: Once the model has been trained and evaluated, you can use it to predict the target variable for new observations or test data.

The formula for calculating feature importance can vary depending on the specific machine learning method or algorithm you are using. Here are translations for the two common methods mentioned earlier:

$$I_j = \frac{1}{B}\sum_{b=1}^{B}\sum_{t\in T} p_b(t) * I_b(t,j) \quad (9)$$

Formula for Decision Tree Construction:

$$split(S) = arg \max_{j\in F} split_j(S) \quad (10)$$

Where, S - set of objects,

F - subset of features,

$split_j(S)$ - splitting criterion dependent on feature j and set of objects S.

One of the potential splitting criteria is the Gini index:

$$Gini(S) = 1 - \sum_{k\in C}(\frac{|S_k|}{|S|})^2 \quad (11)$$

Where, C - set of classes,

$|S_k|$ - the number of objects in set S belonging to class k,

$|S|$ - the total number of objects in set S.

The formula for assessing the accuracy of classification on the training dataset is as follows:

$$Accuracy = \frac{1}{n}\sum_{i=1}^{n} 1(y_i = \hat{y}_i) \quad (12)$$

Where, n - the number of instances in the training dataset,

y_i - true class of the i-th instance,

$\hat{y}_i$ - predicted class of the i-th instance.

The formula for calculating the Mean Squared Error (MSE) for regression models is as follows:

$$MSE = \left(\frac{1}{n}\right) * \sum(i = 1\ to\ n)(y_i - \hat{y}_i)^2 \quad (13)$$

Where, n - the number of observations,

y_i - represents the actual value of the i-th observation,

$\hat{y}_i$ - the predicted value for the i-th observation.

The formula computes the average of the squared differences between predicted and actual values. A lower MSE indicates a model that closely aligns predicted values with actual values.

MSE is one of the most common metrics used for assessing the quality of regression models and is employed in various machine learning algorithms to compare different models.

The formula for calculating the Mean Absolute Error (MAE) for regression models is as follows:

$$MAE = \left(\frac{1}{n}\right) * \sum(i = 1\ to\ n)|y_i - \hat{y}_i| \quad (14)$$

Where, n - the number of observations,

y_i - represents the actual value of the i-th observation,

$\hat{y}_i$ - the predicted value for the i-th observation.

The formula calculates the average of absolute deviations between predicted and actual values. A lower MAE indicates a model that closely aligns predicted values with actual values.

MAE is also one of the most common metrics used for assessing the quality of regression models and is employed in various machine learning algorithms to compare different models. Unlike Mean Squared Error (MSE), MAE doesn't square the deviations, making it more robust to outliers and providing more interpretable results.

IV. RESULTS

An example of the dataset is presented in Table 5, which includes the parameters and the composition names of human saliva.

TABLE 5. DATA SET PARAMETERS

Data set parameters	The name of the composition of saliva
Parameter_1	Protein
Parameter_2	Mucin
Parameter_3	cholesterol
Parameter_4	Glucose
Parameter_5	Ammonium
Parameter_6	Uric acid

The initial training process was conducted using a dataset comprising 100 patient samples (refer to Figures 5 and 6).

	Patient	Parameter_1	Parameter_2	Parameter_3	Parameter_4	Parameter_5	Parameter_6
0	1	1.4	0.8	0.02	0.10	0.01	0.005
1	1	1.5	0.9	0.03	0.11	0.02	0.006
2	1	1.6	1.0	0.04	0.12	0.03	0.007
3	1	1.7	1.1	0.05	0.13	0.04	0.008
4	1	1.8	1.2	0.06	0.14	0.05	0.009
...	...	...	...	...	...	...	...
94	3	10.9	10.2	0.97	1.04	0.95	0.099
95	3	11.0	10.3	0.98	1.05	0.96	0.100
96	3	11.1	10.4	0.99	1.06	0.97	0.101
97	3	11.2	10.5	1.00	1.07	0.98	0.102
98	3	11.3	10.6	1.01	1.08	0.99	0.103

99 rows × 7 columns

Fig 5. Data set of 100 patients.

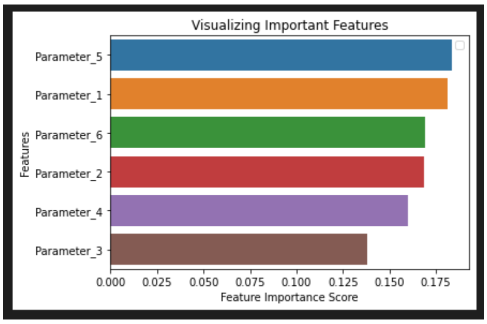

Fig 6. Importance of parameters from the data set (100 patients)

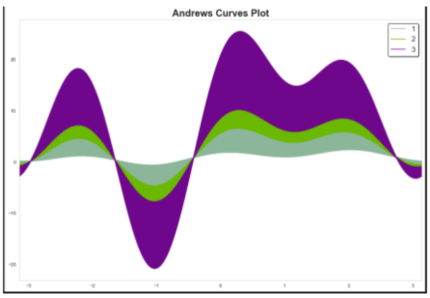

Fig 7. Determination of parameter importance and prediction of patient illness likelihood using Random Forest.

- Violet color represents a higher probability of illness.
- Green color indicates a lower probability of illness.
- Pistachio color represents a healthy state.

The training process was repeated using a dataset consisting of 1000 patient samples (refer to Figures 8 and 9).

	Patient	Parameter_1	Parameter_2	Parameter_3	Parameter_4	Parameter_5	Parameter_6
0	1	1.40	0.80	0.020	0.10	0.010	0.0050
1	1	1.41	0.81	0.021	0.11	0.011	0.0051
2	1	1.42	0.82	0.022	0.12	0.012	0.0052
3	1	1.43	0.83	0.023	0.13	0.013	0.0053
4	1	1.44	0.84	0.024	0.14	0.014	0.0054
...	...	...	...	...	...	...	...
994	3	11.34	10.74	1.014	10.04	1.004	0.1044
995	3	11.35	10.75	1.015	10.05	1.005	0.1045
996	3	11.36	10.76	1.016	10.06	1.006	0.1046
997	3	11.37	10.77	1.017	10.07	1.007	0.1047
998	3	11.38	10.78	1.018	10.08	1.008	0.1048

Fig 8. Data set of 1000 patient

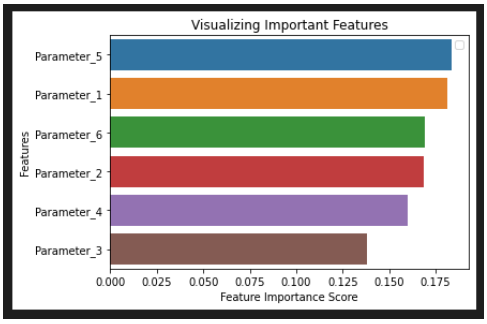

Fig 9. Importance of parameters from the data set (1000)

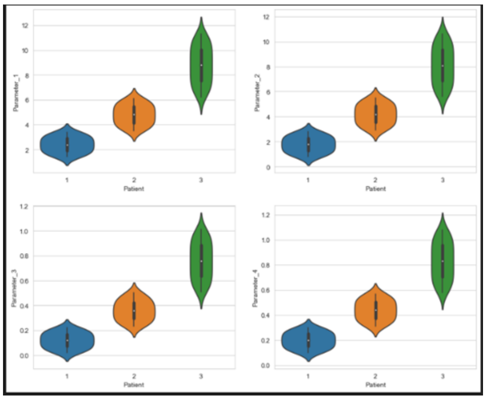

Fig 10. Determining the importance of parameters and predicting the likelihood of a patient's illness. (Random Forest)

- The color violet indicates a higher probability of illness.
- The color green signifies a lower probability of illness.
- The color pistachio represents a healthy state.

The overall appearance of the finalized hardware-software complex "Saliva" is depicted in Figure 11.

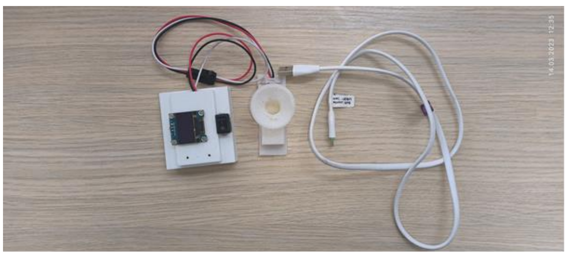

Fig 11. Hardware-software complex "Saliva"

V. CONCLUSION

The Random Forest algorithm achieved an accuracy of 98.5% when trained on datasets ranging from 100 to 1000 patients. In future research, the number of patients and parameters will be progressively increased, and each iteration will be evaluated for accuracy.

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Improving Data Security in IoT Networks Using Blockchain

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***Abstract*— The growing prevalence of intelligent devices in Internet of Things (IoT) networks has significantly increased security concerns regarding device communications. This paper proposes an innovative multi-level blockchain security architecture specifically designed for 5G-enabled IoT networks. The proposed architecture introduces an adaptive clustering approach called Intelligent Swarm Evolutionary Search (ISES) to organize diverse IoT networks more efficiently. Through the utilization of this strategy, cluster leaders (CL) are designated for managing nearby authentication and authorizations, thereby reducing communication spans between CLs and Internet of Things (IoT) devices. Consequently, overhead and latency are reduced, significantly improving network performance. This further enhances the architecture's flexibility and adaptability in dynamic IoT environments. For secure communication, a localized private blockchain structure is utilized to facilitate interactions between cluster heads and base stations. This structure incorporates an authentication mechanism that enhances security and instills trustworthiness within the network. Through extensive simulation, the proposed clustering algorithm has demonstrated superior effectiveness when compared to existing methodologies. In particular, the lightweight blockchain approach presented in this study exhibits a remarkable balance between network latency and throughput, surpassing the capabilities of conventional global blockchain systems.**

***Keywords*— blockchain; Internet of Things (IoT); Intelligent Swarm Evolutionary Search (ISES); data security.**

I. Introduction

The Internet of Things (IoT) architecture enables the deployment of interconnected devices using cloud platforms in a centralized network. However, the predicted heterogeneity of IoT devices faces constraints related to scalability, limited resources, throughput, centralized control, overhead, and latency [1]. These centralized systems have several shortcomings, including the potential for data overload when multiple smart devices are connected, leading to significant network bandwidth requirements and memory usage for cloud software operators. Moreover, the failure of critical components within the centralized network can result in catastrophic system failures [3]. In centralized systems, third-party involvement for additional data manipulation raises privacy concerns and challenges in demonstrating IoT performance and security [4]. As a consequence, most existing centralized systems are unable to guarantee data confidentiality and security [5]. Additionally, IoT devices often have limited transmission capabilities due to low-power wireless receivers and transmitters [6]. To address these challenges, the Multihop Cellular Network (MCN) concept can be utilized to enhance IoT networks by reducing signal coverage [7]. Creating a large-scale network with diverse nodes poses challenges as conventional blockchain implementations require high-performance nodes [8]. To overcome these obstacles and provide robust security, an autonomous defense mechanism is necessary in IoT networks [9].

The rise of 5G in the new IoT era presents primary challenges, including an increasing variety of connected devices, the heterogeneity of gadgets and automakers, data volume, network traffic, bandwidth demand, communication latency, and trustworthiness. To address complexity and bolster IoT security, this research proposes a multi-level structure with a special clustering method suitable for blockchain integration [10,11]. This approach prevents compromised entities from accessing the blockchain and ensures data validity [12]. Moreover, the new multi-level architecture allows for updates to the primary cloud server, facilitating widespread rollouts. Smart contracts are used to implement a lightweight authorization and authentication method within each cluster, ensuring only authorized users can access network resources [13].

Various security and privacy systems, such as public key infrastructure, blockchains, smart cards, and passwords, have been developed. However, some of these protocols may be too complex for IoT devices and may possess serious privacy and security flaws. To overcome these issues, this study presents multiple contributions:

- An innovative approach for immediate, decentralized verification of interacting entities via biometric data and elliptic curve cryptography, addressing potential vulnerabilities associated with a sole focal point of failure.
- An authorization framework employing security tokens for access and membership validation, along with admittance rights groups, to prevent user cooperation and insider attacks.
- Formal security analysis using the well-known BAN logic, verifying the existence of a session key between interacting entities, along with informal security analysis under various threat model assumptions.
- A comparative performance study showing the protocol's effectiveness, revealing minimal computing and communication difficulties compared to other protocols.

The paper is organized into sections, with Section 2 covering the literature review, Section 3 detailing the proposed methodology, Section 4 presenting the results and discussion, and Section 5 illustrating the conclusion.

II. Literature Review

The study [14] proposes a unique approach to building trust in supply chains that incorporate various IoT components. Through simulations, the model's applicability is demonstrated. Additionally, research [15] explores the use of blockchain technology to safeguard communication and data in an IoT-enabled WBMS (Wireless Body Sensor Network) against cyberattacks [16]. Experimental experiments validate the feasibility of the proposed blockchain-based IoT network for WBMSs. The paper considers cloud storage options for sensors and introduces a novel group signature system with minimal computational and communication costs to enable anonymous authentication and secure data storage and sharing. A blockchain-based cloud storage protocol for sensors in IIoT (Industrial Internet of Things) is then constructed, utilizing smart contracts and proxy re-encryption to facilitate secure data transfer with minimal computational overhead. The purpose of this study is to present Edge Share, a data-sharing framework based on blockchain, designed for facilitating data exchange in edge-based services across diverse network environments. This is achieved through a two-level overlay network architecture and edge computing, reducing scheme stress and transmission delay, thereby enhancing information efficiency. The proposed framework is rigorously evaluated against several security criteria in comparison to conventional mechanisms. It suggests a novel attribute-based encryption method, utilizing a multi-level authorization hub and hierarchical attribute structure to enable flexible and fine-grained access control. This technique is integrated with Fabric blockchain technology to address high decryption costs for Internet of Things consumers. To reduce consumers' decryption overhead, smart contracts on the blockchain utilize high-complexity partial decryption algorithms, employing a blockchain-based dynamic secret-sharing mechanism. The study also introduces the power blockchain sharing approach, which creates a reliable trading center capable of sharing power trading books, enabling secure power data transport matching through power data consensus and dynamically linked memory. Secure SVM (Support Vector Machine), a privacy-preserving SVM training scheme over blockchain-based encrypted IoT data, is proposed, creating a secure and dependable data-sharing platform for numerous data sources. The study presents a unique Decentralized Blockchain-based Security (DeBlock-Sec) solution to address security challenges in resource-constrained IoT environments. However, the decentralized nature of blockchain poses challenges in managing and updating security protocols across numerous devices. Integrating blockchain with existing IoT networks and protocols may necessitate significant changes to the underlying infrastructure, entailing potential costs and time constraints.

III. Proposed Methodology

The proposed network architecture aims to leverage cellular systems' capabilities and performance while ensuring efficient and reliable security for IoT networks. The multi-level structure is encrypted using the Intelligent Swarm Evolutionary Search (ISES) approach. This research introduces a framework that enables lightweight authentication and authorization of IoT networked devices (objects and nodes) through the use of blockchain technology. In the suggested multi-level network paradigm, the entire cellular-enabled IoT network is divided into several levels. Level 1 encompasses a variety of IoT nodes and clusters, while Level 2 encompasses sink nodes and supervisory components such as cluster heads. At Level 3, cellular network base stations are situated. The decentralized blockchain mechanism can be implemented at Level 3 by the base stations with the necessary servers and CPUs. Figure 1 provides an overview of the entire system model.

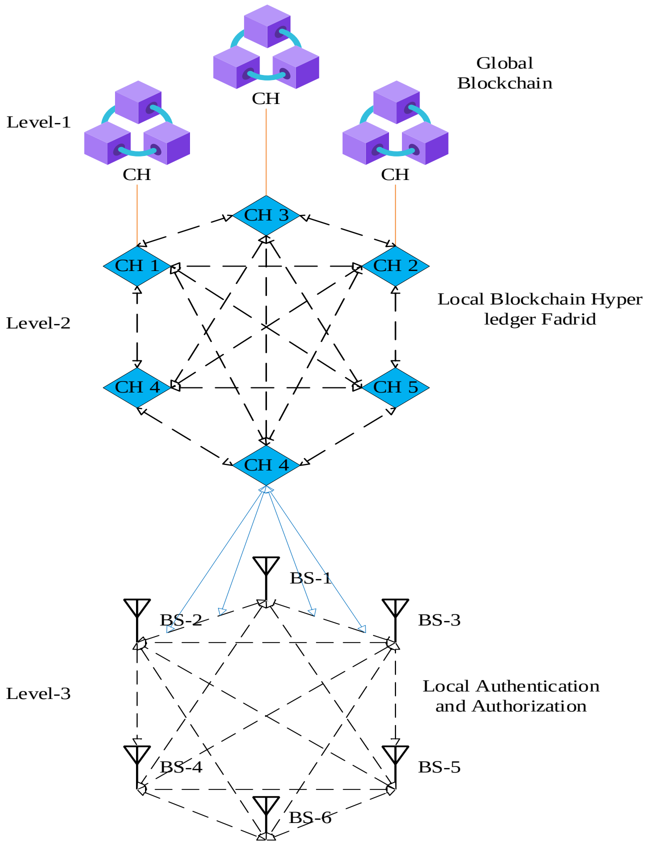

Fig. 1. Model of a multi-level IoT network.

To address potential scalability issues with the introduction of blockchain technology, a multi-level network concept is employed (Figure 2). This concept aims to reduce redundancy, accelerate responses, improve data organization, maintain private conversations, and accommodate future growth.

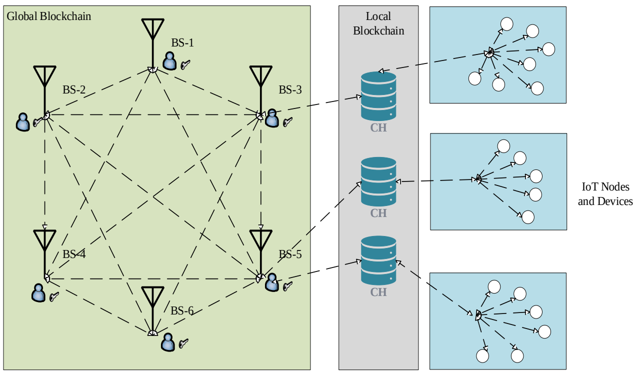

Fig 2. The network idea is divided into three levels: infrastructure with a local authorisation service, local blockchain, and public chain.

The first level comprises various modules and nodes with varying computational and resource requirements. Cluster heads on this level provide authentication and authorization functions for regionally embedded systems in the IoT system's regional authorization program. These cluster heads can securely interact in a blockchain environment through a thin consensus mechanism. A permission-based local Hyperledger Fabric (HLF) blockchain is implemented at this level. The top level is composed of cellular network base stations (BSs). This level allows for the deployment of reliable asymmetric cryptography methods. By employing cutting-edge security measures at the highest levels (Level 3), the global system ensures privacy and security. By utilizing this multi-level network architecture and integrating blockchain technology, the proposed system aims to overcome potential scalability challenges and provide robust security features for cellular-enabled IoT networks.

3.1. Implementation of the Framework

3.1.1. Network Self-Clustering

The core of metaheuristic algorithms lies in their close connection with computational techniques and optimization processes. One significant advantage of these techniques is their ability to avoid getting trapped in local optimum points. Consequently, these methods explore the entire search space comprehensively, facilitating widespread search for optimal solutions. Moreover, metaheuristic algorithms enable a distributed control structure involving network nodes and participants, fostering localized communication among them. This decentralized approach enhances the system's responsiveness and agility, enabling it to swiftly adapt to changes in the environment. In Figure 3, the IoT network's clustering strategy is illustrated.

This paper introduces Intelligent Swarm Evolutionary Search (ISES) as a novel approach for clustering heterogeneous IoT networks. The clustering method aims to minimize the average distance that data must travel between IoT devices and selected cluster heads, thereby optimizing the efficiency of the IoT system. By forming clusters, only a fraction of nodes needs to establish long-distance connections to the Base Station (BS), resulting in reduced overall energy consumption and expanded network reach.

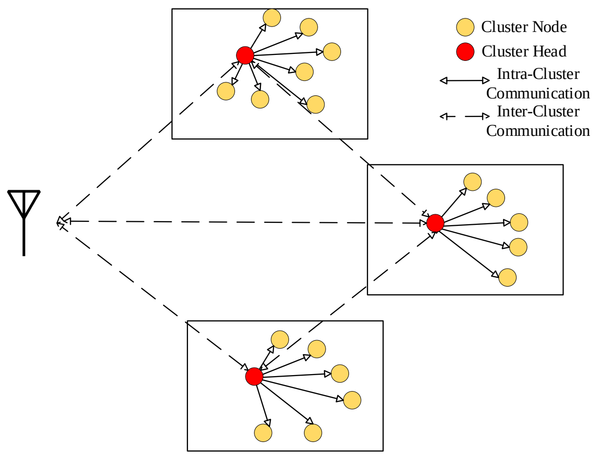

Fig 3. Scheme for cellular IoT network clustering.

The clustering-based approach streamlines the deployment process of blockchain applications, further enhancing their effectiveness. Cluster heads (CH nodes) play a crucial role in organizing the entire network into functionally independent clusters. Other nodes within each cluster interact with the CH nodes to exchange information. The clustering process is achieved through evolutionary computing techniques, simulating the diverse components present in the IoT infrastructure. The number of clusters and nodes within each cluster can vary based on the specific network configuration and requirements. Furthermore, the proposed clustering strategy enhances the adaptability of the IoT network's node placement, considering that nodes are not uniformly distributed within clusters. This factor significantly impacts the clustering process, ensuring an efficient and flexible network configuration.

3.1.2. CH Selection with Intelligent Swarm Evolutionary Search (ISES)

The IoT network architecture prioritizes meeting energy constraints as a crucial aspect. To achieve extended network operation and reduced power consumption, communication and transmission links can be shortened by arranging nodes into autonomous clusters. This clustering approach facilitates easier data aggregation and forwarding since each cluster member exchanges information with the associated Cluster Head (CH). In our proposed paradigm, Intelligent Swarm Evolutionary Search (ISES) is utilized to represent vector data. The sparrow placements are randomly determined within defined limits and represented in a linear system using Equation (1), where a randomly generated distribution number, Rand [0, 1], initiates the vector. Each row in the optimization problem represents a fitness function solution.

$$f(x) = \begin{bmatrix} f(SP_{1,1} & SP_{1,2} & \cdots & SP_{1,d}) \\ \vdots & & \ddots & \vdots \\ f(SP_{n,1} & SP_{n,2} & \cdots & SP_{n(k),d} \end{bmatrix} \begin{bmatrix} f_{obj_1} \\ \vdots \\ f_{obj_n} \end{bmatrix} \qquad (1)$$

The mutation operator employs the Mutation Rate (MR) to select the best vector TaV from the population, as shown in Equation (2). The likelihood of $SP(g+1)$ producing two unique vectors is random, modified by three random values. The differences in the mutation operation, represented by $r1$, $r2$, and $r3$, play a crucial role in determining the resultant vector's outcome. Thus, the method generates the vector's component differences in a way that adheres to the specified range. Each sparrow undergoes population-wide evolution until the optimal solution is found.

$$SP_{g+1} = SP_{r1} + MR * (SP_{r2} - SP_{r3}) \qquad (2)$$

Equation (3) computes the Euclidean distance between the selected optimal sparrow and every other sparrow.

$$dist = \sqrt{\sum_{i=1}^{N} (SP_{i,j} - SPbest_{i,j})^2} \qquad (3)$$

Similarly, Equation (4) is used for recombination to create a new generation of children known as $DV\ TaV$, a trial vector. A preset Crossover Probability Rate (CPR) is applied with binomial cross-over. If ($r \le CPR\ BestDV$), the donor vector is chosen; otherwise, the target vector is selected.

$$SP_{i,j,g+1} = \begin{Bmatrix} BestDV_i & if\ (r \le \text{CPR}) \\ BestTaV_i & if\ (r > \text{CPR}) \end{Bmatrix} \qquad (4)$$

When $AV < ST$, indicating no predators, producers engage in a wider search mode, as represented in Equation (5). In rare cases when $AV \geqslant ST$, predators are present, and sparrows must defend themselves by fleeing to safer areas. Only infrequent scavengers significantly follow producers.

$$SP_{i,j}{}^{t+1} = \begin{Bmatrix} SP_{i,j}{}^{t} * \exp\left(\dfrac{-1}{a.\,l_{max}}\right) & if\ AV < \text{ST}) \\ SPTV_{i,j}{}^{t} + Q.L & if\ AV \ge \text{ST}) \end{Bmatrix} \qquad (5)$$

The location of the scavenger can be found in Equation (6) for a fixed number of iterations, where I max β mean is the variable step controlling the parameter's average value, and variation is 1.

The algorithm is the ISES algorithm, combining the current particle position with the difference between the global best and personal best positions, scaled by β. This allows the particle swarm algorithm to efficiently explore the search space and converge to a good solution.

$$SP_{i,j}{}^{t+1} = SP_{GBest}{}^{t} + \beta * \left[SP_{i,j}{}^{t} - SP_{GBest}{}^{t}\right]^{t+1} \quad (6)$$

Algorithm: ISES

Generate nodes randomly in a two-dimensional space.

Initialize the population "G" with random data.

Assess the objective function for each "sparrow" node.

Repeat until a certain condition is met:

a. Iterate through each node "I" in cluster "k".

b. Loop through the range of nodes from 1 to "N".

c. Select three nodes randomly from the population.

d. Compute node distances using the Euclidean formula.

e. Examine a new population known as the "mutant sparrow population".

f. Create a fresh population via a recombination process.

g. If a specified condition "r" holds, conduct a selection operation.

h. If the condition is not met, update the population by replacing nodes based on optimal fitness.

i. Reassess the objective function for each sparrow.

j. Modify the position of the population's "Spbest" and designate it as "CH".

k. Increment a counter "t" by 1.

End the loop when a certain criterion is fulfilled.

Provide the best solution achieved during the process.

IV. RESULT AND DISCUSSION

To assess the performance of the suggested clustering methods, researchers conducted a simulation of an IoT network. The simulation was conducted in a 2-D network, featuring 100 nodes randomly selected for the experiment. For the simulation, MATLAB 2018a was utilized as the platform, owing to its reputation for reliable clustering algorithms and the ease with which various techniques could be simulated, facilitating a comprehensive comparison of results.

The selection of a 2-D network with 100 randomly chosen nodes mirrors real-world IoT scenarios, where devices are often deployed in unpredictable and diverse locations. Using MATLAB for the simulation ensures accurate and consistent outcomes, providing a dependable environment for testing and evaluating different clustering approaches.

The primary objective of the simulation was to assess the performance of the Intelligent Swarm Evolutionary Search (ISES) algorithm. Both of these algorithms were utilized to optimize the clustering of the IoT network, with a focus on enhancing energy efficiency, communication effectiveness, and overall system performance.

By conducting the IoT network simulation and analyzing the results of the ISES algorithm, researchers obtained valuable insights into the efficacy of the proposed clustering techniques. The simulation outcomes offer valuable guidance for implementing these algorithms in real-world IoT networks, taking into account factors such as energy consumption, network coverage, and data transmission efficiency.

4.1. Clustering Results

To evaluate the effectiveness of the proposed clustering approach, researchers conducted a comparative analysis with four other existing algorithms previously documented in the literature: the cascading model [22], Low Energy Adaptive Clustering Hierarchy (LEACH) [23], Gateway Clustering Energy-Efficient Centroid (GCEEC) [24], and Black Hole and Ant Colony Optimization (BH-ACA) [25]. All algorithms were tested using the same simulated network architecture to ensure fair comparison and consistent evaluation. Each method produced a different number of clusters and cluster heads (CHs) after optimization. The simulation results demonstrated that the suggested ISES clustering model outperformed the existing algorithm. The proposed approach showed significant improvements in reducing network load, minimizing communication distances, and increasing overall network coverage, as depicted in Figure 4, Figure 5, and Figure 6.

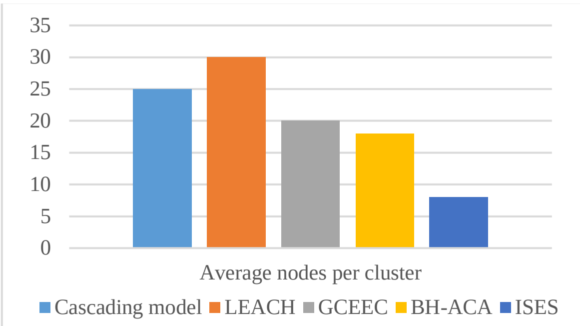

Fig 4. Comparison of average nodes per cluster of the proposed model with cascading model [17], LEACH [18], GCEEC [19], and BH-ACA [20].

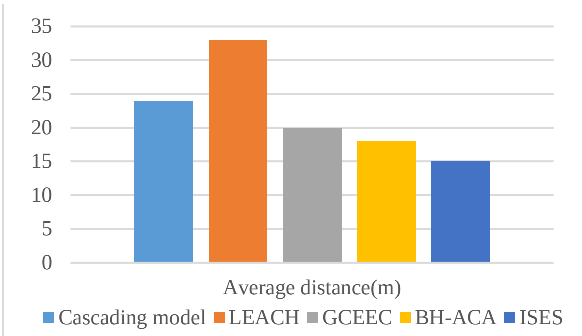

Fig 5. Comparison of average distance of the proposed model with cascading model [17], LEACH [18], GCEEC [19], and BH-ACA [20].

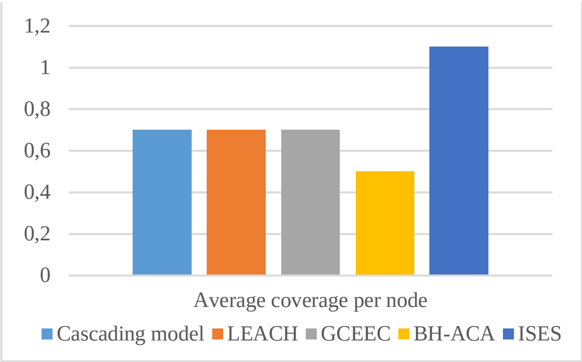

Fig 6. Comparison of average coverage per node of the proposed model with cascading model [17], LEACH [18], GCEEC [19], and BH-ACA [20].

V. Conclusions

This study introduces a novel distributed security model tailored for IoT devices communicating via cellular networks with multiple hops, employing a blockchain-based approach within a multi-level architecture. The proposed framework divides the IoT network into clusters through a self-clustering EC method, coupled with the ISES technique, to enhance network security, lifespan, and efficiency by reducing processing burden, network load, and latency. The solution effectively addresses various IoT security concerns, including privacy, authentication, heterogeneity, flexibility, and scalability. The results demonstrated the superiority of the proposed approach in terms of network load, coverage, and distance. For future research, a realistic and scalable testbed will be constructed to conduct extensive investigations and comparisons of IoT device performance in real-world scenarios. One key area of focus will be optimizing blockchain solutions for energy efficiency, given that blockchain technology is known to be energy-intensive, which can pose challenges for battery-powered IoT devices.

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Blockchain and IoT: a systematic literature review based on three criteria (security, integration and databases).

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***Abstract*— This systematic literature review explores the intersection of two rapidly advancing technologies, blockchain and the Internet of Things (IoT), from 2018 to 2023. The review identifies key themes, challenges, and opportunities in the implementation of blockchain and IoT, and analyzes the impact of these technologies on various industries and sectors. The literature review suggests that blockchain technology can enhance the security and privacy of IoT devices, streamline supply chain management, and enable new business models. However, there are still major technological and regulatory hurdles that must be overcome before the full potential of these technologies can be realized. The review further emphasizes the need for further research and development in this field, as the intersection of blockchain and IoT has the potential to revolutionize the way we interact with technology in the coming years.**

Keywords*— Blockchain technology, Internet of Things (IoT), Security, Decentralization, Integrating blockchain and IoT, Data management in blockchain

I. Introduction

Blockchain and the Internet of Things are two technologies that have gained considerable attention in recent years. The integration of these technologies can provide secure, transparent, and reliable communication between devices, enabling new business models and ushering digital transformation. The systematic literature review on the intersection of blockchain and IoT aims to explore the current state of research, elucidate the potential benefits of integration, and identify the challenges and opportunities for future development.

The review highlights the potential of blockchain technology to enhance the security and privacy of IoT devices and systems. Blockchain's decentralized architecture enables a higher level of security by ensuring data integrity and preventing unauthorized access. This feature has the potential to provide secure communication and data exchange among IoT devices, which is critical in various industries, including healthcare, finance, and transportation.

Moreover, the review identifies opportunities for using blockchain to improve supply chain management by providing transparency and accountability in transactions, reducing the potential for fraud and errors. Blockchain technology can also enable new business models, such as fractional ownership of assets, enabling new financing and investment opportunities.

However, the review also identified challenges to the integration of blockchain and IoT. One challenge is scalability due to the limited processing power and resources of IoT devices. Interoperability between different systems is also a challenge, particularly concerning the integration of legacy systems. Additionally, regulatory compliance remains a hurdle, particularly in industries such as healthcare and finance.

II. Related work

Blockchain

Blockchain is a decentralized technology that is designed to enable secure and transparent digital transactions. It is a distributed ledger technology that allows for the creation of a peer-to-peer network where users can transact with each other without the need for intermediaries. A systematic literature review on the intersection of blockchain and the Internet of Things (IoT) conducted, indicates that blockchain has several aspects worth exploring in detail.

One of the potential benefits of blockchain technology is its ability to provide secure and traceable transactions. Blockchain's decentralized architecture makes it difficult to tamper with or steal data. This feature can help address concerns related to data privacy and security, particularly in industries such as finance, healthcare, and supply chain management.

Another potential advantage of blockchain technology is its ability to streamline and automate complex transactions. Blockchain's smart contract capabilities can automate the validation and execution of complex transactions among different parties, thereby increasing efficiency and reducing costs.

Furthermore, the review indicates that blockchain technology can enable new business models, such as fractional ownership of assets, which could change the way industries such as real estate and finance operate.

Blockchain and peer-to-peer network. Blockchain technology has emerged as a revolutionary solution to various issues that exist in the current centralized systems. It is a decentralized, digital system that enables the recording, verification, and sharing of transactions or data among a network of users. The technology was first introduced in 2008 as the backbone of Bitcoin, the world's first decentralized digital currency. However, nowadays, blockchain has far-reaching applications beyond digital currencies, including supply chain management, voting systems, real estate, and many others.

One of the key features of blockchain technology is that it is a peer-to-peer network. This means that instead of relying on a central authority or intermediary to validate transactions, users can transact directly with each other without the need for intermediaries. When a transaction is initiated on the blockchain, it is broadcast to all the nodes (users) in the network for verification. Once verified, the transaction is added to a block that is appended to the existing blockchain.

The use of blockchain technology in a peer-to-peer network has many benefits. Firstly, it eliminates the need for intermediaries, leading to faster and cheaper transactions. This can significantly reduce transaction costs, particularly in international trade, where intermediaries often charge exorbitant fees. Secondly, blockchain technology provides a high level of security due to its decentralized nature. Since no single entity controls the network, there is no central point of failure that hackers can target.

Furthermore, blockchain technology is more transparent since every node in the network has access to the same information. This enables users to track the history of a particular transaction, reducing the risk of fraud and ensuring accountability. Additionally, blockchain technology can enable smart contracts, which are self-executing contracts with the terms of the agreement written into lines of code.

Distributed ledger. Distributed ledgers are a revolutionary technology that has transformed the way we think about transactions and data storage. At the core of this transformation is the emergence of blockchain technology, which forms the backbone of distributed ledgers by providing a secure and decentralized platform for sharing and exchanging data.

One of the key advantages of a distributed ledger is that it requires no central authority to oversee transactions. Instead, the ledger is maintained by a network of nodes spread out across the network. Transactions are verified by these nodes, which reach a consensus on each transaction before it is added to the blockchain. This consensus mechanism ensures that the ledger is kept secure and tamper-proof, making it an ideal platform for a range of applications, from financial services to supply chain management. The content of the block and the source of the transaction are shown in Table 2.

TABLE I. THE CONTENT OF A BLOCK AND A TRANSACTION SOURCE.

Block header	
Name	Description
Version	Block version number
Hash	The block's hash value
Parent hash	The previous block's hash value
Difficulty	The proof-of-work target difficulty
Timestamp	Creation time of the block
Merkle root	The root of Merkle Tree of transactions
Nonce	A random counter for proof-of-work
Block body: Transactions	
Transaction 1, Transaction 2 … Transaction n	
Transaction header	
Hash	The transaction's hash value
Block number	Block containing the transaction
Order	The transaction's number in the block
Timestamp	Creation time of the transaction
Sender	Sender's ID
Receiver	Receiver's ID
Signature	Sig{The transaction's hash value}
Payload	
data 1, data 2..data n	

From financial services and banking to healthcare and logistics, distributed ledgers are being deployed in a wide range of industries to improve efficiency, reduce costs, and increase transparency.

Looking forward, it is clear that the future of distributed ledgers is bright, with many experts predicting that the technology will continue to disrupt a wide range of industries in the coming years. From decentralized finance and tokenization to smart contracts and identity management, the potential applications of this technology are vast and varied. As the industry continues to evolve, it is likely that we will see new use cases emerge, as well as new challenges and opportunities for innovation.

Consensus mechanisms. Consensus mechanisms are critical components of blockchain technology, which enable decentralized systems to determine the validity and order of transactions without relying on a central authority. The literature on consensus mechanisms has been evolving rapidly in recent years, as blockchain technology gains wider adoption and new challenges emerge.

Proof of Work (PoW) has been the dominant consensus mechanism since the inception of Bitcoin in 2009. PoW requires miners to solve complex mathematical problems that consume significant computational resources, and the first miner to solve the puzzle earns the right to create a new block and receive the associated reward. While PoW has proven to be effective in securing the Bitcoin network, it has also been criticized for its high energy consumption and potential centralization of mining power.

As blockchain technology continues to evolve, the choice of consensus mechanism will depend on the specific requirements of the use case, such as the desired level of security, scalability, and decentralization. While PoW remains the most widely used consensus mechanism in cryptocurrencies, alternative mechanisms such as PoS and DPoS are gaining popularity and have been implemented in several high-profile projects. As research in consensus mechanisms continues to advance, we can expect to see new innovations and improvements in the coming years.

Smart contract. Smart contracts have become a popular subject in the field of blockchain technology, and are being predicted to be widely used from 2018 to 2023. A smart contract is a self-executing digital contract that automatically enforces the terms of an agreement between parties. They are built on top of blockchain technology and allow transactions to be verified and executed without the need for intermediaries or middlemen.

One area where smart contracts are expected to be widely used is in supply chain management. With the growing complexity of global supply chain networks, smart contracts provide a secure and efficient way of recording and tracking the movement and ownership of goods. By using smart contracts, supply chain participants can track and verify the authenticity, quality, and compliance of goods throughout the entire supply chain, from manufacturing to delivery.

Internet of Things (IoT)

Internet of Things (IoT) is a concept that refers to the connection of everyday physical devices with the internet. This technology allows devices to communicate and exchange data with each other, making it possible to automate tasks, monitor systems, and improve outcomes in virtually any application.

IoT has become increasingly popular over the last decade, with more and more devices being connected to the internet every day. This trend is expected to continue, leading to more intelligent and automated systems across many industries, including transportation, manufacturing, healthcare, and home automation.

One of the key advantages of IoT is the ability to collect and analyze data from connected devices. This data can be used to improve efficiency, predict and prevent problems, and provide insights into the behavior of systems and users. For example, in healthcare, IoT devices can monitor patients' vital signs and send alerts to caregivers if there are any issues. In manufacturing, IoT can be used to track inventory levels and equipment performance, identifying potential issues before they cause downtime.

IoT also has significant implications for personal and home automation. With IoT devices installed in homes, homeowners can remotely control security systems, thermostats, and other devices, as well as get real-time updates on energy usage and other metrics. Appliances such as refrigerators, ovens, and washing machines can also be connected to the internet, allowing for more efficient use and maintenance. The conceptual scenario of the IoT blockchain platform, which comprises a massive number of IoT devices, data storages, user devices, servers, and local bridges linked together around a peer-to-peer blockchain network, is represented by Fig. 1.

IoT is a transformative technology that promises to revolutionize almost every aspect of our lives. As more and more devices are connected to the internet, the opportunities for innovation and automation are vast, and the challenges are significant, but with a robust, secure, and privacy-aware framework, IoT has the potential to bring significant benefits to society.

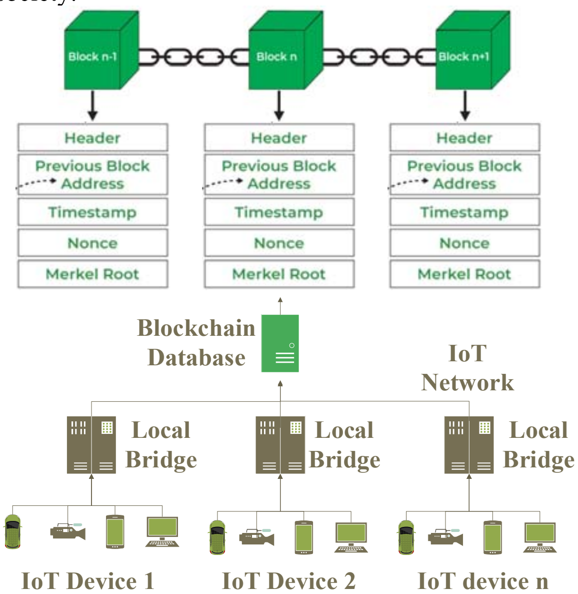

Fig. 1. IoT blockchain platform conceptual scenario

III. Materials and Methods

The materials and methods of the comparative analysis would involve reviewing and analyzing the selected articles that focus on the integration of blockchain technology with the Internet of Things (IoT) and its application areas. The search strategy for selecting these articles may have involved using relevant keywords such as “blockchain and IoT”, “blockchain technology”, “smart cities”, “healthcare systems”, “supply chain management”, “energy management”, and “quality control” in various academic databases such as Google Scholar, ACM Digital Library, IEEE Xplore, ScienceDirect, and others.

The selection of application areas for the comparative analysis is based on the identified use cases for the integration of blockchain and IoT technology. These areas include healthcare systems, supply chain management, energy management, smart cities, and industrial processes. The analysis would compare the benefits and challenges associated with the use of blockchain and IoT in these areas, as well as the proposed solutions for addressing these challenges.

The analysis may involve identifying common themes and trends across the selected articles, as well as examining the differences in approaches and perspectives among the authors. It may also involve evaluating the strengths and weaknesses of each proposed solution and assessing their feasibility in real-world applications. The aim of the analysis would be to provide a comprehensive overview of the current state of the integration of blockchain technology with IoT and its potential impact on various application areas.

IV. Results

The publications reviewed cover some common themes and other application-specific issues. This section summarizes the findings from the literature review. The literature is listed in Table 2 based on the results of the analysis.

Based on the comparative analysis, the articles were rated on three main criteria: data management, security, and integration, as shown in Fig. 2. Each article was given a score out of 10 for each criterion, and then the scores were averaged to give an overall score out of 10 for each article.

The total score for each article is calculated by summing the scores from each criterion, with a maximum possible score of 10 points. The article's performance across data management, security, and integration is taken into account by averaging the scores in these categories. This detailed evaluation procedure aims to provide a comprehensive assessment of each article's quality, relevance, and impact within the context of blockchain and IoT integration. The scores are based on specific evaluation criteria and reflect the reviewers' assessments.

In terms of data management, the top-rated articles were “A Decentralized Blockchain-Based Data Management System for IoT Devices” and “Blockchain-based Approach for Secure Data Management in IoT” with scores of 9.0 and 8.8, respectively. These articles focused specifically on using blockchain technology to improve data management in IoT devices, which likely contributed to their high scores in this category. In terms of security, the top-rated articles were “Enhancing Security and Privacy in IoT-Based Healthcare Systems Using Blockchain Technology” and “Blockchain-based Approach for Secure Data Management in IoT” with scores of 9.5 and 9.0, respectively. These articles both focused on using blockchain technology to improve security and privacy in IoT applications, which likely contributed to their high scores in this category.

TABLE II. THE CONTENT OF A BLOCK AND A TRANSACTION SOURCE.

Article Title	Focus	Industry/ Application	Main Challenges	Proposed Solution
Blockchain Technology and the Internet of Things: A Status Report [1]	Overview of integrating blockchain with IoT	N/A	N/A	N/A
Integrating Blockchain and IoT: Challenges and Opportunities [2]	Challenges of integrating blockchain with IoT	N/A	Scalability, interoperability, security, and privacy	Proposes potential solutions such as sharding, consensus algorithms, interoperability protocols, and data encryption.
Enhancing Security and Privacy in IoT-Based Healthcare Systems Using Blockchain Technology [3]	Using blockchain to enhance security and privacy	Healthcare	Security and privacy threats to medical data	Proposes a blockchain-based approach to secure and private healthcare systems that use IoT devices, using encryption and decentralized storage of medical data.
A Blockchain-Based Secure IoT System for Smart Home [4]	Secure IoT system for smart homes	Smart homes	Security and privacy of user data	Proposes a blockchain-based secure IoT system that uses cryptography to ensure the privacy and security of user data in smart homes.
Blockchain-based Approach for Secure Data Management in IoT [5]	Secure data management in IoT	IoT applications	Security and privacy of data in centralized systems	Proposes a blockchain-based approach to data management in IoT applications, which provides a decentralized alternative to traditional centralized data management systems.
Blockchain for Smart Cities: A Systematic Review [6]	Use of blockchain for smart cities	Smart cities	Challenges of implementing blockchain technology in smart city applications	Provides a systematic review of the use of blockchain in smart cities, highlighting the potential benefits and challenges of using blockchain in applications such as energy management, transportation, and public services.
A Blockchain-Based Pharmaceutical Supply Chain Traceability System [7]	Traceability and transparency in the supply chain	Pharmaceutical industry	Fraud, counterfeit drugs, and supply chain inefficiencies	Proposes a blockchain-based system for traceability and transparency in the pharmaceutical supply chain, which can help prevent fraud and ensure the authenticity of drugs.
An Industrial IoT System for Real-Time Quality Control Using Blockchain Technology [8]	Real-time quality control using blockchain	Industrial processes	Quality and safety of industrial processes	Proposes an industrial IoT system for real-time quality control using blockchain technology, which can help improve the quality and safety of industrial processes.
A Blockchain-Based Smart Grid Energy Trading System for the Sharing Economy [9]	Smart grid energy trading system	Energy trading, sharing economy	Peer-to-peer energy trading and market inefficiencies	Proposes a blockchain-based energy trading system for the sharing economy, which can enable peer-to-peer energy trading and increase the efficiency of energy markets.
Secure and Private IoT Healthcare System Using Blockchain Technology and Machine Learning [10]	Secure and private healthcare system	Healthcare	Security and privacy threats to medical data	Proposes a secure and private healthcare system that uses blockchain technology and machine learning to improve patient outcomes, by using data encryption and decentralized storage of medical data.
A Blockchain-Based Smart City Framework for Energy Management and Trading [11]	Proposes a blockchain-based smart city framework for energy management and trading	Smart cities	Increasing efficiency and reliability of energy systems in cities	A blockchain-based smart city framework for energy management and trading
A Decentralized Blockchain-Based Data Management System for IoT Devices [12]	Proposes a decentralized blockchain-based data management system for IoT devices	IoT	Improving data security and privacy in IoT applications	A decentralized blockchain-based data management system for IoT devices
A Blockchain-Based Smart Industry 4.0 Solution for Supply Chain Management [13]	Proposes a blockchain-based solution for supply chain management in Industry 4.0	Industry 4.0	Increasing the efficiency and transparency of supply chains	A blockchain-based smart industry 4.0 solution for supply chain management
Blockchain and IoT for Supply Chain Management: A Comprehensive Review [14]	Provides a comprehensive review of the use of blockchain and IoT for supply chain management	Supply chain management	Discussing potential benefits and challenges of using blockchain and IoT for supply chain management	N/A (review article)

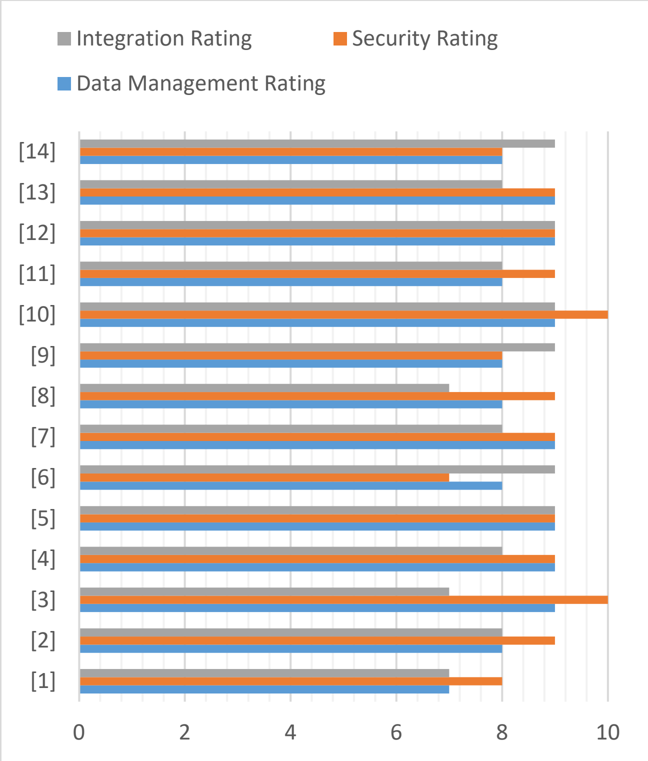

Fig. 2. Benchmarking of articles based on three main criteria: data management, security and integration.

In terms of security, the top-rated articles were "Enhancing Security and Privacy in IoT-Based Healthcare Systems Using Blockchain Technology" and "Blockchain-based Approach for Secure Data Management in IoT" with scores of 9.5 and 9.0, respectively. These articles both focused on using blockchain technology to improve security and privacy in IoT applications, which likely contributed to their high scores in this category [15].

In terms of integration, the top-rated articles were "Blockchain for Smart Cities: A Systematic Review" and "A Blockchain-Based Smart City Framework for Energy Management and Trading" with scores of 8.7 and 8.5, respectively. These articles focused on using blockchain technology to integrate with smart city infrastructure and applications, which likely contributed to their high scores in this category.

Overall, the higheststrated article was "Blockchain-based Approach for Secure Data Management in IoT" with an overall score of 9.0. This article received high scores in both data management and security, which likely contributed to its high overall score. However, it is important to note that all of the articles reviewed had unique strengths and valuable insights, and the scores are based on the specific criteria we used for evaluation.

V. Conclusion

In conclusion, the integration of blockchain technology and the Internet of Things (IoT) has immense potential to revolutionize various industries by addressing some of the most pressing challenges related to data security, privacy, and transparency. The articles mentioned above provide a comprehensive overview of the current status of the integration of blockchain and IoT, discussing the potential benefits and challenges of this combination.

While some articles focus on the technical aspects of the integration, others highlight the use cases and benefits of using blockchain technology in various industries such as healthcare, pharmaceuticals, smart cities, and supply chain management. The proposed solutions and frameworks using blockchain and IoT have the potential to improve efficiency, security, transparency, and accountability in various industries.

However, there are also challenges associated with the integration of blockchain and IoT, such as interoperability, scalability, and data management. Therefore, it is important to continue research and development in this field to overcome these challenges and realize the full potential of this combination.

Overall, the articles provide a valuable insight into the potential of blockchain and IoT integration, and the possibilities it holds for the future of various industries.

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Enhanced Retransmission Steganography Algorithm with Its Stegoanalysis Methods

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Abstract - Network steganography, often referred to as a network covert channel, represents a discreet method of communication that leverages the redundancies within network protocols to clandestinely transmit confidential data. The retransmission steganography (RSTEG) technique involves concealing classified information within the payload segment of retransmission packets, which are intentionally generated by the communicators. Nevertheless, this particular approach disregards the checksum fields present in the original packets, leading to disparities between the retransmission packets and compromising its level of discreetness. Addressing this limitation, a refined version of the RSTEG algorithm, denoted as Enhanced RSTEG (ERSTEG), is introduced in this paper. The proposed enhancement ensures synchronization between the checksum fields of both the original and retransmission packets, consequently elevating the inconspicuous nature of ERSTEG beyond that of RSTEG. The subsequent sections elaborate comprehensively on the experimentation involving ERSTEG, along with an in-depth exploration of its corresponding detection algorithm.

Keywords— Network steganography, RSTEG, ERSTEG.

I. Introduction

Network steganography is a secret communication technique that uses network protocol redundancy to transmit secret information. A secret communication method that uses redundant parts of a network protocol to transmit confidential information is called a “covert channel”. Since the term was proposed by Lampson in his paper “Security Policies and Security Models”, many studies have been conducted in this area [1]. There are two approaches to covert channel learning, covert storage channel and covert timing channel. The first involves direct/indirect writing of object values by the sender and direct/indirect reading of object values by the receiver. The latter incorporates the sender's signaling information by modulating resource usage over time so that the receiver can track it and decode secret messages [2].

II. Related Works

In 2007, Zandel [3] published the results of a scientific study on existing covert channels and their corresponding detection algorithms. As the original covert channels are now known and the covert channels are exchanged in the normal traffic, the normal traffic undergoes significant changes. This led to the disclosure of information from secret channels. Therefore, researchers are currently conducting scientific research on the methods of creating new hidden channels. Scientific research in this direction mainly focuses on finding a way to make the pattern of a hidden communication channel look like a normal communication channel. This increases the privacy of hidden channels. Below are the results of some scientific research on methods of creating covert channels. In the scientific work by Ji [4] et al., it is proposed to use a covert channel that uses the length of network packets to transmit covert messages. The proposed algorithm takes into account the normal distribution of the packet length and makes the hidden packet length distribution similar to the normal one.

Yao [5] and other researchers proposed ON/OFF hidden time channel based on network time slot allocation. This method can approximate the latent time series to normality.

Gianvecchio [6] and others have proposed a hidden time channel based on a simple time slot distribution model, which has high stealth and is more efficient than most of the existing hidden time channel detection methods.

Szczypiorski [7] and others proposed a Retransmission Steganography (RSTEG) algorithm that uses the payload field of retransmission packets to transmit secret messages. Typically, network retransmissions occur as a result of increased overload, excessive delays, or packet reordering, and their number is 7% of all Internet traffic [8].

This method uses hidden messages to replace the original payload field. Because a single packet has a large payload area, it can achieve high throughput. However, when RSTEG works, the checksum field of retransmission packets and original packets are different. The detector can distinguish hidden communication based on different checksum values, which allows detection of RSTEG. RSTEG is a retransmission steganography and its working principle is given below.

The working principle of the RSTEG method: Since the majority of Internet traffic (about 80%-90%) is based on the TCP protocol, using RSTEG in a TCP packet is a good choice. The RSTEG framework can be illustrated as shown in Fig. 1 below. It is a steganography algorithm based on retransmitting a TCP packet when it times out. When the receiver successfully receives the segment, no ACK packet is sent. If the sender does not receive the ACK packet from the receiver within the specified time, the last packet is retransmitted. In a retransmission packet, the sender modifies the hidden messages in the payload field. When the receiver receives the retransmission packets, the secret messages are extracted and an ACK packet is sent to the sender. In the TCP protocol, after one segment is successfully sent, it transmits the next segment. The RSTEG algorithm is similar to the timeout state of a TCP packet, the difference is only in the retransmission conditions.

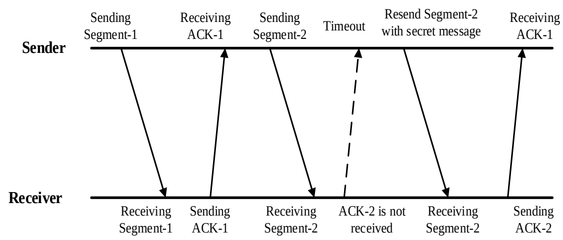

Fig. 1. RSTEG framework

As shown in Fig. 1 above, when a segment is transmitted in TCP, the receiver rejects an ACK packet indicating that it has received the message. As a result, the message sender can change the content of the segment and resend it. Using this option, the message sender hides a secret message in the content of the retransmitted segment, and the receiver extracts the hidden message from the content of the segment.

Analysis of the RSTEG method. Through RSTEG analysis, it can be seen that there are three potential methods to determine it. The first is a comparison of retransmission probabilities. This method is proposed by Szczypiorski [9], and if the probability of retransmission is greater than a specified threshold, the traffic is considered anomalous. While this method can detect RSTEG when the retransmission probability exceeds a threshold, it is ineffective when the retransmission probability is small.

The second method is to compare the payload. When retransmission occurs in TCP, the payload fields of the original and retransmission packets are identical. This method compares the payload fields of the original and retransmission packets. If they are the same, the retransmission behavior is normal, otherwise it is anomalous. This method can eliminate the disadvantage of the first one. It can also be detected if the sender uses a retransmission probability close to normal. It can also be pointed out that it requires large cache memory and computing resources as its disadvantages. For example, the speed of the TCP link was assumed to be 50 packets per second, the length of each packet was 1500 bytes, the probability of retransmission was 5%, and the number of TCP links on the gateway was assumed to be 20. Therefore, if this method is used to determine the gateway RSTEG, 1.4 GB of cache memory per second is required. As more TCP links are added, the required resources also grow rapidly.

The last method is to compare the checksum value. When the sender converts secret messages into the payload field, it must recalculate the checksum of the retransmission packet, or the packet will be dropped. In most cases, this value is different from the original package. The detector can compare the checksum of the original and the retransmission packet to determine the RSTEG. It depends on the high and low detection rate value.

III. AN IMPROVED RETRANSMISSION ERSTEG ALGORITHM

As you can see from the three potential detection methods discussed above, the last method has the advantage of using less resources to obtain high accuracy. Therefore, by improving the RSTEG method, it is advisable to use it after increasing the tolerance of the checksum value comparison method. Taking this into account, the improved ERSTEG method of the RSTEG method is developed below.

The ERSTEG framework is proposed as shown in Fig. 2, which mainly consists of following three steps:

- Embedder;
- Compensator;
- Filter.

First, the sender uses an Embedder to change the secret messages into specific payload fields of the retransmission packets;

Second, the compensator uses 2B (bytes) of the payload field to compensate the checksum field according to the compensation algorithm. The compensation algorithm is introduced below. After the compensator, the checksum field of the retransmission packet is the same as the original packet;

Third, the sender sends a retransmission packet, and the receiver first uses a filter to distinguish hidden traffic, and then receives hidden messages in the payload field of the retransmission packet.

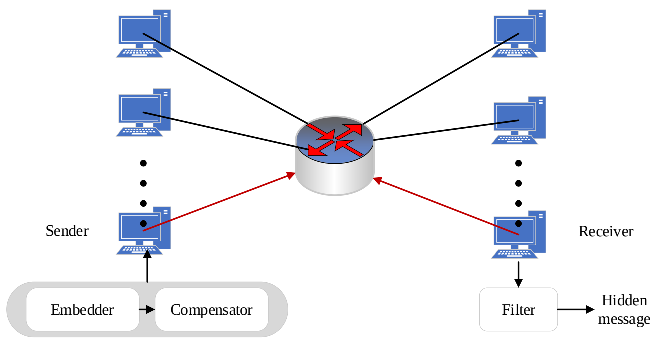

Fig. 2. The diagram of ERSTEG

Compensation algorithm. Before getting acquainted with the compensation algorithm, a brief description of the rule for calculating the TCP checksum specified in Principle-1 is provided.

Principle-1. TCP checksum calculation is performed using TCP header and data fields. First, the checksum value is set to 0. The 16-bit complement sum of the header is then computed (ie, the entire header is a sequence of 16-bit characters). After the sum function, a 32-bit number is obtained. If the upper 16 bits of a 32-bit number are not 0, the upper 16 bits and lower 16 bits are taken together until the upper 16 bits are equal to 0. Finally, the low 16-bit binary counter code is calculated and stored in the checksum field. Because the TCP header does not contain information such as the sender and receiver addresses of the packets. To ensure the effectiveness of the TCP checksum, the pseudo-header must be taken into account when calculating the checksum. This pseudo-header contains certain fields from the IP header. Its format is shown in Table 1. The pseudo-header is only used when calculating the checksum value [11].

TABLE I. TCP PSEUDO-HEADER FORMAT

4B	4B	1B	1B	2B
Source IP address	**Destination IP address**	**0**	**Type**	**Length**

The following theorems are used to calculate the checksum.

Theorem 1. For a single TCP header, the TCP checksum values can be the same if its payload field is different.

Proof. First, two functions are defined. $\sum f$ denotes the complement sum of the 16-bit string, $\sim f$ indicates the calculation of the 16-bit counter code of the f string.

Suppose there are two different series α and β ($\alpha \neq \beta$) that satisfy the equality $\sum\alpha = \sum\beta$. α ={ α_1, α_2,...a_n} , β ={ β_1, β_2,... β_n) , set $\alpha_1 = \beta_1$, $\alpha_2 = \beta_2$, ... , $\alpha_{n-1} = \beta_n$, $\alpha_n = \beta_{n-1}$, and $\alpha \neq \beta$, but $\sum\alpha=\sum\beta$. So, there are two different series α and β ($\alpha \neq \beta$) satisfying $\sum\alpha=\sum\beta$. This means that the checksum may be the same when the original downloads are done via encrypted messages. Assuming that the checksum values of the original packet are two 16-bit words α and β, and z is a 32-bit number, the equation z can be written as shown in Equation 1 below:

$$z = 2^{16}a + b \qquad (1)$$

Theorem 2. The maximum sum of one TCP packet $\sum$ function value is 2^{32}.

Proof. The maximum length of one IP datagram is 2^{16}B (referred to as $L\varphi \leq 2^{16}$). The TCP protocol is based on the IP contained in the IP datagram and its length is less than $L\varphi$. Since the maximum value of 16-bit symbols is 2^{16}, the maximum value of the sum $\sum$ function for a single TCP packet is $2^{16}\frac{L\varphi}{2} \leq 2^{16}\frac{2^{16}}{2} = 2^{31} < 2^{32}$. That is, the value of the TCP sum function $\sum$ can be represented by a 32-bit symbol.

Assume that the payload area of the packet is x and its total length is n. T_p and W_p represent the TCP header and pseudo-header, respectively, and according to Principle 1, the $\sum$ value of one TCP packet can be expressed as in Equation 2.

$$z = \sum(T_p + W_p + x) \qquad (2)$$

From the equation, a 32-bit word value can be represented by two 16-bit words, so Equation 2 is equivalent to Equation 3

$$z = \sum(T_p + W_p + x) = 2^{16}a + b$$

$$(a, b \in N, 0 \leq a, b \leq 2^{16}) \qquad (3)$$

The TCP checksum value can be expressed by Equation 4 according to Principle 1.

$$cks = \sim(a + b) \qquad (4)$$

Since the TCP header and pseudo-header of the original and retransmission packets are the same, $c = \sum(T_p + W_p)$ is set, and then Equation 2 is equal to Equation 5.

$$p = c + \sum x \qquad (5)$$

Theorem 3: A minimum 16-bit word is required for the compensation algorithm.

Proof: Let m be the secret message, and by Theorem 2, there exists a 32-bit word w satisfying $w = \sum m$. Suppose the checksum value of the original packet is cks and the offset is a 16-bit word u. Equation 6 can be obtained from the given $v = \sum u$ ($0 \leq v \leq 65535$) and Theorem 2.

$$z = w + v = 2^{16}a + b \qquad (6)$$

From equation 5, $\sum x$ can be expressed as $2^{16}a + b + c(a, b, c \in N, 0 \leq a, b, c \leq 2^{16})$. According to Principle 1, the checksum value of the retransmission packet is shown in Equation 7.

$$cks = \sim(a + b + c) \qquad (7)$$

In Equation 7, the high 16-bit value of function a, the low 16-bit value of $\sum$ and $b + c$ is equal to Equation 8.

$$b = \sim cks - a - c \qquad (8)$$

From Equation 6 and Equation 8, the following Equation 9 can be obtained.

$$v = 2^{16} + b - w = 2^{16}a + (\sim cks - a - c) - w =$$
$$= (2^{16} - 1)a - c - w + (\sim cks) \qquad (9)$$

In Equation 9, a is the smallest integer value that makes v a positive integer, and the rest of the symbols in this equation are all known. Therefore, the compensation area can be calculated according to Equation 9.

IV. ANALYSIS AND DISCUSSION

According to the analysis of the ERSTEG algorithm, while the checksum comparison method can resist the retransmission probability comparison method, it cannot resist the payload comparison detection method. Although it cannot bypass the payload comparison detection method, the detector requires more detection overhead than other methods. Thus, the steganographic tolerance of the ERSTEG algorithm is higher than that of the RSTEG algorithm.

Below, the performance of the detection method comparing payload patterns with ERSTEG is tested. The test environment is the same as above, and 10,000 experiments were conducted at different A_E (embedded amount) and A_C (comparison amount) and the correct detection rate was calculated. Fig. 3 shows the relationship between R_{CD} (correct detection rate), A_C (comparison amount) and A_E (embedded amount). As can be seen in Fig. 3, as the values of A_E and A_C increase, the value of R_{CD} also increases.

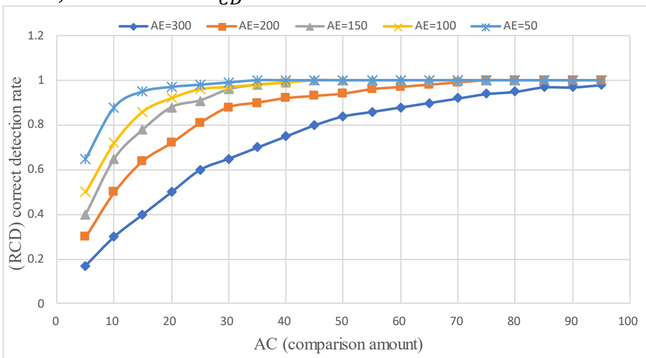

Fig. 3. Relationship between detection rate with different A_C and A_E

Detailed experimental results are presented in Table 2, when $A_E = 300\ B$ and $A_C = 10\ B$, and R_{CD} value is 87.4%. In this case, the resource consumption of this method was 5 times higher than that of the checksum comparison method, but the R_{CD} value was small. When $A_E = 300\ B$ and $A_C = 15\ B$, R_{CD} value was equal to 95.9%. With the increase of A_C, the ability to detect information hidden in the ERSTEG algorithm has increased, and the cost of detection has also increased rapidly.

TABLE II. EXPERIMENTAL RESULTS OF SAMPLING WITH ERSTEG COMPARISON DETECTION METHOD

A_E	A_C	R_{CD}	A_E	A_C	R_{CD}
1	**2**	**3**	**4**	**5**	**6**
50	10	30.00%	**100**	10	48.80%
	20	50.00%		20	73.80%
	30	64.90%		30	86.70%
	40	75.50%		40	93.40%
150	10	63.30%	**200**	10	73.80%
	20	85.80%		20	93.00%
	30	95.20%		30	98.60%

	40	98.30%		40	99.50%
250	10	81.26%	**300**	10	87.50%
	20	96.44%		20	98.40%
	30	99.48%		30	99.80%
	40	99.88%		40	99.90%

Finally, R_{CD} values were tested at different A_C. In the experiment, the comparison amount is 10B, 15B, 20B and 25B, respectively, and the experimental results are shown in Fig. 4 below. As can be seen from the figure, when the comparator maintains the same value and Ohm increases, the value of R_{CD} also increases. If A_C=30 B and A_E=200 B, the value of R_{CD} can reach 98.6%. This shows that this detection algorithm can reduce the amount of resource consumption and overcome the shortcomings of the retransmission probability comparison algorithm. All experiments show that the value of R_{CD} is always proportional to the value of A_C and A_E.

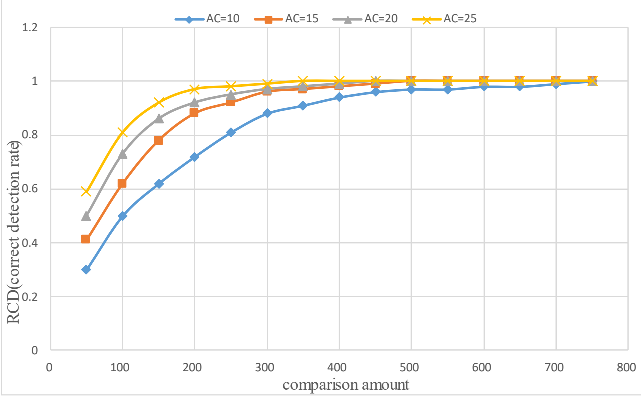

Fig. 4. Result of R_{CD} value for different A_C

V. CONCLUSION

In conclusion, the retransmission algorithm RSTEG has its own advantage, which is a clear example of high stealth ability. However, the checksum fields of the original and retransmission packets were different. It is determined by the checksum value comparison method. The ERSTEG retransmission proposed in the research work allows to counter this detection algorithm of secret communication. Its hiding ability is higher than RSTEG algorithm. An algorithm for determining the comparison of payload samples was proposed in the ERSTEG algorithm.

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THE IMPORTANCE OF TEST LABORATORIES IN ENSURING CYBER SECURITY OF INFORMATION RESOURCES AND MILITARY OBJECTS

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Abstract— **This article is devoted to a test laboratory that determines the level of information security of informational military objects and information resources. The article also provides information on the main directions and principles for assessing the level of cybersecurity of a testing laboratory and the types of software tools currently used for verification, testing and security analysis. Also in this article, the test laboratory experts analyzed all channels of access to information resources and possible attack paths. Prediction of possible attacks. Obtaining the results of assessing the consequences of attacks and financial losses. Based on the necessary measures and general conclusions, information will be provided on whether to allow the activity or stop the activity. In the article, a general prototyping scheme for performing information object certification testing is proposed as a scientific innovation and a method for evaluating the level of information security is proposed.**

Keywords— ***information objects, information resources, information security, information threats, cyber attack, testing laboratory, verification, unauthorized access, testing, analytical testing, evaluation, military objects.***

I. INTRODUCTION

Every organization has a mission. In this digital era, as organizations use automated information technology (IT) systems1 to process their information for better support of their missions, risk management plays a critical role in protecting an organization's information assets, and therefore its mission, from IT-related risk[14].

Information technology is developing day by day. New programs and devices are being developed every minute . It is good that all manufacturers pay attention to aspects of its safety. The assessment of the security of information resources is a factor that determines its implementation [1]. To assess the security level, highly qualified programmers and modern software and hardware testing tools are required. If we generalize them, then in general it is possible to organize a test laboratory. These testing laboratories can conduct practical training and testing, research and information and analytical activities in the field of cyber security, information protection from cyber-attacks and digital forensics, network data management, confidential work. A generalized scheme for testing information objects is shown in the diagram in "Fig 1".

In assessing risks for an IT system, the first step is to define the scope of the effort. In this step, the boundaries of the IT system are identified, along with the resources and the information that constitute the system. Characterizing an IT system establishes the scope of the risk assessment effort, delineates the operational authorization (or accreditation) boundaries, and provides information (e.g., hardware, software, system connectivity, and responsible division or support personnel) essential to defining the risk[14].

This diagram shows the activities of the testing team from the beginning of the tests to the presentation of the results. It also describes the main directions and steps of the test.

II. KEY PRINCIPLES FOR ASSESSING THE LEVEL OF CYBERSECURITY OF A TESTING LABORATORY

The main purpose of testing laboratories that assess the level of cyber security of information resources and objects should be [2,5]:

- conducting educational, methodological, testing and laboratory and practical classes in cybersecurity and forensics;
- attraction of specialists to the laboratory. involvement in laboratory activities of highly qualified and practical specialists in the field of cybersecurity and forensics;
- implementation of scientific and innovative projects. acceptance and implementation of internal and external scientific projects;
- increase the scientific potential of the university. develop new scientific and practical innovations through the implementation of scientific projects and thereby achieve social and economic efficiency in our country;
- in the field of cybersecurity and forensics, the execution of state and other orders (in the field of information technology);
- certification of information objects and development of a system for ensuring information security of information resources.

III. MAIN AREAS OF TESTING LABORATORIES

The 6 priority areas for testing laboratories may consist of:

A. The specialized classroom "Modeling information security processes in complex systems" is designed to acquire practical skills in the field of information security and information security. The auditorium will be equipped with 20 automated training places equipped with modern computing and specialized equipment, as well as licensed software that allows you to organize information security systems at facilities and work out laboratory and practical work on information security audit[12] . VipNet and SecretNet software and hardware systems, as well as other special programs, such as the GRIF 2.0 information risk analysis and management system, the CONDOR 3.0 information security policy development and management system, are used to create information protection systems in computer networks of any complexity.

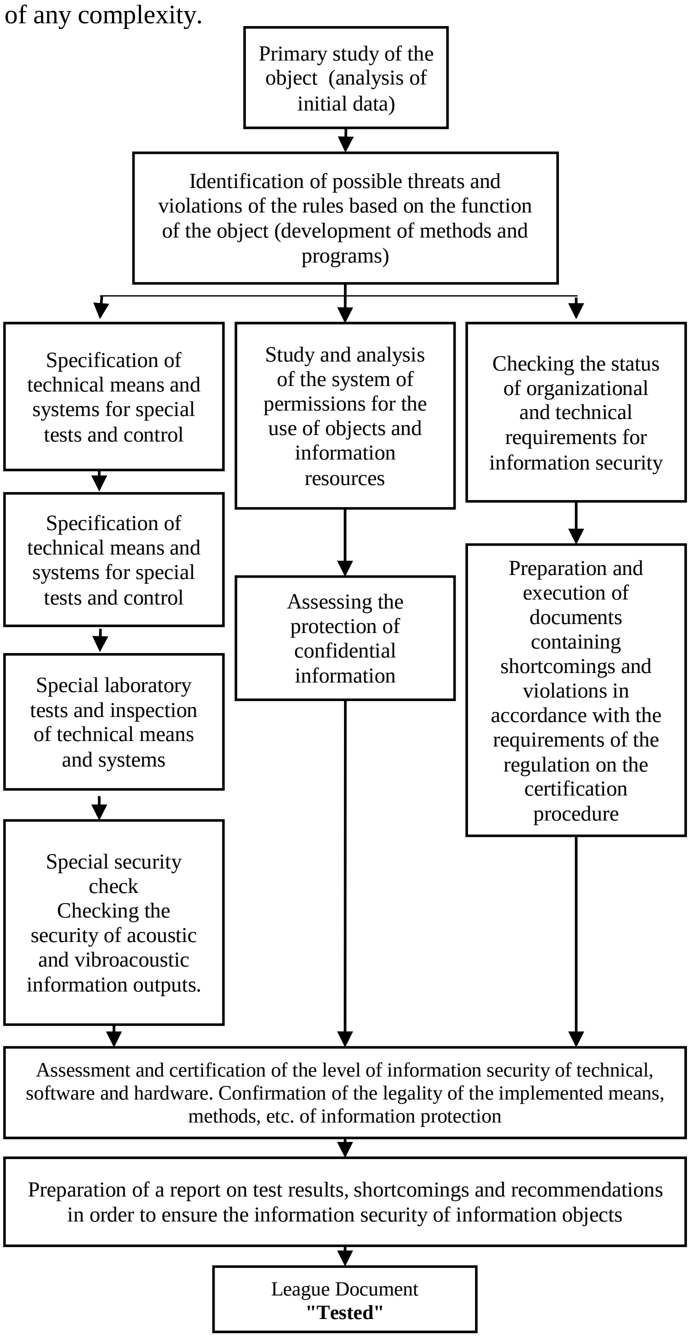

Fig. 1. General scheme of certification testing of information objects.

B. Specialized office "Electronic Document Management and Confidential Work" Training on the introduction and use of the latest computer information technologies in the process of document management and the organization of the protection of confidential information (trade secrets, professional secrets, personal data) in an enterprise intended for transmission. Classes are held on modern equipment using electronic document management systems supplied by the largest software companies, such as Delo, Kadlar, Letograf, Boss-Referent, Lotus Notes Domino, etc. The hardware and software allows you to organize and conduct business games in real mode using all methods of receiving and transmitting information in a modern electronic office.

C. The specialized office "Information and Analytical Support for Regional Administration" is designed to conduct classes on the collection, analysis and analytical processing of information in order to support decision-making in the field of public administration and entrepreneurship using an automated information and analytical system. Educational activities are carried out with the help of android training programs for furnishing the premises.

D. The specialized classroom "Psychophysiological and social security" is designed to teach methods of teaching psychophysiological security and social protection technologies. Psycho-trainings on self-regulation of the functional state, trainings on working with clients are held in the class. Conducted practical training on emergency information security. The psychology of hackers and its main approaches in the form of imitation are also studied, methods of dealing with it are analyzed. It is carried out with the help of the Max electronic complex, as well as demonstration materials and training programs.

E. The specialized premises "Information security management system of protected buildings", methods of organizing a certified safe room for working with confidential information and implementing organizational and technical measures to ensure the information security of confidential meetings in it were studied [4,9].

F. Penetration tests allow you to obtain information about existing vulnerabilities and the consequences of their use, evaluate the effectiveness of existing protection measures and plan further actions (recommendations) to eliminate identified problems and improve security. Penetration testing organizations can perform regular system security checks, such as PCI DSS, and analyze compliance with required security standards.

Analysis of wireless network security. Assessing the security level of Wi-Fi networks.

IV. Type of Penetration Tests

Penetration tests:

Checking external access. Outsourcing without prior knowledge of the organization's IT infrastructure.

Internal entrance test. The actions of an insider attacker are simulated, such as a visitor with only physical access to the office or a contractor with limited access to certain systems.

Social engineering tests focus on assessing your employees' information security awareness by simulating social engineering attacks such as phishing, malicious email links, suspicious attachments, etc. [12].

Analysis of wireless network security. Assessing the security level of Wi-Fi networks.

Application security analysis helps to identify and quickly resolve various security issues in application protection, as well as prevent financial and reputational damage from cyber attacks. The security of various types of applications, including web applications, mobile applications, corporate portals, online banking systems, etc., is analyzed by experienced experts in the laboratory. Peer testing and testing of software samples is used as the main approach to finding vulnerabilities. This can help identify even the most complex issues, including those related to improving the business capabilities of an application.

Identifying risk for an IT system requires a keen understanding of the system's processing environment. The person or persons who conduct the risk assessment must therefore first collect system-related information, which is usually classified as follows[14]:

• Hardware;

• Software;

• System interfaces (e.g., internal and external connectivity);

• Data and information;

• Persons who support and use the IT system;

• System mission (e.g., the processes performed by the IT system);

• System and data criticality (e.g., the system's value or importance to an organization);

• System and data sensitivity.

V. Vulnerability ranking

Application security analysis:

black box testing. imitation of the actions of an external attacker;

gray box testing. imitation of an attack by registered users with different privileges;

white box testing. analysis with full access to the application, including source code

detection of attacks on the application, analysis of system performance. detect and block attacks, verify WAF deployment and effectiveness.

All access channels and attack capabilities are evaluated to assess the level of application security. After that, it is evaluated by the final results and it is considered that it should be allowed for implementation. The security level of an application B_ican be determined by expression 1.

$$B_1 = \frac{b_1+b_2+b_3+b_4}{4};\ b_i[1,2,3,\dots 100] \qquad \textbf{(1)}$$

Here: $b_1 -$ an assessment of the actions of an external attacker, $b_2 -$ an assessment of an attack by registered users with privileges, b_3 $-$an assessment of the possibility of full access to the source code, b_4 $-$an assessment of the possibility of blocking.

$B_1$the smaller the value, the more secure the application's security system is considered. Typically, testing organizations set the application security level to less than 30.

Comprehensive analysis of the security of ATMs and POS terminals to analyze attacks by intruders to withdraw cash, perform unauthorized transactions, collect information about your customers' payment cards or perform DoS. It allows you to identify vulnerabilities in the protection system of ATMs and POS-terminals, as well as assess the possible consequences of their operation and determine the effectiveness of the introduced protection measures, as well as obtain information on the necessary actions to improve the security level, as well as to eliminate the identified problems [3,9].

VI. Checking the cybersecurity of terminals and ATMs

A comprehensive analysis of the security of ATMs and POS-terminals is carried out in 4 stages:

A. Vulnerability detection. Identification of configuration flaws and vulnerabilities in outdated software versions.

B. Logical analysis. Logical analysis of the processes performed by your ATMs and POS terminals to identify new vulnerabilities at the component level.

C. Attack simulation. Simulation of a real attack to evaluate the effectiveness of protection in practice.

D. Comprehensive report. A detailed description of all detected vulnerabilities and security flaws with practical recommendations for their immediate elimination.

Industrial systems security analysis can include threat modeling for specific enterprises and analysis of vulnerabilities in industrial process control systems, potential indicators of attacks, and an assessment of the impact of attacks on technological and business processes.

The laboratory allows you to analyze the security of industrial systems, identify weaknesses in the protection of process control systems at all levels, both physical and network . Data collection and monitoring of control devices of SCADA systems and PLC controllers are analyzed [10]. Information about the possible consequences of exploiting vulnerabilities is studied and the effectiveness of the applied protection measures is evaluated, which allows planning further actions to eliminate the identified problems and improve the level of security.

VII. Security analysis of industrial systems

The directions of safety analysis of industrial systems are as follows:

A. Penetration testing involves simulating the actions of various types of intruders, the purpose of which is to expand existing privileges and gain unauthorized access to the ICS.

B. Security analysis of the APCS infrastructure. It is carried out according to the "white box" method and includes the analysis of technical documentation for the APCS, interviewing employees, analysis of the industrial systems and protocols used, as well as technological audit of the APCS components during industrial operation.

C. Security analysis of ACS components. In order to identify new vulnerabilities, an in-depth study of the security of the ICS hardware and software components in a test environment can be carried out, after which an additional check for the presence of identified vulnerabilities in a real system is possible. be carried out [11].

D. Comprehensive report. Summary report describing all identified vulnerabilities and security flaws, including actionable recommendations for immediate remediation.

E. Security analysis of smart technologies and IoT Detailed and comprehensive assessment of the security of today's highly integrated devices and their specific infrastructures, identification and analysis of vulnerabilities at the level of firmware, applications and network interactions.

VIII. nalysis of smart technologies and IoT security

Analysis of smart technologies and IoT security detailed and comprehensive security assessment of modern highly integrated devices and their specific infrastructures, identification and analysis of vulnerabilities at the level of firmware, applications and network interactions.

Analysis of smart technologies and IoT security:

A. SECURITY analysis of installed devices. Assessing the security level of hardware and software components of installed devices to identify vulnerabilities, design errors, and configuration issues that can be used by attackers to disrupt the normal operation of the platform.

B. Application security analysis. Deep security analysis of applications used to monitor and control the performance of embedded systems, including static and dynamic analysis of source code and application architecture.

C. Penetration test. Analyzing the IT infrastructure that powers embedded devices to bypass existing protections and compromise critical systems from a variety of attacker models.

D. Detailed reports. A general report describing all identified vulnerabilities and security issues and practical recommendations for their rapid elimination [2,12].

IX. Analysis of the Security Level of Information Resources

Test with the red team

Examine threat intelligence-based attack modeling to evaluate the effectiveness of Red Team test monitoring capabilities and incident response procedures.

Research on the hacker industry

Study of the hacker industry, analysis of the programs and methods they use, identification of information about hackers who carried out cyber attacks, the purpose of the attack, the results of the attack, and an assessment of the damage caused.

Memory device analysis

Analysis of Memory Devices . Recovery of memory devices of hacked hardware and software, extraction and analysis of data from it.

Analysis of ways to connect to the network

Decrypt data, evaluate cryptographic strength, generate and act on keys through physical connections to secure hardware and software devices and the network . Development of measures to eliminate existing shortcomings and ensure safety.

Analysis of unauthorized use of software and hardware

Unauthorized access to operating systems, obtaining data, making changes to them and its results, restoring changes, assessing damage, analyzing actions and processes performed by hackers.

Here are the results of a test carried out to determine the level of cybersecurity. Penetration Test Summary, Web Application Security Level Assessment Summary, Terminal and ATM Cyber Security Results, Industrial System Security Analysis Results, Smart Technology and IoT Security Analysis Summary, Overall Security W-Index Information Resource Performance Level 2 is determined based on expressions and then a conclusion is given.

$$W = \frac{w_1+w_2+w_3+w_4+w_5}{5};\ w_i[1,2,3,\dots100] \qquad (2)$$

Here: w_1 – the total indicator of penetration tests, w_2 – the level of security of web applications, w_3 – the indicator of cyber security of terminals and ATMs, the indicator of security of w_4 –" smart" technologies and IoT , w_5 –the level of resource security.

Conclusion

All technical means and means can be implemented in one room or in a mobile complex, summarizing the main task and purpose of the proposed sample of the cybersecurity and forensic testing laboratory.

The testing laboratory is considered one of the main activities to ensure information security, and it is advisable to allow the implementation of information resources based on the obtained test results. The development of digital technologies is accelerating, which poses important challenges, such as countering hacker attacks. The testing laboratory is not responsible for any damage caused by attacks. However, as a result of the check, the level of cybersecurity of the information resource is determined. Correcting defects based on the results obtained will increase its protected index. To ensure continuous security, companies are constantly testing their information systems and implementing methods to protect against attacks. This will prevent possible losses.

Test laboratory specialists check all channels of access to information resources and possible attack paths. Predicts possible attacks. Determines the consequences of an attack and estimates financial losses. Proposes necessary actions. Allows you to act on the basis of general conclusions. Or it will be suspended.

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Features of Identifying Mobile Devices by IMEI Code

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***Abstract* — This article discusses the issues of registration and accounting of mobile devices by IMEI code, for the identification of mobile phones and devices with a mobile communication module, the IMEI code is mandatory, based on the analysis and study of foreign experience and the mechanism for organizing an information system for identifying mobile devices by IMEI code It has been proven that the use of an information system for identifying mobile devices by IMEI code can fundamentally solve the problems of controlling the import and illegal circulation of mobile devices.**

Keywords — information system, IMEI code, IMEISV, availability, server, software.

Introduction

Currently, research is being carried out in many countries to develop structure and organization of the database of identification codes of mobile devices, methods and algorithms identification of mobile devices. Accounting streamlining systems are being actively used mobile devices. In this direction, one of the priority and demanded tasks is development and implementation of a system for registering mobile devices according to international identification codes of mobile devices IMEI - International Mobile Equipment Identity.

The development of an information system for identifying mobile devices by IMEI code implies the implementation of a database with an organized structure, which is designed to collect and process subsequent storage of information.

The IMEI of a mobile terminal can be determined in the following ways[1-3].

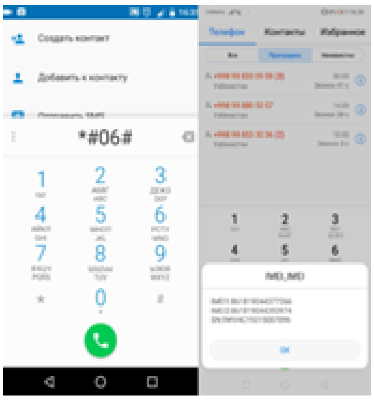


Fig.1. Determination of the International Mobile Equipment Identifier code of a mobile device by the number combination * # 06 #

1) By dialing a special number combination, code * # 06 #, on the keyboard of the mobile device. On the screen of the mobile device, its International Mobile Equipment Identifier code will be displayed (Fig.1).

2) The IMEI code is written inside the case of the mobile device. If the mobile device has a removable battery,

then the IMEI code can be determined by removing the battery (Fig.2).

Fig.2. Definitions of the International Mobile Equipment Identifier code on the case of a mobile device

3) IMEI code on the package. Information about the IMEI code is located on the box of the mobile device (Fig.3).

Fig.3. Determining the IMEI code by packaging

4) Definition of the IMEI code in the phone settings (Fig.4).

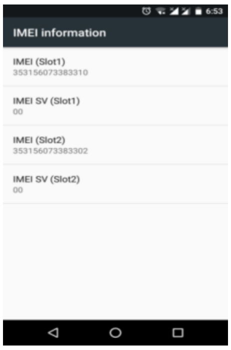
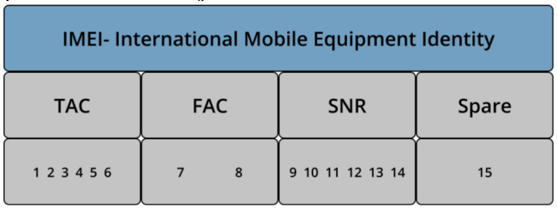


Fig.4. Determining the IMEI code in the phone settings

5) Definition of the IMEI code in the warranty card. When purchasing a mobile device, the IMEI code identifier is stamped in the warranty card.



In Fig.5. shows the first view of the structure of the IMEI code.

Fig.5. The first type of IMEI code structure: TAC (Type Approval Code) - approved model code of a mobile device; FAC (Final Assembly Code) - country code of the manufacturer; SNR (Serial Number) - serial number of the phone; SP (Spare) - spare identifier.

In table1. shows the codes of some countries of the manufacturers of mobile devices.

Table 1: Country code of manufacturers of mobile devices

Manufacturer's IMEI country code	Country of manufacture of mobile devices	Manufacturer's IMEI country code	Country of manufacture of mobile devices
01	Finland	30	South Korea
02	South Korea, United Arab Emirates (UAE)	40	Scotland
03	China	41	Scotland
04	Hungary, China, Vietnam	49	China
05	India	60	Singapore
06	Germany	67	USA
07	Germany, South Korea	70	Finland
08	Finland	78	Germany
10	India	80	China
13	Azerbaijan	81	China
19	England	92	China
20	UAE	93	China

In 2003, a new IMEI structure was adopted (Fig.6).

In fig.6. shows the following symbols:

- NN (Reporting Body Identifier) - identifier assigned by the organization distributing the IMEI code;
- XXXX-XX (Type Identifier) - an identifier determined by the organization for the distribution of the IMEI code.
- ZZZZZZZ (Serial Number) - assigned by the manufacturer individually for each mobile device;
- A (Check Digit) - is a verification code for Phase 1 mobile devices - digit 0. For Phase 2 and Phase 2+ mobile devices, it is a verification code calculated based on all digits of the IMEI code.

Since April 1, 2004, the 7th and 8th digits of the IMEI code are equal to 00, TAC instead of the 6-digit one, became 8-digit - NN-XXXX-XX (Fig. 6).

You can check the IMEI code of a mobile device online and get information about it on one of the following resources:

http://imei-number.com/imei-lookup/
http: //www.numbering...ysis&sub=imeinr
http://xsms.com.ua/phone/imei/ IMEISV.

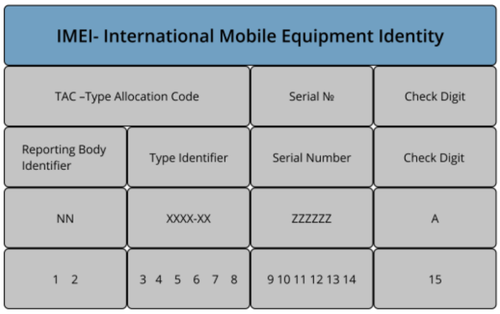


Fig.6. Modern IMEI structure

The International Mobile Equipment Identity and Software Version number (IMEISV) uniquely identifies each mobile equipment and ensures that the software version installed on the mobile equipment matches. Consists of 16 digits (Fig.7).

The Temporary Mobile Subscriber Identity (TMSI) is a temporary number given to a mobile station upon registration. TMSI is used to protect the subscriber from eavesdropping and unauthorized access in the radio frequency path.

The structure of the TMSI is the same as that of the IMSI and is similar to the international subscriber number in the public network[1-7].

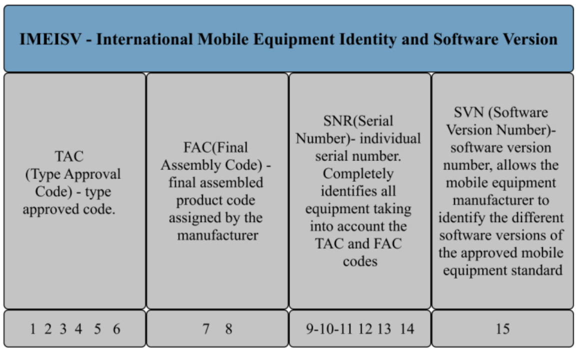


Fig.7. IMEISV ID.

2.MATERIAL AND METHOD

At present, wireless communication systems have received great development in the world: satellite, cellular, broadband wireless communication systems, etc. The most developed in many countries of the world is the mobile communication system of the GSM-900 standard (Global System for Mobile Communications), a global system for mobile communications. GSM-900 is a digital standard operating in the frequency range 890 - 960 MHz Fig.8. shows the functional structure and interfaces that are adopted in the GSM-900 standard [2-7].

The structure of the GSM-900 mobile communication network consists of two parts: BSS and SSS. BSS includes base stations (BTS), base station controller (BSC), transcoder (TCE), communication lines. MS - Mobile Stations. The SSS includes a mobile switching center (MSC), position register (HLR), movement register (VLR), authentication center (AUC), equipment identification register (EIR). The GSM-900 mobile network also has the following centers: Operations and Maintenance Center (OMC), Network Management Center (NMC), Administrative Center (ADC).

In the GSM standard, subscriber identification (using a SIM card) and equipment (IMEI code) are separated. The IMEI code acts as the serial number of the device, which is transmitted over the air when authorized in the network. In the GSM core network, the IMEI code is stored in the Equipment Identity Register (EIR) (Figure 9). The IMEI code is not permanently related to the subscriber and is used only to identify the device. To identify the subscriber, the IMSI identifier is used, which is stored on the SIM card. However, there are special systems that allow one phone to use only one specific SIM card. The EIR register allows mobile operators to track devices by IMEI code and block the device's access to the network. The EIR register contains a list of IMEI codes of mobile devices that can be denied access to the network, the mobile device is under surveillance, etc.

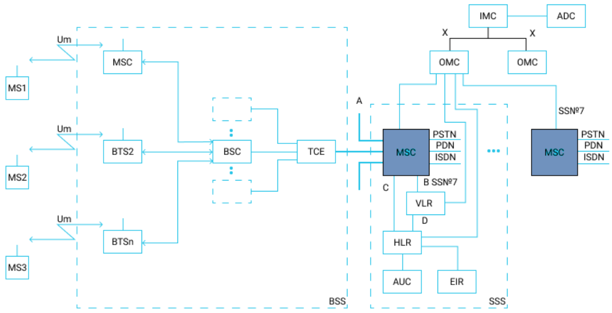


Fig. 8. Block diagram and composition of equipment for communication networks of GSM-900 standard.

In the GSM standard, subscriber identification (using a SIM card) and equipment (IMEI code) are separated. The IMEI code acts as the serial number of the device, which is transmitted over the air when authorized in the network. In the GSM core network, the IMEI code is stored in the Equipment Identity Register (EIR) (Figure 9). The IMEI code is not permanently related to the subscriber and is used only to identify the device. To identify the subscriber, the IMSI identifier is used, which is stored on the SIM card. However, there are special systems that allow one phone to use only one specific SIM card. The EIR register allows mobile operators to track devices by IMEI code and block the device's access to the network. The EIR register contains a list of IMEI codes of mobile devices that can be denied access to the network, the mobile device is under surveillance, etc.

The result of checking the IMEI code is transmitted to the MSC / VLR, where a decision is made on whether or not access to the system of this mobile device is allowed or not (Fig.9).

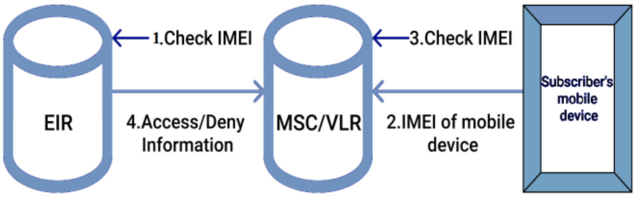


Fig.9. Equipment identification procedure by IMEI code.

The rapidly developing market of information and communication technologies in the world is hard to miss. Along with this, the mobile device market is also developing dynamically. Such a rapid development in the world was facilitated by the active growth of the market for the industry of mobile devices and the access of mobile technologies to various spheres of public and private life. With the development of modern devices and technologies, serious negative factors arise that harm both economic and reputational, image damage to the country and citizens.

International Mobile Equipment Identifier code control is regulated in the following countries: France, Netherlands, Germany, Italy, Austria, Great Britain, Ireland, Sweden, Denmark, Belgium, Czech Republic, Finland, Norway, Spain, Portugal, Costa Rica, Chile, Egypt, Colombia, Venezuela, Kenya, Uganda, Tanzania, USA, India, Nepal, Sri Lanka, New Zealand, Australia, Malaysia, Azerbaijan, Turkey, and Uzbekistan [40].

The full implementation of the IMEI code control is possible on the basis of the interaction of mobile radiotelephone operators with the GSMA (GSM Association), which is a trade organization representing the interests of mobile operators.

The GSMA offers a procedure for synchronizing the database (DB) of IMEI codes, which allows you to:

1) exchange data on stolen or lost subscriber mobile devices between all operators connected to the GSMA CEIR database;

2) receive data on ranges (TAC) registered in the GSMA and certified subscriber devices.

Conventional name of the area of regulation	Key regulatory options	Country
"Theft"	Blocking of lost or stolen subscriber devices.	All countries except Egypt, Indonesia and Kenya
"Counterfeit"	Blocking of counterfeit devices, including those with zero IMEI codes, fictitious IMEI codes and duplicates of original IMEI codes.	Turkey Azerbaijan Egypt Kenya
"Smuggling"	Control over the import of devices into the territory of the state. It implies that the importer transfers the values of the IMEI codes of all imported devices to the customs authorities for subsequent inclusion in the "white" list of the Central database of IMEI codes. Counterfeit (invalid IMEI) is prohibited for import.	Turkey Colombia Azerbaijan Egypt India Indonesia

Currently, 118 mobile operators from 43 countries, including: Azerbaijan, Australia, Austria, Great Britain, Hungary, Belgium, Ghana, Denmark, Turkey, Kenya, are connected to the GSMA CEIR (Central EIR) database of International Mobile Equipment Identifier codes. , Egypt, France, Italy, Sweden, Ireland, Finland, Czech Republic, Norway, Spain, Portugal, Costa Rica, Chile, Colombia, Venezuela, Uganda, Tanzania, USA, India, Nepal, Sri Lanka, New Zealand, Cyprus, Kazakhstan, Malaysia, Zealand, Germany, Netherlands, Uzbekistan, South Africa and others.

An analysis of the experience of implementing the main possibilities for controlling the IMEI code is given in table 2.

Thus, the following combinations of IMEI control control regulation can be distinguished:

1. "Theft" + "Counterfeit" + "Contraband";
2. "Theft" + "Counterfeit";
3. "Theft" + "Contraband";
4. "Counterfeit" + "Contraband".

Table 2: International experience in the implementation of the main capabilities of the IMEI code control.

Benefits of implementing a database of IMEI codes for subscribers:

- reducing the number of thefts of mobile devices (it is possible to block a stolen mobile device);
- a mechanism for additional identification and verification of a user of a mobile device (this is necessary when performing any significant actions);
- the likelihood of various fraudulent actions is significantly reduced (the subscriber becomes less exposed to the threat of using his personal data or paid services if his mobile device is lost);
- the likelihood of purchasing a mobile device with a low level of quality decreases, including counterfeit devices that can harm the health of the subscriber, have a negative impact on the performance of communication networks, and also do not have warranty and service from manufacturers;
- registration of IMEI codes in the central database can be done through the web portal in a very short time and the subscriber will be able to manage the registration of his mobile devices.

International experience in creating information systems for identifying mobile communication devices.

Different countries approached the creation of systems for identifying abundant systems using the IMEI code in different ways[1-16].

CONCLUSION

Based on the analysis, it was found that there are various methods for identifying mobile equipment, with the help of which the description of the physical parameters of the mobile device is made. Permanent and temporary identifiers are used to identify mobile equipment. Based on the analysis and study of foreign experience and the mechanism for organizing an information system for identifying mobile devices by IMEI code, it has been proved that the use of an information system for identifying mobile devices by IMEI code can fundamentally solve these problems in controlling the import and illegal circulation of mobile devices.

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Algorithm for detecting regions with integrity violation in video frame images

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Abstract – this paper presents an algorithm for detecting integrity violations in sequences of video images. Based on a comprehensive approach, the algorithm includes stages of background image extraction, background subtraction, brightness pixel histogram analysis, and violation zone determination. The primary innovation lies in its ability to accurately identify areas with integrity violations, enabling effective response to such situations. The application of the algorithm showcases its versatility across various domains such as security, automated monitoring, and robotics. The results indicate that this algorithm can significantly enhance the efficiency of video surveillance systems and provide high accuracy in detecting integrity violations in video images.

Keywords – integrity violation detection, video images, background extraction, background subtraction, brightness histogram, violation zones, efficiency of video surveillance systems, security, automated monitoring.

INTRODUCTION

With the development of video capture and processing technologies, the use of video images is becoming an integral part of many areas, from surveillance and security to autonomous vehicles and robotics. However, on the way to reliable and efficient analysis of video images, there is an important task of ensuring the integrity and accuracy of data. In this context, modeling the integrity of the video image field plays an essential role in ensuring the high quality and reliability of video information [1].

The integrity of the video image field covers aspects related to understanding and taking into account various distortions and anomalies that affect the quality and reliability of video images. These distortions can be caused by various factors such as camera settings, lighting conditions, weather and environment. Despite the active development of methods for analyzing and processing video data, ensuring the integrity of images remains a pressing problem for ensuring the accuracy of conclusions and the reliability of results based on video image analysis.

During the analysis of the literature in the field of approaches to detecting the integrity of the video image field, significant results were presented. Key factors affecting image quality were highlighted, including camera parameters such as focal length and exposure time. In the works, it was found that the presence of occlusion and the movement of objects in the scene can significantly distort the integrity of the image field, requiring adaptive analysis methods [2].

The use of deep neural networks has made it possible to achieve high accuracy in the analysis and prediction of distortions in video images. This approach was applied to model the relationships between factors and distortions, which significantly increased the efficiency of the analysis.

In addition, research has shown that despite advanced techniques, challenges remain. Adaptation of analysis methods to diverse and dynamic conditions remains an urgent task to ensure high reliability and accuracy of results.

In general, the literature review demonstrates the importance of research in the field of approaches to detecting the integrity of the video image field. New methodologies and innovative approaches can significantly improve the quality and reliability of video information analysis, which underlines the importance of further research in this area [3].

In this research paper, widespread manifestations of field integrity violations in video images are physical frame degradations, such as artifacts, noise, distortion, or image quality degradation. When such anomalies are detected, the algorithm helps to recognize potential problems associated with the state of the equipment or environmental influences, which contributes to a prompt response to such aspects and contributes to an overall improvement in the quality of video monitoring [4].

In addition, it is possible to customize the violation detection procedure for specific types of anomalies or violations specific to a given context. For example, the proposed model can be successfully applied to detect unauthorized access to prohibited areas or to detect suspicious behavior of passengers in a video surveillance system in order to ensure security in public transport [5]. The specialized nature of the proposed approach enhances its accuracy and adaptability to the individual needs of a particular video surveillance system.

II. Algorithm for detecting regions with integrity violation in video frame images

When a variety of anomalous events mentioned above are detected using video surveillance systems, it becomes necessary to take into account the specific characteristics of each of these events. This avoids the disadvantages associated with using a common discovery model. In this research work, we focused on the problem of detecting violations of the integrity of video images and propose a new approach to its solution.

Video integrity analysis is critical in many areas such as security, video surveillance, robotics, and autonomous vehicles. However, when solving this problem, there are difficulties associated with a variety of anomalies and degradations that can occur in video frames. In particular, our goal was to develop an algorithm for detecting areas with integrity violations in a sequence of video images received from stationary video cameras.

In this paper, we offer a detailed description of the developed algorithm, covering each stage of its work. We pay special attention to the selection and analysis of signs that contribute to the detection of violations, and apply new methods of analysis and classification. In addition, we adapt our algorithm to specific types of violations, emphasizing its ability to respond quickly and efficiently to changes in the environment. The block diagram of the algorithm is shown in Figure 1.

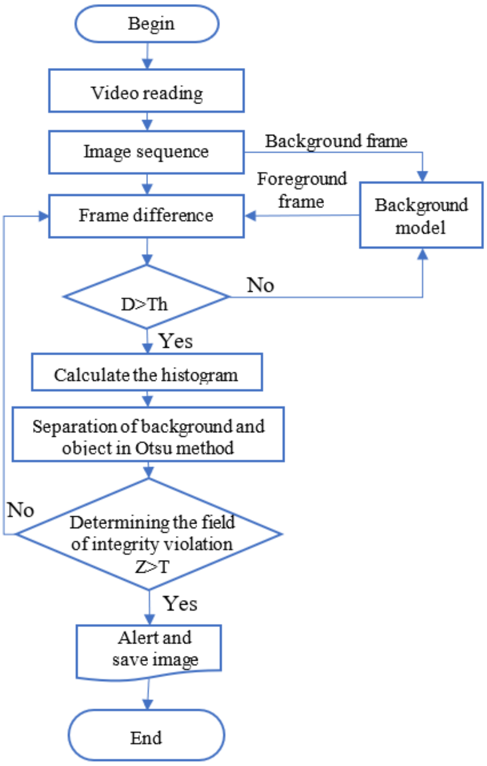

Figure 1. Scheme of the algorithm for detecting integrity violations in video frame images.

Step 1. *Detect and separate the background image from the video*. This stage is aimed at extracting the original background image (background) by calculating the average value of the brightness of the pixels at each point of the video frame [6].

$$B(x,y) = \frac{1}{N}\sum_{i=1}^{N} I_i(x,y) \quad (1)$$

Expression (1) is used to calculate the average value of the background pixels B(x, y) at a certain point (x, y) of the video frame. Where $B(x,y)$ – is the average of background pixels at (x,y) coordinates; $I_i(x,y)$ – denotes the pixel value at (x,y) coordinates in the i-th frame; N – represents the number of frames in the video sequence.

This mathematical formula allows you to calculate the original background image by combining the average brightness of the pixels from all frames in the sequence. The resulting initial background image serves as the basis for the subsequent segmentation of objects in the frame and determining their movement relative to the background.

Step 2. *Subtraction of the background.* This stage involves the use of the background removal method to identify objects located in the video surveillance area [7]. For this purpose, the original background image obtained at the first stage is subtracted from each frame of the video sequence, which leads to the formation of a difference image.

To remove the background component from the current frame, the following expression (2) is used:

$$D = |I - B|, \quad (2)$$

where I – denotes the current image in frame t; B – represents the original background image.

The background subtraction process allows you to reveal differences between the current image and the background, which ultimately highlights moving objects and their changes in the frame.

Step 3. *Calculation of the pixel brightness histogram*. The next processing step is to create a histogram of the brightness of the pixels after obtaining the difference image. The brightness histogram allows you to analyze the distribution of pixel brightness and identify peak values that can serve as thresholds for motion detection.

To calculate the brightness histogram H(i), expression (3) is used, where:

$$H(i) = \sum_{x=1}^{m}\sum_{y=1}^{n} I(x,y) * \delta(i - I(x,y)), \quad (3)$$

$H(i)$ represents the brightness histogram value for the i-th pixel; $I(x,y)$ – indicates the brightness of the pixel with coordinates (x,y) in the difference image; m and n represent the width and height of the image, respectively;

$\delta(x)$ is the Dirac function defined as:

$$\delta(x) = \begin{cases} 1, & if \quad x = 0 \\ 0, & if \ x \neq 0 \end{cases} \quad (4)$$

After creating a histogram of the brightness of the difference image pixels, the method of determining the threshold value is used to separate the object and the background. In this work, the Otsu method was chosen [8]. This method automatically selects the optimal threshold value, maximizing the difference between pixel classes (background and object) around the border.

$$\sigma^2{}_b(t) = w_1(t)w_2(t)[\mu_1(t) - \mu_2(t)]^2, \quad (5)$$

Expression (5) describes the interclass dispersion between the background and object classes. A feature of the Otsu method is that the previous values $w_1(t), w_2(t), \mu_1(t), \mu_2(t)$ can be easily expressed in terms of the current values (t) using (t is the current limit). This property allows you to use a fast algorithm for calculating the optimal threshold:

1. Histogram Calculation. First, all pixels of the difference image are traversed to create its brightness

histogram. However, once the histogram has been built, post-processing does not require a complete traversal of the image.

2. Initialization.The initial threshold is set to $t = 1$ and the maximum variance $\sigma_b(\max) = 0$.

3. Choosing the optimal threshold. At each step, the entire histogram is analyzed, recalculating the interclass variance $\sigma_b(t)$. If the value of $\sigma_b(t)$ is greater than the current maximum of $\sigma_b(max)$, then $\sigma_b(max)$ is updated and T is set to the current value of t.

4. Final Threshold Selection. At the end of the histogram traversal, the desired threshold value T corresponds to the last stored value t corresponding to the maximum interclass variance $\sigma_b(max)$.

Thus, the developed fast algorithm reduces the computational complexity and ensures the choice of the optimal threshold value for motion detection.

Step 4. *Determining the integrity violation zone based on the information received*. This stage is aimed at highlighting the area where integrity violations occur, using the processed data obtained in the previous stages of the video sequence analysis. In this area, a space is formed where movement or deviation from the expected state is observed.

When determining the integrity zone, it is important to take into account the data obtained in the previous stages, such as the difference image of the frames, and the motion detection threshold chosen for this purpose. One common technique involves using a frame or search box, which may be user-defined or automatically determined by the system.

At this stage, taking into account the information obtained earlier, the following general formula is formulated for determining the integrity violation zone:

If the value $D\,(x, y, t)$ of the image pixel obtained by the difference image method in coordinates (x, y) at time t exceeds the specified threshold T, and the desired area has already been determined at the previous stages, then inside this area for each position (x, y) the integrity violation zone is defined as follows:

$$Z(x, y, t) = \begin{cases} if\ |D(x, y, t) - B(x, y)| > T, 1 \\ otherwise \qquad 0 \end{cases}, \tag{6}$$

where $B(x, y)$ represents the original background image obtained in the first step of the algorithm.

According to equation (6), $Z(x, y, t)$ takes the value 1 if the difference between the brightness of a pixel in the current frame and the corresponding pixel in the original background image exceeds the specified threshold T. Otherwise, $Z(x, y, t)$ is equal to 0, indicating that there is no integrity violation at that position.

As a result of applying the proposed method for detecting integrity violations, an area of violation is identified in a sequence of video images. This stage includes the selection and definition of the area of interest, as well as the application of specific models and methods to detect violations. The results obtained provide a more accurate identification of areas requiring additional analysis and form the basis for responding to invalid events. The developed method improves the ability of the video surveillance system to detect and analyze integrity violations in real time.

III. CONCLUSION

This research paper presents an innovative algorithm for detecting integrity violations in a video sequence. It provides more accurate and efficient detection of areas with integrity violations, which contributes to improved detection accuracy. The algorithm is versatile, successfully adapting to various types of disturbances, such as the movement of objects and changes in lighting. Its use promises to increase the efficiency of video surveillance systems, facilitating a prompt response to violations and providing a high level of security. In addition, the algorithm has prospects for applications in various fields, including security, automated monitoring, and robotics. In general, the developed algorithm represents a significant contribution to the academic and practical development of the field of detecting integrity violations in video images.

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DETERMINATION OF OPTIMAL DECISION-MAKING CONDITIONS FOR DIAGNOSTICS OF CATTLE DISEASES

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***Abstract*—The paper considers the determination of optimal decision-making conditions for diagnosing diseases in cattle, since systems for making semi-structured decisions under conditions of various types of uncertainty and, in particular, fuzzy uncertainty, represent an important class of intelligent systems. In designing a fuzzy logic system, the dominant issue is the choice of a rational knowledge base, or rather, a rational number of rules and effective values of their membership functions. In this regard, the paper considers the main problems and tasks of intellectualization of information processing systems and ways to solve them.**

***Index Terms*—Decision making, diagnosis, fuzzy set, model, algorithm, knowledge base, cattle.**

I. INTRODUCTION

Intelligent information technologies are created simultaneously with the formalization of professional knowledge and experience of specialists in the field of management, the accumulation and updating of professional knowledge in this area, the development of mathematical models, the processing of empirical knowledge and data, and the construction of a mechanism for the logical inference of analysis results [1].

The paper looks at [2] forms of artificial intelligence (AI) already being implemented in clinical settings, and research into its future use in healthcare is accelerating. Despite this trajectory, more research is needed regarding the impact on patients of increased AI decision making. In particular, the impersonal nature of AI means that its application in highly sensitive contexts of use, such as healthcare, raises issues related to patients' perceptions of (dis)worthy treatment. We explore this issue through an experimental study comparing people's perceptions of dignified and respectful treatment in different health care decision-making contexts. However, we found that for perceptions of respectful and dignified interpersonal treatment, decision makers in diagnostic cases matter more and outcomes matter more in resource allocation cases.

Intellectualization of decision-making systems provides the possibility of forming alternative solutions, disseminating the knowledge and experience of the most highly qualified specialists and formulating a logical argument for the validity of each solution option [2-3].

The decision-making process in management is complicated by the occurrence of fuzziness. In these cases, the apparatus of the theory of fuzzy sets, fuzzy logic and fuzzy inference makes it possible to evaluate the states of such complex situations. With the help of this apparatus, the problems of human behavior in certain situations are successfully solved. If the decision maker is aware of what can happen during the operation of the system, then he will be able to make a more reasonable decision [4].

In conditions when a decision-maker (expert, designer, manager) has to operate with a variety of parameters and conditions that need to be taken into account in the decision-making process, systems designed to support decision-making under conditions of uncertainty can provide invaluable assistance as support, in particular, fuzziness. These include expert and advising decision support systems, which represent an important class of applied intelligent decision support systems.

The basis of all human activity is the decision-making process, which is the choice of one of several choices. We make many decisions without thinking, because we have an automated view of the management of our actions, which is formed in practice. However, there are times when a person has to think deeply and for a long time about a given situation. In such cases, a person is faced with the choice of new types of objects or environment [5-8].

II. Materials and methods

Decision making is usually expressed as follows.

$D = \{d_1, ..., d_i, ..., d_m\}$– a set of choices. For all $d_i \in D$ a function is given $w(d_i)$ indicator of the effectiveness of the variant [3].

Need a better option $d_{i0} \in D$, corresponding to function values $w(d_{i0})$, i.e.

$$d_{i0} = \arg\max w(d_i), d_8 \in D.$$

Function $w(d_i)$ can have different values and mathematical expressions. For example, this can be expressed as follows [9]:

$$W(d) = (q(d), c(d), t(d))^1$$

where $d \in D$ — solution (action, management), formed in accordance with any operator (X – sets of parameters reflecting the problem situation); $q(d)$ – function of efficiency of utility of realization d; $c(d)$ – resource function used to implement d; $t(d)$ –time spent on implementation d.

These functions have both quantitative and qualitative value. All or some of these functions are taken into account depending on the purpose and conditions of the decision-making task.

A clear representation of the functions $d = F(X), q(d), c(d)$ and $t(d)$, where function $W(d)$ itself, as well as all or all factors for finding a value greater than $W(d)$, determines the choice of an appropriate solution method, and this leads to a variety of solutions for the decision problem.

Decisions are divided into political, economic, technical, etc.; by the duration of the activity and the scale of the future - operational, tactical, strategic; according to the appearance of the decision maker - individual and collective (institutional); according to the degree of non-repetition - rigid, non-creative and non-repetitive, creative; according to the degree of uncertainty (completeness of information) - can be in the form of decisions on accuracy, risk (in terms of probable accuracy) and uncertainty [10].

The static model is defined as the decision status. Based on the Wald criterion, such an alternative choice is optimally chosen so that in this case the normalized value is maximum [3]

$$f_{k_0} = \max_{\phi_k \in \Phi} \min_{\theta_j \in \Theta} \overline{f_{jk}}$$

In the process of applying the Wald criterion, the indicators with the smallest value are selected first, and then those with the largest value.

If the $\mu = (\mu_1, ..., \mu_n)$ membership function is given, you can view the dimensions in the following representation [11-14]:

$$\{\mu_j / \sum_{s=1}^{n} \mu_s\}_{j=1}^{n} \text{ and } \{f_{jk} / \sum_{s=1}^{n} f_{sk}\}_{j=1}^{n}$$

where μ is the membership function of the subjective distribution of probability values, and F – the evaluation function for solution $\phi_k \in \Phi$.

The optimal solution $\phi_{k0} \in \Phi$ of the Wald-type criterion in a fuzzy environment is found from the following condition [14]:

$$V(\mu, \phi_{k0}) = \max_{\phi_k \in \Phi} \min_{\theta_j \in \Theta} \sum_{s=1}^{m} f_{jk}^s \mu_s / \sum_{r=1}^{m} \mu_r$$

The optimal strategy for the dynamic decision-making process for the Wald criterion is found using the following recursive equation [3]:

$$f_N^0(\phi_{k_N^0}^N(a_r^{N-1}), a_r^{N-1}) = \min_{\phi_k^N \in \Phi^N} \max_{j=1,...,n_N} f_{jk}^N(a_r^{N-1})$$

,

$$f_l^0(\phi_{k_l^0}^l(a_r^{l-1}) = \min_{\phi_k^l \in \Phi^l} [\max_{j=1,...,n_l} f_{jk}^l(a_r^{l-1}) +$$
$$+ \sum_{r_l=1}^{m_l} f_{l+1}^0(\phi_{k_{l+1}^0}^{l+1}(a_{rl}^l), a_{rl}^l) g_{rl}^l(a_r^{l-1}, \phi_k^l)].$$

A characteristic model of the environment C is formed based on the concepts of fuzzy sets, the use of which made it possible to form a visible state of making a decision of type $\{\Phi, A_0, F\}$, where A_0 - is a fuzzy set or a fuzzy random state C, determined by μ_A- membership function and distributed by probability P.

When solving the problem, we use the Bayes criterion and recurrent equations for the mathematical expectation of the Bayesian value of the evaluation functional.

Let some solution be given [13-15]

$$\phi = (\phi_{k_1}^1, ..., \phi_{k_l}^l) \in \Phi = \{\Phi^1, ..., \Phi^l, \ \Phi^{l+1}, ..., \Phi^N\},$$

Let $f_l(\phi_{k_1}^1, ..., \phi_{k_l}^l)$ - the total mathematical expectation of the Bayesian value of the evaluation functional on solution $\phi_{k_1}^1 \in \Phi^l$ when using solutions $f_l(\phi_{k_1}^1, ..., \phi_{k-l}^{l-1})$ at $1, 2, , ..., (li0)$ -th stages and optimal solutions at $(l+1), ..., N$-th stages, equal to [9-10]

$$f_l(\phi_{k_1}^1, ..., \phi_{k_l}^l) = f_{l+1}(\phi_{k_1}^1, ..., \phi_{k_l}^l, \ \phi_{k_{l+1}^0}^{l+1}) +$$
$$+ \sum_{\nu=1}^{m_{l-1}} B^l(\phi_{k_l}^l \, |a_\nu^{l-1}) \Re(a_\nu^{l-1} \Big| \phi_{k_1}^1, ..., \phi_{k_{l-1}}^{l-1}),$$

where $B^l\left(\phi_{k_i}^l | a_v^{l-1}\right) = \sum_{j=1}^{n_l} p_j^l f_{jk_l}^l(a_v^{l-1})$ - Bayesian value of the evaluation functional; $f_N(\phi_{k_1}^1, ..., \phi_{k_N}^N)$)- And the mathematical expectation of the Bayesian value of the evaluation functional on the set of solutions $\phi_{k_N}^N \in \Phi^N$ when using $\phi_{k_1}^1, ..., \phi_{k_{N-1}}^{N-1}$ [11]:

$$f_n(\phi_{k_1}^1, ..., \phi_{k_{N-1}}^{N-1}) = \sum_{v=1}^{m_{N-1}} B^N(\phi_{k_N}^N | a_v^{N-1}) \Re(a_v^{N-1} | \phi_{k_1}^1, ..., \phi_{k_{N-1}}^{N-1})$$

Here

$$B^l(\phi_{k_j}^l, a_r^{l-1}) = \sum_{j=1}^{k} p_j^l f_{jk}^l(al - 1_r),$$

$$f_{jk}^{i}(a_r^{i-1}) = \sum_{S=1}^{k} \mu_{jk}^{S}(a_r^{i-1}) / \sum_{j=1}^{n} \mu_j,$$

$$\mu_j = \sum_{S=1}^{k} \mu_{ji}^{S}.$$

Solution $\phi^0 = (\phi^1_{k_1^0}, ..., \phi^N_{k_N^0})$ is called the optimal solution according to the Bayes criterion (in the absence of a source of information on the object) and can be found, starting from the last N-th stage and ending with the l-th stage, as follows.

For the N th stage, the optimal decision strategy $\phi^{N^0}_{k_k^0} = (\phi^1_{k_1}, ..., \phi^{N-1}_{k_{N-1}} \in \Phi^N_0)$ or all possible combinations of solutions $\phi^1_{k_1}, ..., \phi^{N-1}_{k_{N-1}} \in [01]$ is found from the condition [14].

$$f_l(\phi^1_{k_1}, ..., \phi^{N-1}_{k_{N-1}}, \phi^N_{k_N^0}) = \min_{\substack{\phi^N_{k_N} \in \Phi^N \\ T_N(\phi^1_{k_1}, ..., \phi^N_{k_N})t}}$$

$$\sum_{\nu=1}^{m_{N-1}} B^N(\phi^N_{k_N} \left| a_\nu^{N-1}\right.) \Re(a_\nu^{N-1} \left| \phi^1_{k_1}, ..., \phi^{N-1}_{k_{N-1}} \right.).$$

For any l-th stage ($l = N-1, ..., 1$) the optimal strategy $(\phi^1_{k_1}, ..., \phi^{l-1}_{k_l})$ is found from the condition [3,15]

$$f_l(\phi^1_{k_1}, ..., \phi^{l-1}_{k_{l-1}}, \phi^l_{k_l^0}) = \min_{\substack{\phi^l_{k_l} \in \Phi^l \\ T_l(\phi^1_{k_1}, ..., \phi^l_{k_l} \left| \phi^{l+1}_{k^0_{l+1}}, ..., \phi^N_{k^0_N}\right. \phi^l_{k_l}) = t}}$$

$$\left[f_{l+1}(\phi^1_{k_1}, ..., \phi^{l-1}_{k_{l-1}}, \phi^{l+1}_{k^0_{l+1}}) + \right.$$

$$\left. + \sum_{\nu=1}^{m_{N-1}} B^N(\phi^N_{k_N} \left| a_\nu^{N-1}\right.) \Re(a_\nu^{N-1} \left| \phi^1_{k_1}, ..., \phi^{N-1}_{k_{N-1}} \right.) \right],$$

where $T_N = (\phi^1_{k_1}, ..., \phi^N_{k_N})$ – expectation of the transition time of an object from the initial state to one of the final states when using solutions $(\phi^1_{k_1}, ..., \phi^N_{k_N}); T_l = (\phi^1_{k_1}, ..., \phi^l_{k_l}) | (\phi^{l+1}_{k^0_{l+1}}, ..., \phi^N_{k^0_N})$ – he mathematical expectation of the transition time of the object from a^0 to a^N when using at stages $1, 2, ..., l$ solutions $\phi^1_{k_1}, ..., \phi^L_{k_l}$ and at subsequent stages $(l+1), ..., N$ optimal solutions $\phi^{l+1}_{k^0_{l+1}}, ..., \phi^N_{k^0_N}$

III. Results

Diagnosis is an important task of modern information and communication technologies and decision-making when building a model for diagnosing and managing them under conditions of uncertainty [2,14].

The application of signs or the level of confidence can be shown using the following fuzzy-logical knowledge base for diagnosing diseases in cattle [15]:

$\exp(-\frac{1}{10}(x-2)^2)$	$\exp(-\frac{1}{3}(x-1)^2)$	$\exp(-1\frac{1}{3}(x-1)^2)$	$\exp(-5(x-1)^2)$	$\exp(-\frac{2}{5}(x-0)^2)$	1
$\exp(-\frac{1}{3}(x-1)^2)$	$\exp(-1(x-0)^2)$	$\exp(-15\frac{7}{38}(x-1)^2)$	$\exp(-25(x-2)^2)$	$\exp(-9\frac{1}{11}(x-1)^2)$	
$\exp(-\frac{4}{9}(x-2)^2)$	$\exp(-\frac{1}{3}(x-1)^2)$	$\exp(-2\frac{16}{17}(x-2)^2)$	$\exp(-\frac{5}{9}(x-2)^2)$	$\exp(-\frac{1}{31}(x-2)^2)$	
$\exp(-\frac{1}{8}(x-1)^2)$	$\exp(-1(x-2)^2)$				

Fig. 1. Result fuzzy-logic knowledge base for diagnosis

IV. Discussion

It is possible to single out the main property of the characteristic of the diagnostic task of cattle diseases - that is, the final point of decision-making is set by a veterinarian. Diagnosis of diseases in cattle is made on the basis of 17 signs of disease, as decision-making issues are one of the most relevant in modern science over the past decade. It is known that the correct operation of a particular system can be achieved as a result of the work of this system in collecting, analyzing, choosing the correct processing, as well as developing the correct managerial influence on them [16].

The knowledge base is a reflection of the intellectual activity of a veterinarian: reflections, conclusions, generalizations of abstraction, which are based on various knowledge - fundamental in scientific research, subjective, obtained as a result of practical activities and experience in veterinary medicine.

The basis for the formation of the knowledge base is the following information [17]:

- a set of information about possible signs of situations and their classification. Signs can be, for example, temperature, pulse at one minute, respiration at one minute, rumination at two minutes, red blood cell count, hemoglobin, total protein, total calcium, organic phosphorus, glucose, reserve alkali, copper, cobalt, manganese, zinc, the number of infusoria, the state of cicatricial fluid;
- information about the causes of certain signs of situations, their classification and systematization;
- information about actions (or a set of actions) to eliminate situations that have arisen for appropriate reasons.

One of the main objectives of this study is an attempt to develop and implement models of weakly formalized processes, such as diagnosing diseases in cattle with fuzzy initial information, expressed in the form of logically justified linguistic statements [18,19].

V. Conclusion

The implementation of the system provides:

- improving the quality of group decision-making in the conditions of various situations due to computer decision-making and machine experiment with imitation of the corresponding situation;
- the possibility of developing management decisions and recommendations to reduce human and material losses;
- saving resources (material, labor) due to the simulation of collective decision-making on a computer, the multivariance

of the decisions obtained and the effective use of pre-prepared decisions in real conditions;

- increasing the effectiveness of training based on the use of modern computer technology and software, mathematical methods and software systems.

The mathematical apparatus used is quite laborious in terms of computational procedures. Therefore, the effectiveness of its use is achieved in the presence of special computer developments.

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Recognition of material extrusion artifacts in FDM printing based on neural networks

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***Abstract*— The paper is focused on real-time visual monitoring of 3D printing defects on extrusion printers. The monitoring is based on the YOLO machine vision system with automatic recognition of unmelted bundles of plastic filaments during the following consecutive stages: segmentation and classification. During testing, 95 percent defect recognition accuracy was achieved.**

***Keywords*— 3D printing, Anomaly detection, Process monitoring, Deep learning, Laser surface profiling, Smart manufacturing, Fused Deposition Modeling, FDM**

I. Introduction

With the advent of 3D printing, the production of components and items has become more affordable, flexible, and efficient. However, when using 3D printers, problems often arise as artifacts that reduce the quality and durability of the print. Recognizing and eliminating these artifacts is an important challenge that will improve 3D printing quality, reduce defects, and increase production efficiency. The relevance of the problem is confirmed by the growth rate of the additive manufacturing industry [1]. According to statistical data, the additive technology industry is developing at a high rate, with an average annual growth rate of 22.3%.

Fused Deposition Modeling (FDM) technology is one of the most common additive manufacturing techniques that uses thermoplastic or composite materials to create 3D objects through layer-by-layer deposition (Figure 1). Specifically, using an FDM 3D printer, a molten material called filament is delivered through an extruder nozzle and applied selectively to a work platform to produce parts with a given shape and properties.

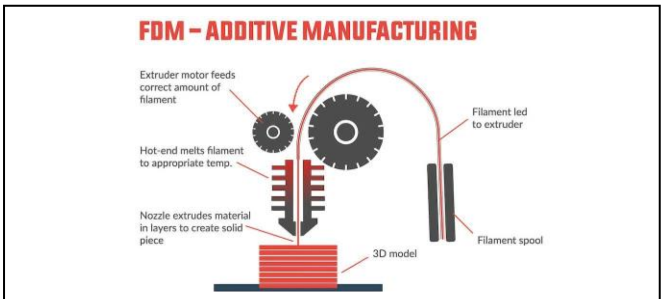


Fig.1. FDM printer operating device.

Similar solutions that optimize models already exist, obviously. For example, Obico, a paid online service, works both in cloud mode and provides an option to deploy a local server. The main disadvantages are security, because all data passes through the developer's servers without encryption, and therefore can be reused. So this solution can not be used for printing objects that are sensitive to distribution: which carry commercial or government secrets.

A number of major 3D printer manufacturers are developing their own solutions. Recently, Creality introduced its flagship K1 Max printer [2], which uses machine vision algorithms and a LiDAR scanner [3].

Previously, Bambu Lab opened access to a similar technology on its X1 Carbon printer [4]. The disadvantages of this solution include:

- Unable to connect multiple 3D printers to a single tracker.
- High hardware requirements. The above printers uses powerful circuit boards that have not been used in this type of machine before.
- Requiring constant internet access.
- Files are sent to print by Wi-Fi, going through the company's servers, which is risky for some types of models.

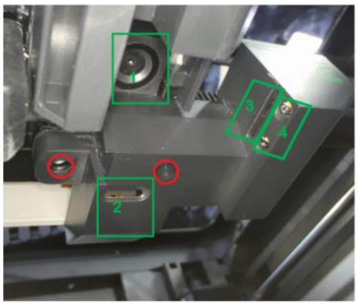
II. Related Works

To improve the quality of the product manufactured by additive methods, software packages have been developed [4, 6] (including by the authors of this paper [7, 8, 9]) that reproduce the physical processes of heat and mass transfer and predict the shape of the printed product under given conditions, its surface morphology, porosity, and strength characteristics. Preliminary simulation of 3D printing allows selecting optimal modes of operation of the plant in advance. However, calculations with the necessary detail at the meso- and macro-levels require serious computing power, which is not always possible in production conditions. Therefore, another aspect of improving product quality is its visual monitoring during the 3D printing process, including both defects of incomplete material utilization (in the case of FDM - plastic filament) and defects in creating the required product shape. This approach cannot predict the shape of the product virtually, without the actual printing process, but at the same time it is faster than full process modeling.

There are two main approaches to artifact recognition in 3D printing. One is to use computer vision [10] and machine learning algorithms to automatically recognize artifacts. The other approach is to use sensors located on the printer to monitor print quality.

The advantage of the first approach is the ability to handle a large amount of data, which allows a more accurate identification of artifacts. However, the implementation of this approach requires significant computational resources and specialized algorithms.

The advantage of the second approach is the ease of implementation in the production environment. The disadvantage of this approach is lower accuracy in artifact identification and limited number of monitored parameters. The integration of the LiDAR sensor (Figure 2) into flagship printer models to detect artifacts during the first layer of printing has been particularly popular recently.



1: Micro LiDAR Camera; 2. Vertical Laser;
3. Horizontal Laser; 4. Micro LiDAR LED

Fig.2. Appearance of the Bambu Lab X1 sensor system.

The authors have had some experience in developing tools for generating synthetic data for training different neural networks [11]. The main advantages of synthetic data are the possibility of their rapid collection and generation, as opposed to the collection and labeling of naturalistic datasets.

III. MEANS OF REALIZATION

The largest consumers are the military, aerospace and manufacturing industries and there is a lot of confidential data in these areas, which means high security requirements, so the application should not use the internet for its work. One of the big challenges of this work is that there is no readily available dataset on the internet to train the model. At the same time, independent data collection is limited by the fact that a single group of photos required four hours or more, which prompted the choice of a synthetic content generation approach for the dataset [12]. In selecting a machine learning algorithm for recognizing objects in videos, the following important algorithm criteria were identified:

1) Ratio of speed to resources consumed, so that the program can work on poor performance devices;

2) The rate at which the artifact is recognized in the frame should be slow enough to ensure real-time recognition.

Presented in [13, 14], YOLOv8 satisfied these simple criteria. To train the model on its own dataset, it is easy to use the detailed instructions [15]. One of the requirements for the developed system is handling real-time video, which required setting up OpenCV and YOLOv8 [16]. One of the tasks in the implementation of this work was the task of data partitioning [17]. AutoML Translation [18] was used as an alternative computer vision model. The library [19] was chosen as the main tool within this work, which is a solution to provide an efficient work with the YOLOv8 model because it belongs to the creators of this model. Since YOLOv8 is a family of models that differ in the number of neurons, which accordingly puts a restriction on the areas of application of the model, it was necessary to determine which model would be best adapted for the purposes of work, for this purpose it was necessary to find out which models run on low-performance computers, which is described in [20]. To improve the quality of segmentation, the following transforms were chosen to the input data [21]. Their selection requires significant refinement [22].

So, a deep learning model was chosen, which allows achieving high recognition accuracy and fast system operation. The solution architecture consists of several stages: input data preprocessing, model training, model testing and validation.

The following tools and libraries were selected during the solution development process:

- Python programming language,
- Libraries for working with images: YOLOv8,
- Deep learning libraries: TensorFlow and Keras, YOLOv8,
- Model training tools: Ultralytics,
- Synthetic dataset generation tool: Stable Diffusion.

The solution architecture was designed to meet the requirements for recognition accuracy and system performance, as well as scalability to handle large amounts of data. The final application will have a solid architecture.

IV. DATASET DESCRIPTION

As a dataset for model training, a sample of found unlabeled images on the Internet containing print artifacts was used (Fig. 3). The dataset includes 78 images and is divided into Train Set, Validation Set and Testing Set in the percentage of 78/12/10 respectively.

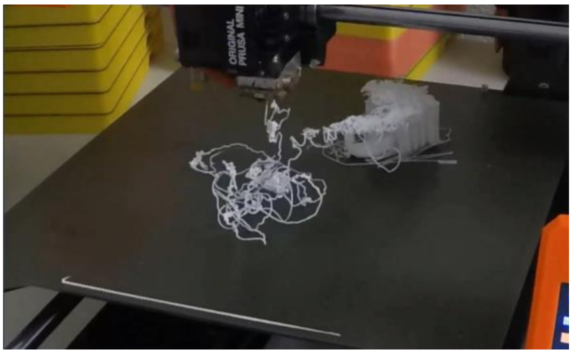


Fig.3. An example of an artifact.

To further train the model, it was necessary to add an annotation for each image (Fig. 4) and add labels (Fig. 5).

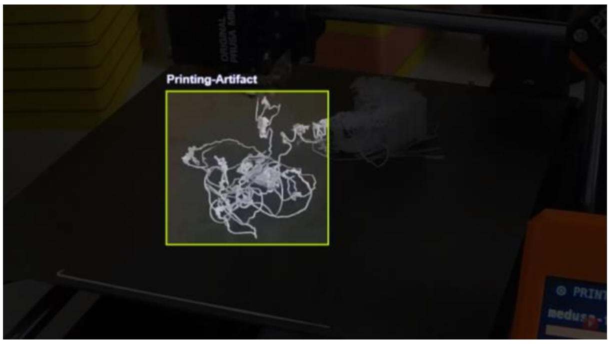


Fig.4. Example of an annotation.

3D-Printer-First-Layer-not-Sticking-to-Bed-digi3dverse-com_jpeg.rf.5ecdafd8bd9f20bfa4dff474612c3978.txt – Блокнот

Файл Правка Формат Вид Справка

```
0 0.09296875 0.31875 0.18515625 0.234375
0 0.5 0.865625 1 0.26875
```

Fig.5. Example of an label.

For these tasks, the roboflow [19] dataset preparation tool was chosen.

It was a hypothesis that this dataset would not be enough to successfully achieve the goals, and since there are no available datasets with a large number of unique images on the Internet. So, one option for enriching the dataset was to synthetically generate images using neural networks - using the Kandinsky 2.1 tool based on Stable Diffusion.

An attempt to use a prompt like "3D Printing Defects" was not successful. The results are shown in Fig. 6.

Fig.6. Example of failed work from Kandinsky 2.1.

Further attempts were made to generate images similar to the Spaghetti artifact using non-FDM printing prompts, but such images only made noise in the sample. The model using synthetically generated images performed worse than a smaller sample with real images.

V. Selection of Neural Network Architecture

Choosing a neural network architecture is an iterative process, and it may take several iterations to find the optimal architecture that best fits the given task.

The first step is to clearly define the requirements and specifics of the task. We need to understand what exactly we want to recognize, what classes of artifacts we are interested in and what characteristics of images are important to us.

The following requirements were made for the future neural network:

1) *Possibility to implement Object Detection algorithms.*
2) *Ability to use the algorithm on low-power devices.*
3) *The speed of artifact recognition per frame should be high enough to ensure real-time recognition.*

There were 3 models that met these criteria:

1) *YOLOv8n.*
2) *YOLOv8s.*
3) *AutoML by roboflow [18].*

AutoML by roboflow performed poorly for this dataset and was excluded from the sample. The results of this model trained on the dataset for 300 epochs are shown in Fig. 7. The model showed false positives and failure to recognize a real defect.

The following requirements were made for the future neural network:

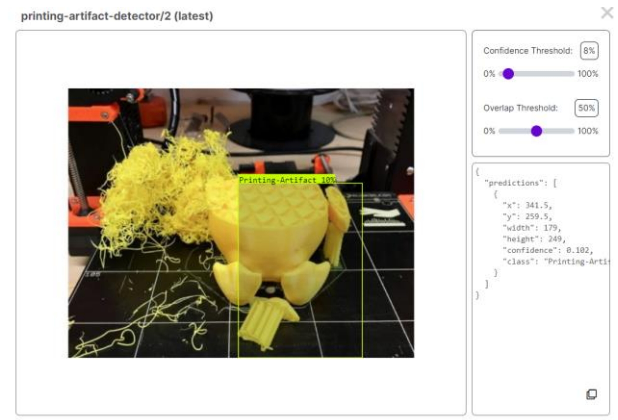


Fig.7. The result of improper detection of printing defects using the AutoML.

The YOLOv8 family models performed well, as can be seen in Fig. 8. There are no false positives here and the artifact was recognized.

Fig.8. YOLOv8-based valid detection of defects at the test image.

The YOLO (You Only Look Once) architecture is a convolutional neural network for real-time object detection in images. YOLO was developed with speed of operation and detection accuracy in mind.

The basic principles of the YOLO model architecture (Figure 9) include:

1) Grid Cell: The input image is divided into a grid of cells of fixed size. Each cell is assigned to detect an object if the center of this object enters this cell.

2) Anchor Boxes: Several anchor boxes of different sizes and aspect ratios are defined for each cell. Each anchor is configured to detect objects of a specific size and shape. YOLO uses bounding box and class predictions for each box and each anchor.

3) Backbone Network: YOLO uses a convolutional neural network as a backbone network that extracts attributes from the input image. For example, the YOLOv3 architecture uses Darknet-53 as the backbone network.

4) Feature Extraction: The core network creates feature maps at different scales. At each level of the feature map, objects are detected using convolution layers and filters.

5) Predictions: For each object in a box and anchor, YOLO predicts the probabilities of belonging to different object classes and the coordinates of the bounding box. The number of predicted classes is determined by the object detection task.

6) Non-Maximum Suppression (NMS): To remove duplicate predictions, YOLO applies the Non-Maximum Suppression algorithm. NMS removes frames with low probabilities, leaving only the most confident and accurate predictions, and removes overlaps between frames.

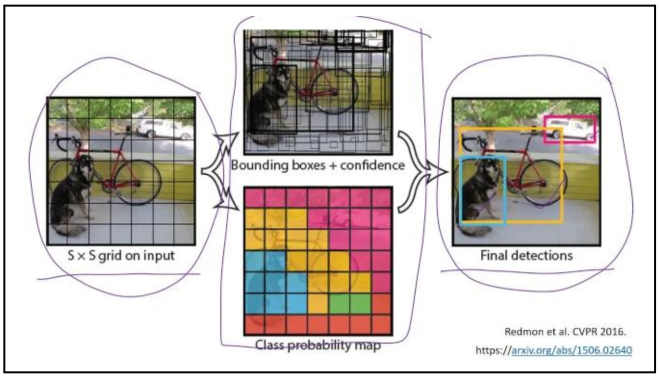


Fig.9. YOLO algorithm working principle.

VI. Building a Basic Machine Learning Model

The first experiment was training the YOLOv8n model, no augmentations or transformations were applied to the input dataset in this experiment. The solution was implemented using the Python programming language. The ultralytics library [18] was chosen as the main tool in this work, which provides a solution to ensure efficient operation of the YOLOv8 model. Initially, the model was trained on 5 epochs, but it did not show significant results and did not recognize any artifact on the test sample. The second time the model was trained on 50 epochs.

Fig. 10 shows the result of the YOLOv8n model on one of the test batches. A similar result is shown by the older model with more layers and YOLOv8s parameters already on 5 epochs.

The model with the "s" suffix shows the best result in terms of accuracy, while it takes more time to process one frame than the lightweight "n" model – 28.67 ms on average for the younger model versus 49.56 ms on average for the model with more parameters. At the same time, the mode of the YOLOv8n model is between 7-8.5 ms, while the YOLOv8s model is 20-22 ms.

Fig.10. YOLOv8n model result.

According to the presented results, we can see that the models have learned to detect artifacts, but the choice of a particular model depends on the power of the hardware on which the model will be run. For Raspberry Pi clones and old laptops it is better to use YOLOv8n [20], for stationary PCs – YOLOv8s.

VII. Improvement of Segmentation Quality

To improve the quality of segmentation, the following transformations were chosen to the input data [21]:

1) Static Crop: This method involves cropping images to a specific size or aspect ratio. By cropping, it is possible to remove unwanted parts of an image or to focus on a particular area of interest. It can also be useful to keep all images to the same size for later processing.

2) Resize: This method is used to resize images. Scaling can be an increase or decrease of the image size, allowing you to adapt the image to the required size or resolution. Resize can be performed with or without preserving the original image proportions.

3) Grayscale: This method converts a color image to grayscale by removing color information. Using only pixel brightness can be useful to simplify the model or when color is not an important feature for the task at hand.

4) Flip: This method reflects the image horizontally or vertically. Reflection can help increase the diversity of the data and help the model learn better from images with different orientations or symmetrical objects.

5) Rotate: This method rotates the image by a certain angle. Rotation can be useful for training a model on images that may be presented in different orientations or viewing angles.

6) Brightness: This method changes the brightness of the image by changing the pixel values. You can increase or decrease the brightness to make the model stable to changes in lighting and contrast.

Data augmentation techniques in machine vision play a significant role in improving the performance of learning models. By using these methods, the following improvements can be achieved:

1) Expanding the training dataset. This is especially significant on datasets with a limited number of training examples.

2) Stability to variations. The use of augmentation techniques allows the model to become resistant to such variations.

3) Preventing overtraining. Overlearning is a problem when a model memorizes training examples too well and is unable to generalize to new data.

4) Improved general performance. Additional data variation allows the model to better represent different classes of objects and scenes, which can lead to improved recognition accuracy and general performance on new, previously unseen data.

Then, augmentation methods were successively applied. When choosing the set of methods shown in Fig. 11, the quality of the sample dropped dramatically, as can be seen in Fig. 12. mAP dropped to 21.3%, precision to 19.9%.

PREPROCESSING	**Auto-Orient:** Applied **Static Crop:** 48-75% Horizontal Region, 10-75% Vertical Region **Resize:** Stretch to 640×640 **Grayscale:** Applied
AUGMENTATIONS	**Outputs per training example:** 3 **Flip:** Horizontal **90° Rotate:** Clockwise, Counter-Clockwise **Brightness:** Between -45% and +45%

Fig.11. Selected augmentation methods.

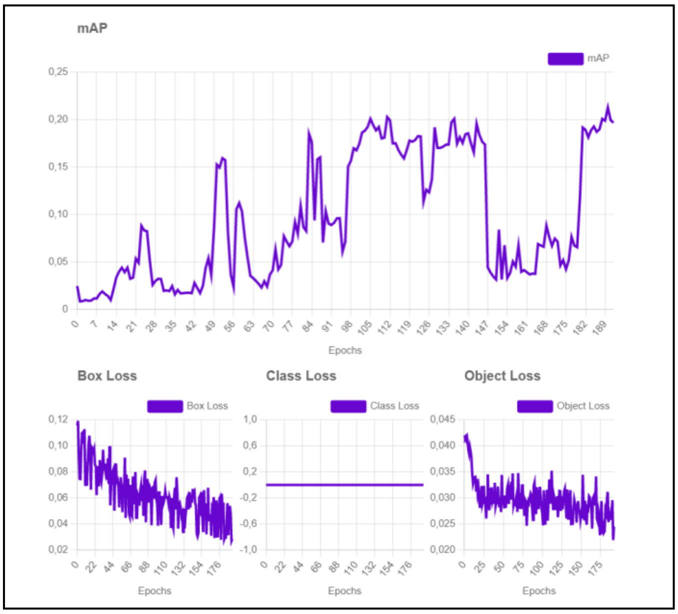


Fig.12. Efficiency of the algorithm with the selected methods.

As a result of empirical studies, the augmentation methods shown in Fig. 13 were the best suited for this dataset. They showed the best results.

PREPROCESSING	**Auto-Orient:** Applied
AUGMENTATIONS	**Outputs per training example:** 3 **Flip:** Horizontal

Fig.13. Final augmentation methods for the model.

Perhaps a more accurate selection of augmentation methods can further improve the quality of the method. The choice of augmentation methods requires considerable refinement [22], but the current quality is already sufficient for the model to work.

VIII. Conclusion

In the current research, methods for recognizing artifacts in 3D printing have been proposed. The problem of lack of sufficient data for model training was revealed. Because of this, the application needs to be improved: training the model on a larger dataset, optimizing the application for low-performance devices, adding new artifacts (except 'Spaghetti') to identify them directly in the printing mode.

The developed tool based on the collected custom dataset [23] can be used in companies using FDM printers of any configuration – to detect the 'Spaghetti' artifact for any 3D printer.

As a result of the implementation, the cost of failed print batches, in which artifacts appear and the print becomes unusable, has been reduced. Both plastic and time costs have been reduced, because the system allows the operator to stop the printing of a defective model in advance and make a new one without waiting for the print to finish.

Acknowledgment

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Design Algorithm for Textual Information Protection with the Vernam Ciphering

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***Abstract*— Vernam encryption algorithm for crypto-processing of information was developed based on the *XOR* logic gate. An experimental check of the Device functioning was carried out using ASCII encoding, and an algorithm for encrypting and decrypting textual information. It is shown that the developed Device can be successfully used for cryptographic processing of texts during confidential information communications.**

***Keywords*— Logic gates, cryptography, data encryption, Vernam encryption algorithm**

I. Introduction

The swift progression of the Internet technologies and IP networks has given rise to a new trend in the use of packet network transport. However, the transfer of corporate data over a public packet network, such as the Internet, is an obvious threat to the security of the network of any enterprise. Internal resources of the corporate network become available to numerous Internet users, and confidential traffic can be viewed by intruders.

Every information system must ensure that data is protected from unauthorized access. This can be achieved by implementing an authentication system within the system itself, which allows only authorized users to access the data. However, if an attacker gains physical access to the data, authentication becomes ineffective, and the confidentiality and integrity of the data can be compromised.

To protect data from unauthorized access, encryption is utilized. Encryption involves transforming information into an unrecognizable form that can only be deciphered with a specific encryption key. This prevents anyone without the key from accessing the original information. Encryption is not only useful for physical data protection but can also make authentication more challenging, thus preventing unauthorized system access.

The exchange of information, both open and closed, occurs mainly using digital technologies and personal computers, so it is possible to use all the advantages of software developed for processing signals in digital and analog format [1-3].

The Vernam cipher uses modulo 2 additions, which is equivalent to the logical exclusive or operation, usually denoted by "*XOR*", and which is easy to implement using the magneto-optical methods we have developed

In 1917, Gilbert Vernam patented a cipher based on this operation. To send a string of bits, a key consisting of the same number of binary characters as the message is required. Each bit of the sent string is added modulo 2 with the corresponding key sign and the cryptogram [4-7] is obtained.

The essence of encryption with the Vernam cipher is easy to understand and implement on a computer. In order to encrypt the plaintext, you just need to combine the binary code of the plaintext with the binary code of the key using the *XOR* operation, the resulting binary code, presented in symbolic form, will be the encryption of the Vernam cipher. If we try to encrypt the encryption received by the Vernam cipher again with the same key, we will again get the plaintext. Actually, the encryption of the Vernam cipher is identical to its decryption, which tells us that the Vernam cipher is a symmetric cipher [7-10].

Any key can be used for encryption only once, hence the name: one-time cipher-notebook. Thus, key distribution is the main problem here. To make sure that trouble is inevitable when encrypting multiple texts with one key, consider a plaintext choice attack. Suppose Alice always uses the same key to encrypt data. Eve attempts to determine this key and performs the following attack:

- generates a message m and sends it to Alice for encryption,
- receives $c = m \oplus k$ where c is encrypted information – disinformation *DISI*, m – information *INFO*, k – key *KEY_1*
- calculates $k = c \oplus m$

Despite its simplicity, the Vernam cipher, according to some analysts, is the only one that is absolutely cryptographically secure due to strict requirements for the Vernam cipher key. The key for encryptions of the Vernam cipher must be as long as the encryption itself, while the Vernam cipher key must also be completely random and one-time. That is why the Vernam cipher is also called the one-time pad system and is used mainly to transfer state secrets

II. Results and Discussion

Let us briefly consider the steps that we directly used to create a device layout for encrypting and decrypting text information in *ASCII* binary format encoding.

Since one of the objectives of this Project was to find a mechanism that allows encoding (for simplicity, we chosen *ASCII)* information signals, the *"Sound Forge"* software by Sony was applied. Encoding textual information does not cause any particular difficulties, since the corresponding standards, such as *ASCII*, have been known for a long time and are widely used in modern information technologies.

We have created a working layout of the Device Simulator designed for information encryption and decryption using the Vernam algorithm, based on the same principles as magneto-optical logic gates which were described earlier in [4, 5].

Let us consider in more detail Alice's actions for transmitting and encrypting information (*info*) in 8-bit encoding of the generally accepted standard using the *"Sound Forge"* audio editor software and the proposed scheme.

Alice (source*)* must transmit encrypted information to Bob (receiver*)*. The protocol and sequence of using one-time keys are agreed upon in advance. It is assumed that simple, compact and reliable optoelectronic peripherals should be used to encrypt and decrypt transmitted and received information. Instead of magneto optical waveguide set we will use its electronic model named Simulator Device. To send information in the form of encryption, you need a disposable key consisting of the same number of binary characters as the message. Each bit of the sent string is added modulo 2 with the corresponding key sign and a cryptogram is obtained.

To conduct experiments to study the possibilities of encryption and decryption, an installation was assembled using a prototype Device with the *XOR* function. For the practical purposes, after conducting preliminary tests, was chosen an option according to the following scheme (Fig. 1). The original text message *info* in binary *ASCII format* is converted into a series of audio pulses using *"Sound Forge"* and write it as a *wav* file format for output channel *1*. To do this, activate the program and create a new file in order to synthesize 3 separate output channels: *info, key_1* and *disi.* For example, consider the procedure for creating an initial file with a pulse duration of *0.2 sec* and a frequency sinusoids of *440 Hz.*

Synthesis occurs by inserting silence functions for *0* and sine functions for *1*. On fig. 2 shows the result of entering the first 8 natural numbers as a sum of harmonics.

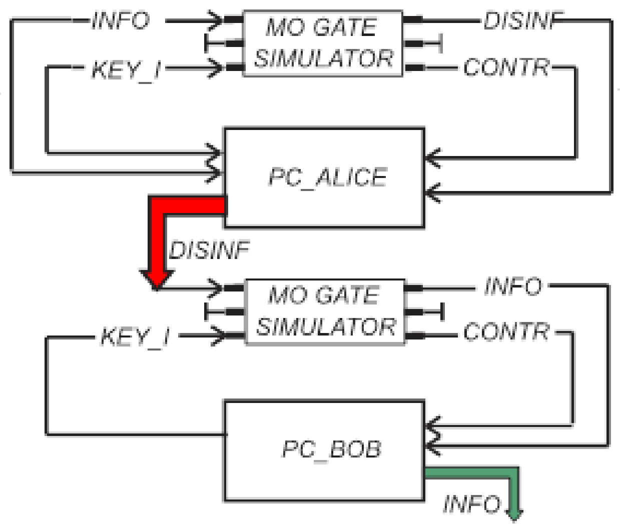

Fig. 1. Evolution of processed signals for XOR gate configuration The wiring diagram used to obtain the Vernam cipher in the mode of the logic magneto-optical XOR gate (binary counter).

Note that the synthesized harmonic signals are not coherent and the result of their usual addition when passed through the mixer will be a simple increase in the volume of the sound.

Let us consider the actions necessary for crypto-processing of textual information. Example of coding information is presented in Fig. 2. Correct crypto-processing of information to be encrypted and subsequent decryption is possible only if a definite time reference is implemented, because otherwise it will not be possible to obtain the primary in-phase of the processed signals. In addition, it allows us to mark the beginning and end of the files through which we want to express the signals.

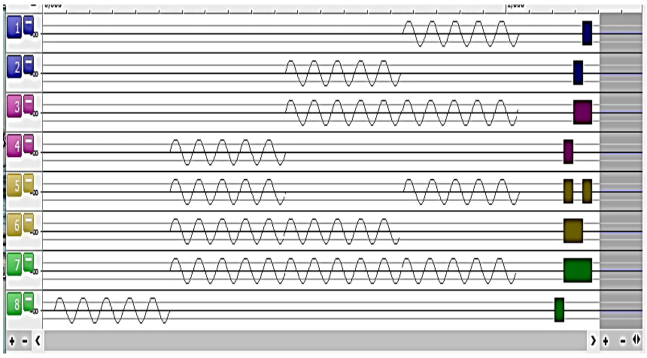

Fig. 2. Using the "Sound Forge" to record information in binary encoding. Representation of the first eight numbers of the natural series using binary code and as a sum of harmonics. Dark rectangles - 1, light gaps - 0

To solve this problem, at the beginning of recording information in each of the channels (channel *info* and *channel disi*) markers are inserted, as shown in the Fig. 3. In rectangles with a turn, indicated by ***I, K, D*** respectively in channels *1, 2, 3 of* the file, signals are recorded corresponding to the ***info (I), key (K)*** and received ***(D)*** after passing through the ***Simulator Device*** in the form of a record of character sequences in binary ASCII encoding:

11101000 11101101 11110100 11100000 (info) - channel1; ***11101011 11101011 11111110 11110111 (key_1) .*** Channel 2; and the result of modulo 2 addition of channels *1* and *2*. - *3* channel, ***(disi)*** as shown in fig. 3

Let us describe the processes of information encryption and its transmission by Alice, and then the reception and decryption of the received *misinformation by the* final addressee Bob in more detail.

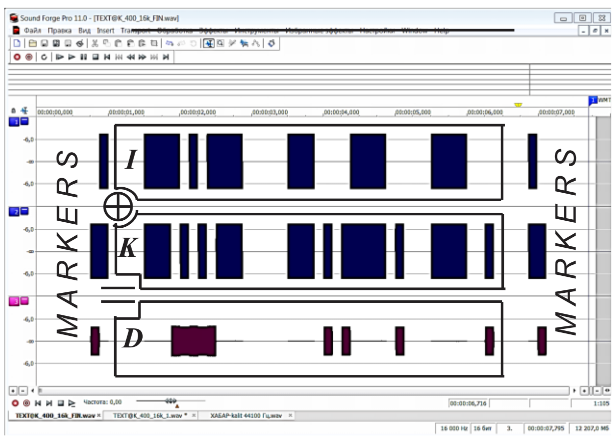

Fig. 3. The process of encryption and getting misinformation on PC_ALICE.

Sequence entry:

11101000 11101101 11110100 11100000 (info) - channel 1***;***

11101011 11101011 11111110 11110111 (key_1) - channel 2 result of modulo addition of 2 channels 1 and 2 - channel 3 ***(disi).***

Let us consider the actions necessary for crypto-processing of textual information. Correct crypto-processing of information to be encrypted and subsequent decryption is possible only if a hard time reference is implemented, because otherwise it will not be possible to obtain the primary in-phase of the processed signals. In addition, it allows us to mark the beginning and end of the files through which we want to express the signals.

To solve this problem, at the beginning of recording information in each of the channels (*info* channel and *disi* channel) markers are inserted, as shown in the Fig. 3. In the rectangles, denoted respectively by ***I, K, D*** in channels *1, 2, 3* of the "Sound Forge", the signals corresponding to ***info (I), key (K)*** and obtained after passing through the Simulator ***(D)*** as a record of character sequences in binary ASCII characters.

Let us now consider the processes of information encryption and its transmission by Alice, and then the decryption of the received misinformation by the final addressee Bob in more detail.

Alice on her computer processes the text to be encrypted and sent in the form of a sequence of segments of sinusoids corresponding to the *ASCII* encoding and together with the *key* (a set of random characters), previously agreed with Bob and known only to both of them, writes to the 1st and 2nd channels of the file created in the "Sound Forge". Then Alice plays this file and sends a mixture of information and key through the output of the sound card and through the Simulator to Bob's computer.

In principle, if necessary, she can easily see the results of encryption on her computer. To do this, Alice can use the control output of the prototype (Control channel — *CTR*), recording the result of the encryption operation through the line input of her computer's sound card.

Bob, in turn, records the received encrypted information *(disinformation)* in the form of audio signals using the same "Sound Forge" program into one of the channels of the created file and then inserts a pre-agreed key into the second channel. After temporal alignment has been performed, Bob passes the created file through his Simulator Device (which now acts as a decryptor), feeds it to the line input of his computer's sound card, and receives the decryption of information sent by Alice on the third channel.

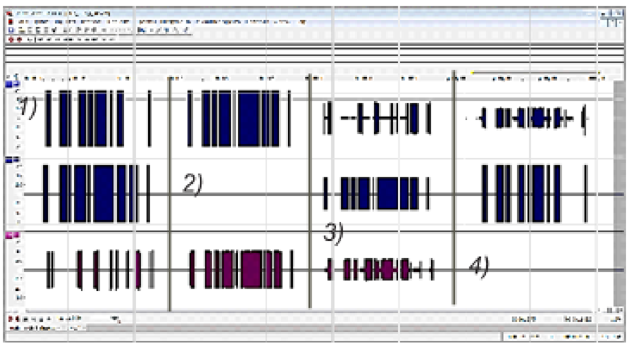

Fig. 4. Processes of encryption and decryption of textual information using the Device Prototype.

Thus, Bob, having received and written down the encryption, performs almost the same actions as Alice, with the difference that instead of *information* with the *key*, he runs the *Disinformation* with a *key* through Simulator Device. As a result, the output receives a decrypted message - the initial *information.*

The proposed method, encryption and decryption occur in the same way and using the same hardware.

The results of the described actions are shown in Fig. 4. For convenience, the results of the actions of Alice and Bob are shown as one common file.

On the far left, through the notation 1), it is shown how Alice receives *misinformation* (third channel below), skipping *info* and *key* through the device. Note that the resulting amplitude for the *desa* turned out to be less than that of information or a key. Therefore, during the following crypto processing operations, it is necessary that Bob's key has the same amplitude commensurate with the received signal in order to obtain correct results. Therefore, Bob must first pass the key through the Device, as shown in area 2).

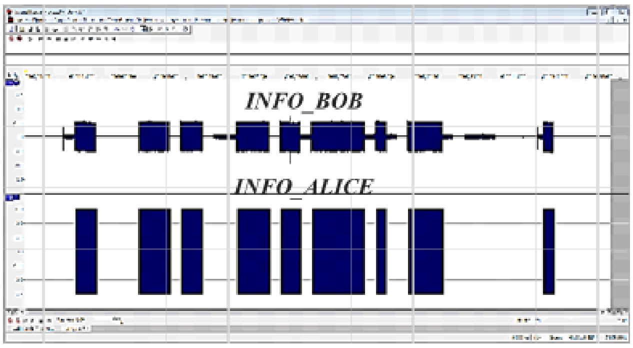

Fig. 5. Info on Bob's PC and the initial view of info on Alice's PC

Next, Bob writes down the resulting *misinformation* and the processed *key*, respectively, on the first and second channels of his computer, then passes through his Device and receives the desired *information* on channel 3. The results of the operations performed by Bob are shown in area 3) of Fig. 4.

Area 4) shows for comparison the original *infa* (channel 2) prepared by Alice and the result of decryption on Bob's computer (info final - channel 1). The amplitude of the signals on Bob's computer is somewhat less than the initial values prepared by Alice, but this is not important. An enlarged version of the comparison of primary and final information is shown in Fig. 5. We see that the information recovered on Bob's computer is completely authentic to the original text prepared by Alice for the secret transmission

III. Conclusion

In this paper a novel approach for faster and secure cryptographic algorithm has been presented and implemented. The secret key for encryption/decryption is remaining the same. Cipher-text is obtained by applying *XOR* (exclusive-or) enciphering operations between data and very strong one time use pseudo-random number sequences (PNSs). The original bits of a message can be recovered by applying the same operation *XOR* on cipher-text using the same key - PNSs.

We have also tested experimentally this method of encryption/decryption and compare with other popular algorithms. Proposed method seems very competitive because it leads to improvement of ciphering/deciphering speed and also needs only simple electronics and small amount of computing resources

We can conclude that the proposed method of cryptographic processing of cipher texts fully complies with the criteria for transmitting information through channels intended for confidential messages.

In the proposed method, encryption and decryption occur in the same way and using the same hardware and can be recommended for special applications in closed communication channels.

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Bidirectional Scaling of TV Images Based on Wavelet Transform

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***Abstract*— The possibility of using wavelet transforms for bidirectional scaling of high and ultrahigh definition TV images is considered in the article. The method's influence at the efficiency of encoding 4K and 8K video streams is researched. The estimation of the distortions introduced by this method in comparison with traditional adaptive and non-adaptive image scaling methods are presented.**

Keywords*— *TV images, video stream, video compression, interpolation, wavelet transforms, wavelet filters, image scaling, bidirectional scaling.

I. Introduction

In modern broadcast television, high-definition formats are increasingly being introduced, and work to transmit ultra-high-definition TV images in 4K and 8K formats is in progress. However, TV transition to the formats greatly increases the amount of video data that needs to be encoded in real time. At the same time, the 4K format with a resolution of 3840×2160 contains about 8.3 megapixels, and the 8K format has 33 megapixels. They both require very high-speed and expensive encoders or special methods that greatly minimize the original images video data. One of such interesting minimizing methods is the approache described in [1]. It's idea based on the Bidirectional image scaling. Those, if you twice reduce of image size before encoding and then restore the original image size after their decoding on the receiving side, then you can significantly increase the efficiency of video compression in the codec. This is due to the fact that 2-fold decreased images contain a divide by 4 amount of initial video data. On the one hand, it makes possible to achieve large values of video stream compression with the same image quality. And on the other hand, more affordable computer technology can be used to process a smaller array of video data. This is especially important for high-definition and ultra-high-definition TV, because larger quantity of high-quality TV programs can be transmitted with more efficient use of the frequency resource.

Previous researches have shown that both simpler non-adaptive interpolation algorithms and more complex adaptive interpolators are used to resize digital images [2-5]. The difference between the methods:

- non-adaptive algorithms process all pixels in the same way, regardless of the image structure,
- adaptive algorithms use pixel-by-pixel image analysis to detect edges and fine structure elements, which need to be saved.

Such approach allows you to minimize distortion in reduced or enlarged images in those places where they are most noticeable. As a rule, these algorithms are designed to save the maximum detail of the original local effects in increased images. In this case, the interpolation methods themselves in non-adaptive and adaptive interpolators can be the same.

As our researches have shown, nowadays in practice such image scaling methods as bilinear, bicubic, splines, Lanczos's, Mitchell's, S-Spline and S-Spline Max and a number of others had got a wide distribution. However, experiments have shown [5] that a number of serious problems arise during bidirectional resizing of TV images, due to the fact that the restored images differ greatly in quality from the original ones.

II. The Statement of Problem

As previous studies have shown [6], the main problem of bidirectional image scaling by the studied methods is a significant decrease their visual quality. First reason is someway removing extra pixels when images are scaled down by 2. Usually this problem is solved by interpolation calculation of the values of the reconstructed pixel from the values of surrounding pixels. So, noticeable distortion or even loss of fine details may occur in the reduced image due to averaging or decimation the pixel values.

So, when reducing the test black-and-white image of a segmented circle (Fig. 1) by the Lanczos-3, Mitchell, bicubic and B-spline interpolation, S-Spline and S-Spline Max methods [6], it was found that all of them led to more or less noticeable distortions of pixel values.

Experiments have shown that even high-quality scaling algorithms such as Lanczos-3 and S-Spline Max also led to noticeable brightness distortion, as shown in Figures 2 and 3, respectively.

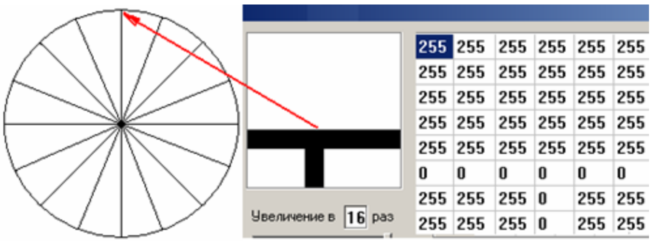


Fig.1. The reference test image with its pixel values.

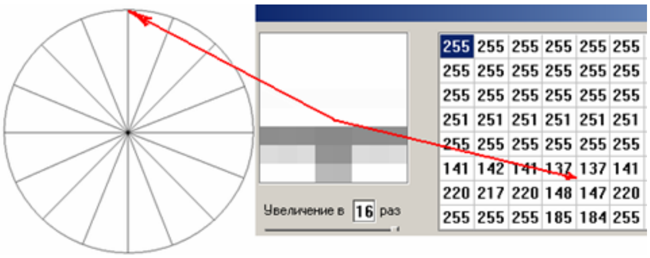


Fig.2. The result of a twofold reduced image by the Lanczos-3 method

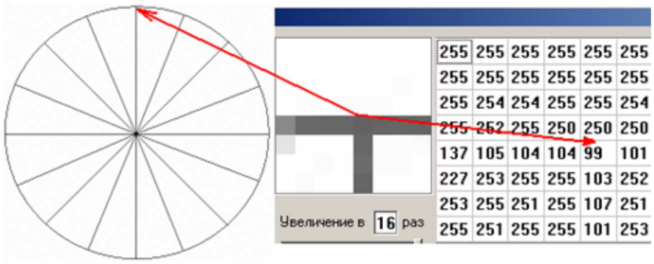


Fig.3. The result of a twofold reduced image by the S-Spline Max adaptive interpolation method.

As can be seen from Fig.2. the Lanczos-3 method not only increases the brightness of black pixels, reducing the image contrast by almost twice, but also expands the line width twice too. The adaptive scaling method based on spline interpolation, S-Spline Max (Fig. 3), unlike Lanczos, safes the line widths the and forms better images. But it also, like Lanczos, reduces the contrast of thin lines by about twice. At the same time, S-Spline adaptive interpolation method has the least brightness distortion among the considered scaling methods. However, it creates gaps in the halon lines (Fig. 4), which is not permissible in bidirectional scaling.

Also, at the stage of increasing the size of images the additional image distortions occur, as far as all elements and lines of reduced images will be increased by 2. It reduces the clarity of the images and forms various artifacts due to the fact, the size increasing algorithms "do not know" that the image being enlarged was previously reduced.

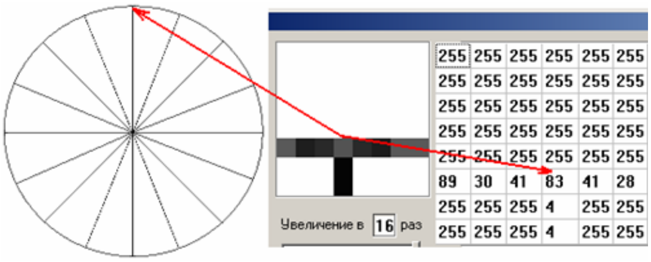


Fig.4. The result of a twofold reduced image by the adaptive method of S-Spline interpolation

Thus, the studies [6] have shown that the usual methods of non-adaptive and adaptive scaling are not suitable for bidirectional resizing because after them the images had a lower visual quality compared to the original. So, to implement the idea of bidirectional image resizing we need more efficient images reducing methods, minimizing their brightness and texture distortions. And the image restoring methods should take into account the features of thumbnail images and should not double the structural elements, where it is not needed. Then the idea of bidirectional image resizing can be used in high-definition and ultra-high-definition broadcast TV. Then the idea of bidirectional image scaling can significantly increase the efficiency of frequency resource using and number of TV programs for transmission with better quality [7].

III. Experimental Research

In recent years, video compression methods based on wavelet transforms have been widely developed. There images are processed by scaling wave functions or wavelets [8]. That is why the possibility of wavelet transforms using for image scaling has scientific and practical interest.

One of the interesting ways to realization of bidirectional image scaling is the use of wavelet transforms (WT), which are themselves scaling functions. Currently, a wide variety of wavelet functions have been created. They are widely used for video data compression in static images and video streams. However, the wavelet transforms by themselves do not change the total volume of the image/video data, but only divide it into arrays of low-frequency (LF) and high-frequency (HF) coefficients. In this case, the array of LF coefficients contains the twofold reduced most informational part of the image, and the array of HF coefficients contains errors of prediction. Thus, as a result of image processing by a two-dimensional wavelet transform, we get an approximated twofold reduced image, consisting of LF coefficients, and 3 regions of combinations of HF and LF coefficients. Moreover, the HF part of the coefficients can be either small or even equal to zero on relatively smooth areas of the image, because of possibility to accurately predict the pixel values. On Fig.5 you may see the pixel values of image part and the results of its two-dimensional wavelet transformation.

For simplicity in the WT lifting scheme usually odd pixels correspond to low-frequency coefficients (H), and even pixels to high-frequency coefficients (L). As can be seen from Fig. 5, the prediction of pixel values in a uniform part of the image is provided correctly, therefore their prediction errors (H) are equal to 0. And the LF coefficients (L) are completely correspond to the pixel values of the original image (30). Thus, an image consisting of 4 segments will be obtained after WT: a 2-fold reduced original image in the LL segment, and the remaining 3 segments HL, LH and HH with zero meanings (Fig.5, d). Accordingly, if we don't take into account these zero coefficients, then we obtain scaling without loss of information. It means, within the reverse wavelet transformation the original image will be completely restored, because the array of zero values has restored too (as default in scaling and WT). But this is possible only on uniform images. On real images with fine details, the prediction errors have arbitrary values and affect the clarity of the image. So, the total image data amount at WT does not change.

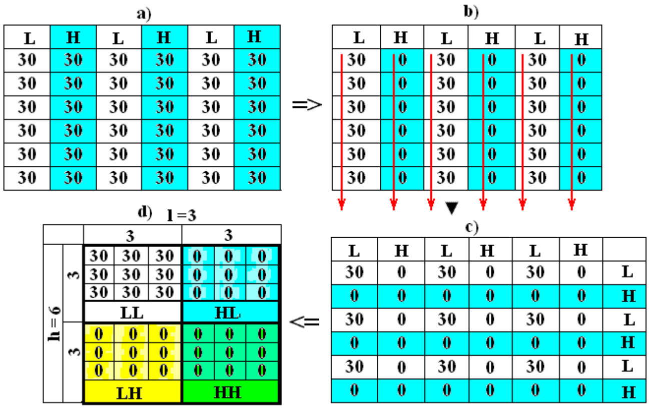


Fig.5. An example of a two-dimensional WT according to the lifting scheme with 6×6 single-color image: a) the pixel values of the original image; b), c) results of horizontal and vertical WT, respectively; d) output array of LF and HF coefficients.

In paper [9] it is proposed to set all LF coefficients to zero, thereby using WT for image scaling. However, the paper does not indicate what the visual quality of the reconstructed images will be after this action. Because of that, we have carried out research of the influence of the HF array values and the length of the wavelet filters on the quality of the restored images. For this purpose, we used the C++ programming language for creating of image scaler software. There are 3 types of wavelet filters with various lengths was chosen for the study from the options of experimental DIRAC video codec:[10]

1. short length filter on LeGall wavelets (5,3);
2. medium length filter on Deslauriers-Debuc wavelets (9.7);
3. long length filter on Deslauriers-Debuc wavelets (13,7).

The common lifting scheme of the direct transformation of these filters is described by the following expressions [9], where D and S are the corresponding arrays of high-frequency and low-frequency coefficients; b – image's pixel values.

LeGall (5,3):

$$\mathbf{D_{2i+1} = b_{2i+1} - (b_{2i} + b_{2i+2} + 1) / 2} \quad \text{- HF filter}$$
$$\mathbf{S_{2i} = b_{2i} + (d_{2i-1} + d_{2i+1} + 2)/4} \quad \text{- LF filter}$$

Deslauriers-Debuc (9,7):

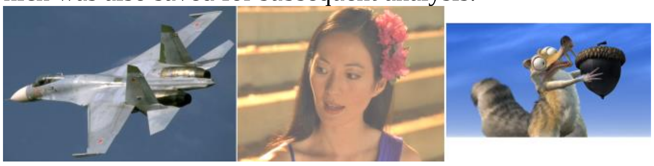
$$\mathbf{D_{2i+1} = b_{2i+1} - (((b_{2i}+b_{2i+2}) \times 9 + (b_{2i-2}+b_{2i+4}) \times (-1)) + 8) / 16}$$
$$\mathbf{S_{2i} = b_{2i} + (d_{2i-1} + d_{2i+1} + 2)/4}$$

Deslauriers-Debuc (13,7):

$$\mathbf{D_{2i+1} = b_{2i+1} - (((b_{2i}+b_{2i+2}) \times 9 + (b_{2i-2}+b_{2i+4}) \times (-1)) + 8) / 16}$$
$$\mathbf{S_{2i} = d_{2i} + ((d_{2i-1} + d_{2i+1}) \times 9 + (d_{i-3} + d_{i+3}) \times (-1) + 16) / 32}$$

In this case, the inverse wavelet transformation is performed by to the same formulas, but in the opposite direction.

For the experiments we took 3 images with low, medium and high detailing, shown in Fig.6. Each image was processed by a two-dimensional WT, based on the LeGall (5.3), Deslauriers-Debuc (9.7) and Deslauriers-Debuc (13.7) wavelets (Fig. 7). Then the reduced image of the low-frequency coefficients was saved, and all segments of the high-frequency coefficients were set to zero (Fig. 8). After that, the LF image was reloaded into its LL segment and a inverse WT was carried out to restore the original image, which was also saved for subsequent analysis.



a) b) c)

Fig.6. Variants of test images with a) low detailing, b) medium detailing and c) high detailing.

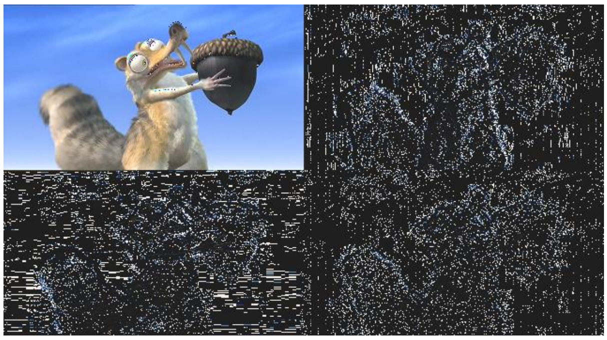


Fig.7. Display of direct two-dimensional WT results

Since television is a visual observation system, first of all, the quality of images was assessed visually, and objective quality assessment metrics were not used in this paper.

As researches have shown, "zeroing" the HF coefficients does not lead to a noticeable clarity decrease of the reconstructed image, but color distortion points appear in some of its areas (Fig. 9). Moreover, the value of such distortions depends on the length of the applied wavelet filter. Thus, the greatest distortions occur when using the LeGall (5.3) filter; and with a long length Deslauriers-Debuc (13.7) filter these distortions are almost invisible (Fig. 9). Therefore, to reduce the visibility of such distortions, you should use longer wavelet functions, and also process the output images with an adaptive recurrent filter, which will level off the pixels' colors.

Also, we had compared the operation of the Deslauriers-Debuc (13,7) wavelet filters with the traditional Lanczos-3 interpolator to evaluate the effectiveness of the method of bidirectional image scaling based on wavelet transforms. Fig. 10 shows the initial image (fine structure image of the squirrel), and Figs. 11 and 12 show the restored images of the squirrel after bidirectional resizing by the WT and after Lanczos-3 filter, respectively.

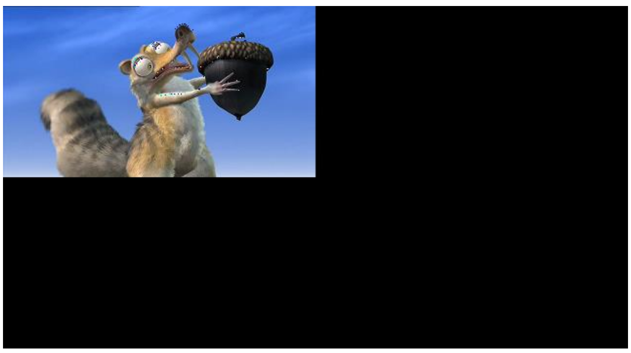


Fig.8. A variant of the LF part of the image with zeroed segments of the HF coefficients

LeGall (5,3) Deslauriers-Debuc (13,7)

Fig.9. Areas of color distortions, introduced by the LeGall (5.3) and Deslauriers-Debuc (13.7) filters in the images.

Fig.10. the initial image of squirrel

a) b)

Fig. 11. Comparative clarity of images after a) bidirectional scaling with Deslauriers-Debuc (13.7) and b) Lanczos-3 filter

As can be seen from Fig. 11, a, the clarity of the image is the same with the initial image, while after Lanczos-3 (Fig. 11, b) the image is more blurred.

IV. Experimental results and conclusion

As a result of the research of the possibility of using WT for bidirectional image scaling, it was found that WT practically does not reduce image clarity. At the same time, bidirectional scaling without setting all LF coefficients to zero forms images that are fully consistent with the original ones. But it does not reduce the video data amount. When the HF coefficients are reset to zero, the result (two-fold reduced) image will have the amount of video data reduced by 4. In this case, the clarity of the images practically does not decrease, but local point color distortions occur. The size of such local areas depends on the length of the applied wavelet and practically does not depend on the structure of the images. Thus, on the short length LeGall filter (5.3) they are maximum, and on the long length Deslauriers-Debuc filter (13.7) the distortion areas are minimal (Fig. 9). That is why for improving the quality of reconstructed images, it is better to use "longer" wavelets, and process the reconstructed image itself with an adaptive recurrent filter that can make the point color changes smoothly.

Comparison of the traditional WT image scaling method with WT, based on Lanczos-3 filter showed better efficiency of first one, since Lanczos-3 degraded image clarity (Fig. 11), while WT did not change it.

So, we can conclude that the idea of using WT for bi-directional image scaling have development prospects and can be useful for increasing the efficiency of videocompression.

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Designing an information security management system for payment systems

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Abstract— **The article discusses the design of the information security management system for payment systems. For this, the problems of ensuring information security in systems are analyzed. An analysis of systems and mechanisms designed to both guarantee and improve the information security of Internet banking was carried out. Attention is paid to the principles of organizing information security in the international payment system SWIFT. The features of the new 3D-Secure technology, which significantly increases the level of information security of international card payment systems, are considered. mathematical model The information security of payment systems optimizes the structure of the optimal plan, regardless of the volume. All formulated mixture problems are solved by linear programming methods.**

Keywords— information security, payment system, mathematical model of payment systems.

I. Introduction

The intensive development of information and telecommunication systems leads to the fact that the information environment, being a determining factor in all spheres of state activity, becomes the center of aspirations on the part of criminal structures. Since its inception, banking and payment systems have consistently aroused criminal interest. And this interest is connected not only with the storage of funds in credit institutions, but also with the fact that they contain important and often confidential information about the financial and economic activities of many people, companies, organizations and even entire states.

Security measures - installation of firewalls and antiviruses, intrusion detection systems and other, of course necessary tools, as well as access management, incidents, integrity, continuity, compliance - these are the details that build a large socio-technical system called "information security".

Special attention is paid to the issues of ensuring information security in computerized systems of the credit and financial sector.

II. Review of problems of information security of payment systems

In the last decade, the growth of losses associated with information crime has become a steady trend. The general risks of the functioning of payment systems arise due to technical failures and theft of funds from banks or customers. In other words, the nature of this risk lies in the field of technical features of the systems operation, and its magnitude is quite significant today. Large payment systems are forced to include expenditure items in their budgets, taking into account possible losses from theft, calculated statistically based on previous periods [1, 2, 3].

Some examples of innovations first seen in the payments industry include tokenization , fingerprint identification, and EMV technology. Last year, card networks debuted the Secure Remote Commerce (SRC) standard, or Click to Pay ", which allows the use of an electronic cash register for the general consumer, which promotes simplicity, convenience and trust. The SRC is a fundamental component to support the "buy button" on retailer websites, effectively creating the online equivalent of a single payment terminal in a physical store [1, 2, 3].

The adoption of cutting-edge technologies such as tokenization , 3D Secure , and AI has particular benefits for small businesses forced to go digital during a crisis, allowing them to offer consumers the same secure checkout experience as much larger businesses, while while also exempting small businesses from liability for fraud, PCI compliance, and "false rejections" where a valid sale is denied due to limitations in legacy security systems. Merchants pay to introduce new point of sale technologies to their customers. For example, merchants buy EMV-enabled point of sale terminals to make them EMV compliant. These fees vary, but funds are used to maintain security measures.

In the event that a cyberattack does occur, the card networks are ready. For example, Visa has a program that shares threat information with merchants and issuers in real time so they can act quickly to protect their payment systems from cyberthreats . Similarly, this year Mastercard introduced a new Cyber Security Center . Based in Vancouver, Canada, the program will continue to provide convenient and secure payments for its customers by developing cyber solutions for the payments ecosystem around the world [1].

Information crime has reached a level that makes this phenomenon one of the most serious and potentially dangerous national problems. Annual losses from it in Western Europe reach 30 billion dollars, and in the United States - more than 100 billion dollars. According to official data provided by banks of the National Bank of Ukraine, the total number of fraudulent transactions in 2013 compared to the previous year increased by 47%, and the amount of losses increased by 20%. At the same time, experts note that 99.7% of the losses caused to banks on transactions with payment cards were made with cards of international payment systems [1].

III. Principles of ensuring information security in international payment systems.

To ensure the information security of international payment systems, a set of hardware, software, organizational and technical means and measures that implement the security system should form a distributed complex that operates under the control of security control centers [2].

The security of information in the information and telecommunication networks of international payment systems is ensured by the implementation of the following general principles:

- protection of information (in order to ensure its confidentiality, integrity and reliability) during its storage, processing and transmission over networks;

- confirmation of the authenticity of data objects and users (authentication of parties establishing communication);

- detection and prevention of violation of the integrity of data objects;

- stability of the communication network in case of compromise of a part of the key system;

- protection of technical means and premises in which confidential information is processed from information leakage through side channels and from electronic devices for retrieving information possibly embedded in technical means;

- protection against unauthorized access to information resources and technical means of networks, including their management tools;

- implementation of organizational and technical measures aimed at ensuring the safety of confidential information [2].

In the light of current trends in the growth of openness of technologies in the financial sector (the use of the Internet and other open networks as transport communications for data transmission), the issue of ensuring the confidentiality, integrity and reliability of payment transactions is of particular importance.

This can only be achieved by using cryptographically strong and efficiently implemented crypto schemes , and by organizing reliable and convenient systems for distributing key information [3].

Unlike traditional encryption systems that use a single key, asymmetric encryption methods, public key systems, have two keys, each of which cannot be calculated from the other. One key is public, used by the sender to encrypt information, the other is private, the recipient decrypts the received ciphertext. The electronic digital signature mechanism is most often used when servicing legal entities by banks, but sometimes it is also offered to individual clients. The advantage of an electronic digital signature is that it allows you to uniquely identify the user. The disadvantage is that an electronic digital signature can also be vulnerable to fraudsters. Attackers can get their hands on the digital signature key by infecting a computer with malware.

Banks are trying to use various systems and mechanisms designed to both guarantee and improve the information security of using Internet banking.

Some banks offer Internet banking customers to purchase or rent a special device - a one-time password generator. The generator connects to a computer via a USB port and does not require special software. It is also proposed to use an external electronic key, which is generated when you first connect to the Internet banking system, recorded on an external medium, and then used during transactions. Such systems are a simplified version of an electronic digital signature.

In addition to the above measures, banks often apply additional measures to ensure the safe use of Internet banking:

- restriction of the use of a personal certificate - the system of some banks allows you to use an electronic key or an electronic certificate only on the computer on which it was generated. Thus, you can make payments through Internet banking only from your personal computer, and you can view account statements using other devices;

- virtual keyboard - the technology is designed to prevent fraudsters from reading registration data when entering them from a regular keyboard using malicious software;

- session duration limitation - if the client is inactive, the session in the Internet banking system will be closed after a certain time. To resume work, you will need to re-authenticate;

- connection history - using this function, the Internet banking user can track all unauthorized transactions. [4]

Today, almost all banks that provide Internet banking services use the SSL standard (Secure Socked Layer) - encryption of data transmitted from the user's computer to the bank system and vice versa. The SSL protocol, which is widely used and has become almost mandatory in Internet commerce, allows all participants in the trade to transfer a wide variety of information with ease. If you try to intercept data, they will be closed with a cipher, which cannot be cracked in a short period of time.

The SSL protocol securely protects information transmitted over the Internet, but still it cannot protect private information stored on the merchant's server, such as credit card numbers. When a merchant receives credit card information along with a purchase request, the information is decrypted and stored on the server until the request is completed. If the server is not secure and the data is not encrypted, then unauthorized access to private information and its further use for fraudulent purposes is possible.

In addition to using the transmitted data encryption protocol, Internet commerce participants use cardholder identification methods such as checking CVV2 / CVK2 codes (CVV2 code for Visa payment system cards and CVC2 for MasterCard).

Interesting identification methods include AVS address verification technology (Address verification service). It is more typical for the North American e-commerce market, but, nevertheless, cardholders of Russian and Ukrainian banks also have to deal with it when using cards to pay for goods with delivery in the United States.

A. Information security in SWIFT

In addition, the SWIFT system can be used to exchange information and make mutual settlements in transactions with securities and traveller's checks. In the future, it is planned to use this system in other areas of the economy, where an operational, high-quality environment is needed for the transfer of financially significant information, requiring a high level of confidentiality.

The long-term success of the SWIFT system lies in the provision of a wide range of services to users in the transmission, storage and security of messages. An important factor is also the timely support of users in technical, administrative and legal, as well as in matters of training and consulting when connecting new users. But the most important thing is a high level of responsibility to users for the safety, timeliness and confidentiality of the transmitted information.

From a technical point of view, the network is a SWIFT international telecommunications network that allows financial institutions from different countries to connect to it using computers and terminals of various types to transfer banking and financial information. The system adopted a special format of bank messages - a standard that is being developed with the help of a working group of bank specialists and the SWIFT organization itself. The SWIFT system uses both international standards developed by ISO and International Chamber of Commerce (ICC) standards.

As a result of the historical development of the SWIFT network, a new network has been formed - SWIFT II, which is based on a 4-layer network architecture and a control system for processors located in the SWIFT operating centers.

The logical architecture of the SWIFT II system follows the basic principles established by ISO (International Organization for Standardization) for the interoperability of open systems. Active components of the SWIFT II architecture - nodes can be interconnected:

- straight highlighted lines;
- local (international) switched lines;
- local networks;
- satellite communication channels.

The system architecture consists of four main components:

- SCP (system control processor);
- SP (switching processor);
- RP (regional processor);
- CP (transmission processor).

At present, in the SWIFT II system, an improved security system architecture has been developed and recommended by the Board of Directors for widespread use, which in a broad sense corresponds to the current level of development of telecommunication technologies and cryptographic methods. The basis of the new approach was the use of smart cards (ICC), a change in the validation algorithm and an increase in the length of the two-way keys that are exchanged by users.

In fact, the core of the SWIFT II system is concentrated in two System Control Centers (SCC), which are located in the Netherlands and the USA. SCC includes two key system components, namely SCP and SP. To improve performance and protection against failures in the SWIFT II system, duplication of each SCP and redundancy of the operation of each SP are used. At any time, only one SCP is active and directly controls the system. The remaining three SCPs are permanently in hot standby and continuously update their state based on the configuration of the active SCP.

All transactions and messages that are transmitted over international communication lines are systematically encoded by SWIFT using ciphers that are valid and change over arbitrary periods of time.

B. 3D Secure Technology

It is impossible to ignore the emergence and widespread introduction of the new 3D-Secure technology, which significantly increases the level of information security of international card payment systems. [7]

3D-Secure technology allows for additional authentication of the cardholder when making payments on the Internet on sites that support this technology.

The name 3D-Secure comes from the English term Three-Domain Secure , indicating that this technology is implemented on the basis of three domains in which transactions are generated and verified:

Issuer domain that supports the cardholder and the card issuing bank;

Acquirer domain , which supports the acquiring bank and its customers;

interaction domain - contains elements that carry out transactions between two other domains, mainly this domain supports networks and services of card associations.

Three independent companies participate in the online verification process - the seller's bank, to whose account the money is transferred, the buyer's bank and the payment system itself. When making a payment with a bank card in an online store that supports this technology (determined by the presence of the Verified logo By Visa), the buyer's details are redirected to the server of the issuing bank that issued the card (the bank must also support this technology). The bank authenticates the cardholder using a password known only to the cardholder and the bank. Based on the results of the check, the issuing bank generates a response message using a digital signature in order to protect information from unauthorized changes.

To enter the customer's private information, such as card number, secure pages of the payment server are used. The entered information is stored on the payment server, and the payee does not have access to this information, which best protects against its loss and theft.

As a result, the buyer opens a dialog box in which it is required to enter a PIN code (as in an ATM) or a one-time password sent as an SMS to the contact phone number (indicated when issuing a card). After entering the password, the operation is considered confirmed and funds are transferred from the client's card to the store's bank account. Thus, if for some reason the attackers obtained information about a bank card, they will not be able to use it, since it will not be possible to confirm the authenticity of the card owner without an SMS password. The specified password is sent immediately at the time of the transaction on the Internet after entering the card details and can be used for confirmation only once.

Such a system has a number of advantages. Firstly, it is quite easy to use - there is no need for special equipment, and the procedure for confirming the operation takes only a few minutes. Secondly, it allows you to protect the account from being used by intruders - even if the login and password for logging in to the system become known to fraudsters, they will not get access to the money, and the user will learn about an attempt to carry out an unauthorized operation from an SMS message. [8-12]

3D-Secure technology not only ensures secure payment processing, but also differentiates the risks of transaction participants due to a clear separation of functions for each.

Services based on 3D-Secure technology have also been adopted by the MasterCard payment system under the name master card SecureCode (MCC) and Japanese payment system JCB International as J/ Secure.

IV. Information security system of the object

The information security system of an object is a complex of dynamically linked elements, the management of which should be based on a scientific basis.

An important feature of systems theory is that it distinguishes between open and closed systems. An example of an open system is a living organism that maintains its state unchanged, but this is a state of dynamic equilibrium, that is, incoming substances, the energy of the system change under the influence of the environment, and the state of the system does not change. This view corresponds to a typical control system: this system is created by man, it interacts dynamically with its environment, it has components that are interconnected and function together to achieve a common goal . The information security management system of an object can be considered as an analogy with the human body is appropriate : leadership is the brain of the system, the system communications - nervous system, executive and service bodies , both of which have the ability to self- regulate and reproduce . In general, the complex protection of an object is part of a larger system, it is influenced by the outside world, and formal and informal relations can exist in it. It is known that formal and informal methods are used to solve control problems, the nature of which requires the decomposition of the control object, that is, the object of study is limited, the relationship with other subsystems is practically not considered, and this leads to the fact that the solution of local problems cannot be combined into a single whole, or this integration gives wrong result. Thus, we can conclude that when forming a comprehensive plan for protecting information on the object of the task: local optimization, due to its simplicity, is of limited use.

A fundamentally different approach is needed, based on the study of the decision-making process. This process is seen as something that brings together a system of relationships, organizational structure, issues of system development and the impact of uncertainties. This approach allows you to create and explore more complex behaviors in the process of administrative management, that is, it will allow you to use the results of research in the field of special management issues.

V. Mathematical model of information security of payment systems

The goal of general systems theory in solving the problem of complex information security is to facilitate understanding of the complexity of the environment, since if a well-thought-out system can be created, within and on the basis of which the manager must make decisions, then the decision-making process is simplified. The principle of a systematic approach requires the construction of a hierarchical control system:

- at the first level - the system of material processes and distribution;
- at the second level - the processes of making programmed decisions;
- at the third level - the processes of making non-programmable decisions belonging to the system, which are necessary to control the processes of lower levels, their rescheduling and reassessment of the system parameters.

The main attention in the hierarchical structure should be given to the analysis of information flows and the synthesis of the information model of the control object.

Models and methods for describing systems. From the many definitions of the term "system" as a working one, the most suitable for the goals and objectives of this study, we will take the following: "system is a formal relationship between the observed features and properties" [56].

The process of designing, developing and operating an information security management system for an object should provide not only planning work to protect information, but also the ability to take into account the strict requirements of decision makers for the quality of planned work, and promptly evaluate the effectiveness of individual groups of measures.

For example, it is possible to include an information system (in our case, this is a payment system) from s groups into the complex protection system; each element of the measures provides at least two protection functions (a and b) and creates certain inconveniences (d) for users. The main goal of this task is to draw up such a work plan that would provide all the requirements of consumers to the quality of the elements of a comprehensive action plan for the information security system with a minimum of costs for its implementation. Conventions adopted in this model:

i - production site number (i - 1, 2, ..., s);

a_i - the effectiveness of the first protection function in the i -th group of elements from the measures;

b_i - the effectiveness of the second protection function in the i -th group of elements from the measures;

d_i - "inconvenience" for the user in the i -th group of elements from the events;;

K_i^{max} and K_i^{min}, accordingly, the maximum possible and minimum required amount of implemented protection functions in the i -th section;

c i - costs for the implementation of the action plan for protection at the i -th site;

k_{pl} - the planned volume of implemented information security functions at the facility;

a_{pl} - planned number of events;

b_{max} and b_{min} respectively, the minimum and maximum allowable values of measures that implement the second protection function;

d_{max} is the maximum allowable number of “inconveniences for the user associated with the implementation of measures to protect information.

As controlled variables, it is proposed to take the number of activities from the i -th group, which will be included in the comprehensive information protection plan at the site x. We will solve the problem, minimize the costs of implementing the plan, subject to the fulfillment of restrictions on the number of activities of each group, on the total scope of functions, and on the quality of protection. This mathematical model is not the only one for this type of problem. By changing the optimality criterion, one can formulate other versions of the model.

1st option . The efficiency criterion is the cost of implementing the integrated protection plan.

Mathematical model of the problem:

1. Objective function: minimum costs for the implementation of a comprehensive information protection plan for payment systems

$$\sum_{i=1}^{s} c_i x_i \to min\,; \quad (1)$$

2. Restrictions on the number of events in each group

$$K^{min} \leq x_i \leq K^{max}\ (i=1,2,\ \dots,\ s); \quad (2)$$

3. Restriction on the total amount of work

$$\sum_{i=1}^{s} x_i \geq k_{pl}; \quad (3)$$

4. Limitation on the quality of protection

$$\frac{\sum_{i=1}^{s} x_i a_i}{\sum_{i=1}^{s} x_i} = a_{pl}; \quad (4)$$

$$b_{max} \geq \frac{\sum_{i=1}^{s} x_i b_i}{\sum_{i=1}^{s} x_i} \geq b_{min}; \quad (5)$$

$$\frac{\sum_{i=1}^{s} x_i d_i}{\sum_{i=1}^{s} x_i} \leq d_{max}; \quad (6)$$

5. boundary conditions that ensure the positivity of the solution:

$$x_i \geq 0 \quad (7)$$

2nd option . Efficiency criterion - the total volume of implemented protection functions or the deviation of the protection quality indicator from the planned quality level. Mathematical model of the problem

$$\sum_{j=1}^{s} x_j \to max, \quad (8)$$

or minimum quality deviation from the planned indicator:

$$|a - a_{pl}| \to min, \quad (9)$$

Where

$$a = \frac{\sum_{i=1}^{s} x_i a_i}{\sum_{i=1}^{s} x_i}. \quad (10)$$

The solution of the same problem according to different optimality criteria makes it possible to make a comparative analysis of the obtained solutions and improve the validity of the solution.

As an illustrative material, the task of forming a plan for the complex protection of an object is given.

It is proposed to include three types of payment system measures in the protection plan: legislative measures (first), organizational and technical (second) and technological (third). Each of the groups of activities allows you to implement two types of functions: protection against unauthorized access (UnAcc) , protection against malicious programs (MalProt). The numerical values of the parameters for each group of protection tools are given in Table 1.

TABLE I. NUMERIC VALUES OF PARAMETERS FOR EACH GROUP OF PROTECTION TOOLS

Measures	***The minimum number of implemented furctions***	***UnAcc, %***	***MalProt, %***	***Total number of implemented functions, %***	***Maximum number of implemented functions***	***Implementation costs***
1	2	3	4	5	6	7
1	22	14	2	75	24	14
2	25	20	0.8	60	28	10
3	15	16	1.2	75	17	12
Planned indicators		< 17	< 1.4	> 35		

Mathematical model of the problem

Efficiency criterion W=14 x_1 +10 x_2 +12 x_3 → min .

Restriction system:

1. By the total number of implemented functions:

0.75 x_1 + 0.6 x_2 + 0.7 5 x_3 ⩾35;

2. By the number of implemented functions for each group:

22⩽ x_1 ⩽24;

25⩽ x_2 ⩽28;

12⩽ x_3 ⩽17;

3. Restrictions on the implementation of the function of protection against unauthorized access:

0.14 x_1 +0.2 x_2 +0.16 x_3 ⩽ (x_1 + x_2 + x_3) ;

4. Restrictions on the implementation of the anti-malware feature:

0.02 x_1 +0.008 x_2 +0.12 x_3 ⩽ 0.014 (x_1 + x_2 + x_3) .

Boundary conditions: $x_{1:9}$ ⩾0.

After bringing the system of constraints to the canonical form:

0.75 x_1 +0.6 x_2 +0.75 $x_3 - x_4$ = 35 ;

$x_1 + x_5 = 24$;

$x_1 - x_6 = 22$;

$x_2 + x_7 = 28$;

$x_2 - x_8 = 25$;

$x_3 + x_9 = 17$;

$x_3 - x_{10} = 12$;

-0.03 x_1 +0.03 x_2 -0.01 x_3 + x_{11} = 0 ;

0.008 x_1 -0.006 x_2 -0.002 x_3 + x_{12} = 0 .

The problem is solved using standard software.

CONCLUSION

Based on the dynamics of connecting banks and, accordingly, online stores to 3D-Secure, it can be assumed that soon Internet payments from bank cards without SMS password confirmation will become inaccessible. In our opinion, only in this case the desired effect will be achieved - an increase in citizens' confidence in online payments using Visa or MasterCard cards .

The mathematical model of the information security system, which is based on the information security model of payment systems, allows you to find such a set of components, their quantitative ratio, which satisfies the specified technological requirements for the quality of object protection, as well as the requirements of the accepted criterion (minimum cost or maximum profit) .

With a fairly extensive list of technological means and measures taken to ensure secure settlements using international payment systems, much depends on the clients themselves. Often the reason for fraudulent access to user accounts is the inattention and negligence of the users themselves. Therefore, in order to avoid possible problems, account holders need to protect access data to them.

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Criminal Face Detection

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***Abstract*—The technique of employing facial recognition technology to identify people who have taken part in illegal activity is known as criminal face detection. The method is looking at pictures or videos of suspects or crime scenes and contrasting them with databases of known offenders or suspects. The aim is to find and follow up on people who are likely to commit crimes in order to stop or solve crimes. However, there are worries over the precision and dependability of criminal face identification, as well as significant ethical and privacy considerations. These issues will be addressed, and the efficiency and fairness of criminal face detection will be improved, according to ongoing research and development in this field. The goal of the criminal face detection project is to create a computerized system that can correctly identify people who have a criminal history based on their facial traits. The technology analyses face photos using cutting-edge computer vision and machine learning algorithms, then compares the results with a sizable database of criminal records. The project's main objective is to increase public safety by giving law enforcement organizations a solid tool for detecting prospective suspects and lowering the danger of criminal behavior. Criminal face identification has the potential to be a highly effective tool for law enforcement, but there are questions regarding its precision and dependability as well as any possible effects on privacy and civil rights. It has been demonstrated that face recognition technology performs less accurately when recognizing members of demographic groups, such as women and people of color. This raises the possibility of false identifications, false accusations, and fraudulent arrests against innocent people.**

***Keywords*— criminal face detection, computerized systems, computer vision, machine learning, public safety, law enforcement**

I. Introduction

This is the start of the body text of your paper. Preventing crime is a vital responsibility since it is one of the most seriousand persistent problems in our society. In any culture, various crime patterns and the careful consideration of citizens' security and safety are important factors that have a direct impact on how well people are able to live their lives. A person's life might be disrupted and stressed out by some criminal acts, such as larceny, identity theft, or even pickpocketing, which can also dam- age his mental health. Criminal face detection is a method that makes use of facial recognition soft- ware to identify people who have engaged in criminal activity or have a criminal past. The technology may examine images or recordings of suspects or crime scenes and compare them to databases of known criminals or suspects. Its major goal is to improve public safety by giving law enforcement agencies a reliable tool for spotting prospective suspects and lowering the likelihood of criminal behavior. In recent years, the use of facial recognition technology in criminal face detection has drawn a lot of attention and developed into a useful tool for law enforcement Organizations all over the world. Criminal face recognition has improved in accuracy and efficiency with the development of computer vision and machine learning algorithms, enabling more rapid and accurate identification of suspects. Due to worries about crime and safety, closed-circuit television (CCTV) systems are now required in both public and private settings. With superior performance and real-time data provided by a deep learning-based strategy, police forces can operate more effectively. Technology and training are used by the AMBER Alert Indian Country (AIIC) Initiative to assist Tribal communities in the secure return of missing or kidnapped children. The public's engagement and reaction capacities are improved by coordinated initiatives with local,state, and federal partners. Overall, these programs and technology have a significant impact on raising public safety standards and deterring crime. Com- munities are instantaneously mobilized by AMBER Alerts to help in the rescue of a child who has been kidnapped or is in risk of becoming missing. Facial recognition software is used for consumer screening at banks, airports, and other establishments. Figure 1 shows a general face recognition diagram. Face recognition technology has been implemented

Fig. 1. Face features to be extracted.

at crossings and customs by nations like Germany and Australia for Automated Passport Control.

II. Literature Survey

The development of effective and efficient ways to identify criminal faces has been a focus of several studies in the recent years, making criminal face detection an active topic of research. A survey of the literature reveals that deep learning-based approaches and conventional computer vision- based methods make up most of the currently used techniques [1]. To identify criminal faces, most computer vision-based techniques rely on manually created features and classifiers. These techniques often require a big quantityof training data and feature engineering, which can be difficult and time-consuming. Comprehensive framework for facial action recognition and its application to facial expression analysis using static face images can be done by extracting relevant features from facial images, such as local descriptors, geometric features, and texture patterns that help represent the different facial actions [2]. In contrast, deep learning-based approaches have recently demonstrated astounding performance in criminal face identification challenges. With the help of deep neural networks, these techniques automatically extract characteristics from the input data and develop powerful classifiers. Open CV based techniques for criminal face recognition can also be used [3].There are many different types of biometric methods that candifferentiate fingerprints, DNA, and face categories. There are many elements in face recognition such as holistic and feature extraction methods. As in much research the face recognitionhas great impact in student life There is no need to enter a keycode, sign a sheet, identity card or swipe machine system Just integrated cameras system can automatically identify a student by face recognition automatically and make data entry effortless and easy [4]. The imbalance of positive and negative samples, with a far greater number of non-criminalfaces than criminal faces, is one of the difficulties in criminal face detection. Studies have suggested techniques including data augmentation, sampling, and cost- sensitive learning to solve this problem. In conclusion, the literature review showsthat both conventional computer vision-based and deep learning-based algorithms have significantly improved criminal face detection.[5] Nevertheless, deep learning-based approaches have performed better recently, and it is still difficult to deal with the imbalance between positive and negative data. Our study intends to advance this area by creating a powerful and accurate criminal face identification tool utilizing deep learning-based techniques [6]

III. PROPOSED METHOD

To ensure that law enforcement officers can use the system effectively, it is essential that it has a user-friendly interface that is simple to use and comprehend. Users should be able to conduct searches and retrieve pertinent information quickly and simply using a well-designed interface that is intuitive and requires no training.

One of the main goals of our criminal face identification project was to develop a user-friendly software solution, even for non-technical users. We focused particularly on the user interface design and overall user experience to accomplish this aim. Users of our programme may quickly and easily identify criminal faces because to its straightforward and easy process. The interface is designed to be user-friendly and includes interactive features and visual aids to make it simple to comprehend and use.

We produced in-depth documentation, which includes user guides and tutorials, to make it even easier for users to adopt the system and be happy with it. These tools aid users in getting started and navigating the tool efficiently while covering every facet of the product. In order to guarantee that our product is user- friendly and satisfies the demands of its target market, we included user feedback throughout the development cycle.

We think that all police officers can use our criminal face detection software since it has a low learning curve.

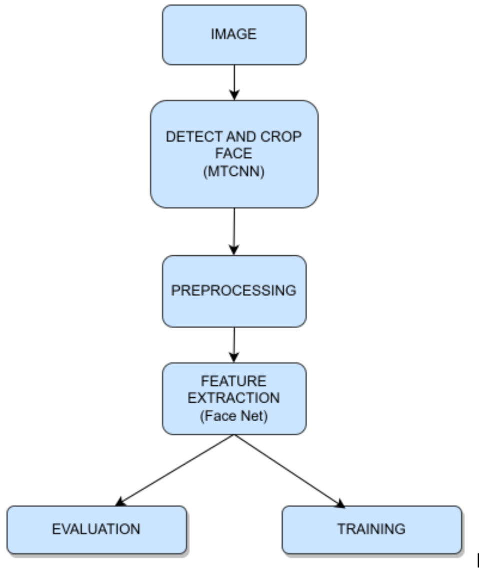

Fig. 2. Flowchart.

In conclusion, the user-friendly interface, thorough documentation, and support resources made accessible to users in our criminal face detection project make it simple to use and navigate. We are dedicated to maintaining the software's usability and accessibility by making further improvements and offering support.

IV. WORKING AND RESULTS

This criminal facial recognition software is a user-friendly programme with two key features: Registration and Detection. As shown in figure 3 the registration and detection phases are carried out. Figure 4 explains how the proposed system can be used in the work environment.

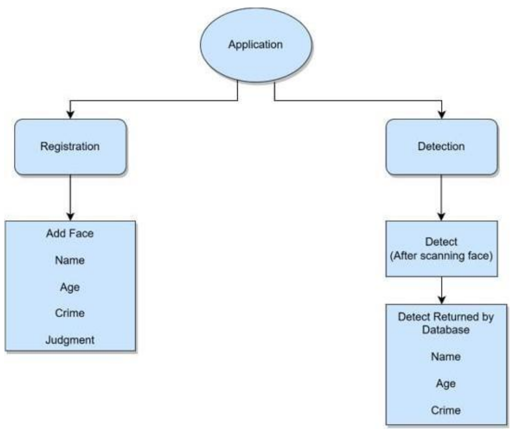

Fig. 3. System Working.

A. *Registration:*

The establishment of a database of known criminals or suspects is a crucial step in the registration process of criminal face detection. This database is used as a resource to compare faces in photos or videos taken at crime scenes with those of

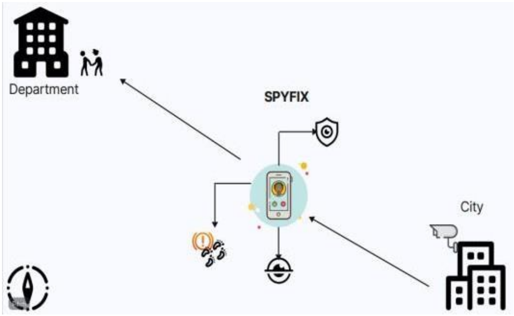

Fig. 4. System used in work environment.

known offenders. A face picture of the subject is collected at registration and entered into the database along with their personal data and criminal background. If they later engage in criminal activity, this information may be utilized to locate them. Anyone can contribute fresh criminal faces to the database by registering. Users using this function must supply a picture of the offender's face along with some basic data like the person's name, age, gender, and any pertinent information about their criminal background. The program then trains the model on the new face using the deep learning-based architecture after the data has been supplied. In order to complete the registration process, high-quality photos of the face must be taken, which can be difficult in some circumstances, such as when the subject is uncooperative, the lighting is bad, or the image quality is subpar. But because to developments in computer vision and machine learning, it is now feasible to extract important characteristics from poor-quality photos, increasing the reliability of the registration procedure.

B. Detection:

The process of recognizing and finding faces in an image or video is known as" detection" in criminal face detection. Computer vision methods like Haar cascades, which are taught to recognize patterns in a picture that match to human faces, are typically used for this. The major function of our programme is the Detection option, which enables users to find criminal faces in input photographs. This feature employs the Single Shot Multibox Detector (SSD) technique to find faces in images after receiving an image as input. When faces are found, the programme employs deep CNN to categorize them as criminal or non-criminal. If a criminal's face is found, the programme gives the user the necessary details on the offender, including their name, age, and criminal background. After a face is identified, the system may carry out additional analysis, including comparing it to a database of known criminals or suspects. Here is when the recognition element enters the picture. The system can identify prospective targets for additional study thanks to detection, which is a vital stage in criminal face identification. But it may be difficult as well, especially when there are lots of faces in the picture or bad lighting or poor image quality. Detection is a crucial step in criminal face detection as it enables the system to identify potential targets for further analysis. However, it can also be challenging, particularly in situations where the lighting is poor, the image quality is low, or there are multiple faces in the scene. To address these issues, researchers are striving to create more sophisticated detection algorithms that can handle a larger range of situations and boost the system's overall accuracy. Convolutional neural networks (CNNs), which have a high degree of accuracy in face identification and are capable of learning complicated patterns in data, are one deep learning approach that may be used to do this.

We have tested this for 50 faces and got 100% accuracy. Might be it is possible if the number of faces get increased, we need to make a few changes to align the criminal database with the face database more efficiently.

V. FUTURE SCENARIO

Enhanced accuracy and adoption: Criminal face detection technology may become more reliable and extensively used in law enforcement and security applications with advancements in machine learning algorithms and access to big datasets. This may result in a more accurate and efficient detection of offenders, but it might also give rise to worries about prejudice, privacy, and monitoring.

Criminal face detection technology has the potential to reinforce or worsen prejudices and discrimination against groups based on their appearance if it is not carefully developed and monitored. The system could over identify individuals of specific racial or ethnic groups as prospective offenders, even if they are innocent, for instance, if the training dataset is skewed towards such groups.

Amber Alert: When a criminal face is recognized, a further feature that may be utilized to send out an alarm is the Amber Alert option. This function notifies the authorities or a pre- defined contact list of the detection and sends them an alert message with pertinent details about the culprit. When a criminal is on the lam and the police need to be notified right away, this can be very helpful.

If it is not carefully developed and regulated, criminal face detection technology has the potential to perpetuate or exacerbate stereotypes and discrimination against specific groups based on their appearance. If the training dataset is biased towards certain racial or ethnic groups, the algorithm may over identify members of such groups as potential criminals even if they are innocent.

Legal and ethical issues: The application of criminal face detection technology may give rise to issues of privacy, due process, and human rights. For instance, people may refuse to use face recognition technology or to legally contest the precision and dependability of the system.

Ultimately, how criminal face detection technology is developed, used, and controlled will determine its future. To ensure that technology is utilized responsibly and successfully, careful assessment of the possible advantages and hazards, as well as the ethical and legal ramifications, will be essential.

VI. CHALLENGES

Bias and discrimination: The possibility of prejudice and discrimination is one of the most difficult difficulties with criminal face detection technologies. If the technology is not carefully created and educated, it has the potential to perpetuate or magnify existing biases against particular groups of individuals based on their appearances, such as race or ethnicity. This might result in false allegations, unjust arrests, and civil rights abuses.

Technical limitations: The quality of the photos, differences in lighting and angles, and the capability to identify faces in actual surroundings are some of the technological constraints on facial recognition technology. The accuracy and dependability of the technology may be impacted by these restrictions, necessitating regular up-grades and enhancements.

Public perception and trust: The usage and possible abuse of facial recognition technology can cause public anxiety because it is a relatively new and contentious technology. Building trust and confidence in the use of technology may be aided by ensuring that it is open, responsible, and subject to proper monitoring.

Accuracy and reliability: Technology for detect- ing criminal faces is not flawless and can result in both false positives and false negatives. It's possible for innocent people to be mistaken for criminals or for real criminals to elude capture. The usefulness and credibility of the technology depend on its accuracy and dependability.

Privacy concerns: The acquisition of personal data and privacy issues are brought up by facial recognition technologies. The collection and storage of biometric data without the subjects' knowledge or agreement may be objectionable to some people, and there is a chance that the information may be hacked or used inappropriately.

VII. Conclusion

In conclusion, criminal face detection technology has the potential to be a highly effective tool for locating and apprehending offenders, but it also presents several difficulties and problems. These difficulties include problems with prejudice and discrimination, veracity and correctness, confidentiality, moral and legal reasons, technical constraints, and public perception and trust. Hence, it's crucial to make sure that criminal face detection technology is created and used in a responsible and transparent manner, with the necessary protections and monitoring. This will help to solve these issues. In doing so, we can reduce the dangers and unfavorable effects of this technology while maximizing its potential advantages.

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ECONOMETRIC MODELING OF MEDICAL SERVICES IN THE TERRITORIES

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Abstract: The development of econometric models of medical services in order to determine the optimal solutions for the provision of medical services in our country, technological progress, the solution of painful problems in medicine, the improvement of human life.

Keywords: Digital technology, empirical model, econometric model, forecast results, information system, endogenous variables, exogenous variables.

I. Introduction

In our country, the health of the population is one of the most important factors in the level of socio-economic development and an integral element of labor productivity in society. While technological advances are addressing painful issues in medicine, unhealthy lifestyles in many countries are making life difficult for millions of people. Therefore, one of the optimal solutions is econometric modeling of medical care.

In international practice, extensive research has been conducted to improve health insurance. As a result, "32 of the 33 developed countries have introduced a system of general compulsory health insurance, which provides for the use of one of the compulsory health insurance" [36].

According to the World Health Organization, almost half of the world's population is not fully covered by basic medical services. "More than 930 million people, or 12 percent of the world's population, spend at least 10 percent of their income on health care."

In our country, the health care system has new tasks for the development of health care organizations and the quality of medical services. The development of effective economic mathematical models and tools for the development of medical services is one of the most pressing issues today.

The purpose of this study is to provide recommendations for improving the use of digital technologies in the market of health insurance services in accordance with modern requirements in health insurance practice and the economic-mathematical model of development of health care enterprises in the compulsory health insurance system (MTS). is to achieve financial results through construction.

II. Research methods

A number of foreign scholars have conducted research on the economic nature of health insurance services, the formation of medical insurance services, opinions and comments on the history and economic content, theoretical, practical and methodological aspects.

Erlangga, D., Suhrcke, M., Ali, S., & Bloor, K. Systematically analyzed the impact of public health insurance on access to health care, financial protection, and health status in low- and middle-income countries [3]. Woolhandler, S., & Himmelstein, D. U. COVID-19 and lack of health insurance. He developed a chronicle of internal diseases [4]. Xie, Y., Valdimarsdóttir, U. A., Wang, C., Zhong, H., Gou, Q., Zheng, H., Lu, D. Health Insurance in Patients with Breast Cancer and conducted research to prevent the risk of cancer-specific death.

Political Entrepreneurs as Catalysts for Broad System Change: The Adoption of Social Health Insurance in India [5]. Kullberg, L., Blomqvist, P., & Winblad, U. Health insurance for the healthy? - Voluntary health insurance in Sweden. They have a health policy. Identified the impact of catastrophic health insurance on catastrophic health care costs for households.

According to the annual stratified norms of the compulsory health insurance system and the number of citizens attached to the medical organization, the financial resources of the medical organization must cover all the costs of the medical institution and provide quality services to the population [6].

Shishkin S.V., Sheyman I.M., Potapchik Ye.G., Ponkratova O.F. He analyzed the state of insurance medicine in Russia and the prospects for its development [7].

Roik V.D. He has conducted research on occupational accidents and temporary disability insurance. Fyodorova T.A. a two-pronged approach to the health insurance system is widespread: on the one hand, as an element of the state system of social protection, on the other hand, the financial mechanism for financing health care and providing funds for the payment of medical services [9] Kiseleva I.A. creates works aimed at solving the socially significant problem of tuberculosis among the population, optimizing the financial resources of medical enterprises, mathematical analysis and assessment of factors affecting cash flows [10,11,12]. But Kiseleva I.A. did not pay enough attention to the specifics of health financing, mathematical modeling of the processes of providing financial resources of medical organizations as integrated corporate structures and small businesses.

Shipova V.M. [13-14] develops economic mathematical methods of organizational and economic design and analysis of business in the medical field. Samoilov D.I. in his works. [15–16] have developed models for the management of medical services of polyclinic associations, but no mechanisms have been proposed for their implementation in medical organizations, taking into account the interests of medical, non-medical and administrative and managerial staff. The models did not take into account the sources of funding for organizational changes that would occur when they were introduced into daily medical practice.

Bakirov R.S., Yarullin A.X., Zaripov R.A. [17], Ivanova V.V., Bogachenko P.V. [18] and Gabueva L.A. [19], in their works, the introduction of advanced technologies of medical care using new media and systems, their application in daily medical activities, improving the quality of medical services, reducing the cost of medical care, mathematical tools and mathematical developed modeling techniques.

Yegorova N.E. [20-21] focuses on multi-level management tasks using health expert expert assessments, simulation modeling, and optimization techniques.

Ermasov S.V. and Ermasova NB considers the health insurance system as a normative-legal form of organization of insurance relations, which implies the formation of the legislative framework, the organization of state control over insurance activities, the development of self-government processes holds. Health insurance is defined as a network of voluntary health insurance that provides for the formation of trust funds at the expense of enterprises, local authorities and citizens and their use to finance medical services to the population [22].

III. Results and discussion

As one of the main tasks of the measures implemented by our government is to protect the health of the population, provide them with medical services at the level of today's requirements, and fully satisfy their demand for medical services, it is one of the important issues to develop the future forecast values of the development of medical services in Kashkadarya region, where the population is growing rapidly. remains one. Because the available statistics show that there are specific problems related to the provision of medical services in the region.

In particular, despite the fact that the provision of health services to the population of the region increased by 3.94 times and the health care costs increased by 4.61 times in 2004-2022, it is observed that the number of beds in hospitals per 10 thousand inhabitants decreased by 13 percent, and the number of doctors decreased by 17 percent. Because, during this period, the population of the region is expected to increase by 1.46 times. That is, the low rate of growth in the mentioned indicators compared to the change in the population caused these negative results. This, in turn, requires the development of measures to improve the health care system in the region, to fully satisfy the population's demand for these services (Table 1).

The interdependence of the mentioned indicators makes it necessary to evaluate their effects. The provision of health care services in the province, in turn, depends on the number and quality of service providers. In addition, the increase in the number of service providers appears as a result of changes in the amount of funds allocated to the sector. For this reason, the pairwise correlation coefficients of the cited indicators were determined based on the data of 2004-2012.

Table 1.

Important indicators of health services and the level of meeting the population's demand in Kashkadarya region

	***SSX*-Provision of health care services to the population of the region**	***SsX*-provincial health expenditure**	***See*-the number of beds in hospitals per 10,000 inhabitants of the region**	***vs*-number of vrash per 10 thousand inhabitants of the region (in units)**	***Hs*-Number of nurses per 10,000 residents of the region (in units)**	**Population of the region (Thousands of people)**	**Number of hospitals providing health care services to the population of the region (in units)**
	Y	***X1***	***X2***	***X3***	***X4***	***X5***	***X6***
2004	9.09	73.48	12.60	24.10	101.10	2378.20	104.00
2005	11.53	79.44	12.60	24.10	100.30	2419.80	102.00
2010	16.40	129.60	11.00	20.80	101.90	2671.00	84.00
2015	19.95	173.18	10.50	16.60	100.20	3025.50	57.00
2020	29,39	313.62	10.60	19.00	116.00	3335.40	88.00
2021	36,21	307.57	10.80	19.00	116.00	3408.30	88.00
2022	35.86	338.59	11.00	20.00	117.00	3482.30	89.00
Change in 2004 vs. 2022	**3.94**	**4.61**	**0.87**	**0.83**	**1.16**	**1.46**	**0.86**

Since two of these indicators, i.e. provision of health services to the population of the region and regional health care costs, are in the form of value, 2010 was taken as the base year and transferred to constant prices based on the GDP deflator (Table 2).

It was found that the provision of healthcare services to the population of the region is highly correlated with healthcare costs, that is, the correlation coefficient between both indicators is equal to 0.95, but a negative and weak correlation is observed with the number of hospitals and doctors per 10,000 inhabitants. The same situation can be observed with the number of hospitals providing health services to the population of the region. One of the main reasons for this is the rapid growth of the population in the region and the relatively low rate of growth in the healthcare system.

Table 2.

Pairwise correlation coefficients of important indicators of health in Kashkadarya region[1]

	Y	*X1*	*X2*	*X3*	*X4*	*X5*	*X6*
Y	1.00						
X1	0.95	1.00					
X2	-0.12	-0.08	1.00				
X3	-0.42	-0.45	0.48	1.00			
X4	0.76	0.82	0.39	0.06	1.00		
X5	0.90	0.94	-0.18	-0.69	0.62	1.00	
X6	-0.26	-0.21	0.55	0.84	0.28	-0.46	1.00

The provision of health services to the population of the region has a high positive correlation with the number of nurses per 10,000 people and the population. It is clear from this that taking into account the growth in the population of the region, it will be appropriate to start the training of personnel with higher education in this direction. The results of the correlational analysis cited in the general account require the reform of the health care system in the region and an increase in the volume of services in the field.

In order to determine the development indicators of the healthcare system in the region based on the existing potential, the forecast values of the mentioned indicators were developed on the basis of multivariate econometric models. The steady growth in population will further increase the demand for healthcare services in the coming years. For this reason, a trend model was developed to calculate the forecast values of the population of the region in 2023-2027, and the coefficients of the model and the criteria presented to justify its adequacy are at the required level, but the Durbin Watson statistic is equal to 0.61 (DL=1.18; DU=1, 40) justifies the existence of the autocorrelation problem.

The level of development of medical services in the region can be observed in the growth of the volume of medical services provided to the population of the region, for this reason, a suitable model was developed in order to calculate the forecast values of this indicator for the next period.

$$(1-L)Y_t = 1{,}40 + 0{,}72 * (1-L)Y_{t-1} - \varepsilon_{t-1}$$
$$t = (4{,}51)\ \ (3{,}41)\qquad (-6{,}11)\ \ R^2 = 0{,}87$$

The dynamics of changes in the volume of medical services provided to the population of the region is rather unstable and does not have a general trend (Appendix 5). For this reason, this indicator is used to calculate forecast valuesThe use of the ARIMA (1 1 1) model was deemed appropriate. According to the results of the model, each coefficient determined is adequate according to Student's criterion and their probability values are less than 0.001. Also, the identified results justify the adequacy of the developed model and its coefficients according to the existing criteria. Only the coefficient of determination is equal to 0.87, which justifies the instability in the change of this indicator. In general, the feasibility of using the developed model to determine the forecast values of this indicator was justified. According to the results of the calculations made on the basis of the model, the forecast values of the medical services provided to the population of the region in the next five years will be as follows (Table 3).

Table 3.

Forecast values of the volume of medical services provided to the residents of Kashkadarya region calculated on the basis of the ARIMA (1 1 1) model[2]

Years	Forecast values	Growth rate	Standard error	95 percent confidence interval
2023	36.25	101.1	2.92	(30.5295, 41.9736)
2024	36.93	101.9	3.60	(29.8790, 43.9785)
2025	37.81	102.4	3.90	(30.1624, 45.4571)
2026	38.84	102.7	4.05	(30.8983, 46.7767)
2027	39.97	102.9	4.13	(31.8846, 48.0569)

According to the developed forecast, the rate of increase in the volume of medical services provided to the residents of Kashkadarya region will be ensured. If the growth rate is low compared to the population growth in the initial period, it causes a general decline in the sector, while the increase in the growth rate in the later periods causes positive results in the sector. In particular, a growth rate of 2.9% by 2027 serves as the basis for improving the quality indicators of the volume of medical services provided to the population.

However, achieving the mentioned results and changing these results in a more positive direction is directly related to the attention paid to the health sector and the funds allocated to the sector. This is supported by the results of the above correlation analysis. Therefore, the increase in health care costs in the region is an important source of the positive results cited. That is, a positive change in the quantity and quality of health care services is naturally associated with costs.

Taking into account the above, we believe that it is reasonable to look at the dynamics of healthcare costs in the region in the following years. As a matter of fact, it can be seen from the data of (Table 1) that this indicator has the highest growth rate and how this trend will continue in the next years was looked at based on the developed model. According to the results of regression analysis, the following model was proposed to calculate the forecast values of

[1]Source: author development

[2]Source: author development

healthcare costs in the region. $X1_t = 236{,}94 + 1{,}98 * X1_{t-1} - 0{,}98 * X1_{t-1} - \varepsilon_{t-1}$ $t = (3{,}05)$ $(84{,}43)$ $(-69{,}31)$ $(-5{,}27)$ $R^2 = 0{,}95$

The results of Student's criterion indicate the adequacy of the coefficients of the proposed model. The coefficient of determination also has a sufficiently high value, moreover, the results of the regression analysis presented in Appendix 6 justify the adequacy of the model. Also, the MAPE indicator equal to 7.2 units shows the level of reliability of the model. This result is supported by the figure in Appendix 7, how close the model-estimated indicators are to the actual indicators. Such results justify the possibility to calculate forecast values of healthcare costs in the region based on this model (Table 4).

Table 4

Estimated values of healthcare costs in Kashkadarya region based on the ARMA (2 0 1) model[3]

Years	Forecast values	Growth rate	Standard error	95 percent confidence interval
2023	353.38	104.37	17.89	(318,324, 388,441)
2024	366.55	103.73	25.00	(317,546, 415,562)
2025	377.95	103.11	30.15	(318,867, 437,041)
2026	387.46	102.51	34,13	(320,559, 454,353)
2027	394.96	101.94	37,27	(321,909, 468,014)

The calculated forecast results provide high growth rates in the initial period, but their decrease is observed in the following years. The main reason for this is the change and instability in the existing dynamics. Because the increase of the indicator in 2019 and 2020, i.e. 33.4 and 23.9%, respectively, but a decrease in 2021, led to the violation of the trend. Naturally, the emergence of the pandemic in 2019-2020 caused a sharp increase in the costs of medical services, as a result of which the above-mentioned growth rates were achieved. However, these growth rates do not represent the natural growth rate. For this reason, the forecast results mentioned above can be called reasonable.

According to the obtained results, the total cost of health care in the region by 2027 is 394.96 billion amounts to soum. This result is 1.16 times higher than in 2022. In fact, the results of the forecast are high in the first years, but decrease in the following years, which serves to justify the proposals given above on the need to develop special programs for the development of the sector.

According to the results of the analysis, health services in the region can be said to be satisfactory, but special attention should be paid to the development of the sector. Despite the fact that the results of modeling and forecasts developed on the basis of them show that the development of the industry based on current trends can achieve positive results in the next years, it is difficult to say that they are at the level of demand. Because, the increase of the population by 9.5%, health services provided to the population of the region by 11.4%, and health care costs by 16.6% can be considered satisfactory.

IV. Conclusion

In conclusion, a separate econometric modeling of each sector of the health care sector is appropriate. Because the development of one service sector has a positive impact on the development of another. Therefore, the use of econometric models in the form of a system of interconnected equations is of particular importance in the development of service networks. In addition, the organizational-economic mechanism of development of service networks is a hierarchical system of interconnected elements and groups (subjects, objects, principles, forms, methods and tools) at different levels. expresses, in addition, their interactions, innovative infrastructure, forming relationships with market entities.

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Artificial Immune System Based Email Spam Filtering Algorithm

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***Abstract* — Email has become a prevalent communication method for businesses, resulting in a rise in cyber threats and spam emails. This paper provides an overview of various spam filtering techniques and highlights the importance of robust anti-spam measures. In addition, investigated a method for spam filtering based on the Artificial Immune System (AIS).**

***Keywords* — spam filtering, rule-based filtering, content-based filtering, artificial immune system.**

I. Introduction

In recent years, email has gradually become one of the main communication methods for business purposes due to its convenience, speed, and affordability. Cyber threats are growing in parallel with the continuous increase in the number of email users each year.

Spam emails remain a major vector for the dissemination of malicious software. While some spam emails are promotional in nature and lack clear malicious intent, they can also be utilized for various forms of attacks. As a result, recipients of such emails should exercise caution when opening electronic messages and take measures to minimize the quantity of spam they receive in their inboxes. Numerous anti-spam measures have been created and extensively implemented to combat the issue of spam.

II. Spam Filtering Methods

Spam filters used in email systems play a crucial role in mitigating the impact of spam emails. Spam filters identify unwanted emails by analyzes the email header or their characteristic content. Currently, there are two main types of spam filtering methods:

1) Rule-based filtering is another effective method used in spam filtering, which includes several subcategories such as header analysis, mass mailing filtering, and keyword exact matching. Rule-based filtering involves several techniques, such as header analysis, mass mailing filtering, and keyword exact matching.

A. Header Analysis

Rule-based filters analyze the headers of incoming emails to identify suspicious patterns or characteristics commonly associated with spam. This can include checking for anomalies in the sender's address, the originating IP address, or inconsistencies in the email routing information.

B. Mass Mailing Filtering

This technique focuses on identifying emails sent in large quantities to a large number of recipients. Spam emails are often sent as mass mailings, targeting a wide audience. Rule-based filters can detect such patterns by analyzing the number of recipients, the frequency of sending, or specific headers indicating bulk mailings [1].

C. Keyword Exact Matching

Rule-based filters can be configured to perform exact matching of specific keywords or phrases associated with spam. These filters compare the content of the email, including subject lines, body text, or attachments, against a predefined list of spam-related keywords. If a match is found, the email is flagged as spam.

These techniques help identify and block spam based on predefined rules and patterns. Although these methods are more efficient, the disadvantage is that the rules need to be manually created and maintained by the user, which involves more human factors and has higher requirements for users.

2) Content-based filtering is one of the commonly used methods to identify and filter spam emails. Several techniques are employed in content-based filtering, including:

A. Keyword Matching

This method involves checking the presence of specific keywords or phrases commonly associated with spam in the email's subject line, body, or headers. If a significant number of spam-related keywords are detected, the email is flagged as spam.

B. Bayesian Filtering

Bayesian filtering uses statistical algorithms to analyze the probability of an email being spam based on the occurrence of certain words or patterns. It calculates the likelihood that an email is spam or legitimate by comparing it to a pre-existing database of known spam and non-spam emails [2].

C. Machine Learning

Machine learning algorithms can be trained to recognize patterns and characteristics of spam emails. By analyzing a large dataset of labeled emails, these algorithms can learn to classify new incoming emails as either spam or non-spam based on the identified patterns [3].

D. Heuristic Analysis

Heuristic analysis involves applying a set of predefined rules or patterns to determine whether an email is spam. These rules can include factors such as excessive use of capital letters, multiple exclamation marks, or suspicious attachments [4].

E. Sender Reputation

Evaluating the reputation of the email sender can be an effective way to identify spam. Reputation-based filtering relies on databases that maintain records of known spammers and assign scores or ratings to senders based on their past behavior.

F. Image Analysis

Since spammers often use images to bypass text-based filters, image analysis techniques can be employed to detect and classify spam emails that primarily consist of images with little or no text content [5].

It's important to note that content-based filtering methods are not foolproof and may occasionally result in false positives or false negatives. Therefore, a combination of different anti-spam measures and continuous updates to adapt to evolving spam techniques is crucial for effective spam prevention.

The task of spam filtering is indeed a persistent problem, as spammers continuously adapt their techniques to evade existing spam protection measures. This ongoing challenge necessitates a reevaluation of spam filtering approaches. In recent years, extensive research has been conducted on various methods of spam filtering, resulting in advancements in accuracy and ongoing investigations.

As a potential solution to this problem, artificial immune systems have been proposed for use in spam detection and filtering.

Email spam filtering based on artificial immune systems is an innovative approach that draws inspiration from the human immune system to detect and filter unwanted emails. Artificial immune systems (AIS) simulate the behavior and mechanisms of the biological immune system to identify and respond to threats.

III. Artificial Immune System for E-mail Classification

Artificial Immune System for E-mail Classification (AISEC) follows the following steps:

- Gene Extraction - it extracts gene fragments from the spam sample library and then added to the gene libraries.
- Immature Antibody Formation - genes are randomly selected from the gene library to form an initial immature antibody.
- Immune Tolerance and Evolution - the immature antibody undergoes immune tolerance with the autologous library, evolving it into a mature antibody. This process involves interactions and adjustments to enhance the antibody's effectiveness.
- Sorting and Library Update - when new mail arrives, it is sorted according to the classification result. The antibody library is updated based on this sorting outcome, integrating new information.
- User Feedback - the user feedback module validates the correctness of the classification. Correctly classified antibodies participate in extending their life cycle and may undergo mutation for further improvement. Incorrectly classified antibodies are removed from the antibody collection.

The AISEC algorithm has some shortcomings, including the following:

- It does not consider the Mutual Information (MI) of words and their impact on email classification. Different words contribute differently to the classification, with some words having a significant impact while others being neutral or less influential. Without considering a statistical measure to extract features, randomly including these words in the autologous library or gene library leads to excessively large libraries, reducing matching efficiency.
- It does not consider the frequency of words and its impact on system performance. Words appear with different frequencies in emails, and highly frequent words are more representative. AISEC algorithm does not adequately utilize word frequency information and does not prioritize matching highly frequent words during email detection, which may lower system efficiency.
- The updating of the autologous and gene libraries lacks quantitative criteria. The algorithm extends the lifespan of antibodies involved in correct classifications while deleting all antibodies involved in incorrect classifications. However, this antibody update strategy lacks quantitative criteria and does not consider the quality and performance differences among antibodies. A more reasonable update strategy should evaluate and adjust based on antibody quality, classification accuracy, and other metrics [6].

In summary, the AISEC algorithm has some shortcomings in considering word contribution differences, utilizing word frequency information, and the antibody update strategy. Improving these aspects can enhance the algorithm's performance and effectiveness.

IV. Artificial Immune Spam Filtering Algorithm

Suggestions for enhancing the AISEC algorithm are as follows:

A. Enhanced Feature Selection using Mutual Information (MI):

- Incorporate Mutual Information (MI) as an additional attribute for each autosomal and gene fragment.
- During the creation of new autosomal libraries and detectors, calculate MI to choose relevant feature words for composing these libraries.

This approach aids in better feature selection and contributes to the control of the size of autosomal and gene libraries.

B. Word Frequency Analysis:

- After segmenting words, compute the word frequency for each word.
- Integrate word frequency information into the autosomal and gene libraries, as well as the detectors.
- When performing email detection, prioritize matching words with higher word frequencies.

This strategy enhances system efficiency by focusing on frequently occurring words.

C. Improved Autosomal and Gene Pool Management:

- Enhance the strategy for updating autosomal and gene pools.
- When users collaborate and provide confirmation, introduce penalties to adjust word frequencies in the autosomal and gene pools.

This adaptation mitigates the likelihood of recurring errors and promotes higher accuracy in subsequent iterations.

The training module generates the autologous library, gene pool, and detectors by preprocessing the samples, calculating word frequencies, performing tolerance processes based on mutual information, and evolving and cloning detectors based on their performance.

Initialization: for each word, calculate the average mutual information between the word and the category.

$$I_{avg}(W, C_j) = \sum_{j=1}^{|c|} P(C_j)\, I(W, C_j) = \sum_{j=1}^{|c|} P(C_j) \log\left(\frac{P(W|C_j)}{P(W)}\right) \quad (1)$$

Where:

- $P(C_j)$ - the probability of the j-th class document appearing in all texts;
- $P(W)$ - the probability of word W appearing in all texts;
- $P(W|C_j)$ - the probability of word W appearing in class C_j.

When the feature item W is independent of the class C_j, its correlation with that class is 0, that is, the average mutual information is 0. When $P(W)$ is smaller and $P(W|C_j)$ is larger, it indicates that the feature item has a high probability of appearing in this class, and the mutual information between the word and the class is also larger. On the contrary, when $P(W)$ is larger and at the same time $P(W|C_j)$ is smaller, the mutual information value is negative, indicating that this feature is less likely to appear in this class but more likely to appear in other classes. In this case, the significance of this feature item for classification is also substantial. Therefore, to improve Equation (1), the improved formula is:

$$I_{avg}(W, C_j) = \sum_{j=1}^{|c|} P(C_j)\, I(W, C_j) = \sum_{j=1}^{|c|} P(C_j) \log\left|\frac{P(W|C_j)}{P(W)}\right| \quad (2)$$

In Equation (2), when evaluating each feature item, only the weighted contribution of that feature item to each class is taken into account, without considering the relative information provided by it to different classes. Considering that the email processing system can only categorize emails into two classes, if a certain feature item provides significantly more information to class C_j than to other classes, it implies that the word has a strong discriminatory ability for class C_j and should be included in the selected feature subset. Therefore, the mutual information difference is used as the evaluation function.

$$difference(W) = \left|\log\left|\frac{P(W|C_1)}{P(W)}\right| - \log\left|\frac{P(W|C_2)}{P(W)}\right|\right| \quad (3)$$

Using the improved mutual information calculation in Equation (3), a threshold is set, and words greater than this threshold are considered as feature values. Here, the threshold is set to 0.3 (the threshold selection is related to the training samples) [7].

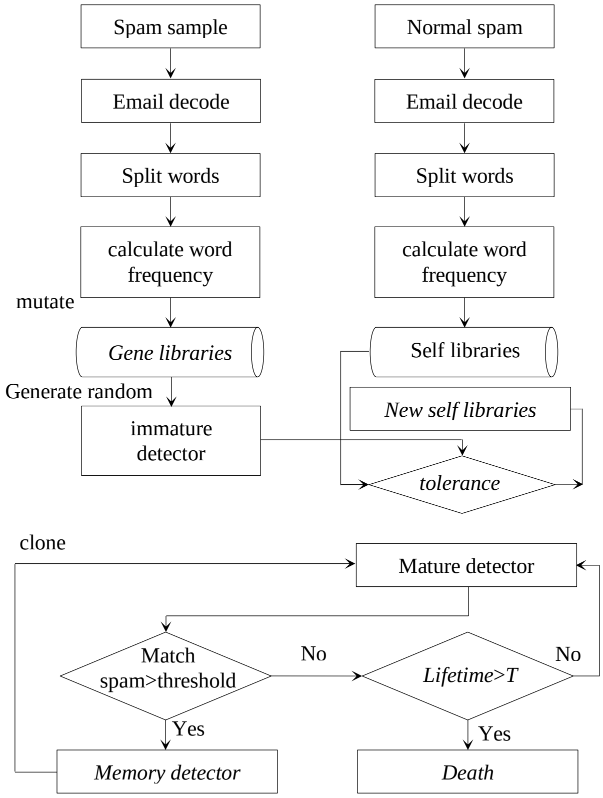

Fig. 1: The generation of self libraries and detector algorithm

False positive refers to mistakenly classifying normal emails as spam. Generally, the harm caused by false positives is greater than that caused by false negatives. The processing of spam email alert signals is accomplished under the influence of user collaborative stimulation signals. The user collaborative confirmation mechanism emulates the principles of T cells in the biological immune system, thereby enhancing the system's detection performance. When an email is collaboratively confirmed by the user and a false positive is detected, to prevent the recurrence of false positives, the increase value of the word frequency in the autosome library is set as follows: the word frequency of that word appearing in this email × weight; the decrease value of the word frequency in the gene library is set as follows: the word frequency of that word appearing in this email × weight.

Training a model on diverse datasets is a common practice, especially for tasks like email spam classification. By using both ham and spam datasets, the model can learn to distinguish between legitimate and unwanted emails. This approach allows the model to develop a comprehensive understanding of the features and patterns associated with different types of emails.

A total of 50,409 emails, sourced from a subset of the Enron email corpus, were employed for both training and testing objectives. Among these, 33,792 emails, equivalent to just under 66% of the dataset, were designated for training purposes. The remaining 17,157 emails, which constitute slightly over 34%, were reserved for evaluation within the test dataset. The table below summarizes the performance result of methods.

TABLE I. PERFORMANCE COMPARISON OF DIFFERENT ALGORITHMS

Algorithm	Recall rate	Precision rate	Accuracy rate
Naïve Bayes	79,6	97,9	90,3
Artificial neural networks	81,3	91,1	88,3
AISEC	81,2	98,5	91,2

V. CONCLUSION

In conclusion, spam filtering remains an ever-important aspect of email security. As technologies evolve, the battle between spammers and defenders continues. We describe the steps of AISEC algorithm in detail and conduct test experiments based on enron corpus, which show that AISEC algorithm outperforms ANN algorithm and Nave Bayesian classification algorithm in spam filtering. The AISEC algorithm, with its unique approach, holds potential in bolstering spam filtering capabilities. However, further research and development are necessary to fully harness its benefits. By combining the strengths of various filtering methods and constantly adapting to new challenges, a comprehensive and effective solution can be achieved in the fight against spam.

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MATHEMATICAL MODELING OF MAGNETOELASTIC OSCILLATIONS OF A CURRENT-CONDUCTING MICROELEMENT IN A MAGNETIC FIELD

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Abstract— **In all deformable and resting media, depending on their electromagnetic properties, more or less strong influences of the electromagnetic field on the motion and macroscopic state of the media and the reverse effect of the motion of the media on electromagnetic fields are observed. When creating a number of technical devices, modern structural materials, it is necessary to take into account the effects caused by the interaction of electromagnetic and temperature fields with mechanical fields. A conductive flexible annular plate under the influence of a time-varying mechanical force and a time-varying external electric current, taking into account anisotropic electrical conductivity, is mathematically simulated in the article. The effect of an external magnetic field on the stress state of an annular plate is studied.**

Keywords—plate, magnetic field, magneto elasticity.

INTRODUCTION

The objects that implement the macro-interaction of the electromagnetic field and the medium are the electric charges of the medium and the currents passing in it, and therefore the interactions are significantly different in the media - conductors, semiconductors and dielectrics. Solid electrical materials can have different structures - crystalline, amorphous, and composite.

Crystals are characterized by strict repetition of identical spatial cells and periodicity of the electrostatic field. Crystals are an example of purity and order in the world of atoms; they differ in the shape of spatial lattices and have different types of symmetry. Single crystals have anisotropy; their reactions to electrical, magnetic, light, mechanical and other influences depend on the direction of these influences relative to the crystallographic planes and axes of the crystal.

Single crystals are distinguished by a more perfect structure, they are the most studied ones, the physical phenomena occurring in them are easily calculated; they provide greater reliability and identity of the parameters of semiconductor devices.

In magnetic semiconductors, the processes of generation of charge carriers and the passage of electric current depend on the direction and value of the magnetic field induction. Metallic magnetic materials conduct electricity. In alternating fields, eddy currents arise in them, which increase with increasing frequency, therefore, the frequency range of their use is limited to direct current devices, as well as industrial and audio frequency currents.

Microminiaturization of electronic devices is a powerful stimulus for the development of nanotechnology, and microelectronics is turning into nanoelectronics before our very eyes.

The direction of technology, which arose on the basis of the synthesis of modern microelectronics, integral magnetically sensitive elements (magnetic field transducers), precision engineering and micro-technologies, can be called micromagnetoelectronics.

Micromagnetoelectronics is the basis for the development and production of modern magneto-electronic devices. This direction makes it possible to implement high parameters of magnetically sensitive elements in equipment, expand the functions of a magnetic field converter, and also successfully solve the problems of micro-miniaturization of magnetoelectronic devices and equipment, increase their reliability, reduce dimensions, mass of power consumption and reduce costs.

In recent decades, considerable attention in the literature has been paid to the study of the process of deformation of electrically conductive bodies placed in an external alternating magnetic field under the influence of non-stationary force, thermal and electromagnetic loads [1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16,17,18,19, 20,21,22,23].

Interest in research in this area is associated with the importance of quantitative studying and evaluating the observed effects of the relationship of non-stationary mechanical, thermal and electromagnetic processes and their practical application in various fields of modern technology in the development of new technologies, in the field of nanotechnology and microelectronics, and in modern measuring systems, etc.

I. BASIC MAGNETOELASTIC EQUATIONS.

Based on the ratios of magnetoelasticity of current-carrying bodies [3] and using the ratios of nonlinear elasticity, as well as

Ohm's law and Maxwell's equations, the basic equations of a constructive conductive microelement of the plate type can be obtained as follows:

Magnetoelastic kinetic equations:

$$\frac{\partial (rN_r)}{\partial r} - N_\theta + r\,(F_r + \rho\,F_r^{\wedge}) = r\rho h\frac{\partial^2 u}{\partial t^2};$$

$$\frac{\partial (rQ_r)}{\partial r} + r\,(F_z + \rho\,F_z^{\wedge}) = r\rho h\frac{\partial^2 w}{\partial t^2}; \qquad (1)$$

$$\frac{\partial (rM_r)}{\partial r} - M_\theta - rQ_r - r\,N_r\vartheta_r = 0.$$

Equations of electrodynamics:

$$-\frac{\partial B_z}{\partial t} = \frac{1}{r}\frac{\partial (rE_r)}{\partial r};$$

$$\sigma_2\left[E_\theta + 0{,}5\frac{\partial w}{\partial t}(B_r^+ + B_r^-) - \frac{\partial u}{\partial t}B_z\right] =$$

$$-\frac{\partial H_z}{\partial t} + \frac{H_r^+ - H_r^-}{h}. \qquad (2)$$

Expressions for deformations:

$$\varepsilon_r = \frac{\partial u}{\partial r} + \frac{1}{2}\vartheta_r^2;\ \ \varepsilon_\theta = \frac{u}{r};\ \ \chi_r = \frac{\partial \vartheta_r}{\partial r};\ \ \chi_\theta = \frac{1}{r}\vartheta_\theta. \ (3)$$

where, $\vartheta_r = \partial w/\partial r$ is the angle of rotation of the normal;

Elasticity ratio:

$$N_r = \frac{e_r h}{1-\nu_r\nu_\theta}(\varepsilon_r + \nu_\theta\varepsilon_\theta);\ N_\theta = \frac{e_\theta h}{1-\nu_r\nu_\theta}(\varepsilon_\theta + \nu_r\varepsilon_r);$$

$$M_r = \frac{e_r h^3}{12(1-\nu_r\nu_\theta)}(\chi_r + \nu_\theta\chi_\theta); \qquad (4)$$

$$M_\theta = \frac{e_\theta h^3}{12(1-\nu_r\nu_\theta)}(\chi_\theta + \nu_r\chi_r).$$

In equations (1)–(4) the following parameters are accepted: $\nu_r = \nu_{\theta r}$, $\nu_\theta = \nu_{r\theta}$, $e_r\nu_\theta = e_\theta\nu_r$; ν_r, ν_θ – Poisson's ratios; e_r, e_θ – Young's modulus; u, w – displacements; N_r, N_θ – tangential forces; M_r, M_θ – bending moments; Q_r – generalized cutting force; χ_r, χ_θ – the main curvatures of the middle surface of the plate; N_r, $B_r^{\pm}$ – known values of the tangential components of magnetic induction on the surfaces of the plate.

The expressions for the Lorentz force have the form

$$\rho\,F_r^{\wedge} = \sigma_1 h\left[E_\theta B_z - \frac{\partial u}{\partial t}B_z^2 + 0{,}5\frac{\partial w}{\partial t}(B_r^+ + B_r^-)B_z\right];$$

$$\rho\,F_z^{\wedge} = -\sigma_2 h\left[\ 0{,}5E_\theta(B_r^+ + B_r^-) - 0{,}25\frac{\partial w}{\partial t}(B_r^+ + B_r^-)^2 - \right.$$

$$\left. + \frac{1}{12}\frac{\partial w}{\partial t}(B_r^+ - B_r^-)^2 - 0{,}5\frac{\partial u}{\partial t}(B_r^+ + B_r^-)B_z\right]. \qquad (5)$$

II. METHODS FOR SOLVING A COUPLED PROBLEM

The developed methods for the numerical solution of coupled problems of magnetoelasticity of plates are based on the consistent application of the Newmark finite difference scheme, the linearization method and discrete orthogonalization [2-6,9, 22-23].

Let us write the resolving system of equations of magnetoelasticity of a current-carrying microelement of the plate type in the following form:

$$\frac{\partial u}{\partial r} = \frac{1-\nu_r\nu_\theta}{e_r h}N_r - \frac{\nu_\theta}{r}u - 0{,}5\vartheta_r^2;\ \frac{\partial w}{\partial r} = -\vartheta_r;$$

$$\frac{\partial \vartheta_r}{\partial r} = \frac{12(1-\nu_r\nu_\theta)}{e_r h^3}M_r - \frac{\nu_\theta}{r}\vartheta_r$$

$$\frac{\partial \vartheta_r}{\partial r} = \frac{12(1-\nu_r\nu_\theta)}{e_r h^3}M_r - \frac{\nu_\theta}{r}\vartheta_r -$$

$$-\left(F_r + \sigma_1 h\left[E_\theta B_z - \frac{\partial u}{\partial t}B_z^2 + 0{,}5\frac{\partial w}{\partial t}(B_r^+ + B_r^-)B_z\right]\right) +$$

$$+\rho h\frac{\partial^2 u}{\partial t^2};$$

$$\frac{\partial Q_r}{\partial r} = -\frac{1}{r}Q_r - \Big(F_z - \sigma_2 h\,\Big[0{,}5E_\theta(B_r^+ + B_r^-) -$$

$$-0{,}25\frac{\partial w}{\partial t}(B_r^+ + B_r^-)^2 + \frac{1}{12}\frac{\partial w}{\partial t}(B_r^+ - B_r^-)^2 -$$

$$\left.\left. -0{,}5\frac{\partial u}{\partial t}(B_r^+ + B_r^-)^2 B_z\right]\right) + \rho h\frac{\partial^2 w}{\partial t^2}; \qquad (6)$$

$$\frac{\partial M_r}{\partial r} = \frac{1}{r}(\nu_\theta - 1)M_r + \frac{e_\theta h^3}{12r^2}\vartheta_r + Q_r + N_r\vartheta_r;$$

$$\frac{\partial B_z}{\partial r} = -\sigma_2\mu\left[E_\theta + 0{,}5\frac{\partial w}{\partial t}(B_r^+ + B_r^-) - \frac{\partial u}{\partial t}B_z\right] +$$

$$+\frac{B_r^+ - B_r^-}{h};\ \frac{\partial E_\theta}{\partial r} = -\frac{\partial B_z}{\partial t} - \frac{1}{r}E_\theta.$$

Applying Newmark and quasi-linearization methods to the resolving system (6), we obtain the following systems of magnetoelasticity of a thin microelement:

$$\frac{du^{(k+1)}}{dr} = \frac{1-\nu_r\nu_\theta}{e_r h}N_r^{(k+1)} - \frac{\nu_\theta}{r}u_r^{(k+1)} + 0{,}5(\vartheta_r^{(k)})^2 - \vartheta_r^{(k+1)}\vartheta_r^{(k)},$$

$$\frac{dw^{(k+1)}}{dr} = -\vartheta_r^{(k+1)},\ \frac{d\vartheta_r^{(k+1)}}{dr} = \frac{12(1-\nu_r\nu_\theta)}{e_r h^3}M_r^{(k+1)} - \frac{\nu_\theta}{r}\vartheta_r^{(k+1)},$$

$$\frac{dN_r^{(k+1)}}{dr} = \frac{1}{r}\left[(\nu_\theta - 1)N_r^{(k+1)} + \frac{e_\theta h}{r}u^{(k+1)}\right] - P_r^{(k+1)} - h\,J_{\theta cm}B_z^{(k+1)} -$$

$$-\sigma_1 h\Big[-E_\theta^{(k)}B_z^{(k)} + E_\theta^{(k+1)}B_z^{(k)} + E_\theta^{(k)}B_z^{(k+1)} - 0.5\Big(-\frac{\partial w^{(k)}}{\partial t}B_z^{(k)} + \frac{\partial w^{(k+1)}}{\partial t}B_z^{(k)} +$$

$$+\frac{\partial w^{(k)}}{\partial t}B_z^{(k+1)}\Big)(B_r^+ + B_r^-) - 2\frac{\partial u^{(k)}}{\partial t}(B_z^{(k)})^2 + \frac{\partial u^{(k+1)}}{\partial t}(B_z^{(k)})^2 +$$

$$+2\frac{\partial u^{(k)}}{\partial t}B_z^{(k+1)}B_z^{(k)}\Big] + \rho h\frac{\partial^2 u^{(k+1)}}{\partial t^2},$$

$$\frac{dQ_r^{(k+1)}}{dr} = -\frac{1}{r}Q_r^{(k+1)} - P_z^{(k+1)} - 0.5hJ_{\theta cm}(B_r^+ + B_r^-) -$$

$$-\sigma_2 h[0.5E_\theta^{(k+1)}(B_r^+ + B_r^-) + 0.25\frac{\partial w^{(k+1)}}{\partial t}(B_r^+ + B_r^-)^2 -$$

$$+\frac{1}{12}\frac{\partial w^{(k+1)}}{\partial t}(B_r^+ - B_r^-)^2 - 0.5(-\frac{\partial u^{(k)}}{\partial t}B_z^{(k)} +$$

$$+\frac{\partial u^{(k+1)}}{\partial t}B_z^{(k)} + \frac{\partial u^{(k)}}{\partial t}B_z^{(k+1)})(B_r^+ + B_r^-)] + \rho h\frac{\partial^2 w^{(k+1)}}{\partial t^2}, \quad (7)$$

$$\frac{dM_r^{(k+1)}}{dr} = \frac{1}{r}\left[(\nu_\theta - 1)M_r^{(k+1)} + \frac{e_\theta h^3}{12r}\vartheta_r^{(k+1)}\right] +$$

$$+N_r^{(k+1)}\vartheta_r^{(k)} + N_r^{(k)}\vartheta_r^{(k+1)} - N_r^{(k)}\vartheta_r^{(k)} + Q_r^{(k+1)},$$

$$\frac{dB_z^{(k+1)}}{dr} = -\sigma_2\mu\left[E_\theta^{(k+1)} + 0{,}5(B_r^+ + B_r^-)\frac{\partial w^{(k+1)}}{\partial t} -\right.$$

$$\left. - B_z^{(k)}\frac{\partial u^{(k+1)}}{\partial t} - B_z^{(k+1)}\frac{\partial u^{(k)}}{\partial t} + B_z^{(k)}\frac{\partial u^{(k)}}{\partial t}\right] -$$

$$+\frac{B_r^+ - B_r^-}{h}, \quad \frac{dE_\theta^{(k+1)}}{dr} = -\frac{\partial B_z^{(k+1)}}{\partial t} - \frac{1}{r}E_\theta^{(k+1)}, \quad (k = 0,1,2\ldots).$$

At the last stage, the magnetoelastic problem of the plate is solved by the discrete orthogonalization method.

III. ANALYSIS OF ELECTROMAGNETIC EFFECTS

Consider the nonlinear behavior of an annular boron aluminum plate of variable thickness, changing in the meridional direction according to the following law $h = 5\cdot10^{-4}(1-\gamma r^2/r_0)\ m$. We assume that the plate is under the influence of mechanical force $P_\zeta = 5\cdot10^3 \sin\omega t\ N/m^2$, external electric current $J_{\theta CT} = 3\cdot10^7 \sin\omega t\ A/m^2$, and external magnetic field $B_{S0} = 0.1\ T$, and that the plate is elastic orthotropic and has a finite orthotropic electrical conductivity $\sigma(\sigma_1, \sigma_2, \sigma_3)$.

Let the problem of magnetostatics for the unperturbed state be solved, that is, the magnetic induction vectors of the initial state for the outer and inner regions are known.

We assume that the external electric current in the unperturbed state is uniformly distributed over the plate, i.e. the external current density does not depend on the coordinates. In this case, the plate is subjected to a combined loading consisting of the Lorentz ponderomotive force and mechanical force.

Let us study the effect of an external magnetic field on the stress state of an annular plate.

The boundary conditions are

$s = r_0 = 0: u = 0,\ w = 0,\ \vartheta_r = 0,\ B_z = 0.5\sin\omega t;$

$s = r_N = 0.0009\,m:\ N_r = 0,\ Q_r = -100,\ M_r = 0,\ E_\theta = 0.$

The initial conditions are

$\vec{N}(s,t)\big|_{t=0} = 0, \quad \dot{u}(s,t)\big|_{t=0} = 0, \quad \dot{w}(s,t)\big|_{t=0} = 0$

The parameters of the plate and the material are:

$r_0 = 0.005\ m;\ r_1 = 0.009\ m;\ h = 5\cdot10^{-4}(1-\gamma r^2/r_0)m;\ \gamma = 0.7,$

$\sigma_1 = 0.454\cdot10^8\ (\Omega\times m)^{-1},\ \sigma_2 = 0.200\cdot10^8\ (\Omega\times m)^{-1},\ \nu_r = 0.262;$

$\nu_\theta = 0.320;\ e_r = 22.9\cdot10^{10}\ N/m^2;\ e_\theta = 10.7\cdot10^{10}\ N/m^2;$

$\omega = 314.16\ \sec^{-1};\ P_z = 5\cdot10^3 \sin\ \omega t\ H/м^2;\ P_r = 0;$

$\tau = 1\cdot10^{-2}\ \sec;\ \mu = 1.256\cdot10^{-6}\ H/м;\ \rho = 2600\ kg/m^3;$

$J_{\theta CT} = 3\cdot10^7 \sin\ \omega t\ A/m^2;\ B_r^\pm = 0.5Tл;$

$B_{r0} = 0.5\sin\ \omega t;\ \Delta t = 1\cdot10^{-3}\ \sec;\ 0 \le t \le 1\cdot10^{-2}\ \sec.$

The solution to the problem is determined over time interval $\tau = 10^{-2}\sec$, the integration step over time is taken as $\Delta t = 1\cdot10^{-3}\sec$ at one hundred points of integration over the length of the shell. The maximum values are obtained at time step $t = 5\cdot10^{-3}\sec$. Fig. 1 shows graphs of the change in time of the normal component of the Lorentz force $F_r^\wedge(t)$ for three values of magnetic induction. Graphs $1\div3$ correspond to magnetic induction 1. $B_{z0} = 0.1$; 2. $B_{z0} = 0.2$; 3. $B_{z0} = 0.5$, respectively.

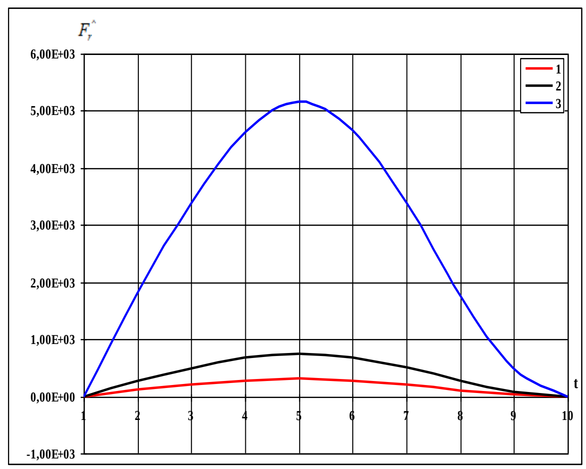

Fig 1. Graphs of changes in time of the normal component of the Lorentz force $F_r^\wedge(t)$ for the values of the normal component of external magnetic induction.

In the figures below, the graphs (1, 2, 3, 4, 5) correspond to the following options of change in the external electric current: 1 . $J_{\theta CT} = 5\cdot10^5\sin\omega t$; 2. $J_{\theta CT} = 5\cdot10^7\sin\omega t$; 3. $J_{\theta CT} = -5\cdot10^7\sin\omega t$; 4. $J_{\theta CT} = -8\cdot10^7\sin\omega t$; 5. $J_{\theta CT} = -1\cdot10^8\sin\omega t$.

Fig. 2. shows the distribution of the maximum values of stresses in the plate depending on time for all options of change in the external electric current $J_{\theta CT}$.

From Fig. 2 it follows that an increase in the value of the external electric current leads to an increase in the values of stresses in the plate and their maximum values occur in the vicinity of point $r = 0.004\,m$ at $t = 5\cdot10^{-3}\sec$.

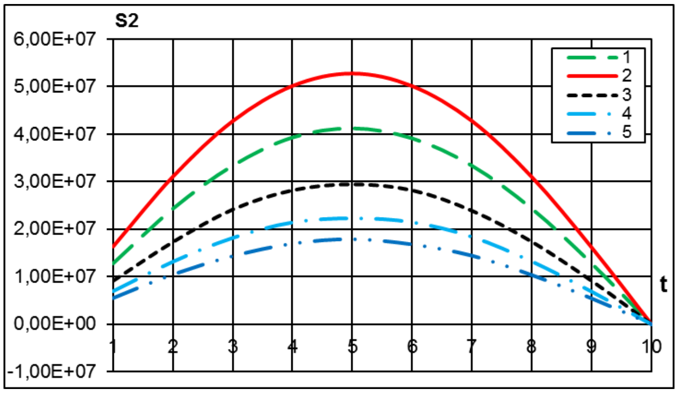

Fig. 2. Stress distribution in the plate depending on time for all options of changes in external electric current $J_{\theta CT}$.

Fig. 3 shows the change in magnetic induction B_{ς} depending on time for all options of change in the external electric current $J_{\theta CT}$.

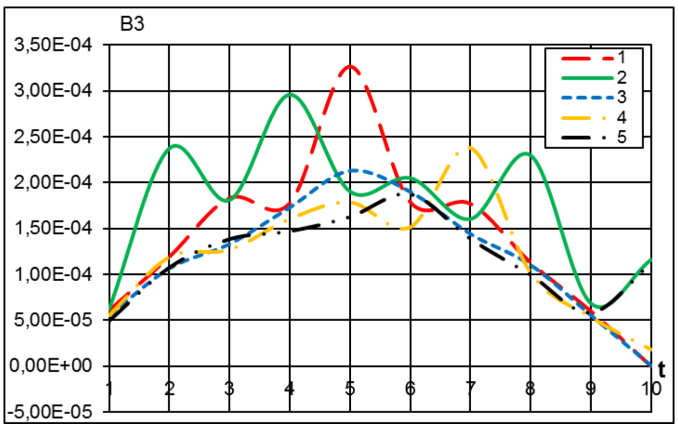

Fig. 3. Change in magnetic induction depending on time for all options of change in external electric current $J_{\theta CT}$

As seen from the figures, with an increase in the values of external electric current, the values of stresses in the shell and magnetic induction increase.

Analyzing the numerical results obtained, it can be seen that with an increase in the values of the normal component of external magnetic induction, the Lorentz force increases.

It was found that with an increase in the value of external magnetic induction, the stresses on the outer surface of the plate change depending on the change in the direction of the Lorentz ponderomotive force and the interaction with the mechanical load.

IV. CONCLUSION

The article deals with the coupled problem of magnetoelasticity for a flexible orthotropic conductive annular plate taking into account the anisotropy of the conductive properties. A solution was obtained for the nonlinear problem of magnetoelasticity of an annular plate taking into account anisotropic electrical conductivity.

The analysis of the results obtained allows us to evaluate the influence of the normal components of magnetic induction on the stress state of a flexible orthotropic annular plate. Based on the results presented, the magnetoelastic nonlinear problem for a conductive annular plate must be considered in a coupled form.

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The Usage of Fractal Antennas in Wireless Communication Systems

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***Abstract*—This article discusses the possibility of using fractal antennas in wireless communication systems, particularly in 4G - 6G mobile communication systems. The main advantages of using fractal antennas, such as miniaturization, broadband, multiband and others, are considered. Fractals are complex geometric structures that have self-similarity at different scales, and they can be used to improve the characteristics of antennas. An overview of the use of fractal antennas in mobile systems, as well as MIMO patch antenna models in the Ansys HFSS microwave device modeling program are presented.**

Keywords*—*wireless, antenna, fractal, 5G, IoT, Wi-Fi, S11, VSWR, Zhanabayev fractal

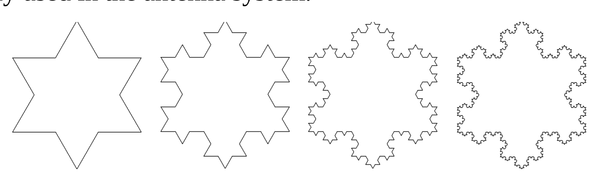
I. Introduction

Currently, in the modern world, the telecommunications services market is experiencing a rapid growth in the development of wireless communication technologies. Wireless technologies are being actively introduced into our daily lives and allow users to stay connected anywhere and anytime. Mobile communication networks, Wi-Fi access points and local wireless networks have become indispensable tools for work, education and entertainment. The Internet of Things (IoT) and Machine-to-Machine Communication (M2M) networks are actively developing. Millions of devices can be connected to a single network without the need for wired infrastructure, which allows for better control, monitoring and management of various aspects of daily life.

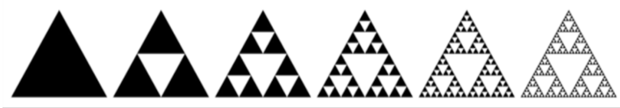
Another, not unimportant advantage of wireless technologies is the provision of communication in remote and hard-to-reach places using satellite communication lines. Starlink and OneWeb are the most well-known projects for providing high-speed Internet in remote or hard-to-reach areas where the deployment of wired infrastructure is difficult or expensive [1, 2]. In addition, with the help of low-orbit small spacecraft, it is possible to perform the functions and tasks of radio monitoring the use of the radio frequency spectrum, which is a limited natural resource [3]

Mobile telecommunications technologies are currently actively developing and undergoing significant innovations. The main direction of mobile technology development is the fifth-generation 5G networks and the further transition to 6G. 5G provides users with higher data transfer speeds, low latency and the ability to connect a large number of devices simultaneously. In turn, this expands the possibilities for high-resolution video streaming, interactive games, virtual and augmented reality (AR/VR), IoT and many other applications [4-6].

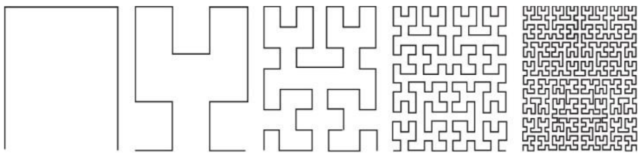
It is worth noting that with the development of wireless technologies, antenna systems have also largely changed. The antenna is an integral and mandatory element in wireless communication. The role of the antenna is very important and the efficiency of transmitting and receiving information between subscribers largely depends on its parameters. To date, there are a diverse number of antennas used in wireless communications. However, one of the main requirements for modern antennas is miniaturization (compactness), multi-band and broadband. Fractal antennas largely satisfy these requirements. Fractal antennas are a relatively new class of antennas [7]. The principle of fractal antennas is based on the use of fractal geometry and the property of self-similarity, suggesting a similar division of the curve or similar segments of the figure of the active part of the antenna. Due to this property, fractal antennas are used in mobile, satellite communication systems and can be used to improve antenna characteristics [8]. There are a large number of types of fractals. Figure 1 shows such fractals as: Koch snowflake, Sierpinski triangle, Peano curve, which are the most widely used in the antenna system.



a) Koch 's Snowflake



b) The Serpinsky Triangle



c) Peano curve

Fig. 1. Types of fractals

For example, the Sierpinski triangle fractal (Fig.1 b) is constructed by dividing the triangle by the middle lines into four similar triangles. Next, the angular triangles are divided recursively, excluding the central one.

II. FRACTAL STRUCTURES IN MOBILE COMMUNICATIONS

As mentioned above, one of the widely used areas of use of fractal antennas are mobile communication systems. The main stages of design and development of various fractal antennas for mobile communication systems of the fourth and fifth generations (4G and 5G) are presented in [9-13].

For example, in [9], the authors describe the development of a fractal antenna with a hexagonal geometry. The antenna resonates at frequencies of 2.6 GHz (LTE), 3.6 GHz (less than 6 GHz 5G) and 5.25 GHz (LTE-U) and is suitable for use in mobile communication systems of the fourth and fifth generations. The simulation results show minimal reverse losses of -20 dB in all three frequency ranges.

The method of combining fractal antennas and intelligent antennas is proposed in [10]. The authors present a new scheme of efficient operation in multi-band mode, which contributes to better use of the spectrum and multipath beam formation. A model of a smart fractal antenna was proposed, which showed good results of reverse losses of -36 dB for 20.6 GHz and gain of 15 dB.

The development of a hexagonal fractal antenna with a lateral power supply system is presented in [11]. The operating frequency of the antenna is 4.2 GHz and has a compact size of 23 mm × 27.5 mm. Figure 2 shows the prototype of the developed antenna.

Fig. 2. The prototype of a hexagonal fractal antenna [11]

According to the simulation results and experimental measurements, this antenna showed good antenna matching (SWR less than 2 for the total operating frequency range from 3.6 to 23 GHz with a bandwidth of 19.4 GHz), as well as gain and directional pattern.

In [12], the authors proposed an ultra-wideband microstrip fractal antenna. This antenna uses a fractal geometry in the shape of a star and has dimensions of 20mm×20mm. The operating range is from 17.22 GHz to 180 GHz, which is applicable for 5G mobile communication systems. The results of modeling the main characteristics of the antenna, such as SWR, S-parameters, radiation pattern also showed good results and presented in the work.

Another promising direction in antenna technology today is phased array antennas (PAA). In this antenna system there are many radiating elements that allow to increase the energy potential of the antenna system, as well as to obtain a narrow radiation pattern, compared with a single emitter [14]. The main advantages of headlamps include: the formation of a narrow directional pattern, electrical scanning of space, high gain, and others [3,14].

Currently, scientists are conducting research on the development of fractal phased antenna arrays [15-19].

For example, work [15] presents the development of a planar fractal antenna array for 5G applications. The antenna design is shown in Figure 3.

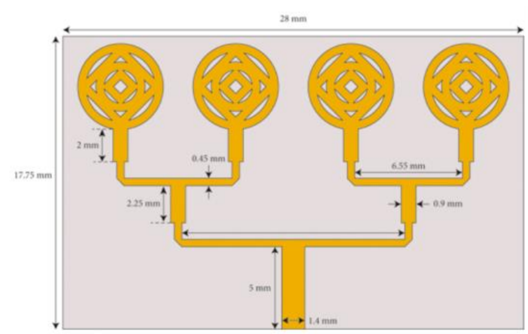


Fig. 3. The constuction of the fractal antenna array [12]

The antenna demonstrates a wide impedance band from 22.28 GHz to 33 GHz and provides peak gain and radiation efficiency of 10.7 dBi and 95%.

An eight-element linear fractal antenna array based on the Fibonacci series and the Koch snowflake is presented in the article [16]. In this antenna array, the gain is 15.18 dB with a bandwidth of 105 MHz and a radiation efficiency of 72.12%.

The paper [17] presents the design of a hybrid four-element (2 × 2) fractal Minkovsky-Serpinsky antenna array for use in IEEE 802.11ax (Wi-Fi 6E) wireless networks and a 6G wireless system. The fractal antenna array operates at 4.17 GHz and 5.97 GHz and has a bandwidth and gain of 85 MHz/4.19 dB and 182 MHz/9.61 dB.

A fractal antenna array using the Moore fractal operating in the frequency range below 6GHz is presented in [18]. The use of Moore's fractal geometry is due to improved antenna bandwidth. The measurement results show good matching results at the resonant frequencies of 2.3 GHz, 4 GHz, 4.7 GHz and 5.4 GHz, and also demonstrates a minimal correlation coefficient between the antenna elements.

A 64-element patch antenna based on the fractal geometry of Vicsek for 5G applications is presented by the authors in [19]. This fractal phased array antenna operates in the 22 GHz band and has a gain of more than 22 dB.

The article [20] shows a fractal antenna based on the Minkowski fractal. The antenna measures 18 mm × 25 mm and resonates at frequencies from 23 GHz to 60 GHz. The average gain is 6.1 dBi.

Studies [21-23] also confirm the advantages of fractal antennas and its applicability for mobile communication systems

Based on the above literature review, it can be concluded that the use of fractal geometry in the antenna system leads to the development of more compact and efficient antenna systems. Further developments in the field of fractal antennas are relevant and of interest in antenna technology due to their advantages.

III. Antenna Design

Let's consider the execution of the MIMO 2x2 antenna patch based on the anisotropic Zhanabaev fractal of the first iteration. An epoxy FR-4 substrate was used for the substrate material. Its dielectric constant is 4.4, and the thickness of the substrate is 1.6 mm. Figure 4 shows a 2x2 MIMO patch antenna model made in the Ansys HFSS microwave device simulation program.

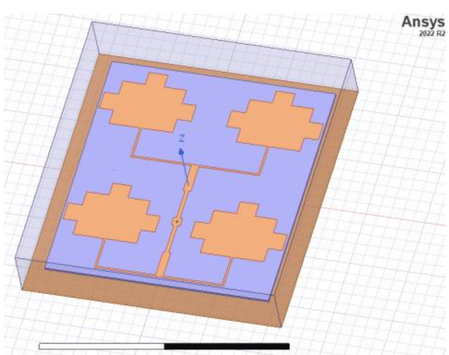


Fig. 4. 2x2 MIMO patch antenna model

The formula 1 is used to calculate the reflection coefficient or parameter S_{11} . S_{11} measures which part of the energy supplied to the input of the antenna or transmission line is reflected back to the source, and which part passes through the antenna.

$$S_{11}\,(\mathrm{dB}) = 20 \log (r) \qquad (1)$$

where r – return loss

The simulation results of parameter S_{11} are shown in Figure 5. The resonant frequencies are 2.13 GHz, 2.91 GHz.

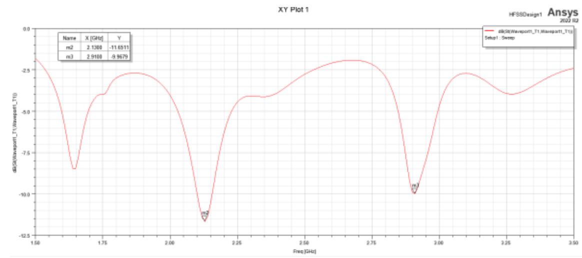


Fig. 5. S_{11} parameter

However, the design of this antenna does not have sufficient coordination, the SWR value is 3. For better matching of the antenna, it is necessary to change the parameters of the thickness of the lines and the power supply circuit.

Next, consider the traditional MIMO antenna shown in Figure 6. The antenna consists of a grid of 4 elements and resonates at frequencies of 1.9GHz and 3.6GHz (Figure 7)

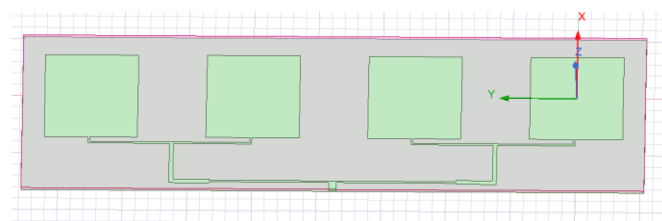


Fig. 6. 1x4 MIMO patch antenna model

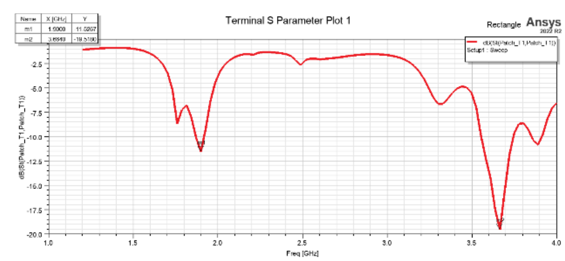


Fig. 7. S_{11} parameter

The SWR results are shown in Figure 8, and is 1.8 at the resonant frequency

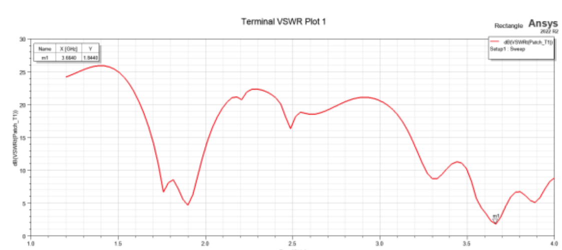


Fig. 8. SWR parameter

The reflection coefficient (S_{11} parameter) and SWR are among the main characteristics of the antenna. SWR is also used to evaluate the effectiveness of antenna radiation. A high SWR indicates poor alignment of the antenna and the transmission line.

IV. Conclusion

This article discusses fractal antennas and the possibility of their use in wireless communication, in particular mobile communication systems of new generations. A literature review has shown that fractal antennas are relevant today and have such advantages as: miniaturization, compactness, multi-band, broadband, which fully meets the requirements for modern antenna systems. However, in this direction, it is still necessary to conduct a number of studies related to signal processing, the creation of phased antenna arrays based on fractal structures and the study of mutual influence between the elements of the antenna system

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Analysis of security protocols used in the Internet of Things

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***Abstract* — This article is devoted to the analysis of security protocols used in the Internet of Things, in which the Internet of Things, protocol categorization, and their analysis are developed.**

***Keywords* — *Message Queuing Telemetry Transport, authentication, authorization,* BACnet, KNX, DNP3, MODBUS.**

I. INTRODUCTION

In the era of current information technology development, all work is being automated and various conveniences are being created. At the same time, the dwellings necessary for human living create a special impression on people, especially with the help of these technologies. In a modern house, it is required to incorporate several modern requirements, such as automated devices, air conditioning, ventilation systems, and so on.

In today's information society, the Internet of Things is becoming more relevant and popular as a result of the expansion of its fields of application. IoT devices collect data from the real environment and transmit it over networks. The Internet of Things (IoT) has now become globalized and has become a dominant research field due to its applications in various fields [1,2]. Because smart transportation, smart logistics, smart healthcare, smart environment, smart infrastructure (smart cities, smart homes, smart offices, smart shopping centers, industry), smart agriculture, etc. contribute to the development of society, it connects many IoT devices to the real world, from tiny sensors to servers, with a number of challenges.

Fig. 1. Internet of Things

As data flows across billions of smart devices running on different platforms during the transition from sensors to servers, there will be a variety of unprecedented problems for their owners or users (for example, security, privacy, interoperability, durability, support, etc.) that arise with the technology's weaknesses [1,2].

Analyzing and improving the protocols used to ensure the confidentiality and integrity of data in the Internet of Things is one of today's urgent tasks.

II. CLASSIFICATION OF PROTOCOLS USED IN THE INTERNET OF THINGS

The protocols used in the Internet of Things can be divided into the following categories according to their general status:

TABLE I. PROTOCOLS USED IN THE INTERNET OF THINGS

Standardized protocols	These protocols are widely adopted and standardized by international organizations or industry associations, have well-defined specifications, and are commonly used in various IoT applications	MQTT CoAP Zigbee Z-Wave Thread
Industry-Specific protocols	These protocols are designed for specific networks or applications and may not be widely used outside of these domains. They consider the unique requirements and constraints of specific sectors	BACnet KNX DNP3 MODBUS OPC-UA
Cellular communication protocols	Various cellular communication protocols are used to enable IoT devices to connect to the Internet and transmit data	NB-IoT LTE-M 5G
Classic protocols	Classical protocols refer to classical communication protocols that were not originally designed for IoT, but are still used in some applications	HTTP TCP/IP SNMP UDP
Proprietary and low-power protocols	Proprietary protocols are developed by specific companies or organizations and are not open or standardized. These protocols will be designed for specific IoT platforms or devices	LORA Sigfox EnOcean INSTEON

III. STANDARDIZED PROTOCOLS

MQTT(Message Queuing Telemetry Transport) protocol

Communication protocols are sets of rules that allow two or more devices or systems to communicate with each other. That is, whether it is done by software or hardware (or both), it carries out the transfer of data by various means and with a specified format [4,6].

In the Internet of Things, two or more devices communicate with through a set of established standards and protocols to communicate and understand each other. Due to the large number of Internet of Things devices, these protocols must meet the requirements beyond the bandwidth, speed, and other limits, that is, it is necessary to be able to add more connected devices without affecting the global system.

MQTT is a lightweight messaging protocol widely used in Internet of Things applications that has several security measures to ensure the confidentiality, integrity, and authenticity of messages, and they are as follows:

TLS (Transport Layer Security)/SSL (Secure Sockets Layer): MQTT is secured using TLS or SSL protocols that provide encryption and authentication. This in turn ensures that the communication between the MQTT client and the broker is protected from eavesdropping and tampering. MQTT over TLS/SSL uses certificates to authenticate the server and sometimes the client [3,4,10].

Authentication and Authorization: MQTT brokers may use authentication mechanisms to verify the identity of clients. This can be achieved through more secure methods such as username/password based authentication or client certificates. Access control lists (ACLs) are used to determine which topics a client can publish or subscribe to.

Quality of Service (QoS) levels: MQTT offers different QoS levels for message delivery. QoS 0 (at most once), QoS 1 (at least once), and QoS 2 (exactly once) provide different levels of reliability. Choosing the appropriate QoS level depends on the importance of the data being transmitted.

Message Encryption: In addition to TLS/SSL, MQTT performs end-to-end encryption of payloads. This ensures that the actual data transmitted within MQTT messages is encrypted, protecting it from unauthorized access even if the communication channel is compromised.

Broker Security: MQTT brokers must be configured securely with appropriate access controls, strong passwords, and regular updates to address known security vulnerabilities.

Network Segmentation: IoT networks must be properly segmented to isolate MQTT traffic and prevent unauthorized access. This will help limit the potential attack.

Security Testing: Regular security assessments and testing are required to identify and address any vulnerabilities in the MQTT infrastructure. This includes penetration testing, vulnerability scanning, and code validation to ensure the overall security of your MQTT deployment.

By applying these security measures, MQTT communication can be made more secure and reliable, which serves to ensure the confidentiality, integrity, and authenticity of data transmitted in IoT applications.

Constrained Application Protocol (CoAP)

It is a specialized web transmission protocol designed for limited devices and low-power networks, typically used in Internet of Things applications. It is designed to provide efficient communication between devices with limited processing power and memory.

CoAP is designed as a lightweight alternative to traditional protocols such as HTTP. It uses UDP as the underlying transport protocol instead of TCP, which reduces the overhead associated with connection establishment and reliable data transmission.

CoAP provides security mechanisms to ensure secure communication between devices in Internet of Things applications [5,6]. The security features in CoAP are designed to protect against unauthorized access and data corruption, and ensure the integrity and confidentiality of communications. The main aspects of CoAP protocol security are:

DTLS (Datagram Transport Layer Security): CoAP can use DTLS, which is a secure version of the UDP transport protocol. DTLS provides protection against eavesdropping, tampering, and unauthorized access to CoAP messages. DTLS is based on the TLS protocol and is designed to work effectively in restricted environments.

Authentication and authorization: CoAP supports various authentication mechanisms to verify the identities of clients and servers. These mechanisms include PSK (Pre-Shared Keys), which involve the use of shared secret keys between clients and servers, and Raw Public Key (RPK) certificates, which enable asymmetric key authentication. CoAP also supports using external authentication protocols such as OAuth or OpenID Connect for authentication [4,5].

Secure communication modes: CoAP supports various secure communication modes. These include "noSec" mode, where no security measures are applied, "PSK" mode, where Pre-Shared Keys are used for authentication and encryption, and "certificate" mode, where digital certificates are used for authentication and encryption.

Resource access control: CoAP provides access control mechanisms to restrict client access to certain resources. Access control is based on authentication credentials such as username, password or tokens, or on access control lists (ACLs) associated with resources.

Implementing security on CoAP-enabled systems requires careful consideration of specific security requirements, device capabilities, and deployment environments. Proper key management, certificate management, and secure configurations are important to ensure the effectiveness of CoAP protocol security.

ZigBee

It is a low-power LAN protocol based on the IEEE802.15.4 standard. ZigBee technology is a short-range, low-complexity, low-power, low-speed, and low-cost two-way wireless communication technology. It is mainly used for short distances, low power consumption, and low transmission speeds of various electronic devices and routine applications with periodic data, uninterrupted data, and low-time data transmission [4,7].

Zigbee, a wireless communication protocol widely used in Internet of Things applications, provides several security mechanisms to ensure secure and reliable communication between devices. Key aspects of Zigbee security:

Encryption: Zigbee uses AES-128 (Advanced Encryption Standard) to encrypt data transmitted over the network. AES-128 is a strong symmetric encryption algorithm that ensures data privacy.

Authentication: Zigbee uses authentication mechanisms to ensure that only authorized devices connect to the network. During network initialization, devices exchange cryptographic keys to confirm each other's identities. This prevents unauthorized devices from accessing the network and participating in communications [1,7].

Key setup: Zigbee uses the TCLK (Trust Center Link Key) protocol. This protocol allows devices to securely exchange encryption keys with the Trust Center, which is the central part responsible for network security. A trust center creates and distributes keys to network devices, ensuring secure communication.

Z-wave. This protocol is a popular wireless communication protocol designed specifically for Internet of Things applications in the home automation sector. It offers several features and benefits suitable for IoT deployments [7]. How to use the Z-Wave protocol in the Internet of Things:

- Home automation;
- Wireless connection;
- Compatibility;
- Security;
- Energy efficiency.

Z-Wave protocol includes several security features to ensure the security and privacy of IoT deployments. Key security aspects of the Z-Wave protocol in IoT:

Encryption: Z-Wave uses the AES-128 (Advanced Encryption Standard) symmetric encryption algorithm to ensure communication between devices. Encryption ensures that data transmitted over a network is confidential and cannot be intercepted or accessed by unauthorized persons.

Authentication: Z-Wave uses authentication mechanisms to verify the identity of devices within the network. Each Z-Wave device has a unique node ID and a secure node authentication key. Devices use NAK to authenticate and communicate securely with other devices on the network.

Secure join: When a new device is added to a Z-Wave network, a secure join process is performed to ensure that only authorized devices join the network. This process involves exchanging cryptographic keys and securely authenticating the new device before allowing it to participate in the network [3,4].

TABLE II. ENCRYPTION ALGORITHMS USED IN INTERNET OF THINGS PROTOCOLS

Internet of Things	Encryption algorithms
MQTT	AES, RSA, ECC
CoAP	AES, RSA, ECC
DTLS	AES, RSA, ECC
Zigbee	AES, ECC
Z –Wave	AES

IV. INDUSTRY-SPECIFIC AND CELLULAR COMMUNICATION PROTOCOLS

BACnet (Building Automation and Control Networks)

This is a communication protocol specially developed for building automation and control systems in the Internet of Things. It allows devices and systems within the building to exchange information, such as HVAC (heating, ventilation, and air conditioning) systems, lighting, access control, and energy management systems [9].

BACnet offers several features and functions tailored for building automation in the IoT, including:

Device discovery and management: BACnet supports device discovery mechanisms that allow devices to be automatically discovered and integrated into the network. It provides methods for discovering and managing devices, including reading and writing device properties, requesting available services, and monitoring device status.

Network topologies: BACnet supports a variety of network topologies, including traditional wired networks and wireless networks. It can work over Ethernet, RS-485, IP, and other communication media commonly used in building automation systems. This flexibility allows BACnet to adapt and integrate with existing infrastructure.

Security: BACnet supports various security mechanisms to protect the integrity and confidentiality of data exchanged between devices. It includes authentication mechanisms for device identification and authorization, as well as encryption methods for secure communication. However, the level of security implementation may vary depending on the specific BACnet devices and systems in use.

KNX

It is a standardized communication protocol used in building automation and control systems. It is designed to provide interoperability and integration between various devices and systems within a building, including lighting, HVAC, security systems, energy management, and more. KNX is widely used and supported by many manufacturers in the building automation industry [8].

Security features of the KNX protocol in the Internet of Things:

Secure device configuration: Proper configuration and protection of KNX devices within the system is essential. This includes setting strong passwords, disabling unnecessary services or features, and keeping devices and software updated to address known vulnerabilities [5,8].

Authentication and access control: KNX supports authentication mechanisms to verify the identities of devices within the network. Enabling device authentication ensures that only authorized devices can communicate and interact with the KNX system. In addition, access control measures must be taken to restrict access to critical functions or data on the KNX network.

Secure communication: It is recommended to use additional encryption mechanisms to protect data transmitted over the KNX network. It is possible to use IPsec or TLS (Transport Layer Security) to implement secure tunnels or to transfer data through KNX systems.

Physical security: Equally important is the protection of the physical infrastructure of the KNX system. It must be ensured that devices, cables, and network equipment are physically protected and inaccessible to unauthorized persons.

Network segmentation: KNX network segmentation can increase security by dividing it into logical sub-networks or zones. Each zone can have its own security policy and access controls, which restrict communication between zones based on trust levels or device roles. This helps prevent potential security breaches and limits their impact on the entire network.

Intrusion detection and monitoring: Implementing IDS or security monitoring tools can help detect and alert you to any suspicious or malicious activity in the KNX system.

Regular updates and audits: KNX devices are kept up-to-date with the latest security and updates provided by the manufacturers.

It is important to note that security is a multi-layered approach, and additional security measures beyond the protocol itself are necessary to ensure a robust and secure KNX-based IoT system.

DNP3 (Distributed Network Protocol)

A communication protocol widely used in the field of industrial automation and control systems, including Internet of Things applications. It was originally developed for the electrical industry, but has been adopted in various industries such as water, oil and gas, and transportation.

Security features: DNP3 includes security features to protect the integrity and confidentiality of data and communications. It supports authentication and encryption for secure device-to-device communication. In addition, DNP3 includes features to detect and prevent tampering or unauthorized access [8,11].

DNP3 has been widely used in critical infrastructure and real-time management systems. Its interoperability and security features make it ideal for IoT applications in a variety of industries. It facilitates effective and reliable communication between devices and systems in the Internet of Industrial Things system, and provides effective control and monitoring of industrial processes.

MODBUS

This protocol is a widely used communication protocol in the field of industrial automation and control systems. It is a simple and open protocol that allows easy integration of devices within a network.

Communication types: MODBUS supports a variety of communication types, including Modbus RTU (using serial communication such as RS-232 or RS-485), Modbus ASCII (using ASCII encoding over serial communication), and Modbus TCP (basic using Ethernet TCP/IP as communication) [8, 14].

Addressing: In MODBUS, each device on the network is assigned a unique address, which allows the host to identify and communicate with specific devices. The correct address is used to specify the target device in the MODBUS message header.

Secure communication channels: When using MODBUS over TCP/IP (MODBUS TCP), it is recommended to protect the communication channels using encryption protocols such as TLS (Transport Layer Security) or IPsec. This ensures that data exchanged between devices is protected from eavesdropping or tampering.

NB-IoT (Narrowband Internet of Things). It is a communication protocol specifically designed for low-power wide-area networks (LPWAN) in the Internet of Things. It enables efficient and reliable connectivity for a wide range of IoT applications.

Data encryption over the NB-IoT network is required to protect against eavesdropping and unauthorized access. Encryption protocols such as IPsec or TLS (Transport Layer Security) should be used to establish secure communication channels between devices and network objects. This ensures the confidentiality and integrity of data exchanged between devices and the network.

TABLE III. INDUSTRY-SPECIFIC AND CELLULAR COMMUNICATION PROTOCOLS

Protocol	Inherent Encryption Support	Encryption Approach
BACnet	No	TLS, IPsec
KNX	No	VPNs, IPsec, OpenVPN
DNP3	Yes	Message-level encryption
MODBUS	No	TLS, IPsec (MODBUS TCP); Manual encryption (MODBUS RTU)

V. CLASSIC AND PROPRIETARY AND LOW-POWER PROTOCOLS

HTTP (Hypertext Transfer Protocol)

It is an application-layer protocol widely used for communication on the World Wide Web. Although HTTP was originally developed for web browsers and servers, it is also used to exchange data between IoT devices and servers.

When using HTTP in the Internet of Things, security is of utmost importance. Because HTTP transmits data in plain text, it is vulnerable to eavesdropping and tampering. To solve this, it is recommended to use HTTPS (HTTP Secure), which uses SSL/TLS to protect the privacy and integrity of data exchanged between devices and servers. Implementing secure authentication and authorization mechanisms is also necessary to ensure that only authorized devices can access and interact with the server [6,12].

HTTPS (HTTP Secure): Use HTTPS instead of HTTP whenever possible. HTTPS ensures that data transmitted between IoT devices and servers is encrypted and protected from eavesdropping and other attacks by encryption over SSL/TLS. HTTPS implementation requires obtaining and installing an SSL/TLS certificate on the server, which ensures secure communication over the standard HTTP port (port 443).

TCP/IP (Transmission Control Protocol/Internet Protocol)

TCP/IP is a computer network protocol, also called Internet Protocol because of its close connection with the Internet. Identification of a computer connected to a computer network is carried out using an IP address. This family of protocols also includes THE User Datagram Protocol, or UDP for short.

Internet of Things devices rely on TCP/IP to connect to the Internet. They can use protocols such as IPv4 or IPv6 to address and route data across networks. These protocols enable IoT devices to communicate with each other and with other devices or services on the Internet [12,13].

The TCP/IP suite includes TCP and UDP. TCP provides reliable, connection-oriented communication, ensuring data integrity through features such as acknowledgment, retransmission, and flow control. On the other hand, UDP is a connectionless, lightweight protocol that is suitable for applications that value speed over reliability.

SNMP is a widely used protocol for managing and monitoring network devices. In the Internet of Things, SNMP can be used to manage, monitor, and collect operational data from IoT devices.

Addressing security issues is critical when using SNMP on the Internet of Things. The latest version of the protocol, SNMPv3, offers advanced security features such as authentication, encryption, and access control that help secure communication between IoT devices and control systems.

LoRa. It is a low-power wide area network (LPWAN) protocol specifically designed for long-distance communications in Internet of Things applications. This allows devices to communicate wirelessly over long distances with minimal power consumption, making it ideal for battery-powered devices and applications that require low data rates and long battery life.

LoRa includes security features to protect data transmission and device authentication. It supports AES-128 encryption for secure communication between devices and gateways.

Sigfox. It is a Low Power Wide Area Network (LPWAN) protocol designed specifically for Internet of Things devices. It allows devices to transmit small amounts of data over long distances with minimal power consumption [6,7].

Sigfox operates in a star network topology, where IoT devices connect directly to Sigfox base stations. This centralized architecture simplifies network deployment and reduces the complexity of device connectivity.

VI. ANALYSIS OF PROTOCOLS USED IN THE INTERNET OF THINGS

Encryption algorithms play a crucial role in securing the communication protocols used by IoT devices. They help protect data transmitted between IoT devices and provide privacy and integrity.

TABLE IV. ANALYSIS OF IOT PROTOCOLS

IoT protocol	Authentication	Encryption algorithms	Hash algorithms	OSI layer
MQTT	TLS (X.509 certificates), SASL	AES, RSA, ECC	SHA-256, MD5	Application, Transport, Network
CoAP	DTLS (X.509 certificates), OAuth, Pre-Shared Key (PSK)	AES, RSA, ECC	SHA-256, MD5	Application, Transport, Network
HTTPS	TLS (X.509 certificates), OAuth, API kalitlari	AES, RSA, ECC	SHA-256, MD5	Application, Transport, Network, Physical
DTLS	DTLS (X.509 certificates), PSK (pre-shared key)	AES, RSA, ECC	SHA-256, MD5	Transport, Network, Physical
Zigbee	ECDSA	AES, ECC	SHA-256, MD5	Application, Network
Z-wave	ECDSA	AES	SHA-256, MD5	Application, Network, Physical
LoRaWAN	LoRaWAN MAC-layer security, Application-layer security	AES	SHA-256, MD5	Application, Network, Physical
Ip	ECDH), AES-CCM	AES, ECC	SHA-256, MD5	Application, Network, Physical

CONCLUSION

The Internet of Things system is developing today, which in turn leads to increased requirements for its security. This article describes in detail the classification of protocols used in the Internet of Things by their functions. At the same time, the article presents an analysis several security features of the protocols used by the Internet. As a result of the analysis, it is possible to achieve high efficiency by improving the encryption, authentication, and hash algorithms in the existing security protocols.

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Types of Koshi functions applied to linear differential equations used in modelling technical processes

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Abstract. This article presents the use of differential equations in the mathematical modeling of technical processes, the models of technical processes brought to differential equations and the boundary conditions imposed on them, the Koshi problem applied to linear differential equations and its types.This paper considers a high-order linear non-homogeneous ordinary differential equation, and some method based on Koshi type function that determines the solution satisfying additional given initial conditions for such an equation. During the solution of the problem, lemmas and examples are given.

Keywords. Differential equations, physical problems, technical problems, electronic devices, mathematical model, homogeneous, non-homogeneous, Koshi problem, derivative, integral function.

I. INTRODUCTION

When solving physical and technical problems, it is necessary to use various mathematical methods. And at the moment, scientists and thinkers faced the question of whether it is possible to calculate processes that are subject to real-time and change along with it. For example, to calculate the unpredictable process of inflation or describe the complex demographic situation in the country with exact equations. If we recall the mathematical meaning of the derivative, which tells us about the rate of change of the function, then we can guess that by composing an equation with the function of interest to us and its derivative, it becomes possible to reflect the time factor that affects the desired function. Such equations are called differential[1,10].

Also, differential equations are important in solving technical and electronic problems, and creating computer systems and technical devices[1,2].

In circuit modelling of electronic devices (ED), mathematical models in the form of a normal system of first-order ordinary differential equations and inhomogeneous differential equations of the n-th order for state variables of the ED have proven themselves in the best way. To obtain a mathematical model of an ED in the form of a normal ODE system in the theory of circuit design, a special method of state variables was developed, which is now widely used both in Russia and abroad. When solving the equations of state, various methods can be used [4,6].

But of no less interest is the second classical form of describing the dynamic processes occurring during the operation of the ED, written in the form of an inhomogeneous equation of the nth order. The model makes it possible to use various equivalent forms for describing the dynamic properties of a device for solving the problems of designing an ED, for example, a transfer function or an impulse transition (weight) function, which is the inverse Laplace transform of the transfer function. When reducing an inhomogeneous differential equation to any of these equivalent forms of description, it is possible to use all the methods for studying the dynamics of an ED that make up the theory of automatic control and regulation, which will significantly expand the range of problems in modelling an ED, since the methods of this theory have not yet found proper application in the design of an ED[2,3].

Therefore, the development of simple, visual, effective from the point of view of using computers, methods for solving nonhomogeneous differential equations is an urgent task. To reduce systems of differential equations of the first order to inhomogeneous differential equations of the nth order, the methods considered can be used.

Mathematical modelling is required in the production and control of most technical, electronic and computer systems. We can see that most problems in the modelling process involve differential equations. A discretionary process will have existing limitations and boundary conditions. In this case, boundary conditions for differential equations and the Cauchy problem are set. In this article, we will analyze the types of KOSHI problems applied to differential equations.

Methodological aspects of studying the theory of differential equations (the concept and ways of its implementation, methodological system, applied orientation) are reflected in the research of R.M. Aslanova, G.I. Bavrina, Kh.A. Gerbekova, V.D. Lvova, P.M. Melnikova, B.A. Naimanova, C.B. Plotnikova, G.E. Polekhina, A.G. Savina, G. Treliński and others, but about university students. Only the scientific works of G.E. Polekhina. She developed a technique for solving equations based on the unity and difference of methods for solving algebraic, transcendental and differential equations. There are many domestic works, in which the problems of using information technologies in education are studied (V.L. Andreev, V.P. Bespalko, B.S. Gershunsky, A.P. Ershov, I.G. Zakharova, V.G. Kinelev, I. L. Lerner, B. I. Mashbits, P. I. Obraztsov, Yu. A. Pervin and others)[4,5].

We can also cite important scientific works of Uzbek scientists on the research of differential equations and their application. For example, in the work "Ordinary Differential Equations" by M.S.Salohiddinov, O.N.Nasriddinov, methods of solving differential equations, boundary conditions and methodological instructions for setting and solving the Koshi problem are given. In the scientific works of A. O. Otarov, differential equations and numerical methods for solving the Cauchy problem put to it are presented[13,15].

II. METHODOLOGY

This scientific problem, the Cauchy problem applied to differential equations can be solved using analytical and numerical methods. Taylor series approximation, Riemann method, Runge-Kutta method, analysis and correction method, Euler method and other methods can be used.

III. TYPES OF KOSHI FUNCTIONS IMPOSED ON LINEAR DIFFERENTIAL EQUATIONS

The theory of differential equations is considered one of the largest branches of modern mathematics. The theory of ordinary differential equations is a rich, widespread theory, and one of the main problems of this theory is to check the existence and uniqueness of solutions of the equation that satisfy given additional conditions, say, initial or boundary conditions, and, if possible, to determine the solution itself [1,3].

This paper considers a high-order linear non-homogeneous ordinary differential equation, and some method based on Koshi type function that determines the solution satisfying additional given initial conditions for such an equation[16,17].

Linear non-homogeneous

$$Ly = y^{(n)} + a_1(x)y^{(n-1)} + ... + a_n(x)y = f(x) \qquad (1)$$

consider a differential equation, where the function $f(x)$ and coefficients $a_k(x),\ k = 1,2,...,n$ are functions that (a,b) are continuous on some interval. Suppose that equation (1) is homogeneous

$$Ly = y^{(n)} + a_1(x)y^{(n-1)} + ... + a_n(x)y = 0 \qquad (2)$$

for the equation

$$y_1(x),\ y_2(x),...,y_n(x) \qquad (3)$$

functions by a system of fundamental solutions. Then we know the general solution of an equation is found to be (2)

$$y(x) = C_1y_1(x) + C_2y_2(x) + ... + C_ny_n(x),$$

where $C_1, C_2,...,C_n$ are arbitrary constants? The next problem is to find one particular solution to the inhomogeneous equation (1). Before determining this particular solution, let us dwell on the Koshi function of the form, where $\tilde{K}(x,t) = \dfrac{K(x,t)}{Y(t)}$ the function (2) is the Vronsky determinant of the system of fundamental solutions of the homogeneous differential equation (3) of the form, i.e

$$Y(x) = \begin{vmatrix} y_1(x) & y_2(x) & ... & y_n(x) \\ y_1'(x) & y_2'(x) & ... & y_n'(x) \\ ... & ... & ... & ... \\ y_1^{(n-1)}(x) & y_2^{(n-1)}(x) & ... & y_n^{(n-1)}(x) \end{vmatrix},$$

the function $K(x,t)$ is determined using the system of fundamental solutions

$$K(x,t) = \begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1(x) & y_2(x) & ... & y_n(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}$$

determinant in appearance. Then function $\tilde{K}(x,t)$

$$\tilde{K}(x,t) = \frac{\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1(x) & y_2(x) & ... & y_n(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}}{\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}}$$

is determined by appearance. The following lemmas hold for $K(x,t)$ $\tilde{K}(x,t)$ and.

Lemma 1. The function $K(x,t)$

$$LK = K_x^{(n)}(x,t) + a_1(x)K_x^{(n-1)}(x,t) + \\ + ... + a_n(x)K_n(x,t) = 0, \qquad (4)$$

$$K(t,t) = 0,\ K_x'(t,t) = 0,...,K_x^{(n-2)}(t,t) = \\ = Y(t),\ K_x^{(n-1)}(t,t) = 0 \qquad (5)$$

is a solution to Koshi's problem of the form. Indeed

$$K_x'(x,t) = \begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1'(x) & y_2'(x) & ... & y_n'(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix} \qquad (6)$$

$$K_x'\big|_{x=t} = \begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix} = 0,$$

$$K_x''\big|_{x=t} = \begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1''(t) & y_2''(t) & ... & y_n''(t) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix} = 0, \qquad (7)$$

if we continue the process, we can see that the derivatives $x = t$ obtained $n-3$ from x the function $K(x,t)$ will be equal to zero. For the order $n-2$ derivative $x = t$ is equal to $Y(t)$. Indeed is

$$K_x^{(n-2)}(x,t) = \begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1^{(n-2)}(x) & y_2^{(n-2)}(x) & ... & y_n^{(n-2)}(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix},$$

$K(x,t)$ and it follows that the or $n-1$ der derivative $x=t$ obtained by x the function $K(x,t)$ is equal to zero again. Indeed

$$K_x^{(n-1)}=\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1^{(n-1)}(x) & y_2^{(n-1)}(x) & ... & y_n^{(n-1)}(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix},$$

Therefore, the function (5) $K(x,t)$ satisfies the condition.

Now we see that the function $K(x,t)$ satisfies the homogeneous equation (4). For this, if we put the function $K(x,t)$ (4) into the equation

$$LK=K_x^{(n)}(x,t)+a_1(x)K_x^{(n-1)}(x,t)+...+a_n(x)K_n(x,t)=$$

$$=\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1^{(n)}(x) & y_2^{(n)}(x) & ... & y_n^{(n)}(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}$$

$$+$$

$$a_1(x)\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1^{(n-1)}(x) & y_2^{(n-1)}(x) & ... & y_n^{(n-1)}(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}$$

$$+...+$$

$$a_n(x)\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ y_1(x) & y_2(x) & ... & y_n(x) \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}=$$

$$=\begin{vmatrix} y_1(t) & y_2(t) & ... & y_n(t) \\ y_1'(t) & y_2'(t) & ... & y_n'(t) \\ ... & ... & ... & ... \\ 0 & 0 & ... & 0 \\ y_1^{(n-1)}(t) & y_2^{(n-1)}(t) & ... & y_n^{(n-1)}(t) \end{vmatrix}=0$$

Here, the last determinant $n-1$ is the element k in the row above

$$y_k^{(n)}+a_1(x)y_k^{(n-1)}+...+a_n(x)y_k=0,\ k=1,2,...,n$$

since all the elements in the row of this determinant $n-1$ are equal to zero. Thus, the function $K(x,t)$ (4) is a solution of the homogeneous equation (5) that satisfies the condition.

Lemma 2. The function $\tilde{K}=\tilde{K}(x,t)$

$$L\tilde{K}=\tilde{K}_x^{(n)}(x,t)+a_1(x)\tilde{K}_x^{(n-1)}(x,t)+...+ \\ +a_n(x)\tilde{K}_n(x,t)=0, \tag{8}$$

$$\tilde{K}(t,t)=0, \\ \tilde{K}_x'(t,t)=0,...,\tilde{K}_x^{(n-2)}(t,t)=1, \\ \tilde{K}_x^{(n-1)}(t,t)=0 \tag{9}$$

will be a solution to Koshi's problem.

In this, if we use the view $\tilde{K}(x,t)=\dfrac{K(x,t)}{Y(t)}$ $\tilde{K}(x,t)$ of the function

$$L\tilde{K}(x,t)=L\frac{\tilde{K}(x,t)}{Y(t)}=\frac{1}{Y(t)}L\tilde{K}(x,t)=0,$$

therefore together

$$\tilde{K}(t,t)=\frac{K(t,t)}{Y(t)}=\frac{0}{Y(t)}=0,$$

$$\tilde{K}_x'(t,t)=\frac{K_x(t,t)}{Y(t)}=\frac{0}{Y(t)}=0,...,$$

$$\tilde{K}_x^{(n-2)}(t,t)=\frac{K_x^{(n-2)}(t,t)}{Y(t)}=\frac{Y(t)}{Y(t)}=1,$$

$$\tilde{K}_x^{(n-1)}(t,t)=\frac{K_x^{(n-1)}(t,t)}{Y(t)}=\frac{0}{Y(t)}=0.$$

Thus, the function $\tilde{K}(x,t)$ (6) is a solution of the homogeneous equation (7) that satisfies the condition.

Lemma 3.

$$\tilde{y}(x)=\int_0^x \tilde{K}(x,t)\mathrm{z}(t)dt \tag{10}$$

the function

$$L\tilde{y}(x)=\tilde{y}^{(n)}+a_1(x)\tilde{y}^{(n-1)}+...+a_n(x)\tilde{y}=f(x), \tag{11}$$

of equation

$$\tilde{y}(x_0)=0,\ \tilde{y}'(x_0)=0,...,\tilde{y}^{(n-1)}(x_0)=0$$

is a solution that satisfies the condition, where $z(x)$ is a function of

$$\frac{dz}{dx}+a_1(x)z=f(x)$$

one particular solution of the equation. If we take a series derivative from the function $\tilde{y}(x)$

$$\tilde{y}(x) = \int_{x_0}^{x} \tilde{K}(x,t)\,z(t)dt,$$

$$\tilde{y}'(x) = \tilde{K}(x,x)\,z(x) + \int_{x_0}^{x} \tilde{K}'_x(x,t)z(t)dt =$$

$$= \int_{x_0}^{x} \tilde{K}'_x(x,t)z(t)dt,$$

$$\tilde{y}''(x) = \tilde{K}'_x(x,x)\,z(x) + \int_{x_0}^{x} \tilde{K}''_x(x,t)\,z(t)dt =$$

$$= \int_{x_0}^{x} \tilde{K}''_x(x,t)\,z(t)dt,$$

....

$$\tilde{y}^{(n-2)}(x) = \tilde{K}_x^{(n-3)}(x,x)\,z(x) + \int_{x_0}^{x} \tilde{K}_x^{(n-2)}(x,t)\,z(t)dt =$$

$$= \int_{x_0}^{x} \tilde{K}_x^{(n-2)}(x,t)\,z(t)dt,$$

$$\tilde{y}^{(n-1)}(x) = \tilde{K}_x^{(n-2)}(x,x)z(x) + \int_{x_0}^{x} \tilde{K}_x^{(n-1)}(x,t)z(t)dt =$$

$$= z(x) + \int_{x_0}^{x} \tilde{K}_x^{(n-1)}(x,t)z(t)dt,$$

$$\tilde{y}^{(n)}(x) = z'(x) + \tilde{K}_x^{(n-1)}(x,x)z(x) + \int_{x_0}^{x} \tilde{K}_x^{(n)}(x,t)z(t)dt =$$

$$= z'(x) + \int_{x_0}^{x} \tilde{K}_x^{(n)}(x,t)z(t)dt.$$

If we replace these findings in equation (9) and use the above lemmas

$$L\tilde{y}(x) = \tilde{y}^{(n)} + a_1(x)\tilde{y}^{(n-1)} + ... + a_n(x)\tilde{y} =$$

$$= z'(x) + \int_{x_0}^{x} \tilde{K}_x^{(n)}(x,t)z(t)dt + a_1(x)z(x) +$$

$$+ a_1(x)\int_{x_0}^{x} \tilde{K}_x^{(n-1)}(x,t)z(t)dt + ... + a_n(x)\int_{x_0}^{x} \tilde{K}(x,t)\,z(t)dt =$$

$$= z'(x) + \int_{x_0}^{x} \frac{K_x^{(n)}(x,t)}{Y(t)}\,z(t)dt + a_1(x)\int_{x_0}^{x} \frac{K_x^{(n-1)}(x,t)}{Y(t)}\,z(t)dt +$$

$$+ ... + a_n(x)\int_{x_0}^{x} \frac{K(x,t)}{Y(t)}\,z(t)dt = z'(x) + a_1(x)z(x) +$$

$$+ \int_{x_0}^{x} \frac{1}{Y(t)}\Big(K_x^{(n)}(x,t) + a_1(x)K_x^{(n-2)}(x,t) +$$

$$+ ... + a_n(x)K(x,t)\Big)\,z(t)dt = z'(x) + a_1(x)z(x) = f(x)$$

that is, the function $\tilde{y}(x)$ determined by the formula (8) satisfies the equation (9). The general solution of equation (1) is in this case

$$y(x) = C_1y_1(x) + C_2y_2(x) + ... + C_ny_n(x) + \int_{x_0}^{x} \tilde{K}(x,t)z(t)dt$$

Is determined by appearance. Thus for equation (1).

$$y(x_0) = y_0,\ y'(x_0) = y'_0, ..., y^{(n-1)}(x_0) = y_0^{(n-1)} \tag{10}$$

if it is required to find a solution that satisfies the initial condition, then

$$y(x) = C_1y_1(x) + C_2y_2(x) + ... + C_ny_n(x) + \int_{x_0}^{x} \tilde{K}(x,t)z(t)dt$$

by putting the solution (10) in the initial condition

$$y(x) = \tilde{C}_1y_1(x) + \tilde{C}_2y_2(x) + ... + \tilde{C}_ny_n(x) + \int_{x_0}^{x} \tilde{K}(x,t)z(t)dt$$

can be determined by appearance, here $\tilde{C}_1, \tilde{C}_2, ..., \tilde{C}_n$

$$\begin{cases} C_1y_1(x_0) + C_2y_2(x_0) + ... + C_ny_n(x_0) = y_0, \\ C_1y'_1(x_0) + C_2y'_2(x_0) + ... + C_ny'_n(x_0) = y'_0, \\ -\ -\ -\ -\ -\ -\ -\ -\ -\ -\ -\ -\ -\ - \\ C_1y_1^{(n-1)}(x_0) + C_2y_2^{(n-1)}(x_0) + ... + C_ny_n^{(n-1)}(x_0) = y_0^{(n-1)} \end{cases}$$

is determined by solving the system.

IV. PRACTICAL EXAMPLE

Let us be given a function as

$$y''' = 6x \tag{11}$$

consider the case of Koshi. Here is a system of fundamental solutions of a homogeneous equation to the given equation

$$y_1(x) = 1,\ y_2(x) = x,\ \ y_3(x) = x^2$$

from being the general solution of the homogeneous equation

$$y_{б.т.}(x) = C_1 + C_2x + C_3x^2 + C_4x^3$$

will be. Now to find one particular solution of the given non-homogeneous equation, we first find $Y(x),\ K(x,t)\ \tilde{K}(x,t)$:

$$Y(x) = \begin{vmatrix} 1 & x & x^2 \\ 0 & 1 & 2x \\ 0 & 0 & 2 \end{vmatrix} = 2,\ K(x,t) = \begin{vmatrix} 1 & t & t^2 \\ 1 & x & x^2 \\ 0 & 0 & 2 \end{vmatrix} = 2x - 2t$$

and

$$\tilde{K}(x,t) = \frac{K(x,t)}{Y(t)} = x - t$$

$z' = 6x$ is a particular solution of the inhomogeneous equation $z(t) = 3x^2$ from having one solution of the equation

$$\tilde{y}(x) = \int_0^x \tilde{K}(x,t)z(t)dt = 3\int_0^x (x-t)t^2dt = \frac{x^4}{4}\ .$$

If we solve this problem with the old Koshi function

$$K(x,t) = \begin{vmatrix} 1 & t & t^2 \\ 0 & 1 & 2t \\ 1 & x & x^2 \end{vmatrix} = (x-t)^2\ ,\quad \tilde{K}(x,t) = \frac{(x-t)^2}{2}$$

the solution

$$\tilde{y}(x) = \int_0^x \tilde{K}(x,t)f(t)dt = 3\int_0^x (x-t)^2tdt = \frac{x^4}{4}$$

will be. As another example $y'' = 6x$, if we consider the equation

$$Y(x)=\begin{vmatrix}1 & x\\ 0 & 1\end{vmatrix}=1,\ K(x,t)=\begin{vmatrix}1 & x\\ 0 & 1\end{vmatrix}=1,\ \tilde{K}(x,t)=1\ ,\quad z(x)=3x^2$$

and the solution will be

$$\tilde{y}(x)=\int_0^x \tilde{K}(x,t)z(t)dt=3\int_0^x t^2dt=x^3$$

If we solve by the previous method

$$Y(x)=\begin{vmatrix}1 & x\\ 0 & 1\end{vmatrix}=1,\ K(x,t)=\begin{vmatrix}1 & t\\ 1 & x\end{vmatrix}=x-t,\ \tilde{K}(x,t)=x-t$$

RESULT

As a result of putting the Cauchy problem for equation (11), we get the following solution:

$$\tilde{y}(x)=\int_0^x \tilde{K}(x,t)f(t)dt=6\int_0^x (x-t)tdt=x^3 \qquad (12)$$

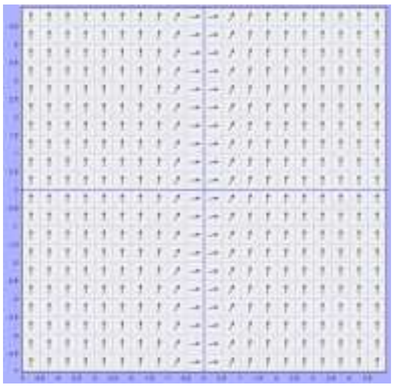

Fig. 1. (11) is the graph of the differential equation

Fig. 2. (12) is the graph of the solution of the Cauchy problem superimposed on the differential equation

CONCLUSION

In conclusion, the Koshi problem and boundary conditions for linear or non-linear differential equations are of great importance. In this article, the Koshi problem for linear homogeneous and non-homogeneous differential equations of the form (1), (2) was considered. As a result, as an example, we put the Koshi problem for the differential equation (11) and got a solution. The solution of the Koshi problem is given in equation (12) and in Fig.1 and Fig.2.

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A SPECIAL METHOD IN THE MANAGEMENT OF INFORMATION SECURITY OF COMPUTER SYSTEMS

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***Abstract*— The paper proposes a systematic approach with application of the dynamic programming method to the problem of information security management, which allows to increase the efficiency of managing the information protection process and organize a system of measures to ensure information security, allows you to find the optimal step control, taking into account its impact on the overall result of the operation.**

***Keywords*— information security, dynamic programming, controls, computer systems, optimization**

I. Introduction

A systematic approach to the scientific substantiation of decisions made operates with such concepts as efficiency, optimality, efficiency criterion [1-8,9]. Speaking about the effectiveness of one alternative over another, it is implied that they are comparable, that is, there is a parameter by which alternatives can be compared. The optimality of the choice is the question to be discussed in this article . The idea of optimality is the basic idea of cybernetics. For strictly formalized problems, in which the concept of optimality has a fairly specific definition and a clear mathematical formulation, Moreover, the criterion by which alternatives are compared and selected in the decision-making process, as a rule, is correctly formulated, the idea of optimization is very effective both in terms of finding optimal options and in terms of subsequent analysis of the results obtained. As a rule, such an analysis makes it possible to assess the available reserves for improvement.

II. 2. The main provisions of systems theory and the logic of the systems approach

The main provisions of the theory of systems and the logic of the system approach, adapted to the problems of information security management, make it possible to classify and identify control objects according to the levels of complexity of the control object:

The first level is the level of static structure or bases. At this level of complexity, the subjects of information exchange in the information security system are considered in statics;

The second level is a simple dynamic system with predefined, mandatory actions, for example, user identification, authorization in the system, etc.;

The third level is the cybernetic system, i.e. a “thermostat” type system, in which the transmission and analysis of information is an essential part of the system, providing the ability to control the system;

The fourth level is an open system, a self-preserving structure. This is the level at which the living begins to differ from the non-living, the level of the cell. At this level, the system is different from the non-living, cell level. At this level of the object security system, the object of protection is divided into its component parts, the formation of individual protection mechanisms for each component;

The fifth level is the level of the plant; at this level, a differentiation of functions appears in a complex system: the separation of objects of protection, respectively, the definition of subjects that implement this protection;

The sixth level is the level of the animal (mobility, awareness and teleological behavior). At this level, there are receivers of information and a highly developed system for responding to external influences. For information security systems at this level of complexity, the profile of a potential intruder is determined, a system for identifying and diagnosing attacks is built, statistical data is accumulated on reflected and implemented threats, etc.;

The seventh level is human. At this level of complexity, in addition to all the previous properties, the ability of the system to analyze the situation, the ability to adapt to self-learning is added. In the information security management system of an object, this level of complexity implies the existence of a comprehensive information protection plan that allows you to implement control either by deviation or by disturbance;

The eighth level is the level of social institutions, social systems. Information security management of an object at this level has a significant impact on the effectiveness of protection. Such factors include the professional incompetence of information exchange participants in terms of information security, lack of responsibility when working with confidential information, etc.;

The ninth level is unknowable systems. The probabilistic nature of the interaction in the system “object of protection - means and methods of protection - intruder” leaves part of the protection system “closed” for study.

Nevertheless, speaking about the merits of the idea of optimality, it is necessary to realistically assess its shortcomings [7,8,9]. When solving optimization problems, the resulting solution may be unstable with respect to minor changes in the initial data (environment, conditions), that is, the optimality criterion must satisfy such requirements as uniqueness, simplicity, representativeness, sensitivity and stability . The introduction of additional requirements leads to a complication of the problem, an increase in the rigidity of the set restrictions. The second disadvantage of the idea of optimality is that even a representative criterion, that is, reflecting the connection of the goal with the main parameters, has such a disadvantage as locality, that is, optimization is carried out without taking into account the relationship of the system under study with systems of a higher level. This is what creates the need to harmonize local criteria with the criteria of the entire system. Whereas, in principle, the systemic approach suggests, when studying a system, to consider it as part of the system , as a subsystem of the system of a higher level. The implementation of a systematic approach [1-5] to the application of the idea of optimality will allow avoiding the problem of matching criteria. The third disadvantage of the idea of optimality is that the relation between the criterion and the goal is the relation between the original (the goal) and the model (the criterion) . The model, having certain limitations, does not always fully reflect the original, so, in deterministic resource allocation problems, as a rule, the assortment list of works / services is not reflected; equipment loading models do not take into account equipment wear, operating time , maintenance costs , etc. The list of such situations can be infinitely large, and the situations can be considered purely technical, techno-economic, economic, socio-economic [1-8,9]. Probably the most serious shortcoming of the idea of optimality is the relationship between the criterion and the introduced constraints. As it turned out, a slight change in the restrictions in the direction of tightening, or the removal of restrictions, or the introduction of new ones can lead to completely unexpected consequences, for example , the introduction of an integer requirement into the resource allocation problem complicates it to such an extent that there may be no optimal solution.

III. Dynamic Programming Method

Considered in the works [5,6,7,8,9] methods of mathematical modeling are static, therefore, their application in the management of complex information protection has limited capabilities . At the same time, there are a number of tasks in which the optimal variant should not be found immediately, but as a result of the transition of the system from one state to another in several stages. Such multi-stage tasks include long-term planning of work on the integrated protection of informatization objects, determining the configuration of computer systems at the facility, building a physical and logical model of computer systems; optimization of information security strategy, etc. [1-8,9] .

These tasks, despite the seeming difference, have one thing in common : it is necessary to obtain the maximum effect as a result of the entire operation as a whole, that is, to achieve an effective end result. Such problems are solved by a special method, which is called dynamic programming [5,6,7,8,9] .

Dynamic programming is a special method of optimizing multi-step problems, in which the optimal solution is found gradually, in stages, since by making a decision at each individual stage, you can influence the entire result. Consider an operation K consisting of m stages. The efficiency of the operation is characterized by the efficiency criterion W, which we will call the gain. Let us assume that the efficiency criterion is additive, i.e., the payoff as a whole is made up of the payoffs at individual steps.

$$W = \sum_{i=1}^{m} \omega_i, \tag{1}$$

where ω_i is the payoff at the i -th step.

The gain at each step ω_i and in general W depends on what decisions will be made at each step, that is, on the so-called step control of operations.

Let's denote the step controls x_1 , x_2 , ..., x_m and the control as a whole x , then the operation control is a set of step controls, and x_1 , x_2 , ..., x_m are numbers, functions, vectors, etc. .

$$W = (x_1 , x_2 , ..., x_m) \tag{2}$$

The task of dynamic programming is reduced to finding such a control x , at which the efficiency criterion becomes a maximum.

The control x^* that achieves this maximum is called the optimal control.

Any multi-step problem can be solved in different ways: either look for solution elements at all steps at once, or build an optimal equation step by step, optimizing one step at each stage [10-16].

The dynamic programming method is based on the idea of step-by-step optimization, and the control at each stage is chosen taking into account its influence on the entire result as a whole: the control at the i -th stage is chosen so that there is a maximum sum of payoffs at all remaining stages plus this one.

Obviously, in order to fulfill such a condition, it is more expedient to start planning from the last stage. That is why the process of dynamic programming unfolds from the end: when planning the last stage, you need to make various assumptions about how (*m-1*), the penultimate stage ended, and for each of these assumptions, find a conditional optimal control; similarly, the (*m-1*) stage is planned, that is, assumptions are made about the possible results of the (*m-2*) stage, etc.; thus, stepping back, optimizing the controls at all stages, we will reach the first one.

After the conditionally optimal control is found, the planning procedure is repeated from the first to the last (*m*) stage and the optimal control x^* and the optimal payoff W^* are determined.

The considered principle of finding the optimal continuation of the process relative to the state reached at the moment is called R. Bellman's principle of optimality [5,6,7,8,9].

The Bellman optimality principle allows you to find the optimal solution for problems of any nature: technical, economic, financial, etc., but regardless of the nature of the problem being solved, the methodology and solution procedure do not change: knowing the initial and final states of the system and the number of planning stages, determine the control at every step for the best possible end result.

Let's introduce the notation: let S_0 be the initial state of the system, S_k - the final state of the system, T - the period of time. Assuming that the entire time period T is a set of individual planning stages, and ω_iis the effect obtained at the i -th stage, it is required to distribute the funds allocated for the organization of the integrated information protection system in such a way that the total effect at the end of the entire period T is maximum.

$$W = \sum_{i=1}^{T} w_i, \tag{3}$$

and $\omega_1=f(x_1),\omega_2=f(x_2)$ etc. , a x_i is the amount of funds invested in year i.

Values x_1 ($i=1,T$) are called step control, and the set of step controls is the optimal control vector $x^*:x^*=\{x_1,x_2,\ldots,x_m\}$.

The search for the optimal control vector, that is, the solution of the problem, is possible using combinatorics or direct enumeration, but this is a laborious method. Time-consuming optimization is expedient, i.e. dynamic programming (DP).

The task of dynamic programming, as noted above, is reduced to determining such a trajectory of the system from the state S_0 to the state S_k, at which the efficiency criterion reaches its maximum. Obviously, step-by-step optimization without taking into account the impact on the entire process as a whole will not only not give the maximum effect, but can lead to serious errors, since the sum of local optima does not give a global optimum.

That is why the application of dynamic programming to solving various multi-step problems can be represented as a generalized algorithm.

Algorithm for solving the dynamic programming problem:
1. The method of describing the process and the method of dividing into stages is chosen.
2. An assumption is calculated or made about the final state of the system: the value of the efficiency criterion at the last stage $W_t(S, x_t)$.
3. The value of the function of changing the state of the system during the transition is determined $S\rightarrow S^0, S^0=f(S,x_t)$.
4. A functional equation is compiled: $W_t=max\{\omega_t(S,x_t)+W_{(i+1)}(f((S,x_{t+1})))\}$.
5. The value is calculated W_T in the last step: $W_T=max\{\omega_t(S,x_t)\}$.
6. Conditionally optimal control is determined $x_{t-1},x_{t-2},\ldots,x_t$.
7. For the initial state of the system S_0 find the value of $W(S_0)$ and then do the back sweep.

The information security system and information security management at business facilities is a complex multi-stage process [10-16], in which the final result can be considered as an additive function of decisions taken at a separate stage. To obtain the maximum effect in solving problems of this class, it is proposed to use a special method based on the Bellman optimality principle. To solve the problem, we determine the factors that affect the effectiveness of the information security management system at stage i:

- the number of measures to protect information according to the work plan Z_i; the number of implemented measures S_i;
- one-time costs for the formation of a work plan k_j;
- the effectiveness of activities moving from stage i to stage $i+1$ -th stage h_i .

Function $C_i(Z_i)$ determining the effectiveness of information protection for a given number of measures Z_i which is determined by the ratio:

$$C_i(Z_i) = \delta_i \cdot k_i + C_i(z_i), \tag{3}$$

Where

$$\delta_i = \begin{cases} 0, z_i=0 \\ 1, z_i>0 \end{cases} \tag{4}$$

For this model of information security management, we believe that the number of measures to protect information according to the work plan is known and changes over time; there is a periodic control of the number of events carried out; it is possible to exceed the number of events at the stage, this forms a "carryover stock", the size of which is determined by the formula

$$X_{i+1} = X_i + Z_i - S_i. \tag{5}$$

The effectiveness of the implementation of measures is proportional to the value of the carry-over stock from i - th to $i+1$st stage i.e. $h_i * x_{(i+1)}$.

For example, if you need to draw up a plan for the implementation of measures that will provide a level of protection that is not lower than the normative one. Graphical interpretation of the task is shown in Figure 1.

By the principle of optimality, we determine the maximum total number of implemented activities at the Nth step:

$$f_N(X_N) = max\{C_N(Z_N)\}, \tag{6}$$

$$ZN + XN = SN, \tag{7}$$

then for the i - th step :

$$f_i(X_i) = \max\{C_i(Z_i) + h_i x_{i+1} + f_{i+1} * x_{i+1}\}, \tag{8}$$

where $C_i(Z_i)$ is the effectiveness of planned activities, $f_{i+1} * x_{i+1}$- the effectiveness of the "carryover stock" is the effectiveness of the activities of the previous stages.

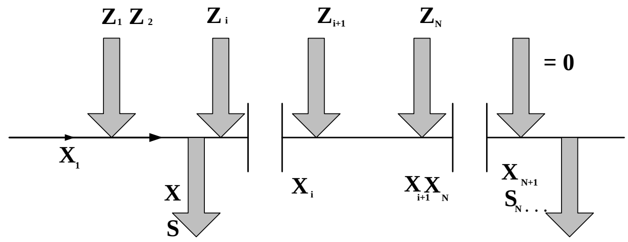

Fig. 1. Graphical interpretation of a dynamic programming problem

To obtain the backward sweep equation, we will assume that $f_i(X_{(i+1)})$ - the maximum overall efficiency of the implemented measures, the total costs for a given margin $X_{(i+1)}$ at the end of stage i , then

$$f_1(X_2) = \max\{C_1(Z_1) + h_1 x_2\}, \tag{9}$$

$$f_i(X_{i+1}) = max\{C_i(Z_i) + h_1 x_{i+1} + f_{i-1}(x_{i+1} - Z_i + S_i)\} \tag{10}$$

Thus, the use of the dynamic programming method in the information security management system of an object allows for effective planning and implementation of various types of activities at different levels: from the organizational to the physical level.

Possible adaptations of dynamic programming to the tasks of planning and management can be given the following example: the management of a production association is considering proposals for updating the software and hardware for complex information protection in three structural divisions that are part of the production department. To implement the plan, 5 million monetary units were allocated, each department submitted projects for consideration, which are characterized by the values of total costs (C) and income

(R) associated with the implementation of projects. The data are shown in Table 1, which also includes projects with zero costs, which makes it possible to take into account the possibility of not expanding any enterprise. The purpose of the production department is to get the maximum effect from the invested 5 million monetary units.

TABLE I. INITIAL DATA FOR THE PROBLEM OF DISTRIBUTION OF CAPITAL INVESTMENTS

Project	***Branch 1***		***Branch 2***		***Branch 3***	
	C1	R1	C2	R2	C3	R3
1	0	0	0	0	0	
2	1	5	2	8	1	3
3	2	6	3	9	-	-
4	-	-	4	12	-	-

When solving problems of this type, one of the possible methods for finding the best distribution of funds is the method of exhaustive enumeration of options. This method is suitable for problems of small dimension, and in this case, solving the problem by simple enumeration gives 3* 4*2=24 solutions, and: some of them are obviously unacceptable, since the costs exceed 5 million monetary units.

The optimal solution will be the one that gives the maximum total income, for example, for departments 1, 2, 3, accept projects 2, 3, 1, respectively.

The exhaustive search method has a number of disadvantages:

- a large amount of calculations when solving problems of large dimensions;
- there is no a priori information about solutions that are not admissible, i.e. reduced efficiency of calculations;
- information obtained as a result of the analysis of some combinations of projects is not used in the future to identify and exclude non-optimal options.

To solve problems of this type, it is advisable to apply the dynamic programming method, since the efficiency of this algorithm does not depend on the dimension of the problem, moreover, the principle of optimality, which is the basis of the algorithm, allows you to find the optimal step control, taking into account its influence on the overall result of the operation.

CONCLUSION

Adaptation of mathematical programming methods to the information security management system requires the joint work of creative teams, which should include mathematicians - problem solvers, a programmer and I T-managers focused on issues related to the specifics of information security.

The proposed approach, which involves the application of the dynamic programming method to the task of managing information security, will improve the efficiency of managing the information protection process, organize a system of measures to ensure information security in accordance with the requirements of regulations, while ensuring high efficiency of the system.

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Application of LoRa Technology for Hybrid Energy Supply System Based on Edge Computing

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***Abstract*— Hybrid energy supply was based on the principles formed at the beginning of the last century. However, in recent decades, due to the rapid development of technology, energy consumption has increased significantly throughout the world. This is reflected in the fact that electricity suppliers are now forced to maximize the load on power grids and generation sources, as well as seek new ways to solve the problems that arise. The introduction of completely new methods based on innovative technologies can raise the global energy industry to a completely new stage of development. For this purpose, the use of edge computing technology to provide flexible management of hybrid energy supply sources aimed at integrating electricity suppliers, electricity producers, and consumers into a single energy network, and this concept through the LoRaWan network involves the active use of new digital technologies, multi-tariff meters, and power distribution devices responsible for ensuring the reliability and transparency of various processes of production, transmission, distribution, and consumption.**

Keywords—hybrid energy supply, LoRaWan, edge computing, cloud computing, smart meter.

I. INTRODUCTION

Electricity production systems. Today, the problems of climate change and the depletion of fuel and energy resources are particularly relevant, and alternative energy sources, in particular, solar photovoltaic systems, wind turbines, tidal and wave generators, generators based on the use of biofuels or the planet heat of the bowels, etc. Pumped storage plants have a huge potential to make more efficient use of the electricity already produced. According to forecasts, the number of sources of this type will only grow, and they will be connected to the common network from different points. This means that in the future system, production capacities will be more distributed than traditionally concentrated. As a rule, the capacities of such sources are relatively small, and the generating power parameters are characterized by instability. Accordingly, a specific management blog is needed to stabilize these parameters and automatically synchronize them with the network. Thus, modernization and development of new types of energy production systems, devices for their automatic control, and communication systems to ensure information exchange between various elements of the energy system constitute one of the directions of the concept of intelligent networks. Fig. 1. shows the structure of the device used in control and monitoring through Internet of Things (IoT) sensors through the management blog [1,13].

Most power grids today consist of radial lines with unidirectional energy flow. In rare cases, power lines are looped. Hybrid energy supply networks will not be hierarchical in the future. Large consumers, many low-power energy sources, some powerful stations, voltage regulators, reactive power compensators, etc. are mixed into one network. That is, the energy network is represented by a complex, branched network that does not have a specific structure [2].

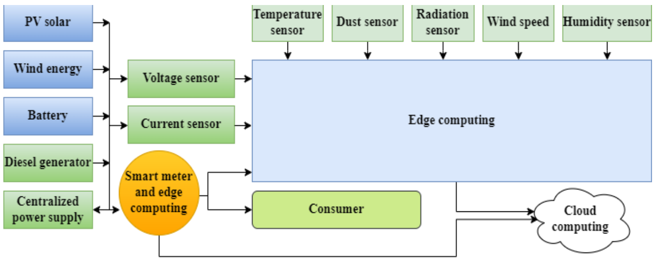

Fig. 1. The structure of the hybrid energy supply system

With data flows, it is natural to include a powerful management system that ensures the coordinated operation of the entire set of such complex network components. To do this, they need to exchange data wirelessly, as well as communicate with the control center. Therefore, the concept of intelligent networks has the following direction - the development of fully controlled powerful network components equipped with monitoring and self-diagnosis systems, and reliable channels for receiving and transmitting information.

II. MATERIALS AND METHODS

Communication and data transmission systems between electric power facilities. To date, various types of communication channels are used to ensure communication and data exchange between various objects. This can be communication through low-voltage wires (low-frequency control cables, coaxial high-frequency cables), optical fiber cables, high-voltage power line wires, directional secure radio channels, etc. Ethernet/Internet networking technologies are becoming increasingly popular. and distributed. This is primarily characterized by such positive features as the low cost, widespread and ubiquitous availability of such solutions, reliable time-tested technology, and communication protocols. The demand for network technologies arises from the ever-increasing need to exchange large amounts of data between many different components of the power system.

Today, there are already all kinds of electronic sensors, transducers, and measurement converters on the market, which are equipped with built-in cheap modems that allow you to connect to the Ethernet / Internet network. Short-range wireless technologies such as Wave, Ultra, Broadband (USB), and Bluetooth can be used to communicate between household grid sensors and edge computing gateways. If edge computing devices and servers are distributed in a small area, DECT, Wi-Fi or ZigBee technologies can be used to organize local wireless networks. Table. I. compares a number of wireless connection technologies.

TABLE I. COMPARISON OF WIRELESS TECHNOLOGIES

Wireless technology	Transfer rate	Range	Endpoint battery life (days)	Requires/does not require licensing
USB	480 Mbps	100 m	more 1000	×
Bluetooth	721 Kbps	100 m	1-7	×
Z-Wave	40-250 Kbit/s	100 m	up to1000	×
IEEE 802.15.4 (ZigBee/6LoWPAN)	250 Kbit/s	200 m	up to 1000	×
IEEE 802.11 (Wi-Fi)	600 Mbit/s	250 m	1-5	×
DECT	552 Kbit/s	300 m	up to 20	×
GSM	14,4 Kbps	1-10 km	1-7	✓
GPRS	170 Kbit/s	1-10 km	1-7	✓
UMTS	2 Mbit/s	1-10 km	1-4	✓
LTE	302 Mbit/s	100 km	1-2	✓
WiMAX	75 Mbit/s	50 km	1-2	✓
CMDA2000 (EVDO)	]73,5 Mbit/s	45 km	1-3	✓

Reliability is critical to ensuring network availability and customer service. It can be used to improve efficiency with real-time data collected from energy usage, fault detection, peak demand anticipation, and more. A smart grid uses the following concepts to overcome the lack of efficiency and reliability in traditional power grids:

Smart meters. Installation of smart meters allows real-time information exchange between customers and providers. A smart meter can control smart devices in a residential building, schedule their working hours and monitor energy consumption. It can receive dynamic pricing information from the utility provider and send energy consumption data over time [3,10].

Microgrid. Small groups of interconnected low-voltage electrical systems are called microgrids. A microgrid with autonomous generation and control mechanisms can improve local distribution reliability. The Microgrid can connect to the grid but will disconnect itself from the grid when there is a grid failure, outage, or other threat [4].

Distributed production. In a smart grid, consumers can generate energy from renewable energy sources such as solar and wind. Excess-generated power can be sold to other consumers through the network. Electricity generation is not limited to conventional power plants (such as fossil fuels such as oil and gas). Renewable energy sources such as wind and solar are included in the production phase. Real-time pricing, supply and demand forecasting, and network monitoring tasks require billing management systems. The generated electricity is then transported to the microgrid for distribution among consumers, including smart homes, smart buildings, data centers, factories and industries, electric vehicles, and more. Microgrids have local control systems and share information with other components of the smart grid [5].

Transformers. In the process of electricity production, the distance of production sources to consumers creates the task of voltage and power distribution. In the power supply system, transformers perform the task of transferring electrical energy from one place to another [6].

IoT devices generally prefer a wireless receiver with high throughput, long range, and low power consumption. Optimizing these three dimensions simultaneously is a challenging task. Wireless technologies can achieve two of the three aspects. Optimizing one aspect leads to degradation of others. The challenges of Smart Grid IoT devices are increasingly integrated, with devices and objects collecting, transmitting and storing large amounts of data. Collected data along this chain (from embedded IoT devices, network infrastructure, cloud computing servers and data centers) creates problems related to data usage, processing and access.

To solve the aforementioned problems, Edge Computing brings the data processing task closer to the edge of the IoT system, where the data is collected. Fig.2. shows this architecture.

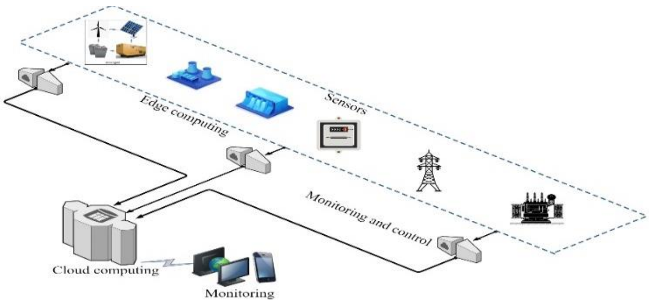

Fig. 2. The structure of the hybrid energy supply system

By reducing the amount of data transfer, it not only reduces network load but can also reduce latency for real-time applications. In EC for IoT, some cloud tasks are distributed among other processing layers. In a non-recyclable or inefficient layer, it is imposed on the upper layers. IoT-embedded devices can perform data pre-processing such as filtering, filtering [7,11]. Smart grid includes distributed and edge computing, infrastructure, architecture design, algorithm and software design to integrate edge devices, load shedding techniques, etc. The technical classification of this calculator is shown in Table II.

TABLE II. TECHNICAL CLASSIFICATION OF EDGE SERVERS USED IN THE ENERGY SUPPLY SYSTEM

Name	Technical requirement	OS or Code
Raspberry Pi ARM BCM2837-	• CPU 1400 MHz • memory 1GB • HDD 1GB	• Linux • Multithreading

system-on-chip (SoC)		
Personal computer	• CPU 1400 MHz • memory 1GB • HDD 1GB	• OS Linux • OS Windows
Microsoft Azure IoT Edge	• Memory: 128 MB • CPU: x86, ARM	• C, C#, Java, Node.js, Python
Arduiono Uno	• Memory: 128 MB • CPU: x86, ARM	• c/c++

The sharp increase in demand for energy and energy supply, the delays in receiving information, and the problems of working with cloud servers have not yet been resolved. The great advantage of the fixed communication channels from the cloud data source is that it is very difficult to ensure the continuity of reception for data processing, because the data can pass through several routers (hubs, gateways) [8, 10].

The management blog of energy supply sources, power transmission line, microgrid, centralized energy supply sources, transformers, smart meters and other indicators are organized through IoT components and data transmission network. It is possible to transmit data and process raw data using LPWAN network technologies such as Sigfox, LoRaWan, NB-IoT. These network technologies use edge computing to process and transmit data from sensors.

III. Results and discussion

The LoRaWAN specification consequently limits the maximum message payload. At the DR6 data rate, the payload can contain 242 bytes, while at DR0, this payload is limited to 51 bytes. The result is presented in Table 2.3. For smart metering applications, limiting the payload to 51 bytes is a good practice to avoid problems with low-speed transmission. All energy is sufficient for the functions of certain parts of the control system. LoRaWAN avoids overcrowding of a network cell, which includes an area and end devices served by a single gateway. According to the source [1,3,9,12], with an increase in the number of these devices, the maximum performance (packet/hour) of the last device decreases sharply, that is, if the network cell consists of 5000, only 7.3 50-byte packets per hour organizes. latest devices and uses only the standard three channels. When it comes to automatic meter reading, traffic changes and emergency monitoring, this is acceptable, but not in real time. In smart metering systems, the cell size must be kept within reasonable limits. For this, you need to choose a suitable place for the equipment. As is usually the case in radio broadcasting, it does not make much sense to install gateways at high altitudes because the number of terminals covered by a single gateway is too high. A better option would be to deploy more local gateways that cover only the part of the area where this coverage is needed. The allowed data rates and payload sizes of LoRaWAN are shown in Table III.

TABLE III. ALLOWABLE DATA RATES AND PAYLOAD SIZES OF LORAWAN

Transfer speed	Expansion factor SF	Bandwidth	Bit rate	Maximum load
0	SF12	125 kHz	250 bps	51 bayt
1	SF11	125 kHz	440 bps	51 bayt
2	SF10	125 kHz	980 bps	51 bayt
3	SF9	125 kHz	1,76 kbps	115 bayt
4	SF8	125 kHz	3,13 kbps	242 bayt
5	SF7	125 kHz	5,47 kbps	242 bayt
6	SF6	250 kHz	11 kbps	242 bayt

Thanks to LoRaWAN, it is possible to create global distributed networks in which a large number of devices work. According to Semtech, the service area of a single LoRa gateway can cover up to five thousand end nodes. This is achieved due to:

- network topology;
- adaptive data rate and adaptive output power of devices determined by the network server;
- temporary separation of access to the environment;
- frequency division of channels;
- A unique feature of LoRa modulation, which allows you to simultaneously demodulate signals transmitted at different speeds on the same frequency channel.

One of the main elements of energy supply is smart meters, which form the basis of energy consumption monitoring and accounting systems. This device is of particular interest for monitoring, where large amounts of data are exchanged at a high frequency. Therefore, in the experimental part of this article, the operation of the Smart meter is simulated. A network based on LoRa, i.e. network efficiency for monitoring work, was evaluated. Thus, it is to get a real idea about the various aspects of the application of LoRa technology in smart grid monitoring systems. The simulation process is carried out in LoRaSim. LoRaSim is a discrete event simulator aimed at studying network expansion and collisions for LoRa networks. LoRaSim is written in Python 2.7 programming language. The simulator includes four scripts for different experiments: loraDir.py, loraDirMulBs.py, directionalLoraIntf.py and oneDirectionalLoraIntf.py. loraDir.py script simulates the operation of a single base station, loraDirMulBs.py - multiple base stations (up to 24), loraDirMulBs.py simulates the operation of an op-amp with directional antennas and several networks, oneDirectionalLoraIntf.py simulates no operation of base stations with fiber antennas and multiple networks. All four scripts require the matplotlib, SimPy, and NumPy libraries to be installed.

In LoRaSim, you can set a number of parameters, such as the number of terminal devices, the number of base stations (or LoRa gateways), the distance between BSs, the number of foreign networks, the presence of directional antennas. The simulator also allows you to check the number of collisions. In addition, LoRaSim can estimate the energy consumption of the entire network. However, the simulator only calculates the power consumed by the radio to transmit packets. This does not take into account idle time or power consumption by the end devices or the radios themselves.

Table IV lists the configuration parameters used in the simulation. In LoRaSim, configurations #1, #2, and #3 correspond to <EXPERIMENT> parameters 0, 2, and 4, respectively. Configuration #1 is the network with the lowest transmission speed. Configuration #2 is the network with the highest transmission speed. Configuration #3 uses the parameters recommended by the LoRaWAN specification [14].

TABLE IV. CONFIGURATION PARAMETERS

Parametr	configuration #1	configuration #2	configuration #3
Number of OS, N	-	-	-
Payload size, B	20 bayt	20 bayt	20 bayt
Average shipping period packages, λ	300 000 ms (5 minuts)	300 000 ms (5 minuts)	300 000 ms (5 minuts)
Cell radius, R	-	-	-
Transmitter power, TR	14 dBm	14 dBm	14 dBm
Carrier frequency, CF	868 MHz	868 MHz	868 MHz
Expansion factor spectrum, SF	12	7	12
Code rate, CR	4/8	4/5	4/5
Bandwidth, BW	125 kHz	500 kHz	125 kHz

In all experiments, the standard packet size is 20 bytes, which is enough to support real applications such as smart metering and, most importantly, monitoring. The number of terminals N, is a positive integer and varies throughout the experiments. All these devices are spread over an area of radius R around the base station. According to the specification of various smart electricity meters, packets can be sent for a period of 5 minutes to a month, depending on the tasks performed.

We assume that the latter devices send packets to the base station every 900,000 milliseconds or 15 minutes, because according to various sources, this is the optimal interval at which smart meters should send a series of energy readings in monitoring systems. It should also be noted that this time interval can vary depending on LoRa use cases, for example, in residential buildings, automatic readings of power consumption can be done every hour or even once a day.

We get the transmitter power equal to dBm. The remaining parameters are as follows: coding rate 4/8 or 4/5, bandwidth 125 kHz or 500 kHz, spreading factor SF 12 or 7, carrier frequency 868 MHz. In these experiments, we use the following symbols for these parameters: TP-transmission power, CF - carrier frequency, SF - spread factor, BW - bandwidth, CR - encoding speed, λ - time interval for sending packets, B - message payload.

To evaluate the performance of the entire network, we use data extraction rate DER - Data Extraction Rate, and energy consumption. DER (1) is calculated according to the formula:

$$DER = \frac{N_{per} - N_{kol}}{N_{per}} \quad (1)$$

where N_{per} - is the number of transmitted packets, N_{kol} - is the number of collisions.

Simply put, DER is the ratio of the number of successfully received packets to the number of transmitted packets in a given time. Under ideal conditions, DER = 1, which means that all transmitted packets are delivered correctly to the base station.

The simplest case of a LoRa network is the structure shown in Fig.3. where N end devices send packets to a single base station or LoRa gateway. For this experiment, we use the three configurations shown in Table IV. Duration of simulation is one day (8 640 000 ms). Standard cell radius: R = 99 m.

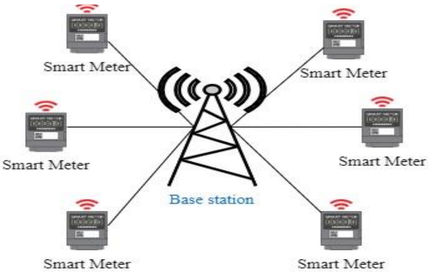

Fig. 3. Set for experiment #1

A visual summary of the experiment, that is, the dependence of DER and power consumption on N, is shown for all three network configurations built after the experiment. Each marker corresponds to a simulation result. The ratio of the number of correctly received messages to the number of sent messages is different for each configuration.

As shown in Fig.4. the ratio between received and sent DER messages decreases exponentially with increasing number of N at low transmission rates. For different values of the number of terminals N, the DER is greater than 0.9.

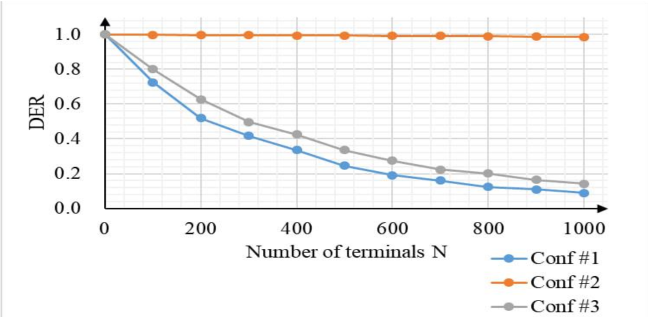

Fig. 4. Dependence of DER on the Number of terminal devices N

In terms of energy efficiency, the network with configuration #2 is the best option (Fig.5.). Such a network consumes a small amount of energy regardless of the number of terminal devices, while in configurations #1 and #3, power consumption increases as N increases.

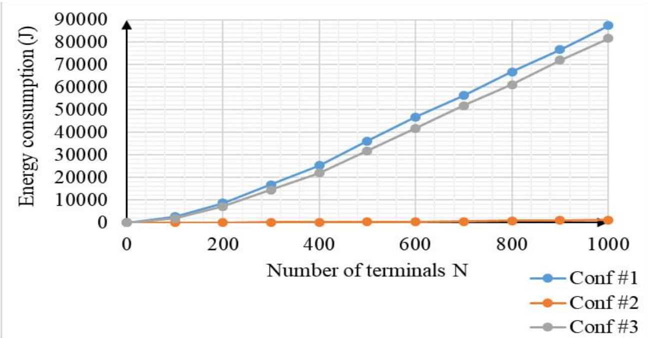

Fig. 5. Dependence of energy consumption on the number of terminal devices N

Thus, it can be concluded that in the case of monitoring, where network power consumption and DER ratio are critical factors, configuration #2 is the ideal solution. However, keep in mind that in LPWAN networks, the topology can have both a positive and a negative impact on the power consumption of each end device. The use of star topology helps improve energy efficiency. In addition, offloading computing functions to servers can further reduce power consumption.

In the second experiment, we will run a series of simulations with two base stations. As in the previous experiment, we will compare the results for the three configurations. For all simulations, we will also use 20-byte packets that are sent every 15 minutes in the same way. In addition, we set that the number of terminals per base station is fixed (N = 500), and the distance within which the terminals are randomly scattered around two base stations will change. The duration of the simulation is one day. The network for experiment No. 2 is shown in Fig.6.

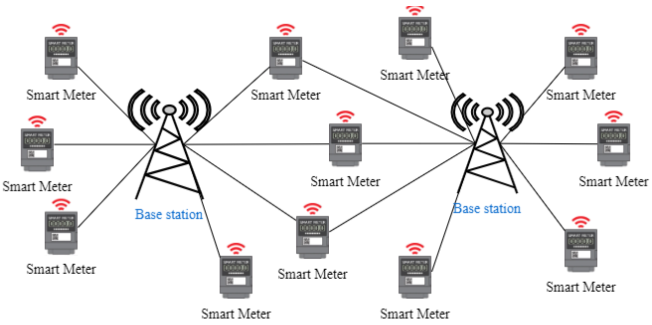

Fig. 6. Network for experiment #2

As a result of the simulation, it turned out that despite the change of the distance between two base stations up to 1000 m, the DER parameter of the network with configuration No. 2 turned out to be greater than 0.8. This is an acceptable value for such applications. With configurations #1 and #3 (125 kHz /SF12/CR4/8 and 125 kHz/SF12/CR4/5, respectively), we achieved $0.20 \leqslant \text{DER} \leqslant 0.33$. The results are shown in Fig.7.

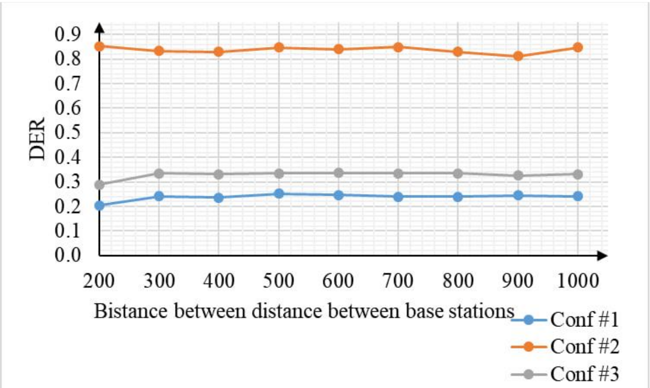

Fig. 7. Dependence of DER on the distance between base station at N = 500

We observe the effect on the operation of the LoRa network. In this part of the experiment, we will use configurations #1, 2 and 3 in the same way. The network under consideration is similar to the previous experiment.

As a result of LoRa field tests, the actual distance of the gateway was found to be 2.5 km for the city and 2 km for the metropolis. Based on the generalized experience of these tests, we take the distance between the base stations as 4 km. Up to 1000 op amps are randomly distributed between base stations. Duration of simulation is 24 hours. In most cases, directional antennas can amplify the signal and reduce noise. Therefore, the network performance, especially the DER performance, should be improved. The simulation result is shown in Fig.8.

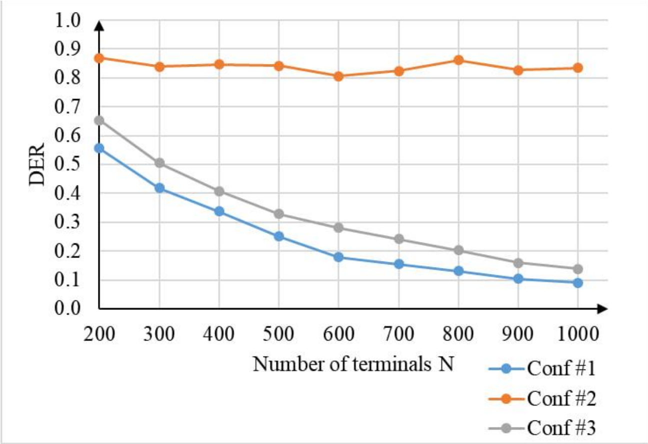

Fig. 8. Dependence of DER on the number of terminals with directional antennas

As expected, although the number of terminals and radius increased, directional antennas improved DER, especially with configurations #1 and 3 ($0.089 \leq \text{DER} \leq 0.556$ from configuration #1 and $0.138 \leq \text{DER} \leq 0.653$ from configuration #3, respectively). Thus, the use of directional antennas has a positive effect on network performance.

IV. Conclusion

Various aspects of the application of LoRa technology in energy supply were studied. The analysis showed that LoRa is the best option for use in the energy supply system due to its technical characteristics and advantages over alternative wireless technologies. In particular, in the main components of the concept: energy accounting and monitoring systems, including real-time systems. In the practical part, 3 experiments were conducted, showing the main cases of using LoRa technology. To determine the strengths and weaknesses of LoRa technology in specific applications for monitoring smart meters, the ratio of correctly received packets to the number of transmitted packets (DER) and network power consumption were evaluated as performance indicators for different configurations.

It has been found that LoRa is very sensitive to the number of terminal devices and their large number can cause a sharp drop in data. The results shown in the figures show that if a high DER is to be achieved, the use of directional antennas is the best solution from a practical point of view.

The efficiency of the LoRa network was evaluated, that is, the dependence of the DER on the distance between the base stations, the number of terminal devices and the presence of directional antennas on the terminal devices. The efficiency of the smart grid can be increased by using the latest devices with directional antennas.

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Influence of the local oxide trapped charge to the gate-source (drain) capacitance of FinFET

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***Abstract*- In this work the influence of the local oxide trapped charge on the capacitance of the gate-to-source (drain) connection of the silicon-on-insulator (SOI) based FinFET. Capacitance-Voltage characteristics of the gate-source capacitance are simulated by using a small AC signal method. The gate-source (gate-drain) capacitance is investigated at a different position along the channel of the local oxide trapped charge. Carrier distribution along the channel at different positions of the local oxide trapped charge is also considered. it is shown the monotonic increase of the gate-source capacitance with increasing the distance between the source-channel border and the center of the local charge**

Keywords: FinFET, lokal charge, gate-source capacitance, p-n junction, C-V.

I. Introduction

Metal-oxide-semiconductor field effect transistors (MOSFET), particularly Fin field effect transistors (FinFET) during functioning can be under the influence of different electrical stresses or radiation and it can lead to degradation of characteristics of the transistor. Among these degradations can be noted as appreciable effects of the hot carrier injection [1], bias temperature instability [2], off stress [3], and the impact of the radiation-induced charge [4]. This degradation effect is the result of the influence of the charges injected or generated in the oxide layer or at the interface. The impact of these effects should be taken into account in designing analog as well as digital integral circuits.

The charge trapped in the oxide can impact some parameters of the MOSFET such as threshold voltage, subthreshold slope of the transfer characteristics, and trans conductance and it leads to degradation of the transistor characteristics. Therefore to define the mechanism and reasons for charge trapping it is expediently to develop the methods to estimate trapped charge localization and distribution along the channel.

One of the simple and fast methods of diagnostics for the detection of the charge trapped in oxide or at the interface is based on measuring the capacitance-voltage characteristics of lateral source (drain)-channel p-n-junctions [5]. Experimental evidence of this method is presented in the [4,6,8]. In [4, 5, 6, 9] it is shown, that the non-homogeneous distribution of the charge in the oxide layer or at the semiconductor-oxide interface is appropriately reflected in source-channel (drain-channel) p-n-junction. Therefore the distribution along the channel of the trapped charge also should be reflected in other capacitance connected with lateral source-channel (drain-channel) junctions.

In this work, the method mentioned above and suggested for the planar MOSFETs is modified for application in SOI FinFET. The main idea of the method suggested in [5] is based on the influence of the oxide or/and interface trapped charge on lateral source-channel (drain-channel) p-n-junction capacitances. Therefore the FinFET should be chosen for the connection which includes the capacitance of the lateral source-channel (drain-channel) junction C_{p-n} and the contribution of this capacitance in the capacitance of the selected connection should be significant.

In the case of SOI FinFET one of the connections which includes C_{p-n} capacitance is the gate-source (gate-drain) connection (Fig.1).

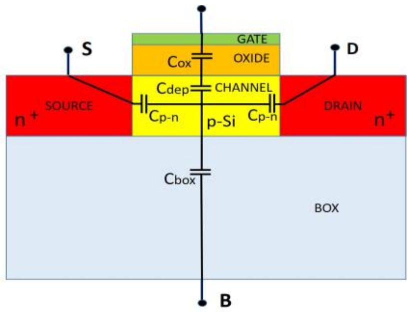

Fig.1. Cross-section of the simulated SOI FinFET with capacitances between contacts.

The gate-source connection as well as the gate-drain connection contains the following in series capacitances: gate oxide capacitance C_{ox}, capacitance C_{dep} of the depletion layer of oxide-semiconductor interface, source-channel p-n-junction capacitance C_{p-n}. Capacitance C_{dep} of the depletion layer can significantly contribute to C_{gs} capacitance only in depletion mode. In the used approach, only barrier capacitance of the source-channel p-n- junction is considered, therefore to the n-type source contact the positive voltage with respect to the gate contact is applied. It results in establishing the accumulation mode at the semiconductor surface near the oxide-semiconductor interface and therefore the capacitance C_{dep} can not be taken into account. In this case, the resulting capacitance C_{gs} can be expressed by the following formula (1):

$$C_{gs} = \frac{C_{p-n} \cdot C_{ox}}{C_{p-n} + C_{ox}} \qquad (1)$$

here, C_{ox} is gate oxide capacitance per unit area, which does not depend on the applied voltage. Estimations show, that the width of the depletion layer of the source-channel (drain-channel) p-n-junction is approximately 0.1 μm while gate oxide thickness tox= 2.5 nm and therefore C_{p-n} is significantly less than Cox. In this case in accordance with the formula (2) C_{gs} is defined mainly by C_{p-n} which is very sensitive to the distribution of oxide trapped charge. Therefore in this work, it is simulated the dependence of the C_{gs} on the position of the local oxide trapped charge along the channel.

II. SIMULATION CONDITIONS AND TRANSISTOR PARAMETERS

3D simulation was provided by using Advanced TCAD Sentaurus. The C-V dependence of the gate-source (gate-drain) connections was simulated on the basis of the small AC signal method. It is used a 1 MHz frequency in the method. The structure of the simulated SOI FinFET is shown in Fig. 2. Gate length L_{gate} and gate oxide thickness are 25 nm and 2.5 nm respectively. The thicknesses of the channel T_{Si} and back oxide T_{box} are 30 and 100 nm respectively. The width of the channel is 12 nm. The doping level of the p-Si channel is $1 \cdot 10^{15}$ cm^{-3}.

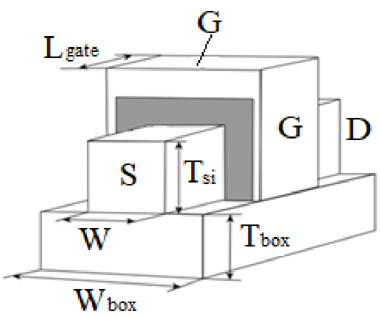

Fig.2. 3D structure of the simulated SOI FinFET

The capacitance C_{gs} of the gate-source connection is simulated at different distances between the center of the local oxide trapped charge and source-channel border. Local oxide trapped charge is modeled as a homogeneously charged area in the oxide layer. The density of charge in the charged area is 10^{12} cm^{-2} (or $4 \cdot 10^{18}$ cm^{-3}) and is appropriate to the value which can take place in MOSFET [7]. Linear size of the local charge along channel d=5nm.

While the depletion layer width of the lateral source-channel (drain-channel) p-n-junction is more than the channel length, the local charge trapped in the oxide at a distance L from the border source-channel has impacts on the carrier distribution in the channel. Therefore this impact should be reflected in the capacitance of the source-channel junction and hence in the C-V dependence of the gate-source capacitance connection.

FinFET has symmetry relative to the channel center and hence both capacitances of the gate-source and gate-drain connections should be the same. Therefore in the following, it is presented the results only for gate-source connection.

III. SIMULATION RESULTS AND DISCUSSION

Results of the simulation of C-V dependence of the gate-source capacitance C_{gs} are shown in Fig.3. It is seen in the figure that at high applied voltages the capacitance C_{gs} significantly and monotonically depends on the position of the local trapped charge along the channel (Fig.4). Position L=2.5 nm is an exception in this dependence (Fig.4, point B) because in this position the local charge area is in contact with the end of the oxide layer.

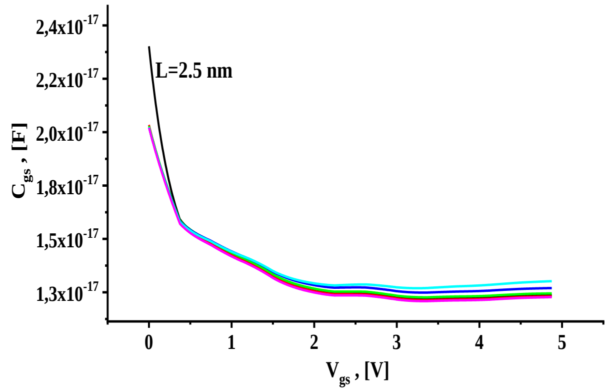

Fig.3. C-V dependence of gate-source connection capacitance at different positions of the local trapped charge.

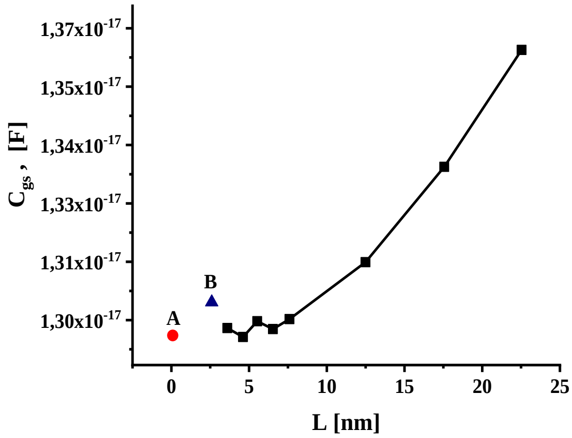

Fig.4. C_{gs} dependence on L at V_{gs}=4.5 V. Point A corresponds to the case when the local trapped charge is absent, point B corresponds to the position of the local trapped charge at L=2.5 nm.

The increase of the capacitance C_{gs} is connected with the influence of the local trapped charge on carrier concentration in the channel. The local charge trapped in the oxide layer increases the carrier concentration near the channel surface (fig.5) and as a result, the capacitance is increased. By definition capacitance is

$$C_{gs} = dQ_V/dV \qquad (2)$$

here dQ_V is a change of the charge in the capacitor C_{gs} at a change the applied voltage by dV. At trapping the local charge in the gate oxide layer the electron concentration in the channel is changed and the charge in the C_{gs} capacitance is changed by dQ_{LC}. Therefore the formula (2) can be rewritten by the following expression

$$C_{gs} = (dQ_V + dQ_{LC})/ dV \qquad (3)$$

This expression explains the increase of the capacitance C_{gs}.

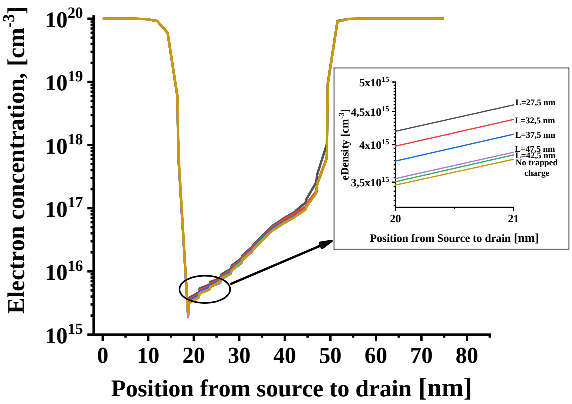

Fig.5. Electron density distribution along the channel at depth 2nm from the channel surface, at different positions L of the local oxide trapped charge.

At position L= 2.5 nm of the oxide trapped charge the configuration of the capacitance C_{gs} is changed because the local charge will be in contact with the end of the oxide layer (Fig.6). In this case the electron density in the channel surface will be redistributed which result in sufficiently increasing the capacitance C_{gs} more than in unbiased case and relatively capacitances corresponding to other positions (Fig.3). At high applied voltages the redistribution of the carrier densities leads to increasing the C_{gs} with increasing L (Fig.7).

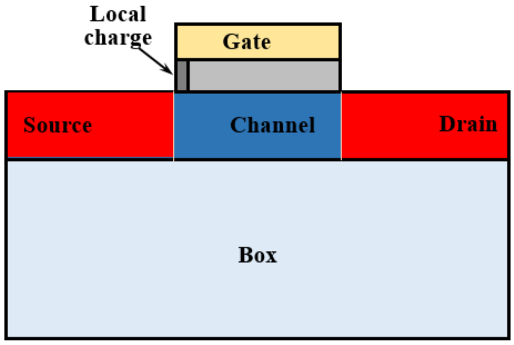

Fig.6. Cross-section of the FinFET with local charge trapped in oxide and which is located at the end of oxide layer. L=2.5 nm.

Due to the symmetry of the FinFET dependence of the gate-drain connection capacitance C_{gd} on the L should be reverse relative dependence C_{gs} on L, which means the decreasing C_{gd} with increasing L (Fig.8). C_{gs} and C_{gd} dependences on the L can be used for estimation the position of the local charge trapped in oxide along the channel. For this purpose, the ratio C_{gd}/C_{gs} dependence on L can be used (Fig.9).

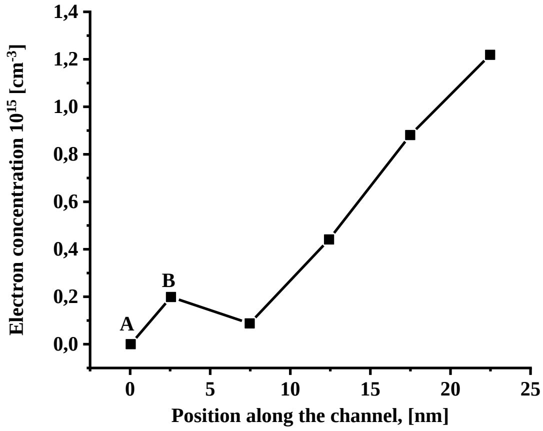

Fig.7. The change of the electron density in the channel at a depth 2 nm from the surface at trapping the local charge in the oxide layer at the different positions. A is point is the case without trapped charge, and B is the position with L=2.5 nm.

It is seen in the Fig.9 that if the local charge trapped is trapped in the oxide in the source side from the channel center the ratio C_{gd}/C_{gs} is less than 1, and if the local charge is trapped in the drain side from the center of the channel the ratio is more than 1. If the local charge trapped in the center along the channel the ratio C_{gd}/C_{gs} is equal to 1.

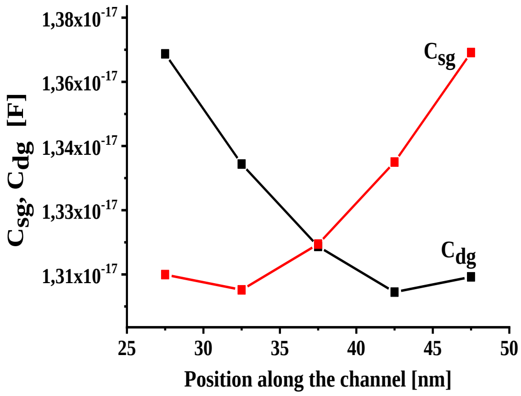

Fig.8. C_{gs} and C_{gd} dependence on the position of the local oxide trapped charge along the channel.

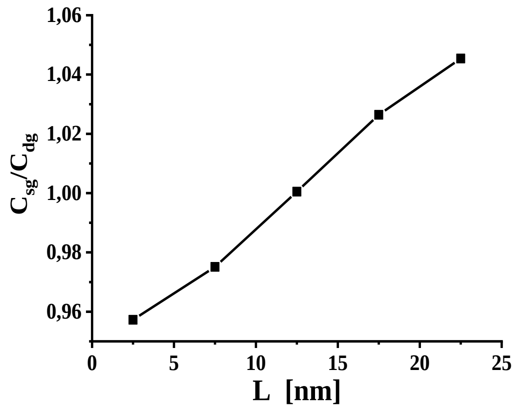

Fig.9. The ratio C_{gs}/C_{gd} dependence on the position of the local oxide trapped charge along the channel.

IV. CONCLUSION

Simulation results show, that in the SOI FinFET at some applied voltage, the capacitance of the gate-source connection monotonically depends on the position of local oxide trapped charge. This dependence is explained by the influence of the local charge on the carrier distribution at the surface of the channel.

The position of the local charge at the end of the oxide layer is an exception in the mentioned above dependence.

It is shown, the ratio C_{gd}/C_{gs} linearly depends on the position of the local oxide trapped charge along the channel in SOI FinFET. This dependence allows the development of a method of confirming the trapping of the charge and estimation of the distribution of the trapped charge along the channel.

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Cybersecurity Issues in Digital Transformation

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***Abstract*— To make systems secure and efficient in the age of digital transformation, they need to be adapted to keep pace with security innovations as well as the technology behind them. It is critical to have systems and methods in place to respond effectively and quickly to certain security incidents when they occur. This article presents important steps and approaches to ensuring cybersecurity in the era of digital transformation, and explores important issues that are in demand by society. The article also highlights the importance of restoring security in digital transformation, protecting systems with security practices and tactics, and implementing change.**

Keywords— digital transformation, cyber security strategy, cyber threats, mentoring.

I. Introduction

In today's digital age, safeguarding data, infrastructure, and connections from cyber threats is a daunting challenge. As digital technology becomes increasingly essential for businesses aiming to thrive, grow, and gain an edge over competitors, the importance of digital transformation becomes undeniable. Digital transformation revolves around leveraging advanced technologies to revamp business processes, customer engagement, and overall business models. This might encompass artificial intelligence, automation, machine learning and enhanced customer experiences [1].

Simply put, the essence of digital transformation lies in harnessing technology to make business operations more innovative, nimble, and efficient. For successful execution, it demands a strategic mindset, emphasizing risk management, security, and effective project oversight. But transitioning digitally is not solely about system shifts. It necessitates a cultural evolution in businesses, understanding that these transitions introduce new operational methods, training demands, and particularly, newer risks. This implies that as more businesses digitalize, the demand for robust cybersecurity tools and expertise will surge, making solid cybersecurity plans integral for a company's resilience [2].

A holistic digital transformation strategy is pivotal, encompassing everything from organizational structure and operations to client engagement and product innovation. Amidst these considerations, cybersecurity often emerges as a pivotal yet undervalued element. This discussion delves into the role of cybersecurity in digital transformation, spanning from risk comprehension and strategy formulation to practical solution implementation. By grasping cybersecurity's significance and actively addressing risks, businesses can shield their digital endeavors from potential threats.

In this digital revolution era, cybersecurity is paramount. It safeguards an organization's digital treasures, intellectual property, and client data. The swift evolution of digital methodologies has reshaped the security realm, elevating cyber threat levels. Given that digital transformation involves incorporating and assimilating new tech systems, cybersecurity has elevated to boardroom discussions.[3]

A. Mentoring

There are several reasons why a business goes through a digital transformation. Perhaps they want to cut costs or improve efficiency. Perhaps they want to serve their customers better or create new sources of income. Whatever the reason, areas of digital transformation can be a major challenge for any organization requiring careful planning and execution.

Guidance throughout the digital metamorphosis can immensely bolster an organization's defense mechanisms. Mentorship, whether within or across various entities, is crucial for enhancing cybersecurity awareness, fostering a resilient organizational culture capable of thwarting numerous threats. Here's how mentorship enhances cybersecurity in digital transitions [4]:

- Awareness Enhancement: Through mentorship, stakeholders become more adept regarding the significance of cybersecurity in digital endeavors, fostering knowledge on digital asset safeguarding.
- Guided Approach: Mentors, with their expertise, steer organizations towards proactive security measures.
- Knowledge Sharing: Mentors, with their wealth of experience, can share insights on cybersecurity implementations, pointing out typical pitfalls and effective tactics.
- Risk Management: Mentors aid in pinpointing and curbing cybersecurity risks, steering the implementation of apt security protocols.

To sum it up, mentorship is a cornerstone for a secure and triumphant digital transformation. Through experience sharing, guidance, and awareness promotion, mentorship empowers businesses with the necessary expertise and proficiency to defend their digital resources, foster a resilient organizational culture, and confidently navigate future cybersecurity landscapes.

Undoubtedly, businesses have varied motivations for digital transformation, whether it's cost reduction, efficiency improvement, superior customer service, or tapping into new revenue streams. Regardless of the motive, venturing into digital transformation is a complex endeavor for any entity, necessitating meticulous planning and execution.

B. Cyber security measures

Digital transformation encourages thinking about how to manage cybersecurity risks as part of a strategy. As more business processes and data move online, there are new risks that need to be addressed. Some cybersecurity measures to take before digital transformation (Figure 1):

- Risk assessment. Before starting a digital transformation, it is important to conduct a risk assessment to identify potential security risks. This will help you determine what cybersecurity measures you need to take to mitigate these risks.

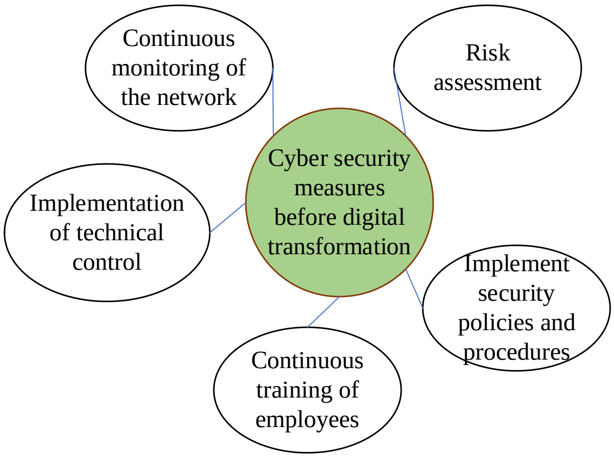

Fig. 1. Cybersecurity measures for digital transformation

- Implement security policies and procedures. Once you have identified potential security risks, you must implement policies and procedures to mitigate those risks. These policies and procedures should be in place to protect your data and systems from attacks.
- Continuous training of employees. It is important that all employees are aware of your security policies and procedures. They should teach you how to follow these policies and procedures to help protect your data and systems.
- Implementation of technical control. Technical controls such as firewalls and intrusion detection systems can help protect your network from attacks. This control must be implemented before the start of digital transformation.
- Continuous network monitoring. After following the above steps, you should regularly check your network for security threats. This helps identify any possible attacks and take steps to mitigate them.

There are also a number of measures to improve cybersecurity in companies undergoing digital transformation, including[5]:

- training employees on cybersecurity risks and best practices;
- implement a strong password policy;
- restrict access to confidential information;
- data encryption;
- regular data backup;
- use of firewalls and intrusion detection systems.

smooth and successful transition to the new digital landscape.

By integrating these precautions, businesses can mitigate the potential of cyber intrusions, facilitating a smoother digital evolution. Moreover, cybersecurity can enhance operational efficiency and cost-effectiveness by automating routine tasks and pinpointing threats before they escalate.

One of the invaluable byproducts of robust cybersecurity is the cultivation of trust among customers, collaborators, and other relevant parties. Given the growing emphasis on data security and privacy in the current digital age, companies showcasing commitment to cutting-edge security measures affirm their seriousness about these concerns. This commitment not only fosters trust but also paves the way for sustained partnerships. In essence, emphasizing cybersecurity during digital transformation is not just a necessity but a strategic move. Investing judiciously in apt security solutions can set the stage for a seamless transition to an advanced digital environment.

II. DEVELOP A CYBER SECURITY STRATEGY

Digital transformation is a risky business. Organizations are increasingly collecting, sharing and storing sensitive data online, making them vulnerable to cyberattacks. To protect themselves, organizations must develop a strong cybersecurity strategy. In this research paper, we review some of the key steps in developing a cybersecurity strategy, including creating a security roadmap, identifying security gaps, and establishing key performance indicators[6]. By following these steps, you can help your organization better protect itself from the threats of the digital world (Figure 2)[7].

A. Create a safety roadmap

The first step in developing a cybersecurity strategy is to create a security roadmap. This roadmap should describe the steps you need to take to protect your data and systems from attacks. It should also identify potential risks and vulnerabilities that could be exploited by cybercriminals. Some of the key elements of a safety roadmap include[8]:

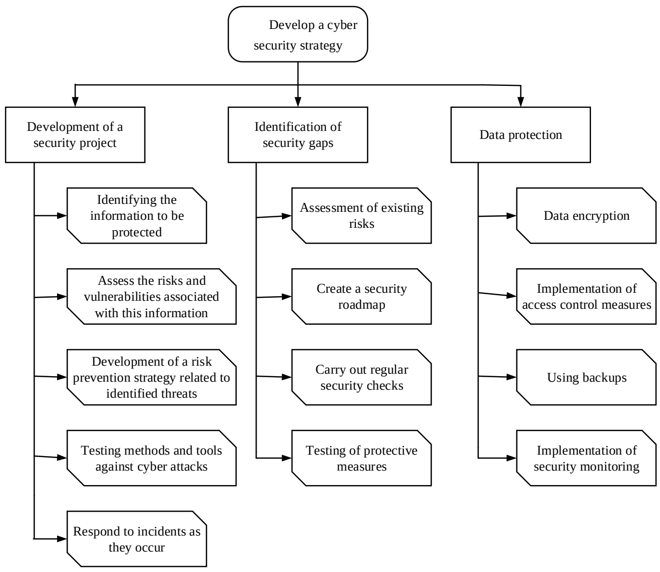

Fig. 2. Cybersecurity strategy for digital transformation

- Determine the information you need to protect. This includes your sensitive data and systems, as well as any customer or employee data stored electronically.

- Assess the risks and vulnerabilities associated with these assets. This includes identifying potential threats and how they exploit vulnerabilities on your system.
- Develop mitigation strategies to mitigate the risks associated with these threats. This may include implementing technical controls such as firewalls and intrusion detection systems, as well as developing policies and procedures to restrict access to critical data and systems.
- Methods and tools for testing against cyberattacks. This includes conducting regular penetration tests and security audits.
- Responding to incidents as they occur. This includes planning for containment and recovery from a successful attack. By following these steps, you can develop a comprehensive cybersecurity strategy to help protect your business from the ever-growing threat of cybercrime.

B. *Data protection*

Before embarking on a digital transformation, it is important to put in place strong security measures to protect your data. Here are a few basic solutions to consider[9]:

- Encrypt your data. Data encryption is the process of converting readable data into an unreadable format. This makes it difficult for third parties to access and use your information. When encrypting data, remember to use strong algorithms and keys that are not easy to crack.
- Implement access control measures. Access controls help restrict access to data based on user roles and permissions. This helps prevent third parties from accessing sensitive information.
- Use data backups. Data backups create copies of your data that can be used if the primary copy is lost or destroyed. Keep your backups in a safe place and encrypt them for added protection.
- Perform security monitoring. Security monitoring includes monitoring activity on your systems and looking for signs of malicious activity. It helps you identify threats and take steps to address them .

III. EFFECTIVENESS ANALYSIS OF CYBER SECURITY APPLICATIONS IN DIGITAL TRANSFORMATION

In the era of digital transformation, cyber security is one of the most important topics. The following methods are recommended for maintaining cyber security in digital transformation[10]:

- Good Practice: Implement secure settings and procedures for good system and network implementation. Keeping operating systems and applications up-to-date makes security patchy, creating a challenge for attackers.
- Security Education: Conduct security education among computer users and system administrators. Users can strengthen their passwords, monitor security inquiries and data from dubious sources or external tools, and help reduce risk.
- Security settings and data protection: Use security settings (such as firewalls, intrusion detection systems, anti-virus software) and data protection systems. It is possible to protect data with old security methods such as monitoring network traffic, detecting fraud and malicious codes, and encrypting data.
- Anti-Phishing: Prepare user data surveys and training to protect users against phishing (farming) attacks. It is also important not to trust e-mail and other communications when they cannot be read.
- Update programs and systems: Install systems and programs that can detect and respond to new security situations. These systems can assist in manning the attack and providing adequate security.
- Regulatory requirements: Adhere directly to the security regulations and laws of the organization and the country related to digital transformation. This helps establish the necessary procedures and standards to ensure safety.
- Distribution and Comparison: Explore the best preparedness and capabilities against system attack. To do this, conduct cyber-attacks (penetration tests), identify vulnerable points of the system and learn ways to eliminate them.
- Detection and response: Good monitoring and 24/7 availability of digital security systems is important for troubleshooting. Learn how to identify and remediate a security situation during an attack to ensure you can quickly identify and respond to security incidents that occur on your system.

By implementing these recommendations and applying cyber security in your digital transformation, you can define tactics to help protect your systems and data. It is important to study and implement security in a specific way, because security situations that are not quickly explained and remedied can pose a significant risk to systems and data.

The table 1 below outlines the steps of a cybersecurity analysis for digital transformation.

TABLE I. CYBER SECURITY ANALYSIS STEPS IN DIGITAL TRANSFORMATION

Analysis Step	Action	Definition
1. Analytical Applications	Start numerical analysis applications.	Initiate digital network or system analysis applications. Collect information from user input, system logs, monitoring systems, and other security sources.
2. Incident Detection	Identify security incidents.	Identify security incidents that occurred in the system during the analysis period. Identify events such as logouts, system outages, and network traffic changes.
3. Incident Analysis	Analyze events in detail.	Detailed analysis of identified events. Analysis of attacks and

		defenses against them. Analyzing the details of the events helps to explain the attacks.
4. Regulation	Define actions against security incidents.	Define actions against incidents. Define steps such as security recovery, data recovery, system isolation, increased monitoring.
5. Data Distribution and Art	Collect and share data.	Collect, analyze, and share digital security analytics data using custom structured and structured methods.
6. Description of Events	Describe the events.	Describe previous attacks, learned attacks, and loss supplements. These descriptions will help you prepare well to avoid such attacks in the future.
7. Eliminate and Zoom	Follow up on identified events.	Take action against detected security incidents. It includes troubleshooting, recovering compromised systems and data, and implementing countermeasures against attacks.
8. Single Supply Restoration	Depending on the results of the security analysis, restore the supply.	Take organizational steps to restore security according to analysis results.

This table can serve as a basis for organizing your cybersecurity analysis in tabular form. It is important to frame each step as steps to collect data, analyze, implement, and change.

IV. Analysis results

In the table 2 below, I present several cyber security practices with coefficients. These are coefficients related to the method of applying cyber security, the importance of the method (a scale of 1 to 5), and the technologies used for the method.

TABLE II. Composition of training and testing data

Cyber Security Method	**Value**	**Application Technologies**	**Coefficient**
Security Settings and Protocols	5	Firevoll, IDS/IPS, Antivirus	0.9
Data Encryption and Unencrypted Sources	5	AES, RSA, VPN	0.9
Support and Monitoring	4	SIEM, Analysis Log	0.8
Training of Users and System Administrators	4	Educational platforms, Tests	0.8
Software and System Updates	4	Automatic updates, patches	0.7
Protection from lies	4	Phishing education, banned sources	0.7
Security Incident Analysis	4	Intrusion detection, malware analysis	0.7
Security Auditing and Penetration Testing	3	Continuity scans, attack tests	0.6
Regulatory Requirements and Standards	3	ISO 27001, NIST, PCI DSS	0.6
Acquisition and Monitoring	3	Network monitoring, system monitors	0.6

Coefficients include the significance level of the method. The higher the coefficients, the more important the method. You can adapt the methods according to the students and resources of your organization. This chart can help you understand how to categorize cybersecurity practices and the importance of applying them.

V. Conclusion

As digital transformation continues to gain momentum, it is important for organizations to be aware of the cybersecurity risks associated with it. By taking a few simple steps, such as conducting a risk assessment, implementing security controls, and establishing a security monitoring program, organizations can help mitigate the risks associated with digital transformation and protect their data and systems from attackers. In this research paper, methods for applying cybersecurity to protect against the above risks were studied and analyzed in order of importance.

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Improvement Of The Case Method For The Development Of Acceptable Risk Skills Based On Including The Properties Of Interactivity

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***Abstract*—The case method is considered one of the most common interactive methods that are widely used in modern teaching methods. It allows you to simulate various production situations in order to identify problems, find alternative solutions and develop the most optimal result of activity. Therefore, the method of interactive cases contributes to the formation of the extreme competence of the future specialist, contributes to the integration of their educational and research activities.**

Key words — interactive case method, accounting and investigation of industrial accidents, case technologies, production situation, acceptable risk skills, practical skills, extreme competence.

I. Introduction

The developed interactive case was chosen based on the need for a more detailed study of the section "Accounting and investigation of accidents at work" of the discipline "Life safety", since only two hours are allocated for it in the curriculum. In addition, these two hours include not only the investigation of accidents at work, but several other sections of the discipline. At the same time, the number of accidents at telecommunications enterprises has increased significantly. For this reason, the algorithm for recording and investigating industrial accidents was chosen as a methodology for developing acceptable risk skills for students of technical higher educational institutions.

II. MAIN PART

The discipline "Life Safety" is considered practice-oriented in technical universities. A distinctive feature of the discipline is considered to be a complex of formation of certain competencies, in particular, the utmost competence in such sections of the discipline as first aid, recording and investigation of industrial accidents, the basics of fire fighting, emergency situations, which involve objectification of the assessment of their development. A necessary requirement for the formation of maximum competence when mastering the curriculum of the discipline "Life Safety" is the development of emergency-cognitive, algorithmic-activity and ultimate reflex skills in students.

Situations associated with risk often arise in production; for this reason, professional training involves the formation of an adequate assessment of one's capabilities in a specific production situation, the ability to obtain the desired results in conditions associated with risk, without endangering one's life. and team health. A risk situation in work activity can arise in a person for various reasons: equipment breakdown, poor ecology or social climate, and, in addition, inappropriate behavior of a person in a professional environment.

Today, the problem of developing students' acceptable risk skills is especially relevant. This can be seen clearly by studying the various laws in our republic.

The Law of the Republic of Uzbekistan "On Labor Protection" states that in higher and secondary specialized, professional educational institutions, in the prescribed manner, training of specialists in labor protection is provided and compulsory study by students and students of a course in labor protection should be organized, taking into account the characteristics of the production of various industries economy and social sphere [1].

The dissertations of foreign scientists widely cover the problems of developing acceptable risk skills and the use of interactive technologies in the educational process: Abu-Alrop Jalal Hafez Ahmad [3], Al-Kaibi Yeman Gabar Abdul Hasen [4], Liu Chunguang [5], Saqr Sadeq Sallam Nasser [6], Pham Viet Dung [7], Zhao Nannan [8], A.A. Mauri [9], E.Yu. Lesite [10], Song Lei [11], A.A. Lyash [12].

All of the above and the analysis of sources confirm that many scientists have discovered the theoretical and practical foundations for the use of case technologies in the system of higher education. However, in the age of global threats and challenges to the security of mankind, in the study of the discipline "Life Safety" there are no monographic studies of the problem of developing skills of acceptable risk based on interactive cases.

Let's consider the interactive format in the case "Recording and investigation of industrial accidents" [13]. Using the interactive case method on a web platform, a deeper study of theoretical material allows you to fruitfully assimilate the educational material. Participants in the case become actors in the situation, developing a strategy for optimal actions in an emergency situation at work. The emphasis is not on comprehending ready-made knowledge, but on its development [14].

Distinctive features of the method of interactive cases. Steps for solving an interactive case:

1) The first stage consists of an analysis of the circumstances of an emergency situation at work (case), in particular "Accounting and investigation of accidents at work".

2) The second stage characterizes the collection and analysis of the missing information. The student studies this production situation [15]. In an interactive case, we study an accident at work, namely, a fall from a height onto a concrete floor while laying an optical feeder.

3) The third stage is the study of various options for the development of events in the current production situation, the search for a solution to the problem [16].

Development of an optimal solution for the algorithm "Accounting and investigation of accidents at work", a questionnaire for solving an interactive case.

4) The fourth stage is a selection of the best solution, from well-developed stages and conclusions made [17]. It should be noted that the case does not have a correct solution and we have many, or one, the most rational solution for a particular situation. It should also be taken into account that the case is based on real facts from a specific life situation, and in conditions of limited time it is not always possible to present a complete picture [18]. In the interactive case "Accounting and Investigation of Industrial Accidents", the optimal solution is to complete the work of the commission on the investigation of an industrial accident and issue an accident report to the relatives of the victim [19].

Interactive case "Investigation and registration of industrial accidents".

Goals:

- familiarization of students with the rules for investigating and recording industrial accidents;
- study of the signs of an accident and the investigation algorithm;
- development of skills of analysis and systematization of information;
- mastering the application of the algorithm for investigating industrial accidents.

Tasks:

- develop the ability to work in a team;
- to develop the skills of caring for one's own health and the health of others;
- be able to apply the learned information and acquired skills in non-standard situations.

Case type: interactive - training.

Description of the case. Students are offered a situation that actually occurred or is possible at a communications enterprise and an interactive case containing information about this situation. Students need to assess the situation, identify the main problem, establish its consequences and propose solutions.

TABLE 1. DESCRIPTION OF THE PRODUCTION SITUATION

Circumstances of the accident	During the work of an electrician as part of a team for laying an optical feeder on the territory of the Yunusabad automatic telephone exchange at a height of 2.75 m, he fell onto a concrete floor. The victim received severe health damage in the form of a craniocerebral injury and a fracture of the spine.
Violations	1. The employer did not provide safe working conditions. 2. Violated the requirements of labor protection during the operation of electrical installations.
Responsibility	Fine.

Tasks: read the information cases and answer the questions, writing the answers in the table:

a) What was the accident at work?

b) Who needs to be notified about the accident;

c) Make an algorithm for investigating an accident at work;

d) Determine the type of accident at work, the stages of work of the commission for the investigation of an accident at work;

e) Suggest measures to prevent accidents at work.

Information cases (distributed to students for review).

Case "Accounting and investigation of industrial accidents" (distributed to students)

1. Determine the nature of the accident (accident at work or domestic injury).
3. If an accident occurred at work, it is necessary to notify the management and relatives of the victim.
4. Call an ambulance.
5. Record the situation at the scene.
6. Define a minor or severe accident.
7. Notify the relevant authorities.
8. Draw up an act of form H-1.

The development of the case solution algorithm is shown in Figure 1.

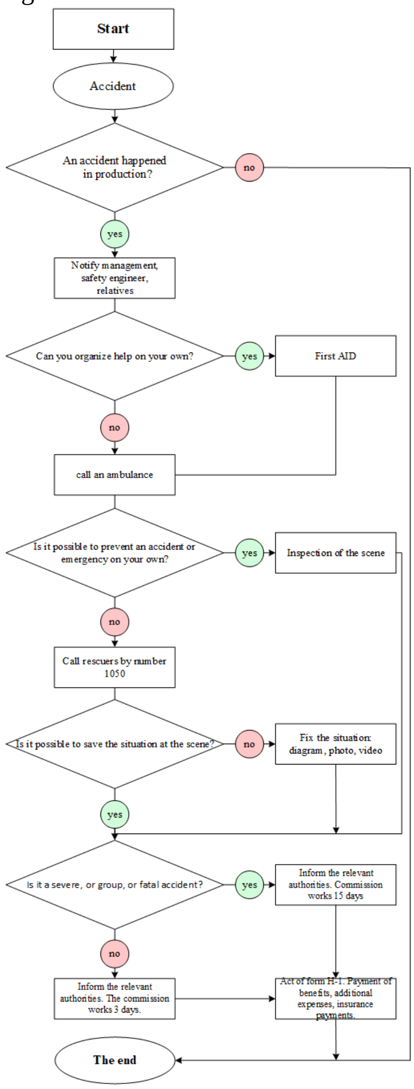

Fig. 1 Algorithm of the interactive case "Accounting and investigation of industrial accidents"

The algorithm describes the sequence of actions that need to be studied to record and investigate industrial accidents.

Analysis of real life situations contributes to increasing students' interest in learning, contributes to the active assimilation of knowledge and skills in collecting, processing and analyzing information, forms the necessary competencies, analytical and practical skills [20].

In order to effectively organize the process of teaching computer animation in an electronic educational environment, a web-oriented platform “Development of an interactive case “Providing first medical aid to a victim of an electric current” has been developed, which contains methodological recommendations for students and teachers and has been introduced into the pedagogical process of higher educational institutions.

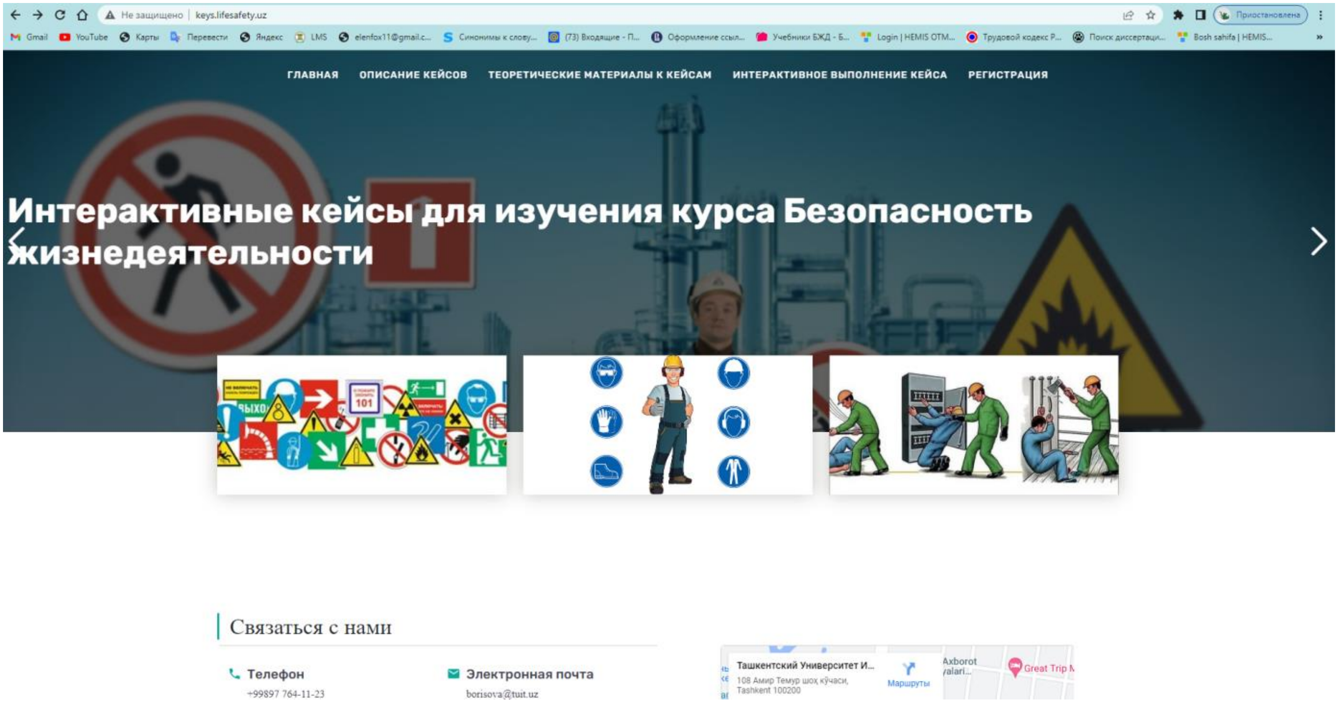

Fig. 2 User interface of the interactive case

After completing the interactive case, a table summarizing the case method is filled out.

After registering on the site, the student will be redirected to the theoretical section.

TABLE 2 CASE METHOD: SUMMING UP

Accident at work (with explanation of choice)	**List of persons to be notified about the accident:**	**Algorithm for investigating an accident at work**	**Determine the type of accident (light-severe) and which authorities need to be informed about the accident. Commission hours.**	**Possible measures to prevent accidents at work**

Discussing the work of students, determining the correct actions in the investigation of an accident.

This interactive case was tested at the Tashkent University of Information Technologies named after Muhammad Al-Khorezmi, the Tashkent State Technical University named after Islam Karimov, and the Bukhara Institute of Engineering and Technology.

The point-rating system of knowledge assessment used at our university to assess the results of mastering the material by students of the discipline "Life Safety" does not fully evaluate practical skills and abilities [21]. In the process of conducting classes, the teacher evaluates the theoretical and practical knowledge of students. The final assessment provides for a cumulative system for all lessons of a topic or section. However, this approach does not allow to objectively evaluate practical skills and judge the formation of practical skills [22].

To assess students' knowledge in the discipline "Life Safety", it is appropriate to talk about another type of competence - "extreme competence", which expresses a person's readiness to work in suddenly complicated conditions, in accidents, or emergencies at work and at home [23].

The main task of each person is to prepare for professional activity in special conditions, to play various extreme situations, to develop methods of optimal behavior in complicated professional conditions [24].

Important qualities of a future specialist are in fig.3.

Consider the competencies that a future specialist should have in more detail (Table 3).

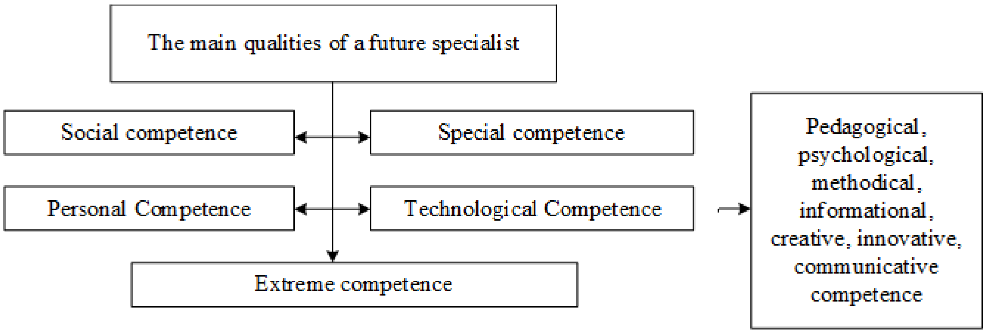

Fig. 3 Specialist competencies

TABLE 3 COMPETENCIES OF A SPECIALIST

№	Qualities of a future specialist	Definition of Competence
1	***Social competence***	an indicator of the level of mastery of a personality by a certain set of socio-psychological knowledge and moral and legal value judgments that allow one to successfully adapt and act actively in a particular social environment
2	***Personal Competence***	these are the internal resources of an employee, formed under the influence of his character and personal qualities, and other psychological attitudes that help employees in the successful completion of tasks
3	***Technological Competence***	this is a generalized method of action, including a system of knowledge, skills and abilities and a system of technological means, a standard procedure for their application for the purposes of training, education, development
4	***Extreme competence***	the ability to act in suddenly complicated conditions, in case of accidents, violations of technological processes
5	***Special competencies***	possession of the professional activity itself at a residually high level, the ability to design one's further professional development

To assess students' knowledge in the discipline "Life Safety", we propose to use "extreme competence". This is a multifaceted concept that can be viewed from different angles:

- a person has the necessary knowledge, skills and abilities for rational decision-making and readiness for emergency situations, natural disasters, technological processes and damages, conflict resolution in problem situations, the manifestation of skills for rational decision-making;
- the determination to act actively in the event of an emergency situation, using the previously mastered algorithm of actions;
- determination and desire to take the necessary action to stabilize the situation;
- finding a person at the workplace at the right time.

TABLE 4. CRITERIA FOR ASSESSING CRITICAL COMPETENCE

№	Criteria/ Levels	Emergency-cognitive	Algorithmic-activity	Extremely reflective
1	***Reproductive***	- incomplete and not interconnected fragmented knowledge on risk prevention and emergency response;	- practical implementation of a set of unrelated actions to prevent risk;	- identification of risk factors and emergency; - unwillingness to prevent risk and eliminate an emergency;
2	***Productive***	- complete but not interconnected knowledge of risk prevention and emergency response;	- slow but conscious implementation of the correct algorithm of actions to prevent risk and eliminate an emergency;	- identification of professional challenges for risk prevention, their transformation into a proven algorithm of actions; - acceptance of obligations to prevent risk;
3	***Automatic***	- complete and interrelated knowledge of risk prevention and emergency response.	- automatic execution of algorithmically correct actions to prevent risk and eliminate an emergency.	- quickly recognizing and accepting professional challenges to prevent risk and eliminate an emergency, transforming them into well-functioning actions; - full commitment to risk prevention and emergency response.

The developed assessment criteria will allow taking into account the acquired skills and abilities in the course of studying the discipline "Life Safety" and assess the readiness of the future specialist to work at the enterprise, taking responsibility for risk prevention, and the ability to resolve emergency situations that may arise in the course of work.

III. CONCLUSION

It is possible to improve the skills of acceptable risk in the discipline "Life Safety" by repeatedly studying the developed interactive cases. The acquired skills for solving an emergency situation can be assessed according to the developed assessment criteria. It is necessary to take into account the diversity of case solutions and the final result of the solution depends on many factors that we take into account when solving an interactive case.

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The structure of tracking suspicious packets in network traffic

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***Abstract*—This paper analyzes the black-and-white lists of traffic filtering, which provide a formal way to consider and describe operations with such lists of threats in network security. White list traffic filtering allows you to clearly define the logic for detecting and responding to malicious elements and threats in the network infrastructure. And black list of traffic filtering allows it to assess the risk of suspicious objects and regularly update it based on new data and changing conditions. Based on the analysis of black-and-white lists, traffic filtering is proposed a structure for tracking suspicious packets in network traffic to check the legitimacy of a web page using hyperlink functions.**

Keywords — filtering, black list, white list, MAC address, suspicious packets, Phishing attacks, network traffic.

I. Introduction

Suspicious Packet Watch Lists are specialized databases that contain information about various threats and malicious activity on the network. These lists are updated regularly and contain data on new and known threats, malicious IP addresses, domains, file hashes, and other characteristics of malicious activity. They provide valuable information about today's cyber threats and help organizations take precautionary measures and counter different types of attacks.

II. Suspicious packet tracking lists

A. Black list

The blacklist contains known malicious IP addresses, domains, URLs, and other network characteristics that are associated with cyber threats and cyber-attacks [1].

Lots of blacklists. Set B is a list of malicious or unwanted elements that we want to monitor and control. The elements in a set can be represented, for example, as hashes or unique identifiers.

Universal set. The universal set U represents all possible elements that can exist in the network or environment in which the blacklist operates. This set includes all possible IP addresses, domain names, hashes, etc.

Ownership check. To determine if an element is part of the blacklist, we can use the membership check operation. For example, for an element x, it can be checked whether it belongs to the blacklist set $(x \in B)$ or the complement of the blacklist set $(x \notin B)$ [2].

Blacklist update. Updating the black list involves the operations of adding new elements to set B (for example, when new threats are detected) and removing elements from set B (for example, after the threat has been successfully neutralized or has become irrelevant).

Operations on sets. Set operations include standard set operations such as union $(B \cup C)$, intersection $(B \cap C)$, and difference $(B \setminus C)$, where C is another set of elements.

Boolean expressions. Boolean expressions use logical operations to define complex conditions. For example, you can create an expression that tests if an item is part of a blacklist and belongs to a specific threat category (for example, the expression «$x \in B\ AND\ category(x) = 'malware'$») [3].

B. White list

The whitelist contains trusted IP addresses, domains, URLs, and other characteristics. They help establish trusted traffic sources and provide a whitelist of known good resources.

Whitelist set (W). The set W is a list of trusted or allowed elements. These may be IP addresses, domain names, hash sums, or other characteristics that are considered trusted.

Universal set. The universal set U represents all possible elements that can exist in the network or environment in which the whitelist operates. This set includes all possible IP addresses, domain names, hashes, etc.

Ownership check. To determine if an element is part of the whitelist, we can use the membership test operation. For example, for an element x, it can be checked whether it belongs to the whitelist set $(x \in W)$ or the complement of the whitelist set $(x \notin W)$ [4].

Whitelist update. Updating the white list involves the operation of adding new elements to the set W (for example, when adding new trusted resources) and removing elements from the set W (for example, if the resource is no longer trusted).

Operations on sets. Set operations include standard set operations such as union $(W \cup C)$, intersection $(W \cap C)$, and difference $(W \setminus C)$, where C is another set of elements.

Boolean expressions. Boolean expressions are used to define complex conditions. For example, you can create an expression that tests if an element is part of a whitelist and belongs to a certain category of trusted resources (for example, the expression «$x \in W\ AND\ category(x) = 'trusted'$») [5]. And so, on Figure 1 a generalized scheme of black-and-white lists of IP addresses is presented. As it is analyzed into Figure 1, the lists have their own features and its serve for well managing the incoming and outcoming packets.

The following is a generalized framework for tracking suspicious packets in network traffic. The suspicious packet tracking structure consists of the following steps:

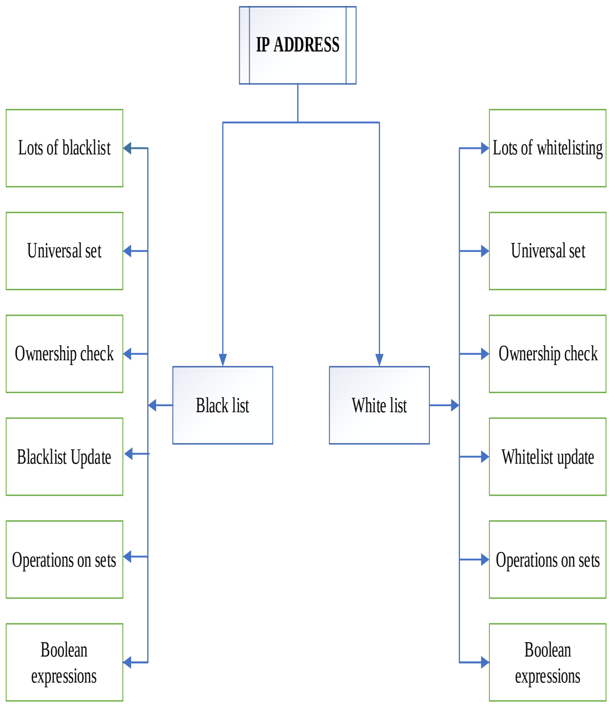

Fig. 1. Generalized scheme of black-and-white lists of IP addresses

III. STRUCTURE FOR TRACKING SUSPICIOUS PACKETS IN NETWORK TRAFFIC

A. *Stage mitigation*

The mitigation stage contains the five presented following table.

1. The blacklist table will block the intruder's MAC address.

2. The white list table will check the source MAC address of the packet. If there is a matching entry, the packet will be redirected. Otherwise, the SYN packet will be placed in the sync-check table, the ACK packet will be placed in the ack-check table, and the rest of the packet will be discarded.

3. The forwarding table forwards the packets to the corresponding output port.

4. The synchronization check table performs if the packet matches one of the 256 entries, the SYN and ACK packets are synchronized, and the attacker is detected.

5. The confirmation table will check the ACK number of the packet. If the ACK number is correct, detect the intruder. Otherwise, the packet is dropped [6].

B. *Stage detection*

There is a hash table to store values in registers, and a slot in the table contains the key and value. The key stores two fields: IP address and MAC address, and the value stores the counter. The detection module has two main actions: adding to the slot and clearing the slot [7].

Adding to a slot

Using the source IP address and the destination MAC address of the packet as a key, then calculate k using various hash functions and get the k corresponding to the index. If the key does not exist in the hash table, check if there is still an empty slot k, if there is no empty slot, the packet will be sent back to the client; otherwise, the key (source IP address, destination MAC address) will be kept and the key and counter will be set to 1.

Also, if the key exists in the hash table, the counter is incremented by 1 and the counter is checked to see if the counter is above a threshold value T. The threshold means that T connection failures are valid. If the counter exceeds the threshold, the switch will send summary information to the controller, and then the controller will add the key's MAC address to the black list table [8].

Clearing a slot

The clear slot step will get the number k of slots that can be accessed using the input element's key. It will then check if the key is in the hash table [9].

C. *Phishing attack detection stage*

The phase of detecting Phishing attacks is divided into two modules. The first module is the URL/DNS mapping module, which contains a whitelist that is used to improve uptime and reduce false positives.

Figure 2 shows Flowchart of Phishing Attack Detection Algorithm.

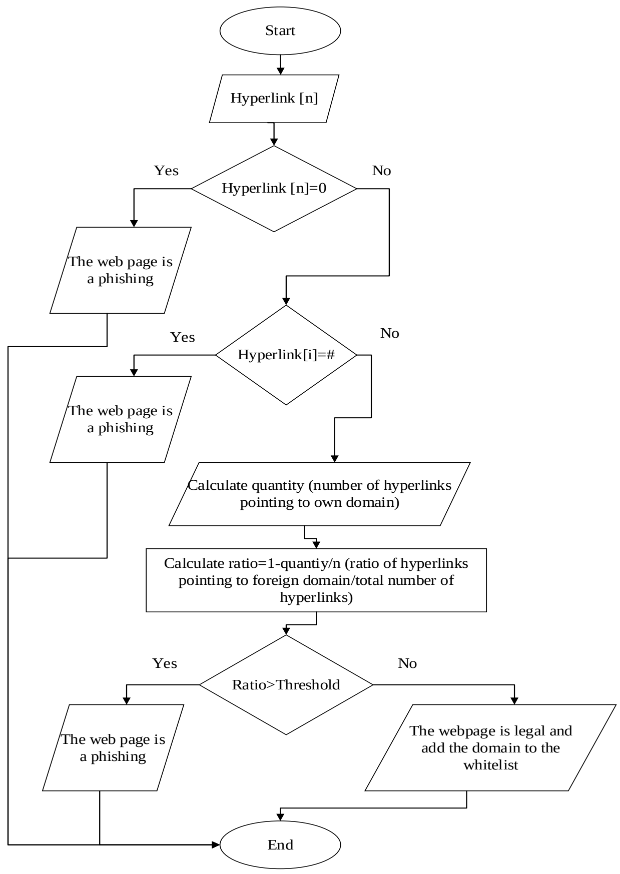

Fig. 2. Flowchart of Phishing Attack Detection Algorithm

The white list supports two parameters: the domain name and the corresponding IP address. Whenever a user accesses a website, the system matches the current website's domain name against the whitelist [10]. If the current website's domain matches the whitelist, then the system matches the IP address to make a decision. When a user accesses a website that is already whitelisted, the subsystem matches the IP address of the corresponding domain to test for a DNS poisoning attack. The white list starts from zero; this means that there is no domain in the list at the beginning, and the whitelist starts growing as soon as the user accesses new web pages [11].

When a user visits a website, there are two possibilities: either the user is visiting the website for the first time, or they have already visited it. If the user visits the site for the first time, then the site domain will not be present in the white list. In this case, our second module starts working. The second module is the phishing identification module, which checks if the web page is phishing. This extracts hyperlinks from a web page and applies a phishing detection algorithm. The phishing detection algorithm analyzes the features of the hyperlinks to make a decision. After checking for legitimacy, if the site is phishing, the system displays a warning to the user [12-15]. Moreover, if the site is legal, then the system updates the domain in the white list. Figure 3 proposes a structure for tracking suspicious packets in network traffic.

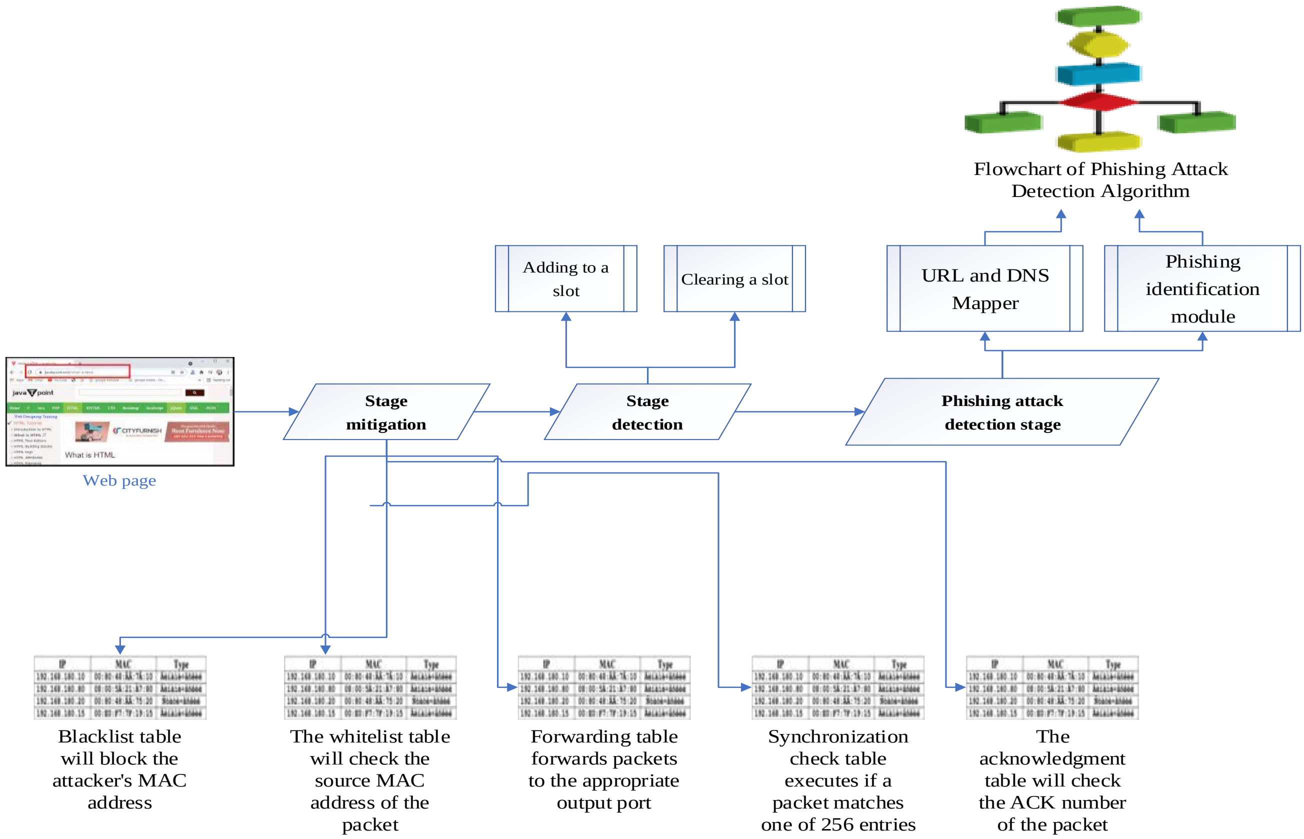

Fig. 3. Structure for tracking suspicious packets in network traffic

IV. Conclusions

In conclusion, it should be noted that the proposed structure for tracking suspicious packets in network traffic, taking into account the implementation of the built steps, allows it to check the legitimacy of a web page using hyperlink functions and protects your domain from fake attacks.

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Methods and algorithms for creating multi-parameter reports in the organization

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Abstract. Methods and algorithms for creating multi-parameter reports play a key role in data management and decision-making in electronic document management systems. When reviewing and analyzing data, multivariate reports help the user to conveniently present information on multiple parameters and provide a better understanding of the current situation and trends, which helps the user to make decisions. Modern organizations are increasingly aware of the importance of data and its analysis for effective business management and development. This article presents methods and algorithms for generating multi-parameter reports in electronic document management systems.

Keywords — Algorithm, electronic document, report, object, meta-information, electronic document circulation system

I. Introduction

Today, there is a need to regulate information processing and document circulation in any organization. In recent years, digitalization processes have been rapidly improved, but little attention has been paid to the quality of information input and storage, database collection, and information processing. As a result, electronic document circulation systems have created problems that must be solved by accessing information, using search modules, and integrating information[1].

The increase of digital documents has changed the requirements for them, it is required to solve the issues of the used technologies, description formats and their presentation in the form of reports, compilation of electronic documents and convenient for use[2].

Methods and algorithms for creating multi-parametric reports play a key role in organizing, analyzing and interpreting data in various fields. Here are some reasons why they are important:

- Inform and make decisions: Multi-dimensional reports provide comprehensive information about multiple dimensions or metrics to help you make informed decisions. Users can see the relationships between various factors and better understand the situation.
- Detect trends and patterns: Analysis of multivariate data can help uncover hidden trends, patterns, and dependencies between parameters. This can be useful for predicting future events or for detecting anomalies.
- Reduce analysis time: The use of automation methods and algorithms can reduce the time that is usually required to manually analyze large amounts of data. This increases efficiency and allows you to respond more quickly to changes.
- Data visualization: Multidimensional reports often include visualizations such as graphs and charts. This makes the data more visual and understandable, which improves the ability to interpret the information.
- Performance Monitoring and Evaluation: Reports allow you to evaluate performance, efficiency and achievement of goals in various aspects of business, science, healthcare and other areas.
- Automation and optimization of business processes: Methods and algorithms for generating reports can be integrated into business processes, allowing you to automatically create and distribute reports in accordance with specified rules and schedules.
- Resource efficiency: Automating the reporting process reduces the need to manually process and analyze data, which saves company resources, time and human resources.
- Ensuring transparency: Multi-dimensional reports contribute to more transparent activities, as they allow you to present information objectively and document processes.

In general, methods and algorithms for generating multivariate reports help organizations and professionals to find valuable knowledge in the data, improve performance and make informed decisions based on quantitative data.

II. LITERATURE REVIEW

Many scientists of the world have conducted and are conducting scientific research on the creation and implementation of electronic document management systems, including L.M. Volkov's research work entitled "Models and algorithms for information processing in electronic document management software systems" shows how to improve the efficiency of public administration by accelerating the flow of information to the automated information systems of state organizations by studying the principles of designing software systems for secure and legally significant electronic document circulation. [3].

Hongok Zuy's researches are devoted to data processing algorithms in electronic document management systems, and in his opinion, in order to increase the efficiency of modern electronic document management systems, which ensures the preservation of high performance, it is necessary to reduce the hardware complexity of implementing high-speed algorithms for information processing[4]. A mathematical model of information processing in electronic document management systems has been developed in educational institutions. Such a model is used to formalize the structure of documents, process documents, optimize interaction and movement processes [5]. In his work entitled "Analysis of algorithms and mathematical models for automation of electronic document flow", Í.O.Chernyak studied in detail the possibilities of using mathematical models and their improvement algorithms used in the automation and improvement of electronic document circulation [6].

III. Proposed Methods and algorithms

The issue of creating reports in electronic document management systems(EDMS) depends on many parameters. That is why we call them multi-parameter reports. After studying multi-characteristic parameters, it was determined that 3 different reporting methods and corresponding algorithms should be developed in EDMS.They are:

1. R_T - Formation of reports on the classification of electronic documents.
2. R_I - Formation of periodic interval reports.
3. R_E - Formation of a report on the implementation of electronic documents.

There are also combinations of multi-parameter reporting, and first of all, we will determine the solutions to the problems of developing these reporting methods and algorithms. [5-6].

A. Forming reports on the description of electronic documents.

R_T - The main idea of creating reports on the classification of electronic documents is to implement them by using the metadata used for the classification of electronic documents. For this purpose, the following designations are made, that is, the information related to one object of the report is denoted by H_i, the totality of all data of the report is denoted by R_T, and it is determined by the following expression (1):

$$R_T = \sum_{i=1}^{n} H_i \quad (1)$$

Where n is the total number of data relevant to the report.

The following expression is given to select each H_i in the report(2).

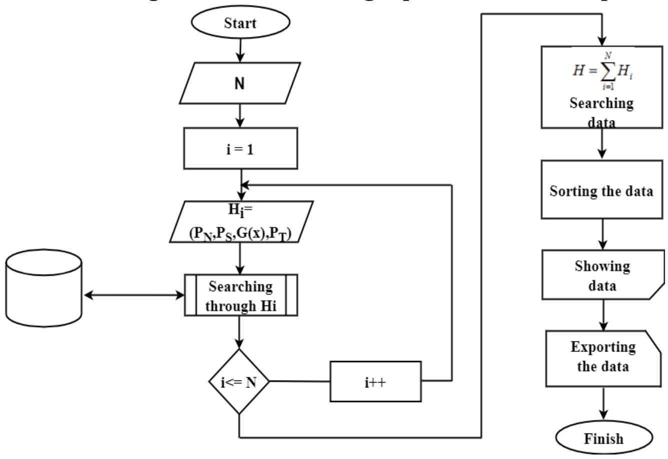
$$H_i = \left\langle P_N^i, P_S^i, G_i(x), P_T^i \right\rangle \quad (2)$$

P_N^i is the field name for object i, which includes all MARC21 or user fields in the EDMS. P_S^i is a quantity that determines the reporting of the field belonging to the i - object, which takes one value (1 or 0). If $P_S^i = 1$, the field values will be displayed, but if $P_S^i = 0$, the field values will not be displayed, but can be used to generate the report.

$G_i(x)$ is the condition or set of conditions applied to the field belonging to object i. Conditions matching the object match the data type x. They are assigned a specific value (25), text ("Tashkent"), references (numerical and/or text array, for example, months of the year). If there are several conditions, $G_i(x) = \left\{ \cup \otimes \cap \left[G_i^j(x) \right] \right\}$ is expressed in the form of judgment, j is the order number of the condition, $j \in 1..J$, $J -$ is the number of conditions.

P_T^i - is the meta information of the field belonging to the i - object. This is entered by the user and is constant throughout the report.

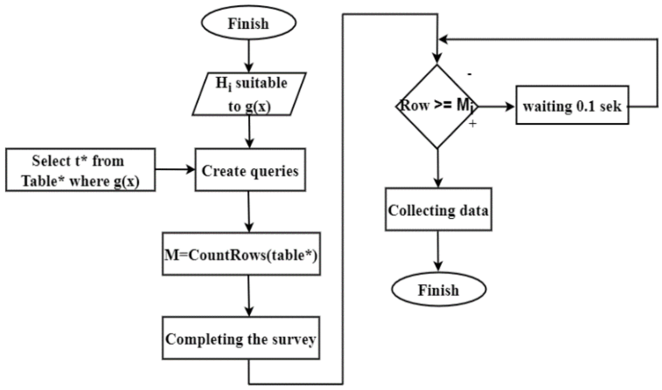
R_T - the algorithms for forming reports on the description



of an electronic document are presented below (Figures 1, 2).

Figure 1. Algorithm for generating reports on electronic document description.

In the algorithm for generating reports on the description of electronic documents, the search auxiliary algorithm is as



follows (Fig. 2).

Figure 2. Search by H_i, a helper algorithm.

In this algorithm, [table*] –[t*] is a table containing meta-information, condition H_i corresponding to $G_i(x)$ is a condition corresponding to type x for the requested metadata, [t*] - $G_i(x)$ is a list of metadata in the condition, which are usually separated by [,] . The most effective algorithm for generating reports on the classification of electronic documents is determined based on two factors [7-8].

1. The asymptotic complexity is $(n+1)\cdot n + 2\cdot n + 10$ because of the total of 10 operations, 2 n iterations and 1 n+1 iterations of n matrix search operations in 2 algorithms for calculation. Since this is a quadratic polynomial, the base is $O(n^2)$.
2. Memory area complexity is 4*4=16 for 4 integers, 20 bytes of memory area based on 4 bytes for array.

B. Creating periodic reports.

R_I – The main idea of creating periodic reports is to create reports depending on the period (time). In it, the information related to one object of each report is denoted by

X_i, and the sum of all the data of the report is denoted by R_I, and is determined by the following expression (3)

$$R_I = \sum_{i=1}^{n} X_i \quad (3)$$

Here n is the total number of data relevant to the report. The following expression (4) is given for selecting each X_i in the report.

$$X_i = \left\langle Gx_i(x), S_{arr}^i \right\rangle \quad (4)$$

In this case, $Gx_i(x)$ is the condition and/or set of conditions for the field belonging to object *i*. If there are several conditions, $Gx_i(x) = \left\{ \cup \otimes \cap \left[Gx_i^j(x) \right] \right\}$ is expressed as a statement, j - is the serial number of the condition, $j \in 1..J$, $J -$ is the number of conditions.

S_{arr}^i is a set of data depending on the periodic interval (time). Depending on the organization's EDMS capabilities, different data sets can be generated. It is recommended to use character, numeric and boolean data types for data sets. Their widely available options are defined by the following expressions.

$$S_{arr}^1 = \left(s_k^1\right) = \{\text{"}\mathit{yearly}\text{"}, \text{"}\mathit{First\ semestr}\text{"}, \text{"Second semestr"}\}$$

, the data set in S_{arr}^1 is given as an array of character strings, which need not be strictly indexed. A report is made on the basis of creating a periodic function for the selected string based on the meaning of the term.

The data set in $S_{arr}^2 = \left(s_k^2\right) = \{1,2,3,4\}$, S_{arr}^2 is given as an array of numbers, which must be strictly indexed. The selected number represents the "quarter" period accordingly, and the report is made based on creating a periodic function for its meaning.

$S_{arr}^3 = \left(s_k^3\right) = (a,b)$, S_{arr}^3, the data set is given as a 2-element array with lower and upper bounds created from times and/or dates, which must be strictly indexed. The first element is the lower limit, the second element is the upper limit. A report is made based on the creation of a periodic function for the meaning of this interval.

Denoting the periodic function in terms of $F(x) = f(a,b,x)$, it can be suggested as follows:

For S_{arr}^3, $i = 1..N-1$, $N = b-a$

$$F(x) = f(a,b,x) = \begin{cases} a, \ if \ x_0 \\ x_i = a + i \times h, \ if \ a < x_i < b \\ b, \ if \ x_n \end{cases}$$

For S_{arr}^1 and

S_{arr}^2 $i = 1..N-1$, $N = b_k - a_k$, $t_k \in \left[a_k, b_k\right]$, *in* S_{arr}^1, *k=3*, in S_{arr}^1, *k=4*,

$$F(x) = f(t_k, x) = \begin{cases} a_k, \ if \ x_0 \\ x_i = a_k + i \times h, \ if \ a_k < x_i < b_k \\ b_k, \ if \ x_n \end{cases}$$

In this case $\left[a_k, b_k\right]$ is the dates corresponding to the selected term or number. R_I - Algorithms for generating periodic reports which are presented in figures 3, 4.

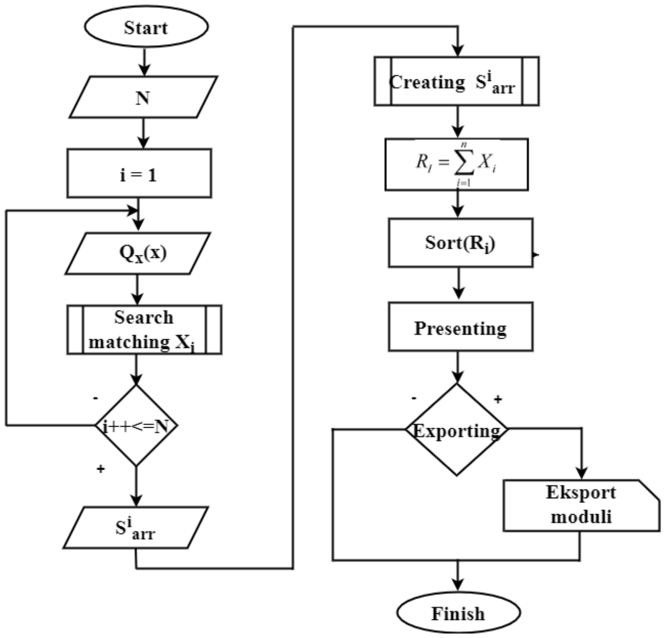


Figure 3. Algorithm of formation of periodic interval reports

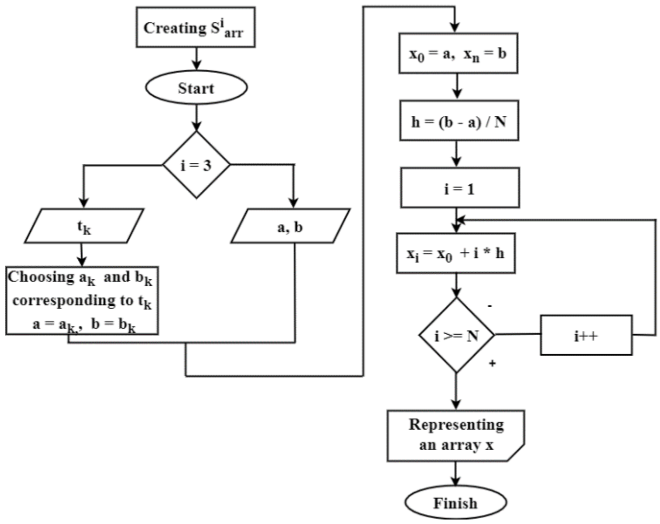


Figure 4. S_{arr}^i construction part algorithm

The most effective algorithm for creating periodic reports is as follows:

1. The asymptotic complexity is $(n+1) \cdot n + 3 \cdot n + 12$ for 3 algorithms to calculate a total of 12 operations, 3 n iterations and 1 n+1 iterations of n search operations. Since this is a quadratic polynomial, the base is $O(n^2)$.

2. Memory area complexity is 5*4=20 for 5 integers, 28 bytes of memory area based on 8 bytes for array.

C. *Forming a report on the execution of an electronic document.*

The main idea of creating a report on the execution of R_E – electronic document is to create reports related to the status of electronic document, types of response, employees[11-12]. In it, we denote the data of each report on one object as Z_i, the totality of all data of the report as R_E, and let it be defined by the expression (5):

$$R_E = \sum_{i=1}^{n} Z_i \qquad (5)$$

Here n is the total number of data relevant to the report.

The following expression (6) is given for selecting each Z_i in the report.

$$Z_i = \left\langle Gz_i(x), T_{arr}^{i}, y_i \right\rangle \qquad (6)$$

In this case $Gz_i(x)$ is the condition and/or set of conditions for the field belonging to object *i*. If there are several conditions, $Gz_i(x) = \left\{ \cup \otimes \cap \left[Gz_i^j(x) \right] \right\}$ is expressed in the form of judgment, j is the order number of the condition, $j \in 1..J$, $J -$ is the number of conditions[9-10].

T_{arr}^{i} is a set of data related to the state of electronic document. Based on the EDMS capability of the organization, the data sets are mainly defined by the status term. Their widely available options are defined by the following expressions. $T_{arr}^{1} = (\text{"Finished"}, \text{"Unfinished"})$,

$T_{arr}^{2} = (\text{"Complated on time"}, \text{"Complated over time"}, \text{"Uncomplated"})$,

$T_{arr}^{3} = (\text{"positive"}, \text{"negative"}, \text{"unresponded"})$,

$T_{arr}^{4} = (\text{"receiving"}, \text{"sending"}, \text{"receiving for the second time"})$,

$T_{arr}^{5} = (\text{"fast"}, \text{"close"}, \text{"open"}, \text{"for date"})$,

$T_{arr}^{6} = (\text{"employee"}, \text{"section"}, \text{"manager"}, \text{"deputy leader"}, \text{"others"})$.

Such situations can be created from the capabilities and operating conditions of the organization.

$y_i = \left\{ y_i^k \right\}$ - set of conflicting cases, $k = 1..K$, K - number of conflicting cases.

R_E -Algorithms of reporting on execution of an electronic document are presented in the following pictures.

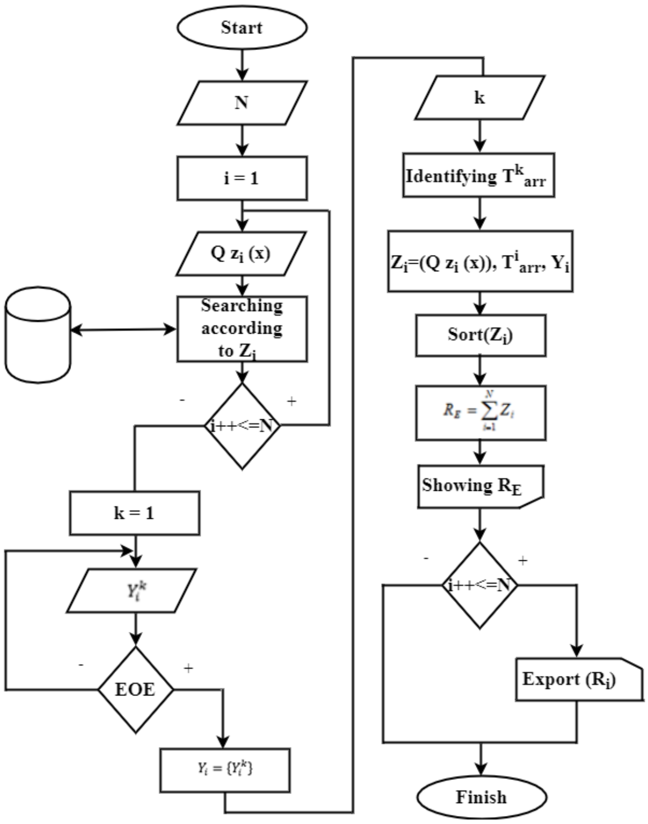


Figure 5. The algorithm of reporting on execution of an electronic document.

R_E - The algorithm for creating a report on the execution of an electronic document is more efficient as follows:

1. The asymptotic complexity for calculation is $2 \cdot (n+1) \cdot n + 5 \cdot n + 16$, since a total of 16 operations, 5 n iterations and 2 n+1 iterations of n search operations are performed in 1 algorithm. Since this is a quadratic polynomial, the base is $O(n^2)$.

2. The memory space complexity is 3*4=12 for 3 integers and 24 bytes of memory space based on 12 bytes for an array.

CONCLUSION

Firstly, most of the analyzed electronic document management systems are using the description and exchange of electronic documents based on standard templates. This causes problems with the description of new types of Electronic Documents, and it was determined that it should be adapted to the standard of information exchange with international organizations.

Secondly, on the basis of research analysis, the capabilities of methods and algorithms for the formation of multi-parameter dynamic reports in a voluntary organization were determined.

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Solving fourth-order partial differential equations and boundary problems in the modelling of technical and electronic devices

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Abstract. This article studies the problem of setting boundary conditions and problems for fourth-order mathematical physics equations. Also, problems of classification and canonicalization of linear differential equations with fourth-order partial derivatives, and correctness of boundary value problems for fourth-order partial differential equations. It is proved that the solution exists and is unique. In addition, checking such issues for second-order equations using the methods presented in the literature [7-9, 14] was carried out, and the importance of creating technical systems and using computer and computing techniques in production was highlighted.

Keywords. Physical processes, computing techniques, technical systems, differential equations, fourth-order equations, mathematical physics mathematical physics, determinant, canonicalization.

I. INTRODUCTION

Currently, much attention is paid to the problems of mathematical physics associated with the frequent description of the application as a mathematical model in various physical, chemical, and biological processes. The theory of these problems, along with great practical importance, is considered a new theory developing in classical mathematical physics. One of the most important classes of such problems is boundary value problems for fourth-order partial differential equations. For example, the study of the problem of the dynamics of one-dimensional flows, the dynamics of a compressible exponentially stratified fluid, the problem of wave propagation in dispersive media, transverse oscillations of a rod and beams, and others, are reduced to solving boundary value problems for a fourth-order equation. In the monograph [1] questions of classification and reduction to the canonical form of linear differential equations with partial derivatives of the fourth order are studied, as well as well-posed boundary value problems for equations of hyperbolic and mixed types are posed and studied. In [2,3], the solvability and spectral properties of boundary value problems for even-order equations are considered. Boundary value problems for the fourth-order equation are considered in the works [4]. During the implementation of this scientific research, several scientific research works were analyzed. When solving fourth-order partial differential equations and boundary value problems in the modeling of technical and electronic devices, we must first put the Cauchy problem in the differential equations and consider its solution. The scientific works of Amirov Sh., Kozhanov A.I. present the solution of boundary value and Cauchy problems for some nonlinear equations of the Boussinesq equation[1,2]. D. Amanov's scientific work presents the application of the Cauchy problem to differential equations of even order and methods of solving them[3]. Dzhuraev TD, Sopuev A. Scientific research works based on the theory of partial differential equations of the fourth order, as well as their practical significance[4]. Also Megraliev Ya. T., Juraev G.U. and Rakhimberdiyev Q.B. applied the theory of differential equations in their scientific works, using computer techniques to obtain numerical solutions and solve complex problems of electronics, and the results of this research were cited in their scientific works[5,6,7,8,9,10].

II. METHODOLOGY

Analysis, synthesis and other scientific research methodologies were used in this scientific work. Also, the Cauchy problem applied to differential equations can be solved using analytical and numerical methods.

III. FOURTH-ORDER PARTIAL DIFFERENTIAL EQUATIONS AND BOUNDARY VALUE PROBLEMS

In this paper, boundary value problems for a fourth-order equation with local conditions are considered. The correctness of boundary value problems for partial differential equations of the fourth order is established by the proof of the existence and uniqueness of the solution. Such problems for second-order equations are investigated in [7-9, 14,16].

A. ***Problem substitution.*** Let in the area $\Omega = \{(x,t): 0 < x < 1,\ -\alpha < t < \beta\}$ consider the equation

$$Lu \equiv u_{xxxx}(x,t) - \operatorname{sgn} t \cdot \left[u_{tt}(x,t) - u_t(x,t)\right] + b^2 u(x,t) = 0 \tag{1}$$

where b is a given number?

Problem 1. Find a function $u(x,t)$ satisfying the following conditions:

$$u(x,t) \in C^{3,1}_{x,t}(\bar{\Omega}) \cap C^{4,2}_{x,t}(\Omega_+ \cup \Omega_-), \tag{2}$$

$$Lu(x,t) \equiv 0,\ (x,t) \in \Omega_+ \cup \Omega_- \tag{3}$$

$$u_x(0,t)=0,\ u_x(1,t)=0,$$
$$u_{xxx}(0,t)=0, \tag{4}$$
$$u_{xxx}(1,t)=0,\ -\alpha\le t\le\beta,$$
$$u(x,\beta)=\varphi(x),\ u(x,-\alpha)=\psi(x),\ 0\le x\le 1, \tag{5}$$

Where $\Omega_+=\Omega\bigcap\{t>0\}$, $\Omega_-=\Omega\bigcap\{t<0\}$ $\varphi(x),\psi(x)$ and are given sufficiently smooth functions, and $\varphi^{(2i+1)}(0)=\varphi^{(2i+1)}(1)=0$ $\psi^{(2i+1)}(0)=\psi^{(2i+1)}(1)=0,\ i=0,1$.

B. *Uniqueness solutions.* For partial solutions of equation (1) that are not equal to zero Ω, we will search in the form $u(x,t)=X(x)T(t)$. Then we have

$$X^{IV}(x)-\lambda^4X(x)=0,\ 0<x<1,\ \lambda=const, \tag{6}$$
$$X'(0)=X'(1)=X'''(0)=X'''(1)=0, \tag{7}$$
$$T''(t)-T'(t)-(\lambda^4+b^2)T(t)=0,\ 0<t<\beta, \tag{8}$$
$$T''(t)-T'(t)+(\lambda^4+b^2)T(t)=0,\ -\alpha<t<0. \tag{9}$$

Problem (6)-(7) has a solution

$$X_0(x)=1,\ X_k(x)=\sqrt{2}\cos\lambda_kx,\ \lambda_k=k\pi,\ k=1,2,\dots. \tag{10}$$

Differential equations (8)-(9) have general solutions, with $k=0,1,2,\dots$

$$T_k(t)=\begin{cases} e^{\frac{1}{2}t}\left(a_ke^{\frac{1}{2}\nu_kt}+b_ke^{-\frac{1}{2}\nu_kt}\right), & t>0,\\ e^{\frac{1}{2}t}\left(c_k\cos\frac{1}{2}\mu_kt+d_k\sin\frac{1}{2}\mu_kt\right), & t<0,\end{cases} \tag{11}$$

Where a_k,b_k,c_k d_k and are still unknown constants, $\nu_0=\sqrt{4b^2+1}$, $\mu_0=\sqrt{4b^2-1}$ $\nu_k=\sqrt{4(\lambda_k^4+b^2)+1}$ $\mu_k=\sqrt{4(\lambda_k^4+b^2)-1}$.

Permanent a_k,b_k,c_k and d_k, where $k=0,1,2\dots$, we choose so that the following conditions are satisfied:

$$T_k(0-0)=T_k(0+0),\ T_k'(0-0)=T_k'(0+0). \tag{12}$$

From (11), taking into account conditions (12), we have $c_k=a_k+b_k$, $d_k=\frac{\nu_k}{\mu_k}(a_k-b_k)$. Then function (11) takes the form

$$T_k(t)=\begin{cases} e^{\frac{1}{2}t}\left(a_ke^{\frac{1}{2}\nu_kt}+b_ke^{-\frac{1}{2}\nu_kt}\right), & t>0,\\ \frac{e^{\frac{1}{2}t}}{\mu_k}\begin{pmatrix}\mu_k(a_k+b_k)\cos\frac{1}{2}\mu_kt+\\ +\nu_k(a_k-b_k)\sin\frac{1}{2}\mu_kt\end{pmatrix}, & t<0.\end{cases} \tag{13}$$

Let $u(x,t)$ – solution of problem (2)-(5). Following [9], we consider the functions,

$$u_k(t)=\int_0^1u(x,t)X_k(x)dx,\quad k=0,1,2,\dots, \tag{14}$$

Where $X_k(x)$ is represented in (10). Based on (14), we introduce the functions,

$$u_{k,\varepsilon}(t)=\int_\varepsilon^{1-\varepsilon}u(x,t)X_k(x)dx,\ k=0,1,2,\dots \tag{15}$$

Where $\varepsilon>0$ a fairly small number. Differentiating equality (15) concerning t t wo times and taking into account equation (1) $k=0,1,2,\dots$, we have,

$$\begin{gathered}u_{k,\varepsilon}''(t)=\int_\varepsilon^{1-\varepsilon}u_{xxxx}(x,t)X_k(x)dx+\\ +b^2u_{k,\varepsilon}(t)+u_{k,\varepsilon}'(t),\ t>0\end{gathered} \tag{16}$$

$$\begin{gathered}u_{k,\varepsilon}''(t)=-\int_\varepsilon^{1-\varepsilon}u_{xxxx}(x,t)X_k(x)dx-\\ -b^2u_{k,\varepsilon}(t)+u_{k,\varepsilon}'(t),\ t<0\end{gathered}. \tag{17}$$

In (16) and (17), by calculating the integrals and passing to the limit $\varepsilon\to0$, we have

$$u_k''(t)-u_k'(t)-(\lambda_k^4+b^2)u_k(t)=0,\ t>0, \tag{18}$$
$$u_k''(t)-u_k'(t)+(\lambda_k^4+b^2)u_k(t)=0,\ t<0, \tag{19}$$

where $\lambda_0=0$. Differential equations (18)-(19) coincide, respectively, with equations (8)-(9) $\lambda=\lambda_k$. Then $u_k(t)\equiv T_k(t)$ $-\alpha\le t\le\beta$ at, i.e. $u_k(t)$ are determined by the formula (13). To find constant a_k and b_k use conditions

$$u_k(\beta)=\varphi_k,\ u_k(-\alpha)=\psi_k, \tag{20}$$

Where

$$\varphi_k=\int_0^1\varphi(x)X_k(x)dx,\ \psi_k=\int_0^1\psi(x)X_k(x)dx. \tag{21}$$

Then we have a system of equations

$$\begin{cases} a_ke^{\frac{1}{2}\nu_k\beta}+b_ke^{-\frac{1}{2}\nu_k\beta}=\varphi_ke^{\frac{1}{2}\beta},\\ \mu_k(a_k+b_k)\cos\frac{1}{2}\mu_k\alpha-\\ -\nu_k(a_k-b_k)\sin\frac{1}{2}\mu_k\alpha=\mu_k\psi_ke^{\frac{1}{2}\alpha}.\end{cases} \tag{22}$$

The determinant $\Delta_k(\alpha,\beta)$ of this system is, respectively,

$$\begin{gathered}\bar{\Delta}_k(\alpha,\beta)=2\Delta_k(\alpha,\beta)=\\ =2\left[\mu_k\cos\frac{1}{2}\mu_k\alpha\cdot sh\frac{1}{2}\nu_k\beta+\nu_k\sin\frac{1}{2}\mu_k\alpha\cdot ch\frac{1}{2}\nu_k\beta\right].\end{gathered}$$

If for all $k\in N_0=\{0\}\bigcup N$

$$\Delta_k(\alpha,\beta)\ne0, \tag{23}$$

then system (22) has a unique solution a_k, b_k.

Then the solution of equations (18)-(19) satisfying conditions (20) will take the form

$$\begin{gathered}u_k(t)=\frac{e^{\frac{1}{2}t}}{\Delta_k(\alpha,\beta)}\left[\varphi_ke^{-\frac{1}{2}\beta}\begin{pmatrix}\mu_k\cos\frac{1}{2}\mu_k\alpha\cdot sh\frac{1}{2}\nu_kt+\\ +\nu_k\sin\frac{1}{2}\mu_k\alpha\cdot ch\frac{1}{2}\nu_kt\end{pmatrix}+\right.\\ \left.+\mu_k\psi_ke^{\frac{1}{2}\alpha}sh\frac{1}{2}\nu_k(\beta-t)\right],\ t>0,\end{gathered} \tag{24,1}$$

$$u_k(t)=\frac{e^{\frac{1}{2}t}}{\Delta_k(\alpha,\beta)}\left[\nu_k\varphi_k e^{-\frac{1}{2}\beta}\sin\frac{1}{2}\mu_k(t+\alpha)+ +\psi_k e^{\frac{1}{2}\alpha}\left(\begin{array}{l}\mu_k sh\frac{1}{2}\nu_k\beta\cdot\cos\frac{1}{2}\mu_k t-\\ -\nu_k ch\frac{1}{2}\nu_k\beta\cdot\sin\frac{1}{2}\mu_k t\end{array}\right)\right],\ t>0. \quad (24,2)$$

Let every one $k\in N_0$ condition (23) be satisfied and $\varphi(x)\equiv 0,\ \psi(x)\equiv 0$. Then $\varphi_k\equiv 0,\ \psi_k\equiv 0$ and for all $t\in[-\alpha,\beta]$ formulas (14) and (24) we have

$$\int_0^1 u(x,t)\cos\lambda_k x dx=0,\ k=0,1,2,\ldots.$$

Hence, due to the completeness of the system $\{\cos\lambda_k x\}_{k=0}^{\infty}$ in space $L_2[0,1]$ and continuity of the function $u(x,t)$ ing area $\bar{\Omega}$, follows that $u(x,t)\equiv 0\ \bar{\Omega}$.

Suppose for some α,β,b And $k=l\in N_0$ condition (23) is violated, i.e.,

$$\Delta_l(\alpha,\beta)=\mu_l\cos\frac{1}{2}\mu_l\alpha\cdot sh\frac{1}{2}\nu_l\beta+\nu_l\sin\frac{1}{2}\mu_l\alpha\cdot ch\frac{1}{2}\nu_l\beta=0.$$

Problem 1 $\varphi(x)\equiv 0,\ \psi(x)\equiv 0$ has a non-zero solution

$$u_l(x,t)=\begin{cases}2e^{\frac{1}{2}t}sh\frac{1}{2}\nu_l(\beta-t)X_l(x),\ t>0,\\ 2\frac{e^{\frac{1}{2}t}}{\mu_l}\Delta_l(-t,\beta)X_l(x),\ t<0,\end{cases}$$

Where $\Delta_l(-t,\beta)=\mu_l sh\frac{1}{2}\nu_l\beta\cos\frac{1}{2}\mu_l t-\nu_l ch\frac{1}{2}\nu_l\beta\sin\frac{1}{2}\mu_l t$.

Now $\Delta_k(\alpha,\beta)$ represent in the form

$$\Delta_k(\alpha,\beta)=A_k\sin\left(\frac{1}{2}\mu_k\alpha+\gamma_k\right), \quad (25)$$

where $A_k=\sqrt{4(\lambda_k^4+b^2)ch\mu_k\beta+1},\ \gamma_k=\arcsin\frac{\mu_k sh\frac{1}{2}\mu_k\beta}{A_k}$.

From (25) it follows that $\alpha=\frac{2}{\mu_k}(m\pi-\gamma_k),\quad m,k\in N$ there is equality $\Delta_k(\alpha,\beta)=0$. With such values α, the uniqueness of the solution to problem 1 is violated.

Theorem 1. If there is a solution to problem 1, then it is unique only when conditions (23) are satisfied for all $k\in N_0$

Lemma 1. It α is an irrational number, which is represented as $\alpha=\frac{l}{\pi q}$, Where $q,l\in N$ $(l,q)=1$, And $(q,4)=1$, then for large k there is a positive constant C_0 such that the following estimate holds

$$|\Delta_k(\alpha,\beta)|\geq C_0k^2e^{\lambda_k^2\beta}. \quad (26)$$

Proof. It is known that $\gamma_k\to\frac{\pi}{4}$ at $k\to\infty$. μ_k represent in the form $\mu_k=2(k\pi)^2\bar{\mu}_k$, where

$\bar{\mu}_k=\left[1+\left(\frac{\mu_0}{2}\right)^2(k\pi)^{-4}\right]^{\frac{1}{2}}$. Provided $\frac{\mu_0}{2\pi^2}<1$ the expression $\bar{\mu}_k$ can be represented as

$$\bar{\mu}_k=1+\frac{1}{2}\left(\frac{\mu_0}{2}\right)^2\left(\frac{1}{k\pi}\right)^4-\frac{1}{8}\left(\frac{\mu_0}{2}\right)^4\left(\frac{1}{k\pi}\right)^8+\ldots=1+\theta_k$$

where for the remainder of the series θ_k fair

$$\frac{3}{8}\left(\frac{\mu_0}{2}\right)^2\left(\frac{1}{k\pi}\right)^4<\theta_k<\frac{1}{2}\left(\frac{\mu_0}{2}\right)^2\left(\frac{1}{k\pi}\right)^4. \quad (28)$$

Considering (27), the relation (25) takes the form

$$\Delta_k(\alpha,\beta)=A_k\sin\left[(k\pi)^2\alpha+(k\pi)^2\theta_k\alpha+\gamma_k\right], \quad (29)$$

Let α - an irrational number, representable in the form $\frac{l}{\pi},\ l\in N$. Then from (29) for all k we have

$$\begin{aligned}\Delta_k(\alpha,\beta)&=A_k\sin\left(k^2l\pi+\bar{\theta}_k\alpha+\gamma_k\right)=\\&=A_k(-1)^{k^2l}\sin\left(\bar{\theta}_k\alpha+\gamma_k\right)\end{aligned}, \quad (30)$$

where $\bar{\theta}_k=(k\pi)^2\theta_k$. Force (28) $\bar{\theta}_k\to 0$ at $k\to\infty$. Then there is a number $k_2\in N$ such that for all $k>k_2$

$$0<\bar{\theta}_k\frac{l}{\pi}+\gamma_k<\frac{\pi}{2}$$

Then, due to the inequality

$$\sin x>\frac{2}{\pi}x,\ 0<x<\frac{\pi}{2}$$

from (30) we have

$$|\Delta_k(\alpha,\beta)|\geq A_k\frac{2}{\pi}\left|\bar{\theta}_k\frac{l}{\pi}+\gamma_k\right|\geq C_0^2k^2e^{\lambda_k^2\beta}.$$

Let now $\alpha=\frac{l}{\pi q}$, where $q,l\in N$. Let's divide $k^2l\ q$ on with the remainder: $k^2l=sq+r,\ 0\leq r<q,\ s,r\in N_0$ Then from (25), we get:

$$\Delta_k(\alpha,\beta)=A_k(-1)^s\sin\left(\frac{r\pi}{q}+\frac{k^2l\pi}{q}\bar{\theta}_k+\gamma_k\right). \quad (31)$$

Let $r=0$. Then this case reduces to the case considered above.

Let $r>0$. Then $1\leq r<q,\ q\geq 2$. Since the expression $\bar{\Delta}_k(\alpha,\beta)=\sin\left(\frac{r\pi}{q}+\frac{k^2l\pi}{q}\bar{\theta}_k+\gamma_k\right)$ has a finite limit $k\to\infty$, then there is a number $k_3\in N$, such that for all $k>k_3$ from (31) we have

$$|\Delta_k(\alpha,\beta)|\geq C_0'\lambda_k^2e^{\lambda_k^2\beta}\left|\sin\left(\frac{\pi r}{q}+\frac{\pi}{4}\right)\right|\geq C_0k^2e^{\lambda_k^2\beta}.$$

Since the numbers q and 4 coprime, then (26) follows. The lemma is proven.

IV. EXISTENCE PROBLEM-SOLVING

Let the conditions (23). Then we look for a particular solution of problem (2)-(5) in the form of the sum of the Fourier series

$$u(x,t)=\sum_{k=0}^{\infty}u_k(t)X_k(x), \qquad (32)$$

Where $u_k(t)$ And $X_k(x)$ is represented in (24) and (10), respectively.

Lemma 2. Let conditions (23) be satisfied, then for all $k\in N$ fair assessments

$$|u_k(t)|\le\begin{cases}C_1(|\varphi_k|+|\psi_k|),\ t>0,\\ C_2(|\varphi_k|+|\psi_k|),\ t<0,\end{cases}$$

$$|u_k'(t)|\le\begin{cases}C_3k^2(|\varphi_k|+|\psi_k|),\ t>0,\\ C_4k^2(|\varphi_k|+|\psi_k|),\ t<0,\end{cases} \qquad (33)$$

$$|u_k''(t)|\le\begin{cases}C_5k^4(|\varphi_k|+|\psi_k|),\ t>0,\\ C_6k^4(|\varphi_k|+|\psi_k|),\ t<0,\end{cases}$$

here and further C_i are positive constants.

The validity of estimates (33) directly follows from (24), (26).

Lemma3. Let $\varphi(x),\psi(x)\in C^5[0,1]$

$\varphi^{(2i+1)}(0)=\varphi^{(2i+1)}(1)=0$ and,

$\psi^{(2i+1)}(0)=\psi^{(2i+1)}(1)=0,\ i=0,1$

Then,

$$\varphi_k=\frac{1}{\lambda_k^5}\varphi_k^{(5)},\ \psi_k=\frac{1}{\lambda_k^5}\psi_k^{(5)}, \qquad (34)$$

.

Proof. Integrating by parts, respectively, five times in the integrals of formulas (22), and taking into account the conditions of the lemma, we obtain (34). The lemma is proven.

Formally, from the series (32), by term-by-term differentiation, we compose the series

$$u_t(x,t)=\sum_{k=0}^{\infty}u_k'(t)X_k(x), \qquad (35)$$

$$u_{tt}(x,t)=\sum_{k=0}^{\infty}u_k''(t)X_k(x), \qquad (36)$$

$$u_{xxxx}(x,t)=\sum_{k=0}^{\infty}\lambda_k^4u_k(t)X_k(x). \qquad (37)$$

Let the conditions of Lemma 2 be satisfied. Then the series (32), (35), (36), (37) in the closed domain $\bar\Omega$ for, estimates (26) are satisfied and are dominated by the numerical series

$$C_7\sum_{k=1}^{\infty}k^4(|\varphi_k|+|\psi_k|). \qquad (38)$$

Under the conditions of Lemma 3, series (38) is estimated by a convergent numerical series

$$C_7\sum_{k=1}^{\infty}\frac{1}{\lambda_k}\left[\left|\varphi_k^{(5)}\right|+\left|\psi_k^{(5)}\right|\right]. \qquad (39)$$

Based on the convergence of series (39), by the Weierstrass test, series (32), (35)–(37) converge absolutely and uniformly in the domain $\bar\Omega$.

Theorem 2. If functions $\varphi(x)$ And $\psi(x)$ satisfies the conditions of Lemma 3 and conditions (26) are satisfied, then there exists a unique solution to problems (2)–(5), which are defined by (32).

V. STABILITY OF THE PROBLEM SOLUTION AND RESULT

We introduce the following norms:

$$\|u(x,t)\|_{L_2[0,1]}=\left(\int_0^1|u(x,t)|^2dx\right)^{\frac12},\ \|u(x,t)\|_{C(\bar\Omega_\pm)}=\max_{\bar\Omega_\pm}|u(x,t)|$$

$$\|\varphi(x)\|_{L_2[0,1]}=\left(\int_0^1|\varphi(x)|^2dx\right)^{\frac12}.$$

Theorem 3. Let the conditions of Theorem 2 be satisfied, then for the solution (2)-(5) of Problem 1 the estimates are valid:

$$\|u(x,t)\|_{L_2}\le C_8\left(\|\varphi\|_{L_2}+\|\psi\|_{L_2}\right),\ t>0,$$
$$\|u(x,t)\|_{L_2}\le C_9\left(\|\varphi\|_{L_2}+\|\psi\|_{L_2}\right),\ t<0,$$
$$\|u(x,t)\|_{C(\bar\Omega_+)}\le C_{10}\left(\|\varphi\|_{W_2^1}+\|\psi\|_{W_2^1}\right),\ t>0,$$
$$\|u(x,t)\|_{C(\bar\Omega_-)}\le C_{11}\left(\|\varphi\|_{W_2^1}+\|\psi\|_{W_2^1}\right),\ t<0$$

Proof. From (32), (24) and the inequality of Lemma 2 $t>0$, we have

$$\|u(x,t)\|^2_{L_2[0,1]}=\sum_{k=1}^{\infty}u_k^2(t)\le C_1^2\sum_{k=1}^{\infty}(|\varphi_k|+|\psi_k|)^2\le$$
$$\le 2C_1^2\sum_{k=1}^{\infty}\left(|\varphi_k|^2+|\psi_k|^2\right)\le$$
$$\le 2C_1^2\left(\|\varphi(x)\|^2_{L_2[0,1]}+\|\psi(x)\|^2_{L_2[0,1]}\right).$$

Similarly, the estimate is obtained for $t<0$.

Let (x,t)- arbitrary point of the area $\bar\Omega$. Then, using formulas (32) to the inequality of lemma 2, we have

$$|u(x,t)|\le\sqrt2C_1\sum_{k=0}^{\infty}(|\varphi_k|+|\psi_k|). \qquad (40)$$

Using views

$$\varphi_k=\frac{1}{\lambda_k}\varphi_k^{(1)},\ \psi_k=\frac{1}{\lambda_k}\psi_k^{(1)},\ \varphi_k^{(1)}=$$
$$=-\sqrt2\int_0^1\varphi'(x)\sin\lambda_kxdx,\ \psi_k^{(1)}=$$
$$=-\sqrt2\int_0^1\psi'(x)\sin\lambda_kxdx$$

from (40) we get

Result.

$$\left|u(x,t)\right| \le \sqrt{2}C_1 \sum_{k=1}^{\infty}\left(\frac{1}{\lambda_k}\left|\varphi_k^{(1)}\right| + \frac{1}{\lambda_k}\left|\psi_k^{(1)}\right|\right) \le$$

$$\le \sqrt{2}C_1\left(\sum_{k=1}^{\infty}\frac{1}{\lambda_k^2}\right)^{\frac{1}{2}}\left[\left(\sum_{k=1}^{\infty}\left|\varphi_k^{(1)}\right|^2\right)^{\frac{1}{2}} + \left(\sum_{k=1}^{\infty}\left|\psi_k^{(1)}\right|^2\right)^{\frac{1}{2}}\right] \le$$

$$\le C_1'\left(\left\|\varphi'\right\|_{L_2} + \left\|\psi'\right\|_{L_2}\right) \le$$

$$\le C_{10}\left(\left\|\varphi\right\|_{W_2^1} + \left\|\psi\right\|_{W_2^1}\right).$$

The theorem has been proven.

Fourth-order partial differential equations (PDEs) are widely used to describe the mathematical models in a variety of physical phenomenon and dynamic processes in physics, engineering and geological science such as fluids in lungs, physical flows include ice formation, episodic vibration of a uniform elastic beams and plate deviation theory (see [17,18]). Several methods have been used to find the analytic solution of linear and non-linear fourth-order PDEs, for instance variation iteration method, homotopy perturbation method [19], Adomian Decomposition Method) and homotopy analysis method. For most fourth-order PDEs the analytic solutions are not available, hence, there is a need to develop an efficient numerical methods to solve these PDEs because the solutions of fourth-order PDEs are of great importance to scientists and engineers.

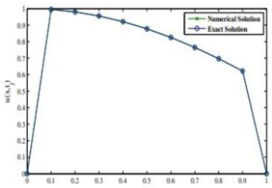

Fig.1: The comparison between numerical and exact solutions of function (40)

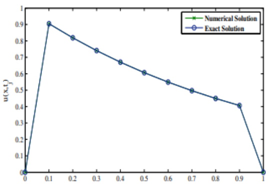

Fig.2: The comparison between numerical and exact solutions of function (41)

Conclusion

In conclusion, the Koshi problem and boundary conditions for linear or non-linear differential equations are of great importance. In this article, the Koshi problem for linear homogeneous and non-homogeneous differential equations of the form (1), (2) was considered. As a result, as an example, we put the Koshi problem for the differential equation (11) and got a solution. The solution of the Koshi problem is given in equation (12) and in Fig.1 and Fig.2.

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Calculation of contributions of different types of features based on data visualization in classification tasks

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Abstract. The detection of hidden regularities in databases when calculating the contributions of nominal features in problems based on the results of displaying the presented objects of classes in two-dimensional feature spaces is considered.

Keywords. classification, data visualization, uncovered patterns, calculation of contributions.

I. Introduction

Mathematical methods for classifying and restoring regression based on machine learning are increasingly used in the problems of modern electric power industry. This is due both to the complication of modern electric power systems (EPS), and to a number of properties of machine learning methods. Modern EPS are becoming more and more difficult for analytical analysis, but at the same time, the introduction of a large number of monitoring devices makes it possible to obtain a huge amount of information about the state of the EPS[1,2].

This state of affairs opens up opportunities for analyzing EPS as “black box” systems using machine learning methods, applying existing data science methods. However, such methods cannot completely replace the classical approaches to EES analysis, but only allow compensating for some of their shortcomings. Such shortcomings often include low speed, the need for complete and accurate information about the parameters of the EPS, while in reality only a part of them is available. To overcome the mentioned disadvantages, the problem can be reduced to building a classification or regression recovery model that establishes the correspondence of the EPS regime parameters and environmental parameters with the target variable based on a data sample with a known value of the target variable. In other words, machine learning methods build an approximation of the target dependence, allowing you to get an approximate solution, but in less time and using a smaller set of input variables. One of these tasks is the assessment of regime reliability. The operational reliability (RR) of an EPS is understood as the property of the system to maintain the specified modes of operation when conditions change, element failures and sudden disturbances. Evaluation of the RR consists in determining the permissible values of the operating parameters, as well as modeling failures taking into account the selected RR criteria. Often, the task of assessing regime reliability is associated with the need for a large amount of calculations, therefore, traditionally, in modeling, methods are used to reduce the number of cases considered, as well as consideration of simplified linear EPS models[3].

An alternative are methods based on machine learning, which are able to build a model that accurately approximates traditional indicators[5].

The topic of artificial intelligence and the problems of classification, clustering and visualization are becoming increasingly popular in the scientific community. The bibliographic and abstract database Scopus.com analyzed scientific papers on the tags neural networks, recognition and other related topics for 2016-2023. He, K., Zhang, X., Ren, S., Sun, J., Deep residual learning for image recognition, subject area – computer vision; a new approach to teaching; deep layers; layers as training residuals with reference to layer inputs. Also Redmon, J., Divvala, S., Girshick, R., Farhadi, A., Liu, W., Anguelov, D., Erhan, D., Fu, C.-Y., Berg, A.C., Dong , C., Clay,C.C., He, K., Tang, X., Zhou, B., Khosla, A., Lapedriza, A., Oliva, A., Torralba, A., etc., have achieved significant results[1,2,12,14]. Deep learning algorithms are also mentioned in these scientific works. Redmon, J., Divvala, S., Girshick, R., Farhadi, A., cited combined image recognition algorithms. Liu, W., Anguelov, D., Erhan, D., Fu, C.-Y., Berg, A.C., SSD and single-shot multi-box detectors and other artificial intelligence techniques are cited[1,6,7,8,9]. Also, among the Uzbek scientists, Juraev G.U. and Rakhimberdiev K., we can see the use of artificial intelligence models in bank lending systems and information protection[10,11,13,14,15,16].

Tasks of Data Mining. The Data Mining technology is based on the concept of patterns, which are regularities. As a result of the discovery of these regularities hidden from the naked eye, Data Mining problems are solved. Different types of patterns that can be expressed in a form understandable to a person correspond to certain tasks of Data Mining. Tasks (tasks) Data Mining is sometimes called patterns (regularity) or techniques (techniques). Usually, the following are distinguished: classification, clustering, forecasting, association, visualization, analysis and detection of deviations, evaluation, analysis of relationships, summing up.

Classification. The simplest and most common task of Data Mining. As a result of solving the classification problem, signs are found that characterize groups of objects of the studied data set - classes; according to these features, a new object can be attributed to a particular class. To solve the classification problem, the following methods can be used: Nearest Neighbor; k- nearest neighbor (k-Nearest Neighbor); Bayesian networks (Bayesian Networks); induction of decision trees; neural networks (neural networks)[6,7].

Clustering. Clustering is a logical extension of the idea of classification. This task is more complicated, the peculiarity of clustering is that the classes of objects are not initially predetermined. The result of clustering is the division of objects into groups.

Association (Associations). In the course of solving the problem of searching for association rules, patterns are found between related events in a data set. The difference between the association and the two previous Data Mining tasks is that the search for patterns is not based on the properties of the analyzed object, but between several events that occur simultaneously. The most well-known algorithm for solving the problem of finding association rules is the Apriori algorithm[5,6,7].

Sequence, or sequential association. The sequence allows you to find temporal patterns between transactions. The task of a sequence is similar to an association, but its goal is to establish patterns not between simultaneously occurring events, but between events connected in time (i.e., occurring at some specific interval in time). In other words, the sequence is determined by the high probability of a chain of events related in time. In fact, an association is a special case of a sequence with zero time lag. This Data Mining problem is also called the sequential pattern problem. Sequence rule: after event X, event Y will occur after a certain time[8].

Forecasting. As a result of solving the problem of forecasting, based on the characteristics of historical data, the missing or future values of target numerical indicators are estimated. To solve such problems, methods of mathematical statistics, neural networks, etc. are widely used. Determination of deviations or outliers (Deviation Detection), analysis of deviations or outliers. The purpose of solving this problem is the detection and analysis of data that differs most from the general set of data, the identification of so-called uncharacteristic patterns[9].

Estimation. The task of estimation is reduced to predicting continuous values of a feature. Analysis is the task of finding dependencies in a data set[10].

Visualization (Visualization, Graph Mining). As a result of visualization, a graphic image of the analyzed data is created. To solve the visualization problem, graphical methods are used to show the presence of patterns in the data. An example of visualization techniques is the presentation of data in 2-D and 3-D dimensions. Summing up (Summarization) is a task, the purpose of which is the description of specific groups of objects from the analyzed data set[11].

II. Methodology

Empirical, analysis, synthesis and other scientific research methodologies were used in the implementation of this scientific research. It is also based on methods of building intellectual models, performing classification, clustering and visualization processes.

III. Data visualization and classification methods

A. Problems of classification and clustering.

Classification problem. Classification is the simplest and at the same time the most frequently solved task of Data Mining. In view of the prevalence of classification tasks, a clear understanding of the essence of this concept is necessary.

Let's give some definitions. Classification - the systemic distribution of the studied objects, phenomena, processes by genera, types, types, according to some essential features for the convenience of their study; grouping of initial concepts and their arrangement in a certain order, reflecting the degree of this similarity. Classification - a set of objects ordered according to a certain principle that have similar classification features (one or more properties) selected to determine the similarity or difference between these objects[12].

Classification requires compliance with the following rules:

- in each act of division it is necessary to apply only one basis;
- division must be proportionate, ie. the total volume of specific concepts should be equal to the volume of the divisible generic concept;
- division members must mutually exclude each other, their volumes must not cross;
- division must be consistent.

Distinguish:

- auxiliary (artificial) classification, which is carried out according to an external feature and serves to give the set of objects (processes, phenomena) the required order;
- natural classification, which is carried out according to essential features that characterize the internal commonality of objects and phenomena.

The latter is the result and an important means of scientific research, because. assumes and consolidates the results of studying the regularities of the classified objects. Depending on the selected features, their combination and the procedure for dividing concepts, the classification can be:

- simple - the division of the generic concept only on the basis and only once before the disclosure of all species. An example of such a classification is a dichotomy, in which only two concepts are members of the division, each of which is contrary to the other (that is, the principle is observed: "A and not A");
- complex - used to divide one concept for different reasons and synthesize such simple divisions into a single whole. An example of such a classification is the periodic table of chemical elements.

By classification we will understand the assignment of objects (observations, events) to one of the previously known classes. By classification we will understand the assignment of objects (observations, events) to one of the previously known classes. Classification is a pattern that allows you to draw a conclusion regarding the definition of the characteristics of a particular group. Thus, for classification to be carried out, there must be signs characterizing the group to which this or that event or object belongs (usually, certain rules are formulated based on the analysis of already classified events). The classification refers to the supervised learning strategy, which is also referred to as supervised or supervised learning.

A classification problem is often referred to as predicting a categorical dependent variable (ie, a dependent variable that is a category) based on a sample of continuous and/or categorical variables. For example, it is possible to predict which of the firm's clients are potential buyers of a certain product and which are not, who will use the firm's service and who will not, and so on. This type of task refers to binary classification tasks, in which the dependent variable can take only two values (for example, yes or no, 0 or 1).

Another classification option arises if the dependent variable can take values from some set of predefined classes. For example, when it is necessary to predict what brand of car a customer will want to buy. In these cases, a set of classes for the dependent variable is considered [13,14].

Classification can be one-dimensional (according to one attribute) and multidimensional (according to two or more attributes)[15].

Classification process. The goal of the classification process is to build a model that takes the predictive attributes as input and receives the value of the dependent attribute. The classification process consists in dividing a set of objects into classes according to a certain criterion.

A classifier is a certain entity that determines which of the predefined classes an object belongs to according to the feature vector. To carry out classification using mathematical methods, it is necessary to have a formal description of the object that can be operated using the mathematical apparatus of classification. In our case, this description is the database. Each object (database record) carries information about some property of the object.

The initial data set (or data sample) is divided into two sets: training and test.

A training set is a set that includes the data used to train (construct) the model. Such a set contains the input and output (target) values of the examples. The output values are for training the model.

The test set also contains the input and output values of the examples. Here, the output values are used to test the health of the model. The classification process consists of two stages: the construction of the model and its use.

Model construction: description of the set of predefined classes.

1. Each sample dataset belongs to one predefined class.

- At this stage, the training set is used, and the model is constructed on it.
- The resulting model is represented by classification rules, a decision tree or a mathematical formula.

2. Use of the model: classification of new or unknown values.

- Assessment of the correctness (accuracy) of the model.

a) Known values from the test case are compared with the results of using the resulting model.
b) Level of accuracy - percentage of correctly classified examples in the test set.
c) Test set, i.e. the set on which the constructed model is tested should not depend on the training set.

- If the accuracy of the model is acceptable, it is possible to use the model to classify new examples whose class is unknown[16].

Methods used to solve classification problems. Various methods are used for classification. The main ones are:

- classification using decision trees;
- Bayesian (naive) classification;
- classification using artificial neural networks;
- classification by support vector machine;
- statistical methods, in particular, linear regression;
- classification using the nearest neighbor method;
- classification by the CBR method;
- classification using genetic algorithms.

IV. A NEW INTELLECTUAL MODEL OF DATA VISUALIZATION AND CLASSIFICATION

It is believed that the set of valid objects represents a training sample in which representatives of non-overlapping classes are specified. The description of objects is made using n nominal features [4].

For the geometric representation of data, the method of data visualization in [3] is used. One of the current approaches to the problem of decision-making in conditions of incomplete information is the use of artificial neural networks. One of the ways to explain the decision-making process of a neural network is the selection of informative sets of features. The work [1] includes the calculation of the contributions of different types of features in classification with a "teacher", and the formation and selection of latent informative features in classification problems used to model the process of intuitive decision-making.

Using the following formula, the value of the contribution of each nominal feature p to the class division is determined

$$\lambda_p = \frac{\sum_{i=1}^{l}\sum_{j=1}^{u_p} z_{pj}^i \left(z_{pj}^i - 1\right)}{\sum_{i=1}^{l} \tau_i} - \frac{\sum_{i=1}^{l}\sum_{j=1}^{u_p} z_{pj}^i \overline{z_{pj}^i}}{\sum_{i=1}^{l} b_{ip}\overline{b_{ip}}}, \qquad (1)$$

where $z_{pj}^i, \overline{z_{pj}^i}$ is the number of values of the j-th gradations of the p-th feature, respectively of the class K_i and its complement $CK_i = E_0 \setminus K_i$, u_p - the number of gradations of the p-th feature, l_{ip} -the number of gradations of the p-th feature respectively K_i, $b_{ip}, \overline{b_{ip}}$ - the number of gradations of the p-th feature without omissions respectively in K_i and CK_i,

$$\tau_i = \begin{cases} \left(b_{ip} - l_{ip} + 1\right)\left(b_{ip} - l_{ip}\right), & \text{если} \quad l_{ip} > l, \\ b_{ip}\left(b_{ip} - 1\right), & \text{если} \quad l_{ip} \le l. \end{cases}$$

Ordering a set of values $\{\lambda_p\}$ allows for a directed selection of informative sets of features.

In the computational experiment of displaying objects in a two-dimensional feature space and calculating the contributions of signs, sociological survey data were used on 24 questions for 50 people. A training sample of 100 objects, the first class was represented by Uzbeks, and the second by Koreans. Each question of the training sample was considered a nominal feature. Gradations of nominal features are the options for answering questionnaire questions. Each question has up to five possible answers to which an integer is mapped by a set of gradations [2]. The mapping of the objects on the plane is shown in Figure 1 [4]. Here, a visual clustering of the sample into four non-intersecting groups G1, G2, G3 and G4 is carried out.

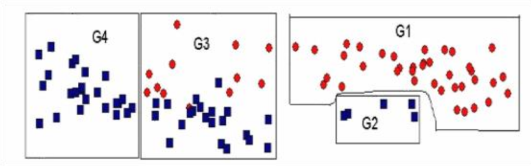

Figure 1. Displaying Object Relationships on a Plane

The detection of hidden patterns in databases is considered when in terms of the number of contributions by (1) in the classification tasks by locations of non-overlapping groups G1 and G2, G2 and G4, G1 and G4, G3 Figure 1.

Hypothesis: When calculating the contributions of different types of features among non-overlapping groups, G1 and G4 have a maximum value than the others.

Result. To test the hypothesis, the values of the contributions are calculated in descending order and of each feature of non-intersecting groups G1 and G2, G2 and G4, G1 and G4, and G3 in the decision-making process. In the results of testing the hypothesis, the values of the contributions of two nominal features are given, as follows:

Table 1

Values of contributions of two nominal features according to G1 and G2

№	**Signs**	**Values of deposits**
1	*How do I feel when I encounter an unexpected obstacle?*	*0,480*
2	*What emotions am I experiencing in this case?*	*0,379*

Table 2

Values of contributions of two nominal features according to G2 and G4

№	**Signs**	**Values of deposits**
1	*How do I feel when I encounter an unexpected obstacle?*	*0,887*
2	*What emotions am I experiencing in this case?*	*0,454*

Table 3

Values of contributions of two nominal features according to G1 and G4

№	**Signs**	**Values of deposits**
1	*How do I feel when I encounter an unexpected obstacle?*	*0,962*
2	*What emotions am I experiencing in this case?*	*0,630*

Table 4

Values of contributions of two nominal features according to G3

№	**Signs**	**Values of deposits**
1	*How do I feel when I encounter an unexpected obstacle?*	*0,362*
2	*What emotions am I experiencing in this case?*	*0,304*

We can compare the data presented in the tables through the graphs presented in Figures 1-2-3-4.

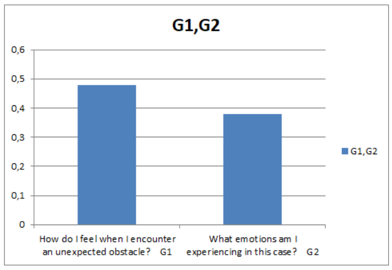

Fig. 1.Graph of G1,G2 values

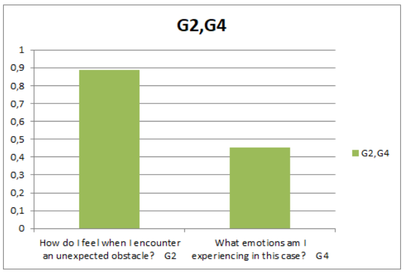

Fig. 2.Graph of G2,G4 values

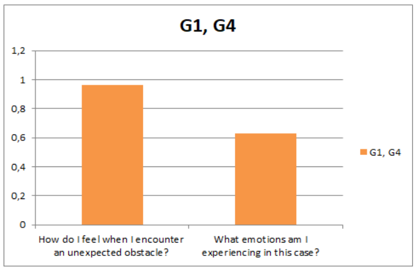

Fig. 3.Graph of G1,G4 values

Fig. 4.Graph of G3,G3 values

CONCLUSION

It can be seen from the results that in all groups the order of calculating the contributions is the same, but their values are different and depend on the positions of the groups. The results of testing the hypothesis of calculating the contributions of two nominal features for different groups confirm the truth of this hypothesis.

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5G Networks and Issues of Reducing the Impact of Electromagnetic Radiation from Cellular Networks

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***Abstract*–This article discusses a brief current vision of some aspects of 5G networks, in particular regarding the need to implement autonomous 5G network deployment. The issues of protecting a person from the effects of electromagnetic fields (EMF) of cellular networks are considered, as well as certain existing approaches to its solution, such as screening/localization of sources of electromagnetic radiation, are identified. The role of mMIMO antennas (massive multiple input and multiple output) in solving the problems of the spectral efficiency of the 5G network is shown.**

***Keywords*–5G network, electromagnetic intensity, autonomy, MIMO antenna, beamforming, infrastructure, optical fiber.**

I.INTRODUCTION

For research purposes, it is difficult to capture the full potential of 5G network technology and some issues are overlooked. This article provides information about 5G technology in terms of autonomy, the use of 5G-enabled technologies, and beamforming. With the further evolution of 5G networks and the use of various scenarios in the future, it is still necessary to permanently monitor the electromagnetic radiation (EMR) environment of cellular networks, which has become a significant source of pollution for our civilization, and determine its changing trend.

The problems of managing the level of radiation exposure in cellular communication networks are widely studied. The implementation of all the requirements to ensure the protection of the population from EMR is becoming an increasingly difficult task, therefore, solutions to the problems of reducing the radiation load of cellular networks and the development of solutions with minimal radiation levels outside the base station (BS) area are relevant.

II. MAIN PART

Since the middle of the 20th century, the problem of electromagnetic pollution of the human environment has been growing in the world. The functioning of cellular communication systems, the radio waves of which create non-ionizing radiation, contributes to this process. In a large city, there is a huge number of telecommunication networks (radio, Wi-Fi, etc.). The power from most microwave signal sources (eg, LTE, ZigBee, Bluetooth) ranges approximately from 4 to 1000 μW.

Compared to previous generations of cellular networks, 5G technology is focused on minimizing the radiation power of devices that support it, which is achieved by a new, improved basic architecture of the 5G standard. 5G base stations can be put into sleep mode when there are no active subscribers. Such functions are not implemented for 4G networks, which broadcast control signals even in the absence of network subscribers [1].

In particular, 5G technology, compared to Wi-Fi 6, enables the simultaneous connection of hundreds and thousands of IoT (Internet of Things) sensors that require a wireless connection, thus enabling wide applications for measurement and control, especially in industry, the agricultural sector, robotics, etc. Especially 5G networks are important for autonomous vehicles, emergency services and industrial IoT (IIoT, Industrial Internet of Things) use cases, in which reliability, localization accuracy have a dominant role.

Also, 5G supports up to 100 times more devices per square kilometer than 4G. An operator network can be connected to millions of devices, ranging from mission- critical smart factory sensors to drones with mobile connectivity [2].

Many new technologies have appeared in 5G (beamforming, massive MIMO (mMIMO (Multiple Input Multiple Output)) mmWave, small cell, NOMA (Non-Orthogonal Multiple Access), mobile edge computing MEC (Mobile edge computing) and segmentation (slicing) of the network, optimization and machine learning), which provide many new functions on the market [3]. Note that the advantage of mmWave communication for 5G is adaptability support for the modernization of architectures and protocols, consisting of integrated circuits, systems, etc.

The 5G cloud infrastructure, combined with an open interface, allows vendors to develop application software applications for various industries using the appropriate info-telecommunication resources and information collected online by the network. Due to the pace of development of the telecommunications industry, experts expect 6G closer to 2030. It is predicted that 6G will provide ultra-long communication with ultra-low latency of 1ms, and the wireless speed will be 1000 times faster than 5G networks. Therefore, it is promising to implement autonomous 5G deployment, that is, the creation of a separate infrastructure for 5G, potentially compatible with 6G, with the rejection of technologies compatible with existing networks. For example, in LTE, dozens of parameters were used to configure the network, and in 5G, there are hundreds of parameters that cannot be manually configured.

Therefore, operators are starting the transition to network autonomy, which allows them to manage network resources and train the network to adapt to a dynamic environment. Today's flexible and dynamic cloud environment requires autonomous systems to automatically manage network resources, and next-generation carriers are delivering dynamic software-driven services. Autonomous tasks of the network - self-healing, self-diagnostics, self-sufficiency [4]. So, the concept of autonomous networks is inextricably linked with new software-defined and managed services that have the characteristics of cloud services, the so-called Network as a Service (NaaS). The implementation of the principles of autonomous intelligent networks is the only way to ensure the compatibility of the dynamic, highly automated world of public cloud services and the traditional static telecom [5].

5G requires new distributed architectures that use software-based infrastructure, as well as transport and fiber infrastructures to create future smart cities. Widespread deployment of mmWave 5G networks will require dense underground fiber optic cabling, which will be the heart of the backhaul network enabling 5G mobile communications. Fiber-optic networks are key for 5G technology, since in the future without 5G there can be no Internet of Things, the spread of smart devices, cloud computing or unmanned vehicles [6]. Fiber optic connections are important not only for new digital services to be offered over fixed networks, but also for delivery over mobile networks.

Note that radio or satellite is an alternative to fiber. In particular, in January 2020, China launched the first test satellite Yinhe-1 into space for the future 5G constellation [7]. 5G technologies will be used to support verticals (e.g. first responders, manufacturing and raw material production, government services and services, public safety, tactical networks, defense, agriculture, entertainment, e-health, communications and smart city applications, " smart (and in the future unmanned) cars, etc.). Enterprises will take advantage of 5G implementation tools (virtualization, Edge Cloud, SDN (software-defined networking), Open RAN (Radio Access Network), network slicing, orchestration and AI (Artificial intelligence)/ML (machine learning), etc.

The issues of protection against the influence of EMF of cellular networks are very relevant. Naren et al. [8] emphasize that if 5G networks are deployed without careful consideration of the expected levels of electromagnetic exposure, then almost all people in the coverage area could be exposed to dangerous levels of power flux-density, the consequences of which could be catastrophic in the near future.

Analysis and forecasting of zones in which the EMR energy flux density has a maximum value serves as a tool to help in making decisions and planning future actions for the optimal organization of environmentally friendly cellular networks. In [9], results were obtained that make it possible to predict and reliably assess the level of radiation exposure of existing and newly introduced new generation cellular communication networks, to optimally place sources of cellular communication EMR and to take measures to reduce the level of their negative impact on biological objects, to provide minimum levels of radiation outside the zone of location of base stations of cellular network, to introduce fundamentally new ways of placing radiating objects in a specific area.

In [10], the electromagnetic properties of Koksu shungite (Republic of Kazakhstan) were studied, which provides great opportunities for using it in shielding electromagnetic radiation in order to protect against EMP exposure or, conversely, to localize the radiation of radio electronic equipment, preventing the appearance of these radiations in the environment.

Antennas significantly determine the limiting characteristics of radio systems. To provide coverage similar to previous generation networks, antenna systems of 5G networks must have a higher gain. Therefore, 5G networks are using more new antennas with smaller sizes and higher gains.

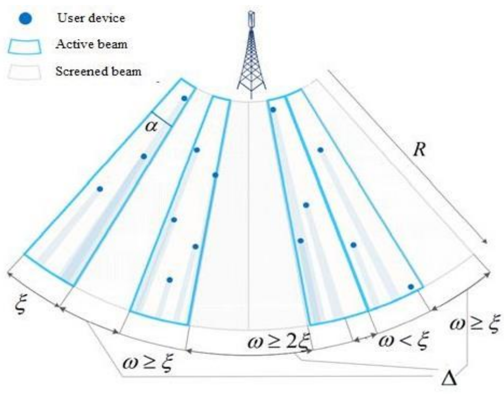

Fig. 1. Rays sifting. Adaptation from [12]

To compensate for high propagation losses and effectively eliminate interference, 5G NR systems will use antenna arrays that form special radiation patterns. Figure 1 shows a cone model with a beamwidth corresponding to HPBW (Half Power Beam Width) - beamwidth at half power level (beamwidth at -3 dB (θ3) level), which allows to increase the coverage area of a 5G NR technology base station cell due to a higher gain and a concomitant reduction in the number of multicast users that can be served using a single beam [11]

On fig. 1: Δ - average number of sifted beams; R is the radius of the BS sector NR (some given BS coverage radius), to which flows of requests for services are received; is the half power bandwidth angle for some R.

The conditions of urban development are characterized by a palette of extended diffusers - multi-storey and one-storey buildings, garages, cars, metal fences, etc.

The use of frequencies up to 6 GHz and higher (tens and hundreds of GHz) in 5G dictates ever higher requirements for BS antennas. The millimeter range (mmWave) 24-90 GHz has the worst penetration of radio waves through obstacles and a shorter range, which requires dense 5G networks.

Diagramming (beamforming) is used to orient radio waves to a target. This is achieved by combining elements into antenna arrays (ARs) in such a way that signals at certain angles are added together, while others are subject to negative interference. In-phase signal summation improves the signal-to-noise ratio in proportion to the number of antenna elements. With the selection/construction of appropriate cellular BS antenna systems, it is possible to form special radio coverage characteristics. The technology of 5G networks, when the system is fully deployed, will allow tracking the location of any person, and in the presence of a face recognition system and a single information register of the population, it will allow tracking any person anywhere on the planet Earth, directing influence on him (since the beam of the 5G network can be well focused) [13].

The use of metamaterials is one of the promising ways to control the characteristics of microwave devices. The use of controlled components in antennas makes it possible to control their characteristics: resonance frequency, operating frequency range, radiation pattern (DN), etc. In [14], an antenna array with a metamaterial integrated into the structure was analyzed, which allows one to control the plane of polarization and the main lobe of the antenna.

A lot of effort has gone into developing system-level spectral efficiency through the use of massive MIMO antennas. A feature of mMIMO systems is the use of multi-element digital antenna arrays, with the number of antenna elements of 128, 256 or more antennas, in which the signal can be adjusted both in azimuth and vertically, which allows for better focusing of energy and accuracy of direction to a specific user terminal device, which reduces inter-cell interference and supports spatial multiplexing with a large number of subscriber units. With a certain configuration of the elements of antenna arrays, spatial 3D diagram formation along the horizontal and vertical lines is possible [15].

5G base stations include beamforming to help mMIMO use spectrum more efficiently. Beamforming is an automatic beamforming technology in the antenna system, which is implemented mainly on the BS and reduces the number of BS required for radio coverage of a given area by up to 40%, reduces the level of interference and facilitates the propagation of signals indoors.

Wider use of adaptive 3D beamforming 3D Beamforming (3D BF) [16] both in the "down" channels (BS → MT (mobile phone)) and in the "up" channels (MT → BS (base station)) became possible in 5G networks by implementing multi-element array antennas in portable devices due to the transition to the millimeter wave range [17].

To realize the full potential of the 5G standard, cylindrical antenna arrays should be used that provide the required radio coverage area with sufficient bandwidth, for the management of which intelligent control systems based on neural network algorithms or fuzzy logic are widely used, which contributes to real-time operational control of the antenna radiation pattern depending on the situation.

One of the effective ways to control the characteristics of microwave devices is the use of metamaterials. The use of controlled components in antennas makes it possible to control their radiation pattern, operating frequency range, resonance frequency and other characteristics. One of the hallmarks of emerging 5G networks is the continuous management of access point antenna patterns. In [18], an antenna array with a metamaterial integrated into the design was analyzed, which makes it possible to control the plane of polarization and the main lobe of the antenna. In order to increase the efficiency of the entire 5G system as a whole, it is necessary to use a new generation of antennas, for example, based on chiral metamaterials, which have improved weight and size characteristics and less mutual influence between emitters.

The installation and operation of base stations is planned in such a way as to minimize the impact on the population of electromagnetic fields during their operation. The issue related to the safety of the impact of EMF emitted by 5G base stations on a person has not been unambiguously resolved. The choice of the optimal radius of the coverage area of the 5G NR base station, and hence their density, is a difficult task, which becomes more complicated when it is necessary to provide a range of services.

5G standards represent a new stage in the improvement of telecommunications standards. A high level of information security is embedded in 5G at the level of standards and architecture through the use of special protocols, solutions at the level of the network core, all its nodes and in the cloud infrastructure. In the future, 5G will converge with other new technologies, and innovative digital technologies (artificial intelligence, IoT, big data analytics, blockchain technology, etc.) will be more effective with 5G technology in various applications. Artificial intelligence will be integrated into the basic structure of networks and will act as a basis for designing, deploying and optimizing networks [19].

III. CONCLUSIONS

The creation of promising 5G cellular networks involves minimizing the levels of radiation outside the area where the network segment is located, as well as external (primarily intentional) interference. To ensure radio coverage in 5G networks, radiant systems using mMIMO technologies should be used, and electromagnetic shielding should be used to minimize radiation outside the building. Also, when building and optimizing 5G cellular communication networks, it is necessary to provide not only the optimization of BS service areas, taking into account the use of mMIMO technologies, but also beamforming, adaptive beam formation (beam pattern), the main task of which is to control the direction of radiation.

In 5G networks, mMIMO technology allows you to move to less powerful and expensive equipment, while obtaining significant advantages in energy and spectral efficiency, while directional signal conditioning increases efficiency and saves network energy, and also offers a safe level of EMI. In previous generations of cellular communication, radio waves often traveled in a wide arc, but in 5G, focusing radio waves on a specific device ensures high connection speeds, reduces the harmful effects of radio waves.

In the future, the complexity of organizing and managing cellular communication networks will require management automation at all levels, implying the complete replacement of key processes with autonomous and intelligent ones. With the use of artificial intelligence technologies, the Internet of things, blockchain, autonomous tasks can be implemented in 5G cellular systems.

The use of the 5G network for the integration of other digital technologies is relevant. It is clear from published sources that 5G-enabled technologies as well as smart systems have promise to improve various types of services, and 5G EMR does not pose a significant health risk below the recommended safety level. In convergence with digital technologies (artificial intelligence and machine learning, IoT, cloud computing, big data analytics, blockchain, etc.), the 5G network will provide a complete transition to a smart society with various promising applications for the needs of the population/industry.

In order to improve the efficiency of the entire 5G system as a whole, it is necessary to use new generation antennas, for example, based on chiral metamaterials, which have improved weight and size characteristics and less mutual influence between emitters, which makes it possible to increase the spectral efficiency in systems with MIMO spatial diversity. Fiber optic networks are key to 5G technology, with wireless communication technologies as an alternative.

5G connectivity provides new enhancements, but room for improvement is also important, as the significant growth of centralized data and autonomous 5G industry wireless networks will not be able to meet the needs of intelligent engineering in the future, and the transition to 6G wireless network technology will open up new horizons for cellular networks to provide new services.

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AI based optimal placement of caches in order to improve the efficiency of content delivery networks

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***Abstract*— In this article, a content delivery network is considered using the example of video services and a cache server is allocated in it, which is located close to consumers. This takes into account the location of the most popular cache data of video files, and the popularity of the video file is determined using machine learning. For this purpose, the article discusses the role of content delivery networks, existing machine learning algorithms, and develops a hybrid machine learning model based on two algorithms LSTM and KNN.**

Keywords—CDN, AI, machine learning, algorithm, LSTM, KNN, caching, VoD, server.

I. Introduction

The role of content delivery networks in society is very significant and increasingly growing with the development of the digital economy. These networks connect Internet users to all the content they need, including web pages, videos, music, and apps. The main role of content delivery networks is to provide fast and efficient data transfer to users. They play a key role in improving the quality of the user experience, reducing latency and ensuring connection stability. Content delivery networks also play an important role in the development of digital business. With the ability to quickly deliver content, companies can expand their online presence, interact with customers and provide them with access to their products and services.

In addition, content delivery networks help improve the availability of content for users in different regions and countries. They provide the ability to download content from remote servers with minimal delays, which is especially important for users with poor Internet connections or located in remote locations. In this regard, content delivery networks have the potential to increase the accessibility of education, information and cultural content to the general population. They help spread knowledge and information, promoting education and improving access to cultural property.

Thus, the role of content delivery networks in society cannot be underestimated. They play a key role in the development of the digital economy, improving the quality of user experience and the availability of content for the general population.

II. Main part

Today, various types of services are distributed mainly through the Internet (and service users connect to the Internet through smartphones or laptops and personal computers, which are considered mobile devices), which store data about the services provided and customer requests for relevant technological resources. required for transmission. In such processes, the most important element in the resource structure is the server. Service-related information may be stored on multiple servers, that is, the service itself is provided through the main server, and the service-related information is provided on geographically distributed servers. This process uses content caching.

Content caching is an effective way to reduce traffic between the content server and the end user. Caching can also reduce latency due to unavailable content and congestion. Improving these factors goes a long way in improving the user experience.

A video service is an online application that can upload or download video data. To date, a number of video services are provided to residents and business users through Internet television (IPTV - Internet television). These services include broadcast, video-on-demand (VoD), and time-varying television. In addition, this service includes voice over IP (VoIP), cable television and Internet/digital mail [1]. The TV content provider has full control over the content, so a seamless flow between provider and user is guaranteed. The effectiveness of CDN in this type of service is quite visible, and on this basis, it is considered appropriate to consider in detail the processes of this type of service, and the relevant information is presented below.

It is desirable to cache the most popular videos on cache servers in order to provide video materials at the request of users [2]. Due to the limited memory and computing resources of cache servers, in order to increase the efficiency of caching, it is necessary to introduce a process of predicting the popularity of future content in order to decide in advance whether to receive the desired content [3]. Today, a lot of research is devoted to predicting the popularity of content. In addition to traditional methods such as LRU (Least recently used) and LFU (Least frequently used), in recent years, machine learning-based content popularity prediction methods [4] have been proposed to predict the popularity of online content using content features and user preferences to pre-control popularity. In addition, the effect of popularity prediction on CDN performance has not been investigated. From this point of view, the development of a hybrid content popularity prediction method and the implementation of this process in a CDN are explored below.

Predicting the popularity of content in a CDN. An alternative modeling technique to traditional regression models are machine learning (ML) models that can be used to estimate predicted (long-term) values. Thanks to the huge advances in computer technology over the past decades, the use of machine learning instead of traditional regression models has become more common than ever before. ML is an artificial intelligence technique that automates the construction of analytic models based on the idea that models can be trained by learning from data and defining approaches (rules). ML includes supervised learning, unsupervised learning, partially supervised learning, reinforcement learning, etc.

The task of developing a CDN content popularity prediction model is accomplished through supervised learning. A schematic representation of supervised learning is presented in the diagram shown in Figure 1.

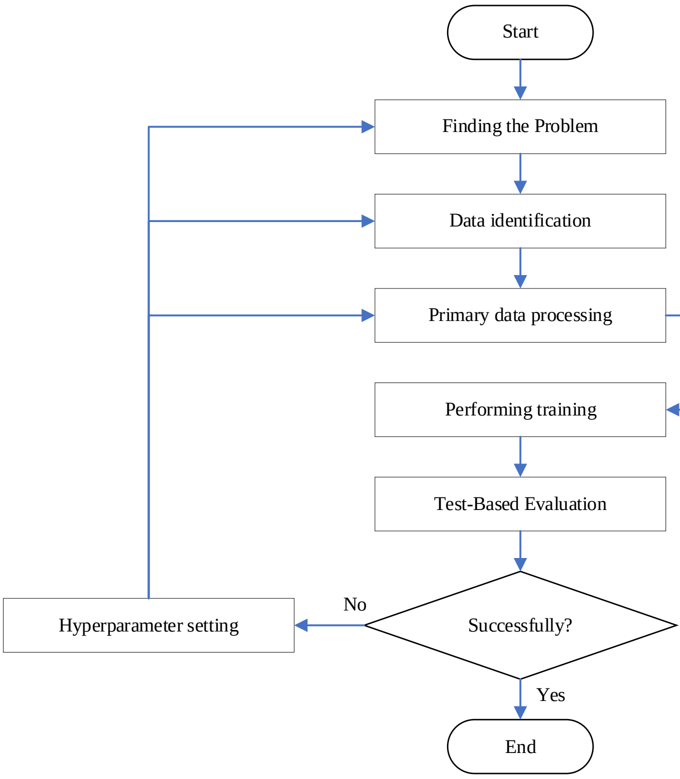

Fig. 1. Supervised learning flowchart [5]

Study of Methods for Predicting the Popularity of Video Content in CDN. This section analyzes the most commonly used machine learning algorithms for regression problems. Regression is a statistical technique used to model the relationship between a dependent variable and one or more independent variables. The goal of regression analysis is to find a model that can predict the value of the dependent variable based on the values of the independent variables. Regression is commonly used in economics, finance, and the social sciences to model the relationship between different variables. There are several machine learning algorithms that can be used for regression problems. Some of the most commonly used algorithms are analyzed below.

- Bayes;
- Support Vector Machines (SVM);
- Nearest Neighbor Learning Algorithm (KNN);
- Decision tree learning algorithm;
- Logical regression;
- Random forest.

Thus, this section provides an overview of various machine learning algorithms for regression problems, including their strengths and weaknesses. While algorithms such as Logistic Regression, Naive Bayes, Decision Tree, Random Forest, SVM, and KNN are commonly used, there are other algorithms that are better suited to specific problems. Choosing the right algorithm requires careful consideration of the data and the problem. In general, machine learning algorithms can improve the accuracy and robustness of regression models, making them a valuable tool for researchers and practitioners in various fields.

Developing a Content Popularity Prediction Model. The CDN network studied in this work consists of a cloud server, multiple cache servers (CS), and users served by each connected CS, as shown in Figure 2. Assuming that there are B CSs in this particular region, then the set of CSs is determined by as $B = \{1,2, \ldots, b, \ldots B\}$. The content library is defined as $F = \{1,2, \ldots, f, \ldots F\}$ where we assume the requested files are the same size. Cloud Server O contains the entire content library and each CS can only store a limited number of files. To simplify the model, let's assume that each CS is equipped with a C_m cache of the same size, where $C_m = n$ means that CS b can only cache n files from the cloud server.

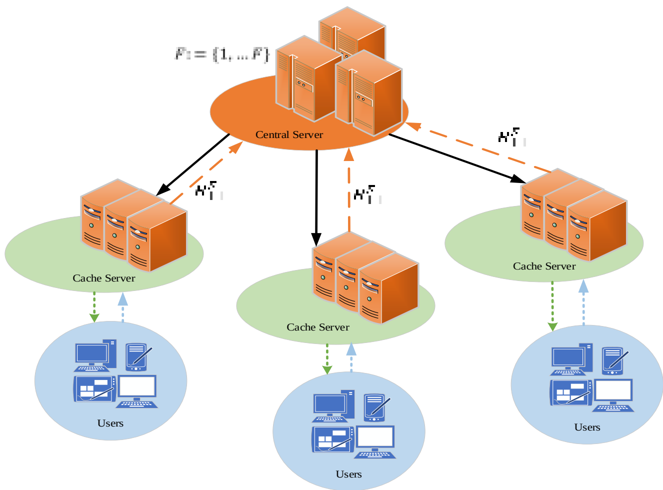

Fig. 2. Topology of user access to the main server

It is assumed that the content is requested and retrieved at discrete time intervals, and the set of time periods is represented as $T = \{1,2, \ldots, t, \ldots T\}$. In each time interval t: 1) according to the previous user request, the local CS and the cloud server jointly create a content popularity prediction model; 2) based on the results of the prediction, the corresponding CS pre-cache the corresponding content from O; 3) When saving the requested file in the local CS, the connected users will receive the requested content directly; 4) otherwise the requested file will be received from the cloud server.

Based on the network discussed above, the main models and the process of operation of the communication system are presented. As you know, predicting the popularity of content is considered the key to the success of the system. For a particular file f, the popularity changes over time, and its popularity sequence is denoted by P_b , $f = \{p_{b,f}^1, p_{b,f}^2, \ldots, p_{b,f}^t\}$, $p_{b,f}^t \in [0,1]$. Thus, the file popularity prediction is converted into a time series prediction problem, and the actual and predicted values are expressed as $p_{b,f}^t$ and $\hat{p}_{b,f}^t$, respectively. In addition, the MSE is taken to evaluate the accuracy of the forecast as follows:

$$MSE = \frac{1}{T}\sum_{t=1}^{T} |\hat{p}_{b,f}^t - p_{b,f}^t| \quad (1)$$

Content popularity is defined as the ratio of the number of requests for a file to the number of requests for all files over a period of time. If a file is frequently requested by users, the more popular the content, the more likely it is to be accessed again later. The popularity of the contents of the file f on the time interval t can be expressed as follows:

$$q_{b,t}^f = req_{t,f} / \sum_{i=1}^{f} req_{t,f} \quad (2)$$

where $req_{t,f}$ represents the number of user requests for file f in time interval t. Therefore, the content library popularity is defined as follows:

$$P_{b,t} = \{p_{b,f}^1, p_{b,f}^2, \ldots, p_{b,f}^t\}, p_{b,f}^t \in [0,1] \; and \; \sum_{f=1}^{F} p_{b,f}^t = 1 \quad (3)$$

Here the files are arranged in descending order of popularity. Due to the limited memory of each CS b, after the prediction task is completed, each CS b must sort predictively popular files, preselect content popular among users for caching, and replace less popular files. If the content is cached locally, you do not need to repeat this operation. For some discrete time interval t, the selected pre-cached files in the local CS are constructed as follows if file f is cached in CS b

$$A_{b,c} = \{a_{b,c}^1, a_{b,c}^2, \ldots, a_{b,c}^f\}, where \; a_{b,c}^f = 1 \quad (4)$$

Otherwise

$$a_{b,c}^f = 0 \; and \; \sum_{f=1}^{F} a_{b,c}^f \leq n \quad (5)$$

Also, cache hit ratio is considered as an important caching metric when we measure a caching-enabled wireless network. The hit ratio of each CS in each time slot is determined as follows:

$$h_b = \frac{1}{n}\sum_{f=1}^{F} a_{b,c}^f \times p_{b,t}^f \quad (6)$$

The pre-cached file refers to the likelihood of popular content used to represent content caching performance. Thus, the network hit rate is averaged over each training episode as an overall hit rate h. Due to the limited amount of data collected by a single CS, multiple on-premises CSs must be brought together by a cloud server to get the full popularity of a content library. However, it also raises the issue of privacy violations to a certain extent. Based on the above issues, this study aims to accurately predict content popularity and maximize the cache hit rate for each time interval while maintaining user privacy. The increase in the hit ratio is carried out by increasing the probability p of the popularity of the content. The increase in this coefficient was carried out on the basis of a hybrid LSTM (Long short-term memory)-KNN model based on machine learning in the content popularity thesis.

Model LSTM-KNN. The LSTM-KNN model includes the KNN algorithm as an updated real-time prediction method. The KNN algorithm [6] is one of the non-parametric methods used for real-time updates in forecasting.

In this study, KNN was used to select the simulation error at each video content arrival time step. To estimate the modeling error using the k-nearest samples, the inverse distance weighting method measured the proximity of the input vectors using the Euclidean distance when determining the k most similar graphs.

Figure 3 shows the implementation of the KNN algorithm in the hybrid model.

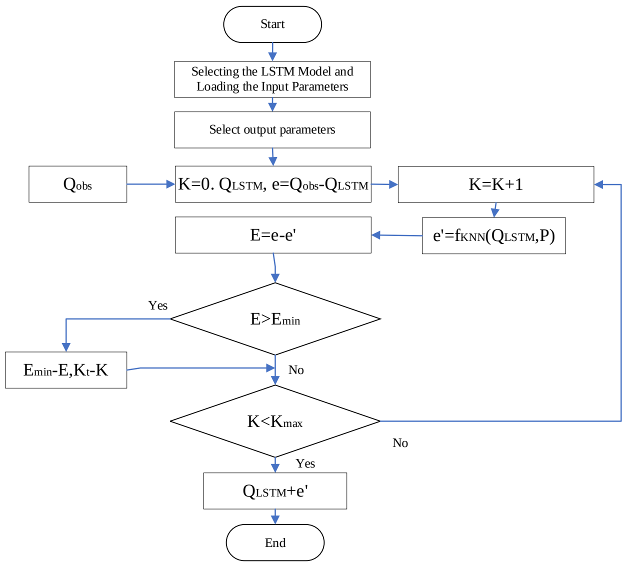

Fig. 3. Block diagram of the nearest neighbor model (KNN) LSTM-k

(1) Creation of a historical database. This was achieved by calculating simulation errors. After training the LSTM model, errors were calculated between the observed values and the LSTM simulation for the training set. In the KNN model, the relationship between errors and input data is expressed by the following equation:

$$e_t = f(Q_{LSTM,t-1}, p_{1,t-i}, \ldots p_{l,t-i}) \quad (7)$$

where e_t denotes the simulation error at time t, which is the difference between the LSTM results and the observed data. $Q_{LSTM,t-1}$ is the result of the LSTM model at time t-i, $p_{1,t-i}, \ldots p_{l,t-i}$ is a vector that affects the incoming video content at time t-i, and l is the size vector.

(2) determination of the optimal number of k-nearest neighbors. Finding the vector most similar to the input at time t took Euclidean distance to measure the distance between inputs; all vectors are sorted in ascending order of distance L_j.

(3) Evaluation of errors. The weights of each historical error were calculated using the inverse distance weighting method as in the following equation, and the errors at time t were determined as the weighted average number k of simulation errors:

$$e_t = \sum_{j=1}^{k}(e_j/L_j)/\sum_{j=1}^{k}(1/L_j) \qquad (8)$$

(4) Update results. The error calculated by KNN has been added to the results calculated by LSTM:

$$Q_{sim,t} = Q_{LSTM,t} + e_t \qquad (9)$$

where $Q_{sim,t}$ is the result of the LSTM model updated by KNN at time t.

The value of K is the only parameter to be tuned in the KNN algorithm, which is optimized by the cross-validation method with the elimination of one in the interval [7,8]. The results of the LSTM model and video data were processed as input to the KNN algorithm. The difference between the simulation error and the error calculated by KNN for each K was minimized to find the optimal value of K, as shown in Figure 3. In addition, using the ability of KNN to estimate errors from historical and newly collected data, even in the case of insufficient data, the model LSTM-KNN uses data more efficiently, thereby achieving more stable performance.

Figures 4 and 5 present a generalized logic diagram and an AI-based CDN network model that was created as a result of generalizing hybrid algorithms based on the optimal placement of the developed content and machine learning.

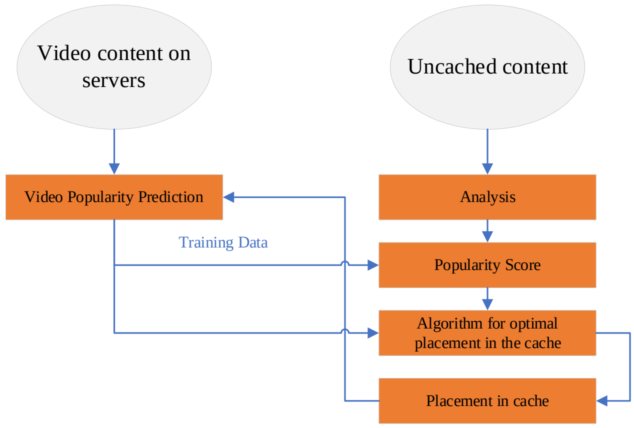

Fig. 4. Logical structure of the developed CDN scheme

As you can see from the diagram above, there are two different types of video content on a CDN. This is non-cached content, as well as cached content that is loaded on central servers but not available on edge cache servers. When hosting non-cached content, cache capabilities are first evaluated based on available files, then videos with a high probability of popularity are evaluated based on video content popularity prediction algorithms on central servers and cached based on optimal caching algorithms. The attributes of the cached files are passed to the central server for use in the next prediction process. Based on the above, a schematic model of the optimal placement of files in a CDN is formed.

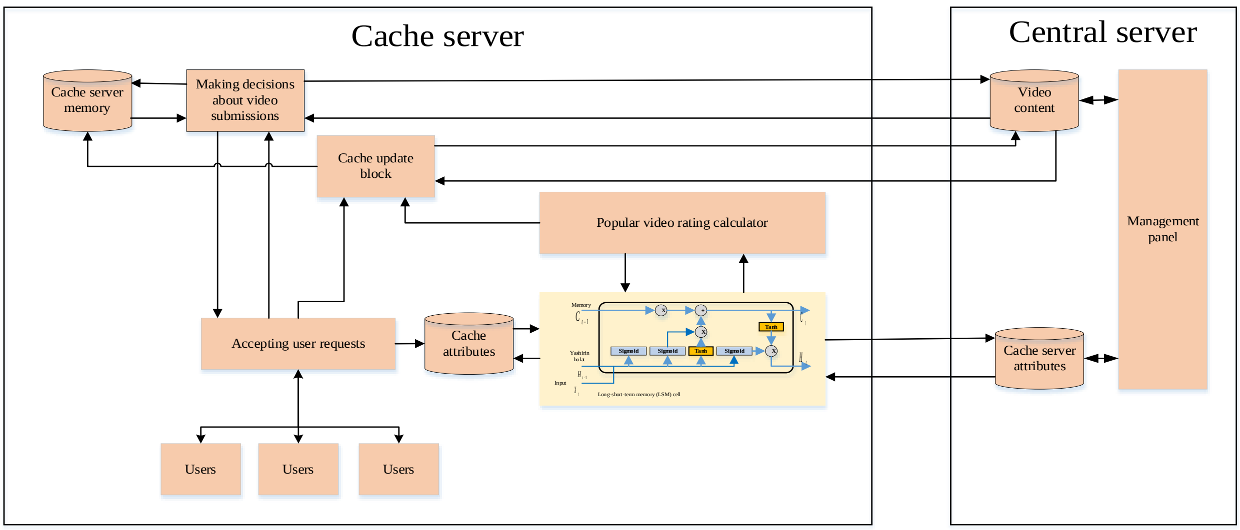

Fig. 5. AI Model for Optimal Caching of Video Content in a Content Delivery Network

The use of simple algorithms in the cache server serves to increase the power consumption of the server. At the same time, due to the fact that confidential information about users of the cache server is not transferred to the central server, there are no problems associated with information security. At the central server, attributes of cache server requests are collected and the popularity ratios of existing and new AI-based videos are calculated in time T. The popularity ratio is calculated based on a hybrid algorithm consisting of LSTM and KNN algorithms. The workflow of the algorithm is shown in Figure 5.

A comparative analysis of the performance indicators of models trained on the basis of several machine learning algorithms for a video dataset is presented in Table 1 and Figure 6.

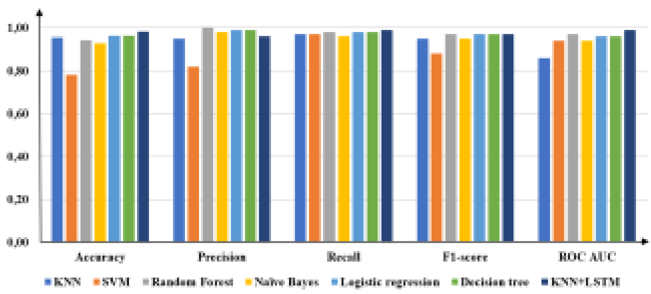

Fig. 6. Comparative analysis of the performance of models trained on several machine learning algorithms for video datasets

TABLE I. BENCHMARKING THE PERFORMANCE OF MODELS TRAINED WITH MULTIPLE MACHINE LEARNING ALGORITHMS FOR VIDEO DATASETS

ML algorithms	Accuracy	Precision	Recall	F1-score	ROC
KNN	97.5064	0.95	0.99	0.97	0.87
SVM	78.0888	0.82	0.99	0.90	0.95
Random Forest	94.4269	1.00	1.00	1.00	0.99
Naïve Bayes	92.9885	0.98	0.97	0.98	0.94
Logistic regression	96.1404	0.99	1.00	0.99	0.98
Decision tree	96.1404	0.99	1.00	0.99	0.98
KNN+LSTM	98.1289	0.96	0.99	0.97	0.99

Each algorithm has a unique feature that makes it superior to other algorithms depending on the situation. For example, Random Forest performs much better with large datasets than small datasets, while Support Vector Machines perform better with fewer datasets. KNN+LSTM has the highest accuracy and ROC.

A comparative analysis of the ROC curve of models trained on the basis of several machine learning algorithms for a set of video data is shown in Figure 7.

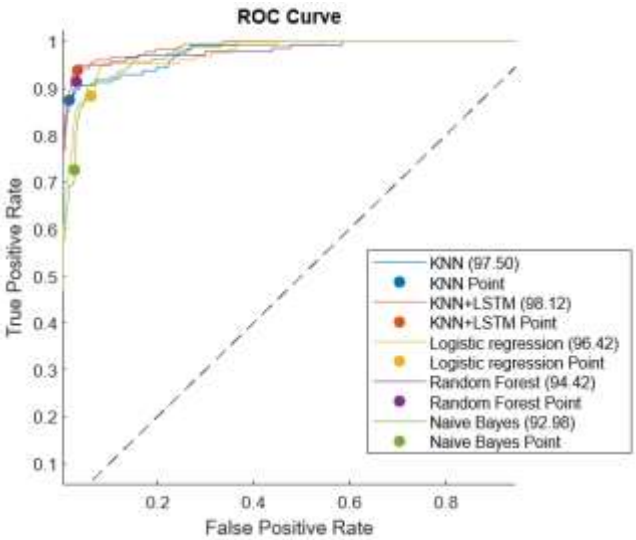

Fig. 7. Comparative analysis of ROC curves of models trained on the basis of several machine learning algorithms for video datasets

The goal of using machine learning algorithms is to build a model that can better predict the popularity of video data with different performance measures. All data was pre-processed and used for prediction during testing. Each algorithm has characteristics that are better in some cases and worse in others. KNN, Logistic Regression, Decision Tree, and Random Forest are models that can work best with the dataset used in this study. The model trained on a hybrid algorithm based on KNN and LSTM showed the highest accuracy compared to others.

III. CONCLUSION

In this research article, a content delivery network was examined in order to improve the efficiency of caching on servers. First of all, the existing machine learning algorithms were determined, after that, based on the existing algorithms, a hybrid model was developed based on the two algorithms LSTM and KNN. At the end of the work, the developed model was compared with existing machine learning models. This model is planned to be used on real servers focused on the provision of video services.

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Development of a Hybrid Module and Algorithm for Classification of Text Data

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***Abstract* – Text classification is one of the main problems of computational linguistics, which includes several fundamental issues, such as determining the topic of a text, semantic analysis, etc. Solving these problems through machine learning algorithms is now widely used, with higher performance compared to other classification algorithms. Currently, classification methods are widely used in the analysis of unstructured textual data in electronic information resources. In this article, a hybrid module and its algorithm have been developed for classification of textual data. Using the proposed algorithm, the problem of classification of 19973 Uzbek-language appeals received from the advice.uz legal portal of the "Madad" institutional non-profit organization in 16 areas has been solved.**

Keywords – Uzbek language, text classification, neural network

I. Introduction

Nowadays, determining the characteristics of the author and the recipient of the text is one of the embarrassing problems within the direction of automatic classification of texts. Mechanisms for solving that problem are widely used in search engines, digital libraries, replication, as well as in determining the age, gender and other characteristics of the author, etc. [1,2]. Methods for solving the problem of determining the author and genre of the text have been presented in [3-6]. The works proposed in [7,8] are aimed at solving the problem of identifying the author of the text, and the main attention is devoted to the development of methods for identifying and searching for repeated texts.

Extensive scientific research is also carried out to determine the text localization. For example, scientific works presented in [9,10], are devoted to the methods and algorithms of creating dialog systems, in which context signs are analyzed and a space of descriptive signs is formed from the point of view of directing the text to different categories of readers. Currently, such factors as the introduction of age restrictions on Internet resources and the development of electronic education increase the urgency of creating tools to solve the problem of determining the text localization [11]. It should be noted that research in this area has not been sufficiently studied by scientists of the Republic of Uzbekistan.

Currently, hybrid models of knowledge representation in intelligent systems are rapidly developing. For a number of scientific fields, it is not enough to use only a numerical or symbolic model of knowledge representation. The use of hybrid models of knowledge presentation has a number of important advantages: firstly, it becomes possible to use a wide range of expert knowledge on the subject in the intelligent system. Secondly, to organize knowledge exchange between different modules of the intelligent system, for example, professional knowledge between modules using different paradigms of presentation can be taken.

The principle of combining expert systems in a hybrid model based on the theory of fuzzy sets and neural networks is actively used. Expert systems work according to known rules embedded in them. Neural networks are developed based on these rules of training examples. In these systems, component generation based on the neural network paradigm is used to fill the knowledge base of the expert system, and the rules of the expert system, in turn, are used to form the initial structure of the neural network. Similar models are used in engineering, medicine, economics, business analysis, etc. [12].

II. The Proposed Method

The proposed neural network model consists of three layers, which are hierarchically structured, generalize the initial units of text (words) into concepts, and then into knowledge domains. One of the important problems of text classification using neural network is the need to convert the text into a digital format. Polygrams, dictionaries, etc. are used for this process. By converting the text into an input vector, the meaning of every single word can be lost, which is related to the structure of the neural network. In contrast, in a semantic neural network, each neuron is assigned a value (or set of values). The structured network includes terms related to certain fields of knowledge and is their simplified semantic space, which combines the main concepts of this field [13].

The first layer consists of neurons that learn the meaning of words. Concepts containing words in a neuron are connected to each other based on dictionary definitions and are directly connected to concepts in the corresponding neuron of the second layer. Each concept corresponds to a word in a row of neurons of the first layer.

The second layer contains the concepts related to the words in the neuron of the first layer and the class neurons (the third layer) included in the definition of neurons. Concepts in a neuron belong to different classes of knowledge.

The third layer organizes neurons as a class. Each class defines concepts that can belong to several classes at the same time. The text indicates which class it belongs to and is output to the third layer.

In this case, universal decimal classification (UDC) is used as the classifier, but a library bibliographic catalog (LBC) or other classifier can be used to implement this approach. The main thing in choosing a classifier is a clear definition of relevance and a formed vocabulary of terms included in the title.

Basically, this model can create classes based on the class and the associative relationships formed with it (for example, similarity to a defined set of documents).

In general, each neuron in the network corresponds to a word, concept or class. Assigning a specific meaning (word, concept, field of definition) to a neuron is done by giving each neuron a serial number corresponding to the word, concept, field of definition located under the same number in the library. A library is created for each layer.The first layer library neurons contain the assigned words, as well as the names of all concepts and classes (the corresponding concepts and classes in the second and third layers). The words in the text are checked for the presence of the first layer in the library and given to the input.

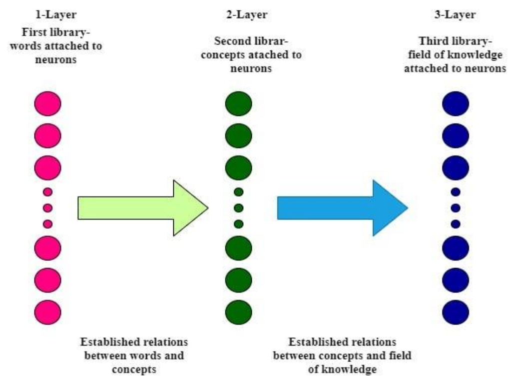

Fig. 1. Connections between layers of neurons.

The strengthening of the relationship between the neurons in the layer and the neurons higher than the obtained layer is carried out using adjacency matrices.The contents of the layers correspond to the libraries, the neurons above as within the layer are connected to each other (Figure 1). A structured network is a hybrid of a semantic and neural network. A set of semantic relations is formed for each neuron of network, and semantic relations are pre-established, which are reflected in the adjacent matrices. If the structure and principle of building a network is semantic, then the method of signal transmission by neurons is similar to the neural network in Fig. 1.

The neuron of the first layer of the constructed network (at the initial stage) has the number of inputs equal to the number of established connections. The weight coefficient of each synapse is reflected in the matrix of weight coefficients. A neuron can receive and transmit a signal [14]. UDC classifier clearly determines the thematic connection of the text and based on its structure, a dictionary of terms included in its subsections is created.

Step 1. Initially, the connection between the neurons of the first layer is established based on the dictionary definitions of the concepts, the words included in one definition are related to each other. For example, the concept of “Family relations” is related to the words included in its definition: child, parent, marriage, divorce, etc.

At this stage, relationships between vocabulary neurons and their importance are established, similar to relationships in semantic networks. The relations in the presented model are based on the definitions of basic concepts presented in the dictionaries of the field of science and in the literature [15]. In general, such connections were established for the following departments:

• https://president.uz/ – public appeals and political processes portal;

• http: //kun.uz/ - Uzbekistan and World news portal;

• https://advice.uz/ - legal advice portal.

Then the hierarchical relationship “word - concept - section \ field of knowledge” is established. Since connections between neurons are established on the basis of their relevance and relationship, they are called semantic in relation to this model in later stages. [16].

Step 2. A part of the text is given to the network input. Words are matched to existing libraries, and if they match, they are assigned a matching number. Thus, certain concepts with numbers come to the input of the neural network, and neuron with the same number in the network moves (the initial movement x is taken as one) and transmits a signal through the connections established at the first stage.

The structure of the three-layer hybrid network is shown in Fig. 2.

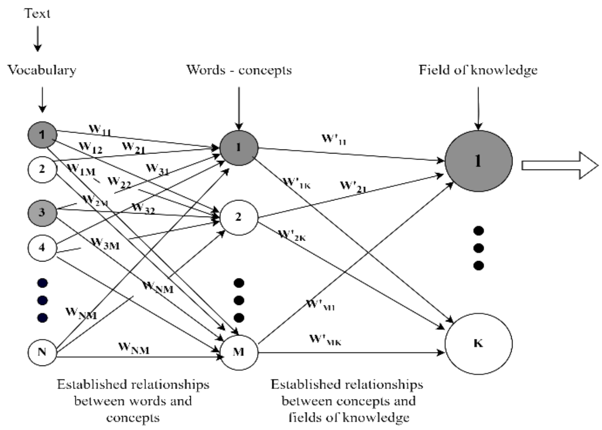

Fig. 2. Three-layer hybrid network structure.

According to the structure of the network, neuron-words included in one definition are connected to each other. When neuron-words corresponding to the definition of concepts are moved, then a link to the second layer will appear. Concepts related to the definitions in the lower layers are triggered, and by increasing the number of solutions, concepts related to the original can be identified.

The concepts of the second layer are not related to each other, only their relevance to the field or fields of knowledge can be determined.

Step 3. The final step is to transform the hybrid network into a network similar to an associative neural network. Due to this modification, the neural network can choose its structure based on the documents presented to it, establish new associative connections and form groups of connected neurons, based on which it receives a new structure for assigning the text to one of the categories. This change is most important for layers 2 and 3 of the network, where the main thematic concepts are present.

For this, the structure of the network changes, each neuron communicates with each other. In fact, the network is fully connected, new drag coefficients are created, but they must be significantly less than the predetermined ones in order for the semantic connections of the 1st stage to be prioritized. The neuron then sends signals to all other neurons.

This change is most suitable for layer 2 of the network. If in the second stage of the network operating in the second layer, the neuron-concepts that are connected to the neurons of the 3rd layer and have no connection with each other are triggered, then in the 3rd stage, the connections of each neuron-concept with the others are determined and the weights are randomly generated. Associative connections are formed between concepts that arrive at the same time or at a certain time interval, and the strength of the corresponding connection is inversely proportional to the time between the movement of neurons (these are "primary" concepts aimed at establishing strong connections between neurons). As a result, using the methods of associative neural network, a semantic approach is implemented - a set of associative (semantic) connections is formed for each concept, and a list of frequently used basic concepts encountered in text sentences is developed. The more often two concepts occur together in text sentences, the more likely they are to be semantically related.

After addressing layer 3, the association of the class \ department \ field of knowledge is inferred, and the resulting class is considered an association.

The information provided by the semantic analyzer can be used in various ways, but only its transformation into an active process is a direct and natural way to create a computer knowledge base, which becomes a solid link in a three-member chain: Uzbek language → Semantic language → Knowledge base.

Step 1: Field-based classes are formed from text sets;

Step 2: Dictionaries are formed based on each class;

Step 3: A semantic network is built based on the vocabulary of each class;

Step 4: A dictionary of constructed semantic networks is formed.

The better the classifier performs, the fewer classification errors it makes. Although deep learning-based convolutional neural networks (CNNs) perform less well than (recurrent neural networks) RNNs in classification, computational performance for capturing relationships between words in a sentence increases with sentence length, similar to RNNs. A transformer neural network overcomes this limitation by calculating each word in a sentence in parallel, forming an "attention indicator" to simulate the effect of each word on the other [17].

A dictionary is formed for the classes that are distinguished in the set of texts, and a semantic network is built on the basis of the dictionary. This network is checked and evaluated by an expert, and a semantic network dictionary is formed by an expert, and relations between dictionary transformers and their importance are established, similar to relations in semantic networks. This architecture provides a sequence of high-level views of the Transformer Neural Network to determine the accuracy of long-term dependency learning and classification results.

The classification module determines whether the text fits into existing categories. Interconnection of the text with categories is carried out on the basis of the classification symbols of the semantic-syntactic analysis module.

The text classification module is implemented step by step. At the first stage, the effect of binary, nominal and ordinal characters is determined. The second step is to check whether there are values that clearly indicate the category of recipients or limit the range of categories to which the text may belong. After checking the values in the third step, if the category of the text is not defined, the next comparison of the texts with the considered categories is carried out using classifiers prepared based on the values of the remaining features measured in the interval.

Experiments have shown that the methods implemented above reduce the time spent on training and using the classification module.

The features of the modular architecture allow for flexible integration into electronic document processing systems to solve text analysis, classification, and storage problems. For example, to integrate the text storage module with the relational database of the electronic library, it is necessary to change the connection string used to open the database and select the necessary records from the data source [18]. The developed software package provides the following formats of text data exchange: .xls, .xml, .txt.

The hybrid algorithm of the classification module consists of the following steps:

Step 1: The incoming text goes through a pre-processing step;

Step 2: The vector value of each incoming word, i.e. Bag of Words value, is obtained;

Step 3: It is the result of positional coding according to the position of the word in the sentence.

$$PE_{(pos,2i)} = \sin(pos/10000^{2id_{model}} \tag{1}$$

$$PE_{(pos,2i+1)} = \sin(pos/10000^{2id_{model}} \tag{2}$$

where pos - is the sequence number of a certain token (word), d - is the size of the character vector given in advance within the algorithm for the token,

$$i = \overline{1, d-1} \tag{3}$$

Step 4: The results of steps 2 and 3 are concatenated.

Step 5: It is transmitted to the multi-head attention layer. In this layer, the weights for the correlations of the words in the sequence are formed and optimized during training.

Step 6: The results of steps 4 and 5 are concatenated and layer-by-layer normalization is performed. The Layer normalization function is used for this step.

Step 7: It is transferred to the fully connected layer.

Step 8: The results of steps 6 and 7 are concatenated and layer-by-layer normalization is performed.

Step 9: The output value is converted into probabilities using the softmax function.

$$\sigma(\vec{Z})_i = \frac{e^{z_i}}{\sum_{j=1}^{K} e^{z_j}} \quad (4)$$

where σ – softmax, $\vec{Z}$ - input vector, e^{z_i} – standard exponential function for input, e^{z_j} – standard exponential function for output, K – number of classes in multiclass classifier.

Categorical crossentropy loss error function is used for model training and Adam optimizer is used for optimization.

$$CCE = \frac{1}{N}\sum_{i=0}^{N}\sum_{j=0}^{J} y_i \cdot log(y_j) +$$

$$+(1-y_j) \cdot log(1-y_j) \quad (5)$$

where N is the number of the training sample, J is the number of classes, y_j - predefined response of the training sample, $\acute{y}_j$ – model prediction value.

Table 1 shows an example of a vocabulary developed based on the semantic network. The total number of appeals received from the advice.uz legal portal of the non-governmental non-profit organization "Madad" under the Ministry of Justice for the intellectual analysis of textual data is 19973, of which labor relations-4978, family relations-1829, issues of housing, land and communal payments-2365, healthcare-314, judicial-legal issues-1217, social protection-2028, education-1476, entrepreneurship-719, taxes-507, banking sector-539, public services-319 , transport-826, consumer rights-277, law enforcement agencies-611, citizenship and migration-465, election issues-18.

TABLE I. VOCABULARY BASED ON THE SEMANTIC NETWORK

№	Healthcare	Legal issues	Education	Banking sector	Employment
1	hospital	citizen	education	credit	work
2	doctor	crime	school	subsidy	profession
3	nurse	right	student	indebtedness	company
4	treatment	the law	teacher	guarantor	organization
5	the patient	decision	pupil	commerce	employee
6	disease	instance	subject	entrepreneur	discussion
7	diagnosis	administrative	lesson	mortgage	manager
...	...	...	...	...	...

III. Results Analysis

It should be noted that several practical issues concern the accuracy and efficiency of the Word2Vec framework. Increasing location sizes improves discrimination, but this requires more information [19]. A typical placement size is a few hundred, although for a very large collection, thousands of sizes can be selected. The size of the context window is usually between 5 and 10, compared to the Continuous Bag of Words (CBOW) model, the skip-gram model uses larger window sizes. The skip-gram model is slower, but it performs better for rare words and large datasets [20].

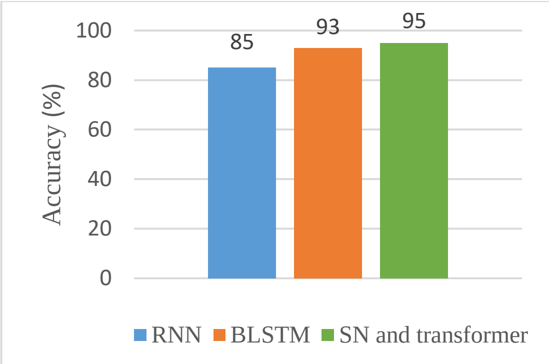

Fig. 3. Accuracy of classification algorithms.

As a result of the research, it is noted that the RNN deep learning method and the bidirectional long short-term memory (BLSTM) hybrid algorithm showed an accuracy of 85% and 93%, respectively. The proposed semantic network and transformer (SN and transformer) hybrid algorithm demonstrated 95% accuracy as a result of experimental studies (Fig. 3).

IV. Conclusion

During this research, several algorithms and their results have been analyzed. Based on experimental studies, algorithms gave different results in different positions. Moreover, the method based on the semantic network reduces the time spent on training. It can be a flexible architecture for new challenges. Its sophisticated input-output design, online training, and the availability of parallel processing make it convenient to process large array data.

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User Behavior In The E-Government System

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***Abstract*—User behavior is the main factor for evaluating any system, and based on this, the structure is optimized, and the system is reorganized to provide high quality services to the users. This work is dedicated to analyzing the dynamics of user behavior in e-government using common techniques, Customer behavior model graphs (CBMG) and Markov chains. The analysis of user behavior showed that, a lot of time is spent on searching for necessary services, browsing information, and filling out corresponding forms and in order for successful use of e-government systems in our country, it is necessary to simplify the process of filling out various forms and increase the level of automation when receiving government services.**

Keywords— E-government, Customer Behavior Model Graph (CBMG), Markov chain, Performance, Capacity Planning for Web Services, Information communication technologies, Web-analytics.

I. Introduction

Nowadays, Infocommunication technologies (ICT) play a significant role in shaping a country's development and competitiveness of Infocommunication enterprises. Uzbekistan is no exception, and the government has taken note of the importance of ICT and is actively investing in its development. As a result, the internet has become a crucial tool for communication, education, and business in the country [1].

As of 2022, there are over 32 million internet users in Uzbekistan, with a penetration rate of 70.4 percent. The government has been working on improving the country's internet infrastructure, including implementing high-speed broadband and mobile internet networks. The total throughput of the connection to the international internet network has increased by 2.6 times, resulting in a bandwidth increase of up to 3,200 Gbit/s. The speed of the internet in Uzbekistan has also improved, and the tariffs for internet services have been reduced by 25 percent compared to the beginning of 2021. Fiber-optic communication lines are also being actively laid, with a total length of 170,000 km.

The e-government system in Uzbekistan started in 2013, and since then, the country has made significant progress in developing its e-government infrastructure. In 2020 the government launched the "Digital Uzbekistan 2030" program, which aims to provide citizens with access to a wide range of e-government services through a single digital platform. Despite these efforts, there are still some challenges that need to be addressed, such as limited internet connectivity in rural areas and gaps in the availability and quality of e-government services.

Electronic government is a new form of organizing public authorities' activities, providing a new level of efficiency and convenience for organizations and citizens to receive public services and information. User satisfaction is crucial for the active development of the e-government system, and dissatisfaction can lead to inefficient use of the system and a bad reputation for e-government in the country [2–4].

Uzbekistan is harnessing the power of ICT for its development, with the government actively investing in improving internet access and infrastructure. The e-government system is a work in progress, with ongoing challenges and opportunities for improvement. Measuring the performance of the system and ensuring user satisfaction are key to the success of e-government in Uzbekistan.

To understand the state of ICT and E-Government in Uzbekistan and make proper decisions, it is essential to measure the performance of the e-government system. In this regard, we use the model of interaction between users and the system. This paper discusses a methodology for measuring the performance of the e-government system, which takes into account the intensity and level of the workload.

II. METHODS

The e-government system has become an integral part of our lives in many countries worldwide, providing citizens, businesses, and foreign nationals with online portals for accessing government services. Users of e-government systems engage in sessions during which they make requests and navigate through various sites. The unique navigation patterns of these users result in varying workloads for the e-government system [5]. To assess the performance of these systems, it is crucial to determine the workload they handle. Workload characterization is a modeling process that aims to replicate user behavior. One effective technique for achieving this is to analyze the Customer Behavior Model Graph (CBMG) [6,7].

Customer Behavior Graph Model is a type of graph-based model that is used to describe and analyze the behavior of customers. This model uses a graph structure to represent the relationships between different customer behavior patterns and how they influence each other. The purpose of a Customer Behavior Graph Model is to help businesses understand the behavior of their customers and make decisions that are informed by this understanding. [8].

The Customer Behavior Graph Model (CBMG) based on markov chain model and valuable tool for understanding and optimizing customer behavior in e-business environments. By capturing both the transitional and temporal aspects of customer navigation, it provides a comprehensive picture of customer behavior that can inform a wide range of decisions in e-business.

CBMG can provide valuable insights into customer behavior and can be used to inform a variety of decisions in e-business. For example, it can be used to optimize site design and layout, to improve the customer experience, and to identify areas where customers may be encountering difficulties. The model can also be used to personalize the customer experience by tailoring the site's response to each customer's individual navigational pattern.

In addition, the CBMG can be used to detect anomalies in customer behavior. For example, if a customer's navigational pattern deviates significantly from the expected pattern, this could indicate a problem with the site or a change in user behavior that could require further investigation.

The CBMG can be constructed from data gathered from website logs or from other sources of user behavior data. The matrix of transition probabilities can be estimated using a Markov chain model, and the “think time” can be calculated as the average time elapsed between requests [9,10].

Log files are an essential tool for web server administrators as they provide valuable information about the activity on a website. The information contained in a log file can be used to identify patterns of behavior, troubleshoot problems, and monitor the performance of the server. When a visitor requests an object, such as a web page, video, or audio, this request is recorded as a line in the log file. If the request results in an error, such as a 404 error (page not found), this error is also recorded in the log file along with the error number (e.g., 404, 403, 400, etc.).

By analyzing these log files, web administrators can gain valuable insights into user behavior, including the most popular pages, the most common sources of errors, and the types of devices and browsers used by visitors. This information can be used to optimize website performance and improve the user experience[8].

The information included in a log file typically includes the date and time of the request, the client's IP address, the type of request (e.g., GET, POST, etc.), the status code returned by the server (e.g., 2xx, 3xx, 4xx, 5xx), the size of the response, the referrer (the URL of the page from which the request was initiated), and the user-agent (the browser identification string).

```
216.199.81.206 - - [30/Nov/2022:21:07:08 +0400] "GET /img/style.css HTTP/1.1" 200 842 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:09 +0400] "GET /img/logo.gif HTTP/1.1" 200 1164 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:09 +0400] "GET /img/logo2.gif HTTP/1.1" 200 11349 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:09 +0400] "GET /img/mn_home.gif HTTP/1.1" 200 319 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:10 +0400] "GET /img/slash.gif HTTP/1.1" 200 80 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:10 +0400] "GET /img/mn_download.gif HTTP/1.1" 200 537 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:11 +0400] "GET /img/mn_order.gif HTTP/1.1" 200 352 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:11 +0400] "GET /img/mn_support.gif HTTP/1.1" 200 408 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:11 +0400] "GET /img/mn_feedback.gif HTTP/1.1" 200 436 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:11 +0400] "GET /img/header2.gif HTTP/1.1" 200 188 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:11 +0400] "GET /img/header3.gif HTTP/1.1" 200 382 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:12 +0400] "GET /weblogsuite/prglogo.gif HTTP/1.1" 200 6277 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:12 +0400] "GET /img/dot.gif HTTP/1.1" 200 49 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:13 +0400] "GET /img/mail.gif HTTP/1.1" 200 1333 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:13 +0400] "GET /img/join.gif HTTP/1.1" 200 1212 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:13 +0400] "GET /img/mailc.gif HTTP/1.1" 200 218 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:14 +0400] "GET /img/separ3.gif HTTP/1.1" 200 107 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:14 +0400] "GET /img/separ2.gif HTTP/1.1" 200 107 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:14 +0400] "GET /img/td_bg1.gif HTTP/1.1" 200 140 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
216.199.81.206 - - [30/Nov/2022:21:07:14 +0400] "GET /img/backgr.gif HTTP/1.1" 200 179 "https://my.gov.uz/ru/all-services?id=22" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)"
```

Fig. 1. Screenshots of Webserver logs.

In order to analyze log files, administrators can use various log analysis tools and scripts to extract meaningful information and insights. For example to extract nessesary information from logs, can be used SQL query scripts [10–12].

By aggregating and visualizing the data in log files, administrators can gain a deeper understanding of how their website is being used and identify potential issues that need to be addressed [13].

The users actions through the site is referred as the user flow, and it is important for online service providers to understand and optimize this flow to improve the users experience and increase online conversion [14,15]. The user's state is determined by the actions they take on the portal, such as browsing, searching, fill the form, get the results and exit.

The possible transitions between states are dependent on the portal's services and the user's actions. For example, the user may go from the home page to the search page, then to the service page, and finally to the checkout page, or they may simply leave the site without using any services. By analyzing the user's state, online service providers can make data-driven decisions to improve the user's experience and increase service usage [16].

Lets consider E-government system of Uzbekistan https://my.gov.uz. and in which users performs following actions. Figure 2. presents an example of a state transition diagram, which shows the different states in a system and the possible transitions between them. In the case of the e-goverment, the “Enter to the portal my.gov.uz” state is the starting point and from there, the users can move to three directions, 1.Browse. 2.Search the service. 3.Directly go to login. The Login state is for users who have not yet logged in into portal. The users in Browse state can move to two direction: 1.Search. 2.Exit. In own turn Search states has direction: 1.Browse. 2.Login and 3.Exit. Login has 2 direction: 1.Move to filling the form and 2.Exit. These states used to search for services. “Filling the form” and “Get the results” the results of these action is receiving a service. Next state is “Exit” The Exit state represents the end of a users visit to the e-government portal.

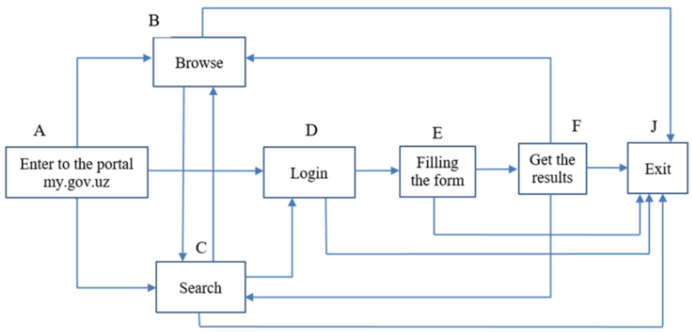

Fig.2. The simpe model of interaction between users and e-government systems.

For the analysis, a log file was selected from the web server that recorded all user actions for the month of November 2022. The total number of visitors was determined by counting the number of IP addresses that accessed the portal and verified with the statistical data from the site www.uz for the same month. In November 2022, 1079654 users visited the http://my.gov.uz portal. This number was taken as 100% and the number of users who went into various states, such as Enter, Search, Browse, Login into portal, Filling the form, Get the results, and Exit was calculated.

III. Results and Discussion

The (CBMG) provides valuable information on the average number of visits, denoted as Vj, to each state of the CBMG for each customer visit to the site. This data can be obtained through the solution of a system of linear equations. The CBMG is a useful tool for capturing customer behavior and incorporating it into the workload model, providing a more accurate depiction of the workload and supporting effective capacity planning [8]. Understanding the patterns of customer navigation and usage of different site functions is essential for improving the user experience and making informed decisions about system capacity. The solution of the equation represents the sum of the multiplication of probabilities. This solution provides a comprehensive understanding of customer behavior by quantifying the average number of visits to each state of the CBMG based on the transition probabilities between states. This information is useful for capacity planning and improving the overall user experience.

As a model, a graph-model of the behavior of users of Web services proposed in [6,7] was modified and used.

The graph model of user behavior can be represented as (P,Z), where $P=[p_{i,j}]$ is an n x n matrix of probabilistic transitions between n states of the model. $Z=[z_{i,j}]$ is also an n x n matrix that represents the average “think time” of model state transitions. State "1" is the entrance to a specific site and state "*n*" is the exit from the site.

In general, the average number of visits to state j of the CBMG can be determined by summing the number of visits to all states of the CBMG, multiplied by the transition probability from each state to state *j*. This can be expressed mathematically as an equation for any state *j* (where $j = 2,\cdots, n-1$) of the CBMG. The equation represents the relationship between the average number of visits to a specific state and the transition probabilities between the states, providing a quantitative measure of customer behavior in the context of the CBMG [17].

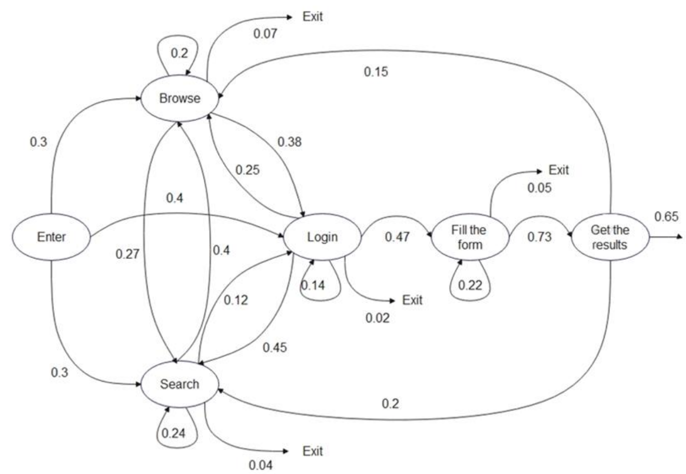

Fig.3. e-government interaction model

The total number of visits to sections can be found using the formula:

$$V_1 = 1; \tag{1}$$

$$V_j = \sum_{k=1}^{n} V_k\, p_{k,j}, \ \text{for all}\ j = 2, \dots n \tag{2}$$

Where where $\boldsymbol{p_{kj}}$ is the probability that a customer makes a transition from state ***k*** to state ***j***.

$$\begin{matrix} [\ P_{i,1}\ P_{i,2}\ P_{i,3}\ \dots\ P_{i,n}] \\ [\ P_{i,1}\ P_{i,2}\ P_{i,3} \dots\ P_{i,n}\ ] \\ [\ P_{i,1}\ P_{i,2}\ P_{i,3}\ \dots P_{i,n}\ ] \\ \dots \\ [\ P_{i,1}\ P_{i,2}\ P_{i,3}\ \dots\ P_{i,n}\ ] \end{matrix} \tag{3}$$

TABLE I. THE PROBABILITY MATRIX

		Enter	Browse	Search	Login into portal	Filling the form	Get the results	Exit	Exit
A	Enter	1	0,3	0,3	0,4	0	0	0	0
B	Browse	0	0,2	0,4	0,38	0	0	0	0,07
C	Search	0	0,27	0,24	0,45	0	0	0	0,04
D	Login into portal	0	0,25	0,12	0,14	0,47	0	0	0,02
E	Filling the form	0	0	0	0	0,22	0,73	0	0,05
F	Get the results	0	0,15	0,2	0	0	0	0,65	0,65
L	Exit	0	0	0	0	0	0		1

To find the solution, we need to calculate the values of each state, V_j, using the formula:
$V_j = \sum_{k=1}^{n} V_k\, p_{k,j}$, for all $k = 1$ to n, where n is the number of states, in our case is 7 states. We can set $V_1 = 1$, as given in the problem, and then solve this system of linear equations to find the values of $V_2, V_3, \ldots, V_n$. These values represent the stationary distribution of the Markov Chain [1], [2].

Given the transition matrix $P = [Pi,j]$, we can set up the system of equations as follows:

$$
\begin{aligned}
V_2 &= V_1 * P_{1,2} + V_2 * P_{2,2} + \ldots + V_n * P_{n,2} \\
V_3 &= V_1 * P_{1,3} + V_2 * P_{2,3} + \ldots + V_n * P_{n,3} \\
&\ldots \\
V_n &= V_1 * P_{1,n} + V_2 * P_{2,n} + \ldots + V_n * P_{n,n}
\end{aligned}
\tag{4}
$$

For the CBMGs in Figure 3, the system of linear equations is expressed as follows:

$$
\begin{aligned}
1 &= V_{s_1} \\
0.3V_{s_1} + 0.2V_{s_2} + 0.27V_{s_3} + 0.25V_{s_4} + 0.15V_{s_7} &= V_{s_2} \\
0.3V_{s_1} + 0.4V_{s_2} + 0.24V_{s_3} + 0.12V_{s_4} + 0.2V_{s_7} &= V_{s_3} \\
0.4V_{s_1} + 0.38V_{s_2} + 0.45V_{s_3} + 0.14V_{s_4} &= V_{s_4} \\
0.47V_{s_4} + 0.22V_{s_5} &= V_{s_5} \\
0.73V_{s_5} &= V_{s_6} \\
0.07V_{s_2} + 0.04V_{s_3} + 0.02V_{s_4} + 0.05V_{s_5} + 0.65V_{s_6} & \\
= V_{s_7} &
\end{aligned}
\tag{5}
$$

Where $s_1, s_2, s_3 \ldots s_7$ the states.

The average number of visits to various states on this model can be represented by the following variables: V_{s1} - Enter, V_{s2} - Browse, V_{s3} - Search, V_{s4} - Login, V_{s5} - Filling the form, V_{s6} - Get the results, and V_{s7} - Exit.

Using Gaussian elimination [3], [4]. To solve Linear equation, we will use following standart steps:

1. Write the given system of linear equations in matrix form $AX = B$, where A is the coefficient matrix, X is a column matrix of unknowns and B is the column matrix of the constants.
2. Reduce the augmented matrix $[A : B]$ by elementary row operations to get $[A' : B']$.
3. We get A' as an upper triangular matrix.
4. By the backward substitution in $A'X = B'$, we get the solution of the given system of linear equations.

We can solve this system and get the following values for V_j :

$$V_{s1} = 3.08,\ V_{s2} = 5.24,\ V_{s3} = 5.68,\ V_{s4} = 4.67 \quad (6)$$
$$V_{s5} = 3.91,\ V_{s6} = 5.36,\ V_{s7} = 5.81;$$

The results of the system of equations indicate the steady-state probabilities for each state in the Customer Behavior Model Graph. These probabilities represent the likelihood that a user is in a particular state at any given time during their session on the e-government system.

From the results, we can see that the highest steady-state probability is for state s_1, which represents the initial state of entering the e-government system. This indicates that a majority of users start their session on the e-government system by entering it.

The next highest probability is for state s_3, which represents searching for information on the system. This suggests that a significant number of users are looking for specific information on the system.

States s_2 and s_4 have relatively similar probabilities, indicating that users are browsing and logging in to the system with similar frequency.

State s_5, representing filling out a form, has a lower probability, indicating that fewer users are likely to fill out forms on the e-government system.

Finally, state s_7, representing exiting the system, has the lowest probability, indicating that most users do not exit the e-government system during their session.

Markov chain method

The given table 1. And fig 3. represents the transition probabilities between states in a customer behavior model. The rows represent the current state, while the columns represent the next state. The states are *Enter*, *Browse*, *Search*, *Login into portal*, *Filling the form*, *Get the results*, and *Exit*. To calculate the Markov chain, we can start by representing each state as a node and drawing directed edges with weights equal to the corresponding transition probabilities between states.

To find the solution of this Markov chain, we need to solve for the steady-state probabilities. This can be done by finding the eigenvector of the transition probability matrix corresponding to the eigenvalue of 1 [5], [6].

The solution of this Markov chain is:

Steady-state probabilities:

Enter = 0.3167, Browse = 0.1778, Search = 0.1267, Login into portal = 0.1056, Filling the form = 0.1267, Get the results = 0.0456, Exit = 0.1011.

This means that in the long run, the system is predicted to spend approximately 31.67% of the time in the Enter state, 17.78% of the time in the Browse state, 12.67% of the time in the Search state, 10.56% of the time in the Login into portal state, 12.67% of the time in the Filling the form state, 4.56% of the time in the Get the results state, and 10.11% of the time in the Exit state.

This information can be used to optimize the customer behavior model and improve the overall user experience. For example, if the goal is to increase the number of users who successfully complete a form, efforts could be focused on improving and simplify the user interface and reducing delay in the "Filling the form" state.

As we can see from the results of the Customer Behavior Model Graph (CBMG) and the Markov chain method may differ because they are two different methods used to analyze and model customer behavior. The CBMG method uses a graphical approach to model customer behavior, where the nodes represent the states and the edges represent the transitions between the states. This method does not consider the probability of each transition, but rather focuses on the overall flow of customers through the system.

On the other hand, the Markov chain method is a mathematical approach that models customer behavior as a stochastic process. It considers the probabilities of transitioning from one state to another and uses them to calculate the long-term behavior of the system.

Therefore, the differences in the results obtained by these two methods may be due to the fact that they have different underlying assumptions and modeling techniques. Additionally, the accuracy of the results obtained by either method may depend on the quality of the data used and the assumptions made about the system.

IV. Future Research

Performing sensivity analysis: Sensitivity analysis can be performed by changing the transition probabilities in the original matrix and observing the effects on the performance metrics broadly reviewed in [7]–[10].

To perform sensitivity analysis on the result obtained from the table, we need to vary the input parameters and observe the corresponding changes in the output values. Here are some possible scenarios for sensitivity analysis:

1. *Varying the average number of visits:* We can increase or decrease the average number of visits to each state and observe the corresponding changes in the other parameters. For example, if we increase the average number of visits to the "Browse" state, we might expect the average time spent and session length to increase, while the average number of visits to other states might decrease.
2. *Varying the average time spent:* We can similarly vary the average time spent in each state and observe the corresponding changes in the other parameters. For example, if we increase the average time spent in the "Login into portal" state, we might expect the average session length to increase, while the average number of visits to that state might decrease.
3. *Varying the average session length:* We can also vary the average session length and observe the corresponding changes in the other parameters. For example, if we increase the average session length in the "Search" state, we might expect the average time spent and number of visits to increase, while the average number of visits to other states might decrease.

By performing such sensitivity analyses, we can gain insights into how the system behaves under different conditions and make decisions about how to optimize e-government system for better performance.

V. Conclusion

The primary goal of this study is to address the challenge of identifying a significant parameter that can serve as an indicator of the effectiveness of E-Government Systems, specifically the average number of visits. To measure the workload of such systems, numerous techniques are available, including the utilization of the Customer Behavior Model Graph (CBMG) to model user behavior and the use of Markov chains as an essential technique for modeling user behavior. In the following section of this paper, a comprehensive discussion and analysis of CBMG and Markov chain modeling are presented.

The results of my findings have several implications to the developers of e-government system and services:

1. By utilizing CBMG or Markov chain modeling, it is possible to identify weak points in the service delivery of e-government systems. The results obtained can be used to propose recommendations for the design of services and e-government systems based on user-system interactions and user behavior;
2. As the results shows, the highest steady-state probability is for state s1, which represents the initial state of entering the e-government system. This indicates that a majority of users start their session on the e-government system by entering it. The next highest probability is for state s3, which represents searching for information on the system. This suggests that a significant number of users are looking for specific information on the system. States s_2 and s_4 have relatively similar probabilities,

indicating that users are browsing and logging in to the system with similar frequency. State s5, representing filling out a form, has a lower probability, indicating that fewer users are likely to fill out forms on the e-government system. Finally, state s7, representing exiting the system, has the lowest probability, indicating that most users do not exit the e-government system during their session.

The data analysis conducted in this paper holds the potential to drive transformative changes beyond web applications. By leveraging insights obtained from user behavior data and improving system performance through modeling, future architectural designs across various domains can be significantly enhanced. This transformative impact extends not only to e-government systems but also to building information systems in transportation and other related fields. Future work could involve conducting sensitivity analysis for the given model.

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Using Deep Learning Cryptanalysis to Derive Data About Simplified AES Keys

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***Abstract*— Cryptanalysis is the scientific domain dedicated to ascertaining the confidential key or level of security inherent in a cryptographic algorithm. Presently, there exist diverse techniques for analyzing modern cryptographic algorithms. Concurrently, there is a burgeoning interest in employing deep learning-based cryptanalysis, which has gained momentum alongside the advancement of artificial intelligence technologies. At present, cryptanalysis methodologies encompass tactics such as plaintext attacks on nimble block ciphers. This article delves into the approach of training an artificial neural network utilizing individual models to comprehend every bite of the key through deep learning. This approach is employed to extract insights concerning the key used in the lightweight block S-AES algorithm. Moreover, a cryptanalysis approach grounded in deep learning is proposed, employing a distinct multi perceptron network for each byte of the key.**

***Keywords*— simplified AES, block cipher, ANN, plaintext, ciphertext, recovery key, deep learning, cryptanalysis.**

I. INTRODUCTION

The field of cryptography has been a subject of continuous evolution and innovation, driven by the ever-growing need for secure communication and data protection. Cryptanalysis, the study of breaking cryptographic systems, plays a crucial role in evaluating the effectiveness and resilience of encryption methods [1]. Traditional cryptanalysis methods have long relied on mathematical techniques and statistical analyses to uncover vulnerabilities in cryptographic algorithms [2], [3]. However, with the emergence of deep learning and artificial intelligence, a new avenue for cryptanalysis has been explored, promising novel approaches to deciphering encrypted data [4].

Cryptanalysis involves deciphering encrypted information without knowledge of the decryption key, aiming to expose weaknesses in cryptographic systems [5], [6]. The integration of deep learning techniques in this field has opened up intriguing possibilities for enhanced attack methodologies, improving the efficiency and accuracy of deciphering encrypted data [7]. One significant focus of these studies is the application of neural networks to perform known plaintext attacks on various encryption algorithms [8]. In a known plaintext attack, adversaries possess partial knowledge of both the plaintext and the corresponding ciphertext, and the challenge lies in deducing the secret key to decrypt the rest of the ciphertext [9], [10].

Another area of exploration is side-channel attacks, which exploit information leaked during the encryption process through unintended channels like power consumption or timing variations [11]. By harnessing deep learning models, researchers have demonstrated the potential to conduct successful side-channel attacks, even against complex encryption algorithms. These findings emphasize the significance of ensuring robust security measures to protect against such vulnerabilities [12].

Furthermore, the research landscape includes attempts to classify and identify encryption algorithms using neural networks [13]. By training models on ciphertext data generated from different algorithms, researchers have managed to achieve high accuracy in identifying the encryption methods employed [14]. This capability not only contributes to understanding the strengths and weaknesses of various encryption techniques but also sheds light on potential vulnerabilities that could be exploited by adversaries. As deep learning continues to revolutionize various fields, its application in cryptanalysis presents both new opportunities and challenges. The results showcased in these studies underscore the potential of deep learning models in enhancing cryptanalysis techniques, raising questions about the future of cryptographic security and the need for more resilient encryption methods. The convergence of deep learning and cryptanalysis represents a dynamic and evolving frontier that holds immense promise in shaping the future landscape of encryption and data protection.

II. BACKGROUND

A. Artificial neural networks

Given a training dataset $D = \{(x_1, y_1), (x_2, y_2), ..., (x_N, y_N)\}$, where x_i represents the i - th feature vector and y_i is the corresponding target value or class label:

1. *Feedforward computation:*
   - Each neuron computes an activation function applied to the weighted sum of its inputs.

2. *Neural Network Layers:*
   - Input Layer: Receives input features x and passes them to the next layer.
   - Hidden Layers: Consist of neurons that transform input through weighted connections and activation functions.
   - Output Layer: Produces the final network prediction or class scores.

3. *Activation Function:*
   - Each neuron applies an activation function to the weighted sum of its inputs.
   - Common activation functions include sigmoid, tanh, and rectified linear unit (ReLU).

4. *Weight Update (Training):*
   - During training, adjust weights to minimize a chosen loss function L that quantifies the discrepancy between predicted outputs and actual targets.
   - Backpropagation algorithm calculates gradients of the loss with respect to weights, enabling weight updates through gradient descent or related optimization methods.

Mathematically, the computation at each neuron j in a hidden layer can be described as: (1)

$$\begin{aligned} z_j &= \sum_{i=1}^{M} w_{ji} \cdot x_i + b_j \\ a_j &= \sigma(z_j) \end{aligned} \tag{1}$$

where w_{ji} is the weight of the connection between neuron i in the previous layer and neuron j, b_j is the bias of neuron j, σ is the activation function, M is the number of neurons in the previous layer, x_i are the input features, z_j is the weighted sum of inputs, and a_j is the output after activation. The loss function L is defined based on the problem type (regression or classification) and may involve terms like squared error for regression or cross-entropy for classification. Training involves adjusting the weights and biases using techniques such as gradient descent or its variants. The gradients are computed using backpropagation, a recursive application of the chain rule. Artificial Neural Networks utilize interconnected layers of neurons to learn complex relationships in data. Through feedforward computation, activation functions, and weight updates, they can be trained to approximate functions for various tasks, making them versatile tools in machine learning and pattern recognition [15].

B. *Simplified AES Algorithm*

Simplified AES (S-AES) is a derivative of the Advanced Encryption Standard (AES) algorithm, conceived by Professor Edward Schaefer of Santa Clara University, primarily as an educational tool. It aids students in grasping AES's structural intricacies, utilizing compact bit cipher blocks and key sizes. S-AES employs a consistently small block size of 16 bits for both plaintext and ciphertext, along with a fixed 16-bit key size. During encryption, S-AES generates a 16-bit ciphertext from a 16-bit plaintext and 16-bit key. Similarly, during decryption, it transforms a 16-bit ciphertext back into a 16-bit plaintext, all the while relying on the same 16-bit key. This procedure is depicted in Figure 1.

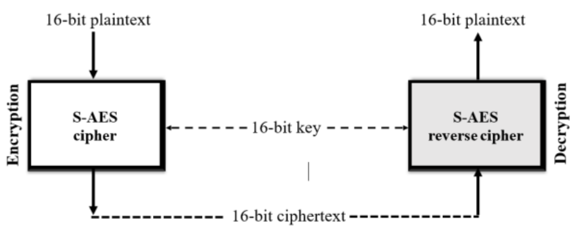

Fig. 1. Encryption and decryption process of S-AES.

The converse operation to encryption, known as decoding, is adeptly executed to restore the initial plaintext. Decoding functions as the antithesis of encryption, leveraging the same key but in an inverted manner. This reversal involves undoing the sequence of operations performed during encryption. The process of decoding effectively untangles the entwined effects of encryption, thereby offering a counterpoint to the encryption process itself [16]. Demonstrations of S-AES encryption and decryption are thoughtfully illustrated in Table 1.

TABLE I. S-AES ENCRYPTION VALUES OBTAINED USING A RANDOMLY SELECTED PLAINTEXT AND KEY

#	**Plaintext**	**Key**	**Ciphertext**
1	1011010111100111	0010110000010101	0011000111010101
2	0001000101010100	0010011000110101	0101100000111000
3	1010011000100110	0100100111000100	1111110001010010
4	1100100010100100	0110011110001000	0111000110001111
5	1100000111100000	1001010111110011	1001010000011100

III. METHODS.

In this paper, we introduce a novel cryptanalysis approach for S-AES, rooted in deep learning methodologies. A medley of deep learning techniques is thoughtfully harnessed to amplify efficacy beyond prior endeavors. Furthermore, our proposal involves the dedicated training of distinct artificial neural networks, each devoted to the individual bits constituting the key. Figure 2 delineates the blueprint of our envisioned system. The process commences with the random selection of plaintext and key, subsequently yielding the generation of ciphertext through the S-AES encryption algorithm. In this instance, the operational key within the algorithm is denoted as K_N. Meanwhile, the genuine key, represented as K, assumes the role of a label accompanying the data under scrutiny. The amalgamation of plaintext and ciphertext forms an input fed into an artificial neural network. Through this process, the neural network assimilates the intrinsic traits of the input data, ultimately culminating in the prediction of K.

The output of the neural network is the predicted key K, which is fed into a loss function to compare with the real key K_N. When the real key and the predicted key are similar, the loss is minimized and the neural network updates the weight to minimize the loss. A neural network is trained by repeating this process to make correct predictions. In this research, we trained each key bit in a separate artificial neural network. In Figure 3 shown the system diagram for the proposed method.

Data Generation

In the process of assembling our Dataset, we start by creating a roster of *N* keys K_N using a random approach as outlined in (2), organized in a matrix configuration. Each row within this matrix signifies an individual key, while the columns delineate the constituent bits of the key. The length of each key, designated as n, conforms to the extent of a key in the S-AES block cipher, specifically 16 bits. Hence, $k_{i,j}$ denotes the *j-th* bit in the *i-th* key. Following this, we advance to the production of N Plain texts P_N utilizing a random methodology as depicted in (3), which will subsequently undergo encryption using the S-AES encryption algorithm in conjunction with the earlier established K_N keys. Each plain text P_N gets encrypted using its corresponding key K_N to yield the encrypted data C_N, as depicted in (4).

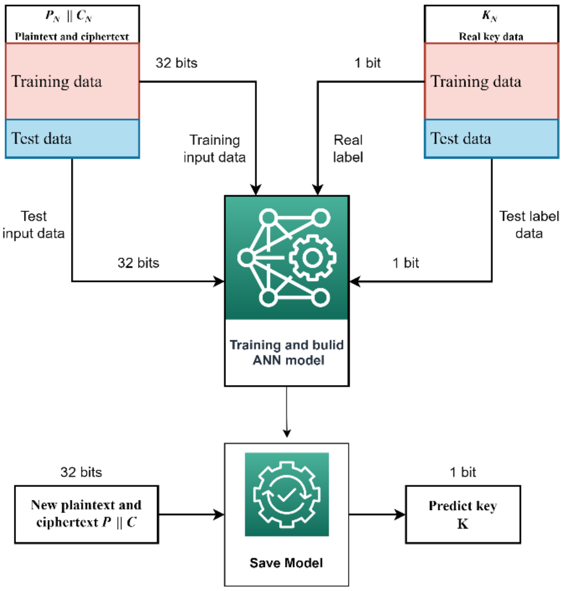

Fig. 2. Diagram of an implemented artificial neural network-based key attack.

$$K_N = \begin{bmatrix} k_{1,1} & k_{1,2} & \cdots & k_{1,n} \\ k_{2,1} & k_{2,2} & \cdots & k_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{N,1} & k_{N,2} & \cdots & k_{N,n} \end{bmatrix} \quad (2)$$

$$P_N = \begin{bmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,n} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{N,1} & p_{N,2} & \cdots & p_{N,n} \end{bmatrix} \quad (3)$$

$$C_N = \begin{bmatrix} c_{1,1} & c_{1,2} & \cdots & c_{1,n} \\ c_{2,1} & c_{2,2} & \cdots & c_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ c_{N,1} & c_{N,2} & \cdots & c_{N,n} \end{bmatrix} \quad (4)$$

Therefore, the full data set is constructed based on P_N, C_N and K_N as presented in (5). Moreover, the split among training and validation data is 70:30. It means that, 70% of entire dataset is used as training set and remaining 30% data are taken as validation set [17].

$$S_{train} = \begin{bmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,n} & c_{1,1} & c_{1,2} & \cdots & c_{1,n} & k_{1,1} & k_{1,2} & \cdots & k_{1,n} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,n} & c_{2,1} & c_{2,2} & \cdots & c_{2,n} & k_{2,1} & k_{2,2} & \cdots & k_{2,n} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ p_{N,1} & p_{N,2} & \cdots & p_{N,n} & c_{N,1} & c_{N,2} & \cdots & c_{N,n} & k_{N,1} & k_{N,2} & \cdots & k_{N,n} \end{bmatrix} \quad (5)$$

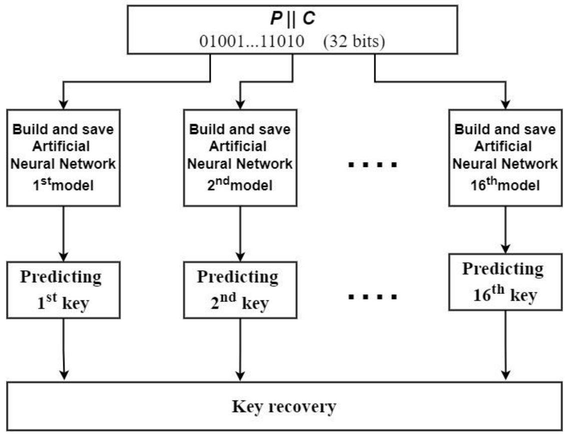

Fig. 3. Diagram of our proposed method.

IV. Attack Experiments and Results.

The attack technique proposed in this article employed the Python programming language, utilizing libraries such as Keras and Tensorflow. The computations were executed on a computer powered by an Intel 12th Generation Core i5-12450H processor, equipped with 24 GB of RAM, and an RTX3050 graphics card. A dataset containing 500 and 20,000 randomly generated datasets was acquired. For each set of keys (K keys), the subsequent parameters were derived. In the first method implementation, seven hidden layers were chosen, consisting of 256, 512, 1024, 512, 256, 128, and 64 nodes, employing the Rectified Linear Unit (ReLu) activation function. The output layer employed the SoftPlus activation function, with Mean Squared Error (MSE) as the loss function, and the Adam optimizer. The dataset was divided into training and testing sets with a test size of 0.3. The neural network was trained over a period of 200 epochs. The analysis of the outcomes is presented in Table 2. In the second approach, the same seven hidden layers were utilized, composed of 256, 512, 1024, 1024, 512, 128, and 64 nodes, this time utilizing the Parametric Rectified Linear Unit (PReLu) activation function. The output layer used the Sigmoid activation function, with MSE as the loss function, and the Adamax optimizer. The dataset was again partitioned with a test size of 0.3, and the neural network underwent a 200-epoch training period. The analysis of the results is outlined in Table 3.

TABLE II. Outcomes derived from the chosen parameters of the multi-layer perceptron in the first experiment

Key	Sample	Accuracy	Loss	Validation Accuracy	Validation loss
k_0	500	1.0000	7.5E-07	0.5400	0.2514
k_1	500	1.0000	1.7E-07	0.5700	0.2491
k_2	500	1.0000	2.9E-06	0.5600	0.2568
k_3	500	1.0000	2.7E-07	0.6100	0.2463
k_4	500	1.0000	2.4E-06	0.5900	0.2513
k_5	500	1.0000	5.8E-06	0.5400	0.2566
k_6	500	1.0000	1.9E-08	0.5500	0.2628
k_7	500	1.0000	5.9E-08	0.5600	0.2487
k_8	500	1.0000	5.6E-06	0.5600	0.2447
k_9	500	1.0000	5.8E-08	0.5800	0.2492

k_{10}	500	1.0000	4.9E-01	0.5600	0.2522
k_{11}	500	1.0000	1.2E-06	0.5400	0.2475
k_{12}	500	1.0000	7.5E-06	0.5200	0.2540
k_{13}	500	1.0000	3.2E-08	0.5900	0.2483
k_{14}	500	1.0000	6.4E-08	0.6000	0.2473
k_{15}	500	1.0000	9.4E-08	0.5700	0.2517
k_0	20000	0.9946	4.5E-03	0.5170	0.2500
k_1	20000	0.9975	2.5E-03	0.5080	0.2499
k_2	20000	0.9943	4.6E-03	0.5160	0.2501
k_3	20000	0.9952	3.9E-03	0.5095	0.2501
k_4	20000	0.9959	3.3E-03	0.5192	0.2500
k_5	20000	0.9921	6.3E-03	0.5165	0.2500
k_6	20000	0.9962	3.1E-03	0.5142	0.2499
k_7	20000	0.9939	5.0E-03	0.5110	0.2502
k_8	20000	0.9950	3.8E-03	0.5130	0.2498
k_9	20000	0.9925	6.4E-03	0.5148	0.2500
k_{10}	20000	0.9957	3.5E-03	0.5105	0.2500
k_{11}	20000	0.9949	4.2E-03	0.5058	0.2503
k_{12}	20000	0.9959	3.3E-03	0.5225	0.2500
k_{13}	20000	0.9959	3.4E-03	0.5188	0.2496
k_{14}	20000	0.9954	4.0E-03	0.5157	0.2498
k_{15}	20000	0.9966	3.0E-03	0.5128	0.2499

TABLE III. OUTCOMES DERIVED FROM THE CHOSEN PARAMETERS OF THE MULTI-LAYER PERCEPTRON IN THE SECOND EXPERIMENT

Key	**Sample**	**Accuracy**	**Loss**	**Validation Accuracy**	**Validation loss**
k_0	500	1.0000	3.8E-08	0.6000	0.2501
k_1	500	1.0000	7.7E-08	0.5800	0.2500
k_2	500	1.0000	1.8E-07	0.5600	0.2482
k_3	500	1.0000	8.3E-08	0.6000	0.2496
k_4	500	1.0000	8.5E-08	0.5900	0.2454
k_5	500	1.0000	7.2E-08	0.5400	0.2496
k_6	500	1.0000	8.4E-08	0.5500	0.2504
k_7	500	1.0000	4.4E-08	0.5600	0.2485
k_8	500	1.0000	2.1E-07	0.5700	0.2463
k_9	500	1.0000	5.7E-08	0.5700	0.2502
k_{10}	500	1.0000	8.9E-08	0.5500	0.2488
k_{11}	500	1.0000	9.2E-08	0.5400	0.2494
k_{12}	500	1.0000	8.7E-08	0.5200	0.2501
k_{13}	500	1.0000	2.1E-07	0.5600	0.2442
k_{14}	500	1.0000	4.9E-08	0.5200	0.2553
k_{15}	500	1.0000	1.8E-07	0.5800	0.2507
k_0	20000	0.9973	2.5E-03	0.5082	0.2499
k_1	20000	0.9970	2.7E-03	0.5142	0.2499
k_2	20000	0.9967	3.0E-03	0.5213	0.2502
k_3	20000	0.9966	3.0E-03	0.5140	0.2500
k_4	20000	0.9968	2.8E-03	0.5200	0.2501
k_5	20000	0.9966	2.9E-03	0.5175	0.2500
k_6	20000	0.9980	3.0E-03	0.5303	0.2498
k_7	20000	0.9964	3.5E-03	0.5088	0.2501
k_8	20000	0.9967	2.9E-03	0.5148	0.2498
k_9	20000	0.9965	2.9E-03	0.5042	0.2500
k_{10}	20000	0.9981	1.9E-03	0.5098	0.2499
k_{11}	20000	0.9965	3.0E-03	0.5113	0.2500
k_{12}	20000	0.9958	3.7E-03	0.5210	0.2500
k_{13}	20000	0.9966	3.1E-03	0.5163	0.2498
k_{14}	20000	0.9969	2.9E-03	0.5230	0.2499
k_{15}	20000	0.9979	2.0E-03	0.5197	0.2500

In the context of this research work, within the multilayer perceptron (MLP) framework 1, employing 500 datasets for comprehending the entirety of keys, the highest metric k_3 was determined, achieving a training accuracy of 1.0, while the training validation accuracy reached 0.61. With the utilization of 20,000 datasets, the optimal outcome was observed for k_{12}, yielding a training accuracy of 0.9959 alongside a training validation accuracy of 0.5225.

Moving forward to the multilayer perceptron (MLP) 2 configuration, utilizing 500 datasets for understanding the complete key spectrum led to the identification of the peak indices, namely k_1 and k_3. These resulted in a training accuracy of 1.0, accompanied by a training validation accuracy of 0.60. Upon leveraging a dataset size of 20,000, the most remarkable performance surfaced for k_6, achieving a training accuracy of 0.9980 and a training validation accuracy of 0.5303.

V. CONCLUCION

This article introduces a cryptanalysis approach using deep learning to analyze each bit of the symmetric block cipher algorithm. As indicated by the findings of this research, meticulous tuning of all the hyperparameters of the artificial neural network holds significance in forecasting outcomes. In our experimentation, favorable outcomes were achieved by employing ReLu and PReLu activation functions, along with the MSE loss function. In comparison to alternative techniques, training distinct models for each key delivers more refined outcomes, particularly with ample training data. It has been observed that by training artificial neural networks using individual models and training sets for each key bit, a reduced amount of training and testing data is necessary compared to previous methodologies. The outcomes of this study suggest that the approach of employing deep learning-based cryptanalysis has potential applicability to other block ciphers. However, it's imperative to emphasize the availability of adequate training and testing data, as well as computational resources. Furthermore, there are plans to leverage results from linear and differential cryptanalysis to enhance key bit prediction through optimization of neural network hyperparameters.

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Modeling Cost Minimization in Electrical Power Transmission Networks

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***Abstract*— Despite the advances achieved in the optimization of distribution networks, certain limitations endure, including oversights in considering specific components and the computational demands posed by large-scale systems. To bridge these gaps, this paper introduces a novel mathematical model with the principal aim of minimizing power losses during the transmission of electrical power across diverse network elements. Notably, the proposed methodology employs a Multi-Echelon approach, furnishing a robust framework to contend with intricate network intricacies. The efficacy of the model is rigorously examined using real-world systems, thereby showcasing its pragmatic applicability and efficacy. This study contributes to the progression of distribution network optimization by shedding light on cutting-edge methodologies and presenting an inventive strategy to confront ongoing challenges.**

Keywords*— Electric power, distribution, transmission, power losses, linear programming, dual problem

I. Introduction

Electric power distribution systems play a crucial role in meeting the surging energy demands of modern society. These systems have become increasingly complex due to rising load requirements and the integration of diverse energy sources. In this context, the optimization of distribution networks has become essential to ensure efficient energy delivery, minimize losses, and enhance overall system performance, making optimization methodologies indispensable tools in the field of power system engineering.

The realm of distribution systems has seen extensive exploration through various research endeavors [1–14]. In work [1] delves into the deployment of optimal capacitor allocations using evolutionary algorithms, aiming to enhance voltage regulation and system efficiency, thereby improving distribution network performance. Similarly, Devabalaji et al. address the challenge of power loss minimization in radial distribution systems, unveiling strategies to mitigate losses and boost overall system effectiveness [2].

To address the growing significance of distributed generation (DG) integration, Prakash and Lakshminarayana propose a unique strategy involving multiple DG placements for power loss reduction. By employing the Particle Swarm Optimization (PSO) algorithm, their approach underscores the potential of DG units in minimizing power losses and enhancing distribution network efficiency [3]. Reconfiguration algorithms also prove to be potent tools for loss minimization. In work [4] introduce a straightforward distribution reconfiguration algorithm designed to minimize losses in distribution networks, highlighting the feasibility of loss reduction through reconfiguration techniques.

Optimization of power plants load allocation garners substantial attention in the literature. The works [5] and [6] present multi-echelon economic dispatch models facilitating detailed load allocation and dynamic dispatch optimization. These models contribute to optimal energy production and distribution by enabling refined control over load allocation.

Integrating economic and environmental objectives presents a burgeoning challenge in power system optimization. Abdelaziz, Ali, and Elazim propose a combined economic and emission dispatch solution using the Flower Pollination Algorithm [7]. This underscores the importance of balancing economic considerations with environmental impact in power system operations.

Hybrid optimization techniques gain prominence in addressing complex optimization challenges. For instance, in [8], put forth a novel hybrid optimizer for solving the Economic Load Dispatch problem, highlighting the efficacy of hybrid methods in handling multifaceted optimization objectives. Furthermore, in [9] and [10] contribute a novel global particle swarm optimization approach to economic emission dispatch, even in the presence of transmission losses.

The integration of energy pricing and network losses emerges as a pivotal research direction. In work [11] introduce network losses-based economic redispatch to optimize energy pricing in congested power systems. Similary, in [12] develop a cost allocation model for distribution networks with high distributed energy resource penetration, emphasizing the interplay between pricing and network optimization.

The convergence of economic and environmental dispatch objectives garners considerable attention. In work [13] present a hybrid metaheuristic approach for the combined economic and environmental dispatch, underlining the imperative of addressing environmental considerations alongside economic goals. In [14] propose a multi-objective multi-population ant colony optimization technique that incorporates power system security, illustrating the multifaceted nature of optimization challenges in power systems.

Despite the advancements in optimizing distribution networks, certain limitations persist. Some studies model the entire network as a generalized entity, overlooking specific components such as substations, transformers, and consumers [5]. Additionally, computational demands for large-scale systems can lead to prolonged calculation times, affecting real-time applications [6].

This paper aims to contribute to ongoing distribution network optimization efforts by introducing a novel mathematical model. The primary goal is to minimize power losses that occur as electrical power traverses through network elements like substations, transformers, and consumers. A distinctive feature of this study is the adoption of the Multi-Echelon approach, offering a robust framework to address intricate electrical network complexities. The proposed methodology undergoes rigorous testing on real-world systems, showcasing its practicality and effectiveness.

II. Formulation of a Mathematical Model for the Problem

The proposed mathematical model aims to address the challenge of minimizing power losses during the transmission of electrical power through distribution network elements, such as substations and transformers. This model adopts a Multi-Echelon approach to optimize the allocation of electrical power while considering the specific characteristics of individual components within the distribution system.

Consider an electrical network composed of substation indices, $i = 1..I$, transformer indices $j = 1..J$, and electricity consumer indices $k = 1..K$. The objective is to establish an optimal configuration for this network, enabling the efficient transfer of electricity from substations to transformers and subsequently to consumers. The primary aim is to minimize the expenses associated with transmitting electricity from substations to consumers.

A. Objective Function

The objective function aims to minimize the total expenses, encompassing the costs associated with power losses during the transmission of electricity from the substation to the end consumer. The formulation of the objective function is as follows:

$$\sum_{j=1}^{J}\sum_{i=1}^{I} h_{ij} p_{ij} + \sum_{k=1}^{K}\sum_{j=1}^{J} z_{jk} p_{jk} \to \min \tag{1}$$

where h_{ij} is the costs of electricity transmitting from substation i to transformer j, z_{jk} is the costs of electricity transmitting from transformer j to consumer k, p_{ij} is the amount of electricity transmitting from substation i to transformer j and p_{jk} is the amount of electricity transmitting from the transformer j to consumer k.

B. Constraints

If L_{ij} represents the line capacity from substation i to transformer j, and L_{jk} represents the line capacity from transformer j to consumer k, then the capacity of the transmission network, encompassing substations, transformers, and consumers, can be expressed as follows:

$$p_{ij} \le a_{ij} L_{ij} \tag{2}$$

$$p_{jk} \le \beta_{jk} L_{jk} \tag{3}$$

where α_{ij} and β_{jk} denote whether it is possible to transmit electrical energy from substation i to transformer j and from transformer j to consumer k, respectively. If the value is 1, transmission is feasible, 0 or not.

Substations and transformers have operational limits, ensuring the safe and efficient functioning of these facilities. Considering these limitations, the subsequent boundary conditions are formulated:

$$\sum_{j=1}^{J} p_{ij} \le S_i^{\max} \tag{4}$$

$$\sum_{i=1}^{I} p_{ij} \le T_j^{\max} \tag{5}$$

where $S_i^{\max}$ and $T_j^{\max}$ represent the upper limits for substations and transformers, respectively.

The power balance constraint can be expressed in the following manner. The amount of electricity entering transformer j should be equivalent to the quantity of electricity exiting the transformer:

$$\sum_{i=1}^{I} p_{ij} = \sum_{k=1}^{k} p_{jk} \tag{6}$$

The amount of electricity transmitted from transformer j to consumer k must be equal to the demand of this consumer:

$$\sum_{j=1}^{J} p_{jk} = D_k \tag{7}$$

where D_k is the demand of k th consumer. And the nonnegative constraint is expressed as follows:

$$p_{ij} \ge 0,\ \ p_{jk} \ge 0 \tag{8}$$

III. Formulation of the Dual Problem

To solve problems (1)-(8), the method of solving linear programming problems can be applied. However, due to the significant number of constraints and variables, a significant amount of computation is required. As a result, instead of directly solving the original problem (1)-(8), it is advisable to consider its dual problem as a more appropriate alternative.

The dual problem corresponding to (1)-(8) is formulated as follows:

$$\sum_{i=1}^{I} S_i^{\max} u_i + \sum_{j=1}^{J} T_j^{\max} v_j + \sum_{k=1}^{K} D_k w_k + G(x) \to \min \tag{9}$$

$$u_i + v_j + x_{ij} + y_j \ge -h_{ij} \tag{10}$$

$$w_k - x_{jk} - y_j \ge -z_{jk} \tag{11}$$

$$u_i \ge 0,\ v_j \ge 0,\ x_{ij} \ge 0,\ x_{jk} \ge 0 \tag{12}$$

where $G(x) = \sum_{j=1}^{J}\sum_{i=1}^{I} \alpha_{ij} L_{ij} x_{ij} + \sum_{k=1}^{K}\sum_{j=1}^{J} \beta_{jk} L_{jk} x_{jk}$ and x_{ij}, x_{jk}, u_i, v_j, y_j, w_k are the dual variables associated with the constraints (2)-(7), respectively.

We employ the dual simplex method to solve problem (9)-(12). Through the application of the duality theorem, we achieve solutions for the original problems (1)-(8).

IV. Numerical Experiments

It is necessary to review the electricity networks connected to 413 consumers in the settlement located inside the district. These consumers receive electricity from 8 transformers. Electricity is supplied to the transformers from 3 nearby substations. It shows which transformer houses can get electricity from and how much it will cost. The current scheme of electrical networks is presented in Fig. 1.

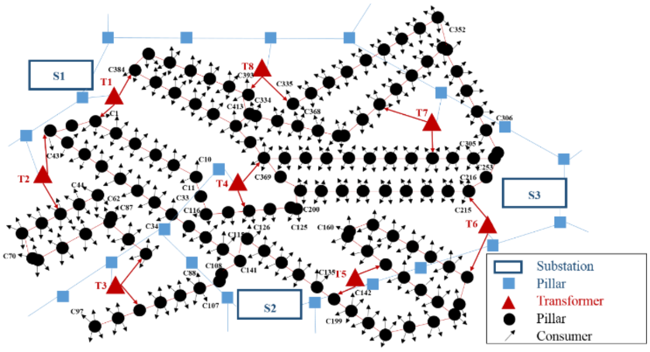

Fig. 1. Location scheme of substation, transformer, consumers.

Maximum power of substations and transformers, as well as the costs associated with transferring from substations to transformers are given in Table I.

TABLE I. MAXIMUM POWER OF SUBSTATIONS AND TRANSFORMERS AND TRANSFER COSTS FROM SUBSTATIONS TO TRANSFORMERS

Sub-stations (MWh)	**The upper limit of the transformer (MWh)**							
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***T7***	***T8***
	400	250	250	250	250	400	250	250
	Costs for the transmission of 1 MWh of electricity from the substations to transformers							
1000	3$	5$	-	-	-	-	9$	7$
500	-	-	6$	6$	4$	6$	-	-
800	-	-	-	-	6$	4$	5$	7$

The cells marked with "-" in Table I mean that there is no electricity network. That is, in the event that the electrical network is not drawn from substation 1 to transformers T3, T4, T5, T6, from substation 2 to transformers T1, T2, T7, T8, from substation 3 to transformers T1, T2, T3, T4 a lot of money is spent.

We also know the costs of electricity transmission from transformers to consumers. But due to the large number of consumers, this information is given in the form of statistics in Table II.

TABLE II. THE NUMBER OF CONSUMERS AND THEIR ANNUAL REQUIREMENTS FOR ELECTRICITY

Number of con-sumers	**Con-sumer demand (MWh)**	**Number of con-sumers**	**Con-sumer demand (MWh)**	**Number of con-sumers**	**Con-sumer demand (MWh)**
1	0.5	3	2.2	13	3.6
1	0.6	6	2.3	10	3.7
3	0.7	20	2.4	14	3.8
2	1	16	2.5	12	3.9
6	1.2	14	2.6	9	4.0
3	1.3	17	2.7	11	4.1
4	1.4	13	2.8	17	4.2
6	1.5	6	2.9	8	4.3
15	1.6	10	3.0	6	4.4
19	1.7	16	3.1	2	4.5
27	1.8	22	3.2	2	4.6
21	1.9	5	3.3	1	5
13	2.0	17	3.4	1	5.2
8	2.1	13	3.5		

The outcomes of our calculations reveal valuable insights into the cost dynamics of electricity distribution within the proposed framework. Specifically, the costs associated with transmitting electricity from substations to transformers amounted to 4,547.20$ (Table III), while the cost from transformers to consumers was 4,152.77$.

The total annual demand for electricity of the consumers listed in Table IV is: 1158.3 MWh. Also, 3.3$ to 5$ is spent on delivering 1 MWh of electricity from transformers to consumers. A total of 9,503$ is spent on the supply of electricity to consumers on the current power grids.

TABLE III. YEARLY POWER TRANSMISSION FROM SUBSTATIONS TO TRANSFORMERS

Sub-stations (MWh)	**Transformers (MWh)**							
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***T7***	***T8***
	373.1	114.2	0	0	108.4	389.7	172.9	0
	The amount of electricity transferred from substations to transformers							
487.3	373.1	114.2	-	-	-	-	0	0
108.4	-	-	0	0	108.4	0	-	-
562.6	-	-	-	-	0	389.7	172.9	0

TABLE IV. YEARLY POWER TRANSMISSION FROM TRANSFORMERS TO CONSUMERS

Con-sumers	**Transformers (MWh)**							
	T1	***T2***	***T3***	***T4***	***T5***	***T6***	***T7***	***T8***
Number	138	44	0	0	43	109	79	0
Demand	240.1	171.3	0	0	178.6	125.1	82	0

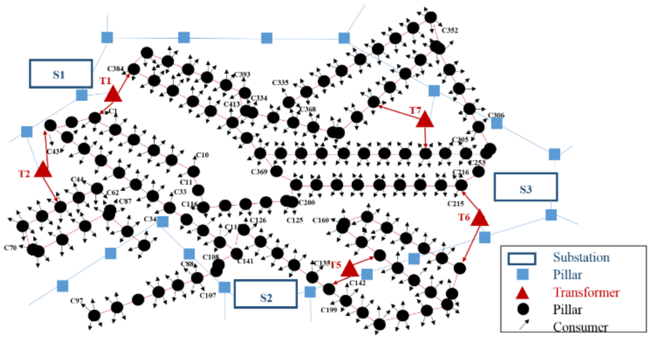

Fig. 2. Optimal scheme of electrical networks.

In total, a sum of 8,699.97$ was expended to supply a cumulative electricity capacity of 1,158.3 MWh. Notably, this cumulative expenditure is 803.6$ less than the costs incurred under the existing scheme.

Furthermore, our analysis provides recommendations for transformer deployment. The current configuration employs 8 transformers, yet our calculations demonstrate that a more efficient setup can be achieved by utilizing only 5 transformers. This optimization not only enhances operational efficiency but also contributes to cost reduction (Fig. 2).

Furthermore, computations were conducted across various electrical networks utilizing the model (1)-(8). The experimental findings reveal minimal discrepancies in expenses within regions characterized by relatively low electricity demand. However, substantial variations emerged in networks with significant supply volumes, demonstrating noteworthy cost reductions as these parameters increased. The outcomes of this experiment are depicted in Fig. 3.

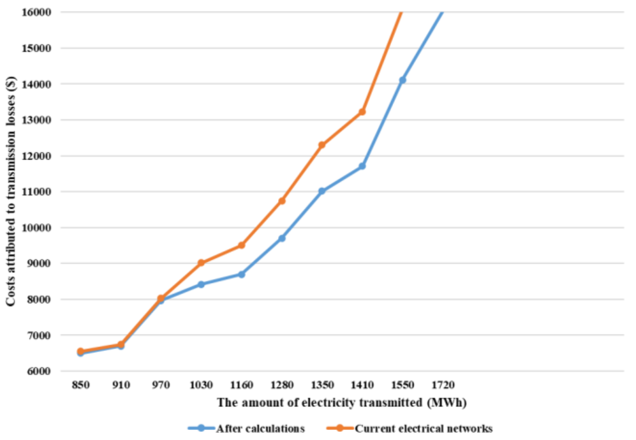

Fig. 3. Results of computations performed across different electrical networks.

These findings underscore the tangible benefits of the proposed approach, both in terms of cost savings and resource optimization. By strategically optimizing the distribution network, our approach presents a practical avenue for advancing the effectiveness and economic viability of electricity distribution systems.

Conclusion

We introduced a novel mathematical model employing the Multi-Echelon approach, offering a robust framework to navigate the intricate interplay of substations, transformers, and consumers. By formulating the problem as a linear programming challenge and applying the dual simplex method, we effectively addressed the extensive constraints and variables inherent in the system.

In essence, our study not only presents a viable solution for the optimization of electricity distribution systems but also showcases the tangible benefits of integrating mathematical modeling, dual problem formulation, and numerical analysis. The results underscore the potential of our approach to significantly enhance the efficiency, economic viability, and sustainability of electricity distribution networks in modern power systems. As we navigate the complexities of energy demands and strive for greener and more resource-efficient solutions, this research contributes to a comprehensive understanding of optimization strategies in the realm of power system engineering.

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COMBINED METHOD OF MEASURING THE POWER OF ROTATING MECHANISMS

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***Abstract*— This article is about the method of measuring the power of rotating mechanisms, in which sensors measuring the angular parameters of rotating mechanisms are analyzed. The method of power dissipation through angular velocity and torque is analyzed in more detail. Connections of input and output quantities are given. A new design was proposed and the principle of operation was analyzed.**

Keywords* — *power, rotating mechanism, sensor, angular parameter, angular displacements, rotating mechanisms, velocity, torque.

I INTRODUCTION

Today, a large part of the economy of our republic is made up of agriculture. Long-term operation of agricultural machinery without damage makes the work of farmers easier and leads to good economic results. Low fuel consumption is also important. In order for agricultural machinery to work without damage for a long time, it is necessary to measure and control the physical dimensions of these machinery.

One of the main working parts of agricultural machinery is the rotary mechanisms, and in this article we will pay attention to the measurement of its dimensions.

When talking about these quantities, angular quantities (angular displacement, angular velocity and angular acceleration) as well as the power of the rotating mechanism are of great importance.

Various sensors [1]–[7] have been developed to measure and monitor the power acting on rotating parts. These sensors make it possible to measure and control parameters such as angular displacement, angular velocity, and angular acceleration of rotating mechanisms.

There are direct and indirect methods for measuring the power of rotating mechanisms, and these [9]–[15] methods have their own advantages and disadvantages. Angular velocity, angular acceleration, and torque measuring sensors were used as primary variables in measuring the power of rotating mechanisms.

[16] the construction presented in the literature works on the optical principle and can measure the torque, power and angular velocity of the shaft. This device is composed of clutch flat disc, metal ball, clutch wave disc, variable surface, inductive sensor, spring, pressureless connection, guide torque/rotation sensor, brake. However, this method has some drawbacks. The following:

The proposed sensor converts the torque into an axial force, generating a measurable axial movement for the proximity sensor. This reading load increases the friction on the rotating parts, creating friction between the driven and driven sides, unless special devices are used. As a result, each side must be installed separately and properly aligned, which increases production costs.

The principle of operation of the sensor shown in [16] is based on measuring the magnitudes of the turning shaft when a moment is applied to it. According to the method of reading the angular sizes of the shaft, they are divided into two types:

1. measurement of voltage.
2. measurement of pulse.

In strainometric measurement, strain gauges are attached to the torsion shaft, the signal from it is amplified, converted into a serial digital code and transmitted to an external measuring device using a non-contact rotating transformer. The transformer also generates the voltage required to power the amplifier, the pulse transmitter, the devices located in the rotating part. The gap between the receiving device in the stator and the rotating transformer is 5 - 8 mm.

A disadvantage of this method is that there is a transient shift in the pulses read by the sensors from the slots in the input and output flanges (or auxiliary gears) that are converted into rotational speed and torque by the receiver. This causes measurement errors.

The torque measurement methods themselves are divided into contact and non-contact types, and you can see different designs in each method.

One such method is the determination of the surface acoustic wave response [9], in which an analysis of the relationship between the entropy of the response energy was carried out. It can be concluded that surface acoustic wave (SAW) sensors can be used. -To measure temperature or torque in a rotating medium; however, some customization components are required to overcome the limitations imposed by off-the-shelf (COTS) sensor solutions.

In another way, new torque magnetostrictive [14] sensors using amorphous are presented, in which amorphous tapes are cut to form a linear pattern and glued to the shaft. In this case, when a pair of tapes is installed, the multivibrator bridge circuit performs the function of torque measurement.

Another way to determine the torque in the tensometric method [19] is using a tensometric bridge circuit and non-contact transmission devices. In this way, signals can be controlled by a computer.

There also flange type [20] and magnetoelastic ring type torque sensors, each of which has advantages and disadvantages. For example, it is impossible to determine the direction of application of the magnetoelastic ring sensor, the material of the shaft should be taken into account in the design, and the maximum speed of the driven shaft of the flanged sensor is not high, the diameter of the shaft should be small to detect the torque at low speed, the contact rings when used at high speed, the sensor has such disadvantages as a short service life, a decrease in the accuracy of the resistance change over time.

The optical [22] sensor is mounted on a two-pin reading tape shaft. Since this is a non-contact method, torque measurement has less error and can be used to determine power. However, in this method, it is necessary to take into account the influence of the external environment. For example, in dusty environments, there are disadvantages such as a decrease in light transmission or light shift due to vibrations.

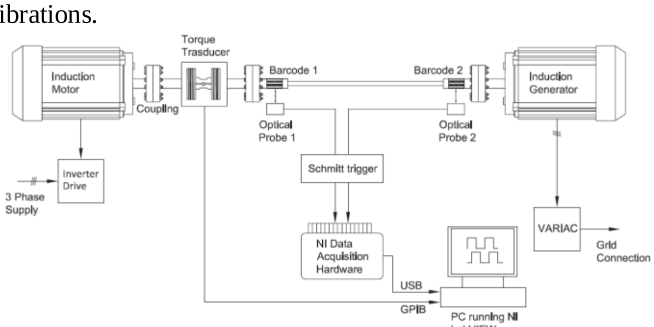


Figure 1. Non-contact torque measurement method.

Capacitive torque measurement [23] is also an example of non-contact measurement methods. The proposed capacitive torque sensor has two angular displacement sensors at a well-defined distance. These voltages are capacitively coupled from the stator to the rotor. The stator is also equipped with a reading electrode. The sine wave at this reading electrode is proportional to the rotor-stator.

There are more indirect measuring methods than direct methods for measuring the power of rotating mechanisms. These methods are different depending on the type and construction of measuring transducers.

II. MATERIALS AND METHODS

According to the first formula, the power of rotating mechanisms is equal to the product of the angular speed of the rotating mechanism and its torque. For this reason, the device we offer consists of angular velocity and torque measuring sensors.

$$P = M \cdot \omega \qquad (1)$$

here is the moment of the M-shaft, (Nm). ω-angular velocity, rad/s.

Figure 1 shows the measuring wheel, which is divided into eight parts. 4 of them are carved forming an angle of 45 degrees. This wheel is attached to the rotating mechanism.

A beam of light is directed vertically into it, and the returned light is received. By analyzing the returned light pulses, the angular velocity is calculated.

A bridge circuit with a tensometric sensor is installed on the back of the wheel.

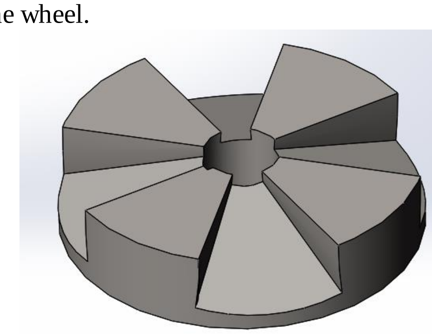


Figure 2. Angular speed measuring device wheel.

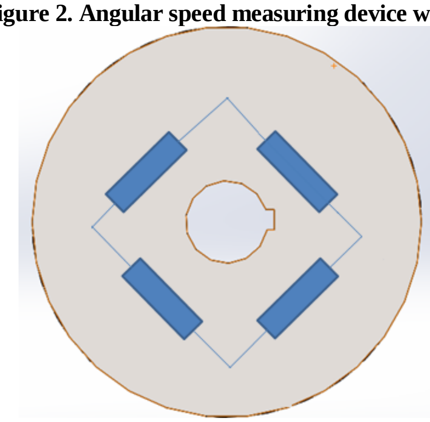
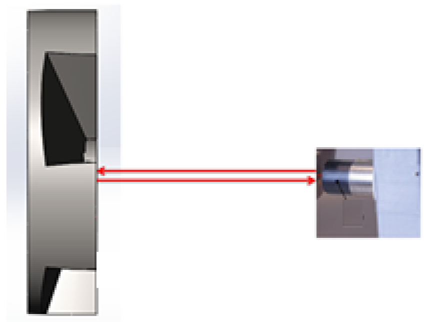


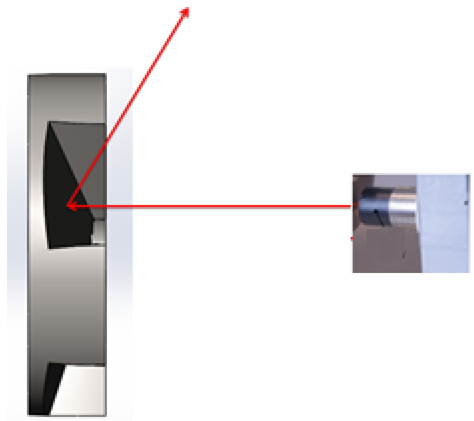
Figure 3. Tensometric bridge scheme.

III. RESULTS AND DISCUSSIONS

Figure 4 shows the flow of light from the light source to the measuring wheel. In this case, the falling wheel in a) picture is moving back from the surface. b) in the picture, the incident light falls on the sloping side of the surface and goes in the other direction at a certain angle, that is, it does not return.



a



b

Figure 4. Optical measurement of angular velocity.

Until the wheel rotates completely, the light falling on its surface returns 4 times and is directed to the other side 4 times, and this process alternates in a row. Figure 5 shows the image of the signal received at the receiver.

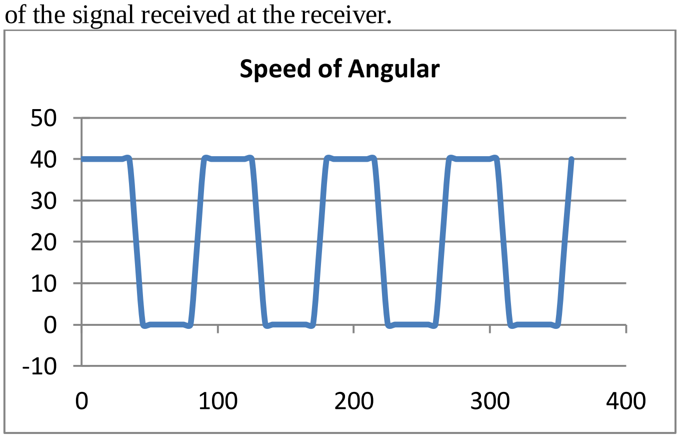


Figure 5. The shape of the signal received in the optical receiver.

Knowing the number of pulses p and the rotation frequency f, we can determine the rotation speed as follows.

$$\omega = \frac{60 \cdot f}{p} \qquad (2)$$

Given that there are 4 pulses in one period, then T=p/4

$$\omega = \frac{240}{p^2} \qquad (3)$$

If we spread the signal in Figure 5 into a Fourier series, it will be as follows.

$$f(\omega t) = A_0 + A_{1m} \bullet \sin(\omega t + \Psi_1) + A_{3m} \bullet \sin(3\omega t + \Psi_3) + A_{5m} \bullet \sin(5\omega t + \Psi_5) \qquad (4)$$

Its image is given in Figure 6.

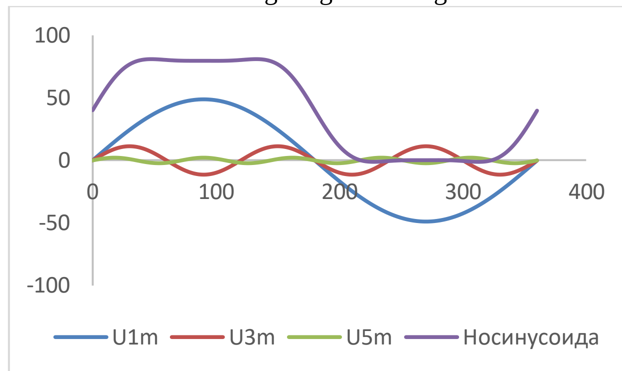


Figure 6. Fourier series propagation of a signal.

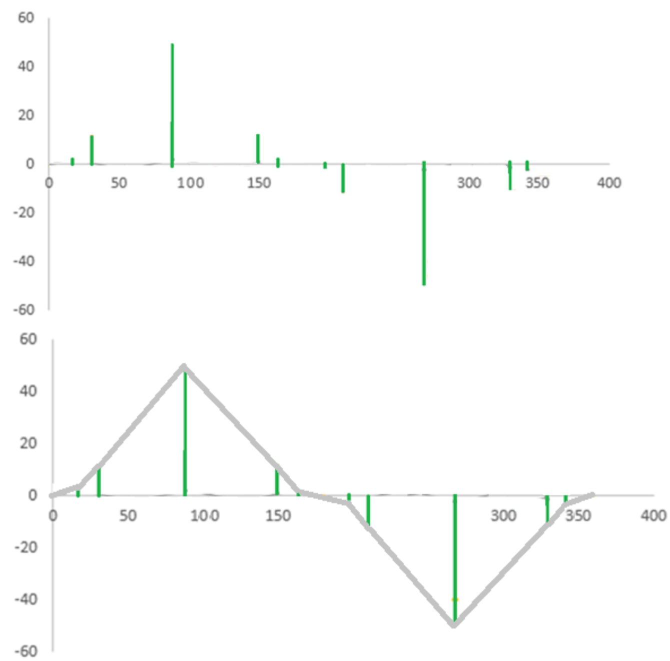


Figure 7. Spectrum representation of the signal.

In this work, a tensometric bridge circuit installed on the back of the measuring wheel is used to determine the torque (Fig. 8). In this case, measuring wheel 1 is made of elastic material, and 2 tensometric bridge circuits are installed on it. When a torque occurs in the shaft, due to the deformation, an unbalanced current is formed in the diagonals of the measuring bridge. The resulting electric signal is transmitted to the amplifier through the non-contact transmission device 3.

This signal is processed and the torque value is determined. The power of the rotating mechanisms is determined by the torque and angular velocity values obtained. This task is performed by an Atmega microcontroller.

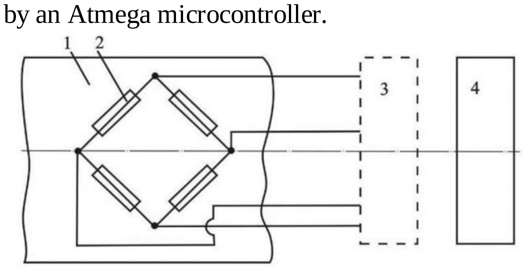


Figure 8. Tensometric bridge scheme.

CONCULATION

In the article, a combination method for measuring the power of a rotating mechanism was proposed, and the following conclusions were reached:

When measuring the power of the rotating mechanism, the non-contact method is considered effective and does not affect the parameters of the shaft.

The construction is very compact and easy to install.

When measuring the power of rotating mechanisms, it is necessary to take into account external influences.

The method of determining the power of rotating mechanisms using torque and angular velocity is simpler and more accurate.

The disadvantage of the design is that measurement errors increase in dusty environments.

ACKNOWLEDGMENT

I express my gratitude to the organizers of this conference for appreciating our work. I thank you for supporting the work of our team and I believe that our cooperation will continue for a long time.

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DEVELOPMENT OF A MATHEMATICAL MODEL OF AUTOMATIC DEPENDENT HYBRID SURVEILLANCE

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Annotation. Automatic Dependent Hybrid Surveillance (ADGS) is an important tool for security and control in various fields such as aviation, medicine, industry and transportation. The main purpose of AZGN is to detect and prevent emergencies, as well as to determine their causes.

The development of a mathematical model of ADGN is of great importance for improving the efficiency of this system. The model should take into account all the main parameters that affect the observation process: types of sensors, location of objects of observation, characteristics of the environment, and other factors.

Keywords: *mathematical model, probability theory, time discriminator, voltage-code converter, code-time delay converter.*

Introduction

Automatic Dependent Hybrid Surveillance is a method of object monitoring that combines the advantages of both autonomous and dependent surveillance. It allows you to effectively control the processes at the facilities, detect possible violations and prevent them.

To ensure the efficiency and accuracy of such monitoring, it is necessary to develop a mathematical model that will take into account all the factors influencing the processes of monitoring objects.

The development of a mathematical model of automatic dependent hybrid observation is a complex process that requires high qualifications and knowledge of various fields of science. However, thanks to this model, it is possible to significantly increase the efficiency of object control and prevent possible accidents and malfunctions.

The mathematical model of ADGN is based on the theory of probability. In the process of developing the model, it is necessary to determine the probability of occurrence of emergency situations under various conditions. To do this, experiments are carried out and data on previous accidents are analyzed.

An important element of the AZGN mathematical model is the system operation algorithm. It should be as efficient as possible and ensure timely detection and response to emergencies. The algorithm can be developed based on artificial intelligence methods such as neural networks, genetic algorithms or expert systems.

An important stage in the development of a mathematical model of ADGN is its verification and validation. Verification is a verification of the conformity of the model to the specified requirements. Validation is a test of the performance of the model on real data.

Main part

The mathematical model of automatic dependent hybrid surveillance is a complex system that combines a dynamic model of an object, a surveillance system, a computer data processing system, and a control system. It allows you to automate the process of monitoring and controlling an object with high accuracy and reliability and can be described as follows:

The object of observation is described by a dynamic system given by the equation:

$$\boldsymbol{dx/dt = f(x, u, t)} \quad (1)$$

where is the state vector of the object, is the control vector, is the time.$\boldsymbol{xut}$

Based on these parameters, the mathematical model will be a complex system of equations and functions that will relate various flight characteristics and provide efficient information transfer between aircraft and ground control stations:

$$\begin{cases} \boldsymbol{P = f(t)} \\ \boldsymbol{A = g(t)} \\ \boldsymbol{V = h(t)} \\ \boldsymbol{C = i(t)} \\ \boldsymbol{B = j(t)} \end{cases} \quad (2)$$

For each of the parameters, you can use different mathematical functions, which will depend on specific conditions and requirements. For example, to determine the position of an aircraft P as a function of time t, the following formula can be used:

$$\boldsymbol{P(t) = P_0 + vt} \quad (3)$$

where - the initial position of the aircraft, - the speed of the aircraft.$\boldsymbol{P_0 v}$

Similarly, appropriate formulas can be used to determine altitude A and speed, depending on the specific flight conditions.$\boldsymbol{v}$

To determine the unique flight identifier C, coding of information about the flight route, type of aircraft and other characteristics can be used. And to select the optimal frequency B of information transmission, you can use the analysis of the radio frequency spectrum and other technical parameters of data transmission.

The development of a mathematical model of ADGN is a complex process that requires knowledge in the field of probability theory, data analysis and artificial intelligence methods. However, a properly constructed model can greatly improve the performance of a surveillance system and provide security in a variety of applications.

The main components of the mathematical model of automatic dependent hybrid surveillance are:

1. Model of the object. This model describes the behavior of an object under different conditions. It must take into account all the features of the object: its physical parameters, structure, possible functional impairments, etc.

2. Model of the environment. The environment in which an object is located can affect its behavior and the operation of the control system. Therefore, it is necessary to take into account the characteristics of the environment: material properties, temperature, humidity and other parameters.

3. Model of observation. This model describes the process of observing an object and includes the characteristics of the sensors used, algorithms for processing the received data, and other parameters.

4. Solution model. This model determines how the system should respond to detected violations or object malfunctions. It includes algorithms for making decisions and actions that must be performed to eliminate the problem.

Let us consider a mathematical model of a digital system for automatic target tracking in range, which, unlike the existing ones, satisfies the requirements for stability and quality of the system for measuring range and automatic target tracking.

The digital automatic range tracking system (ADS) provides range measurement to the target and guidance, performs automatic temporal selection of radio pulses reflected from the target - range tracking, and performs automatic range measurement [5].

Estimation of the parameters of signals that carry information about the coordinates and characteristics of air targets is one of the main operations of the primary processing of radar signals. The evaluation of the parameters begins after the decision to detect the target is made. Digital systems of automatic range tracking have a high stability of parameters [10], which do not depend on the influence of the external environment. In addition, with digital implementation, the automatic range tracking system significantly reduces the operating costs associated with periodic adjustment work for its maintenance [8].

1. Mathematical model of the analog time discriminator

The time discriminator (TD) is designed to measure the time mismatch between the time position of the Energy Center of the signal reflected from the target and the time position of the state of the two next pulses.

The time discriminator performs the function of comparing a block that generates a voltage that depends on the mismatch [9]:

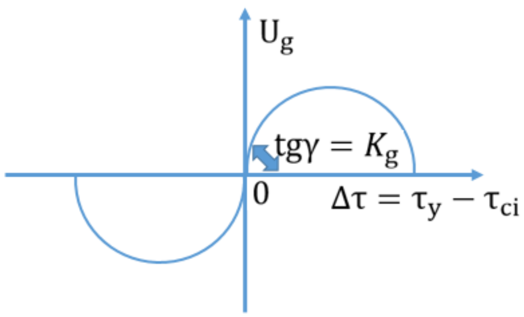
$$\Delta\tau = \tau_y - \tau_{ci} \tag{4}$$

The voltage at the output of the time discriminator (VD) is defined as:

$$U_g(kT) + \xi(kT), \tag{5}$$

where is the mathematical expectation of the initial voltage; t is the repetition period of probing pulses; k-number of the next radio contact; is the fluctuation component of the output voltage.$U_g(kT) U_g(kT) = M\{U_g\} \xi(kT)$

The mathematical expectation of the output voltage depends on the magnitude of the mismatch. This dependence is called the discriminator characteristic of the VD (Fig. 1).U_g



Rice. 1. Discriminatory characteristic of VD (developed by the author)

$$Kg = dUg/d\Delta\tau, \tag{6}$$

$\Delta\tau = 0$ - discriminator gain, represents the steepness of the discriminator characteristic BD at $\Delta\tau = 0$.

With a sufficiently small mismatch, we can assume that the output voltage of the discriminator has the form:

$$U_{ВД}\big(nT, \Delta r(nT)\big) = U_{ВД}(\Delta r) + \xi(nT, \Delta r(nT)) \tag{7}$$

Based on the above and equations (1-2), the generalized linearized mathematical model of the VD will have the form (Fig. 2).

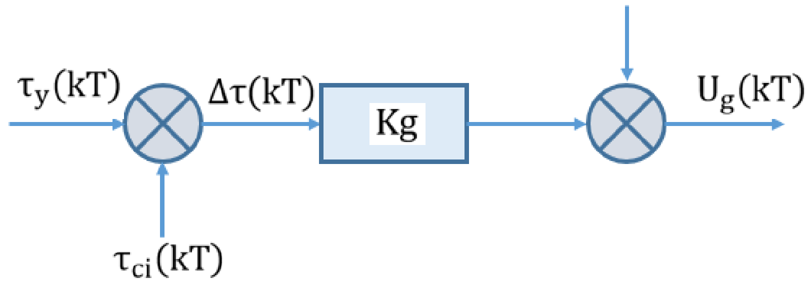


Fig.2. Mathematical model of the time discriminator

2. Mathematical model of the voltage-code converter (PNC)

The voltage-code converter is one of the varieties of analog-to-digital converter (ADC), it is designed to convert a continuous load into a sequence of digital codes [6]. To solve this problem, the voltage-to-code converter digitally encodes the analog voltage by performing operations of its time discrimination, level quantization, and scaling.

In the future, we will consider the voltage-to-code converter using the example of an analog digital converter.

Due to the fact that the radar station (RLS) uses a pulse signal [2], that is, the impact at the input of the analog digital converter is a lattice function of time, the need to use time sampling of the signal is discarded. With this in mind, we obtain a mathematical model of an analog digital converter (Fig. 3).

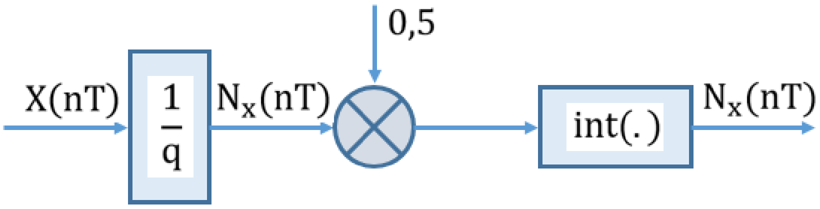


Fig.3. Mathematical model of the ADC

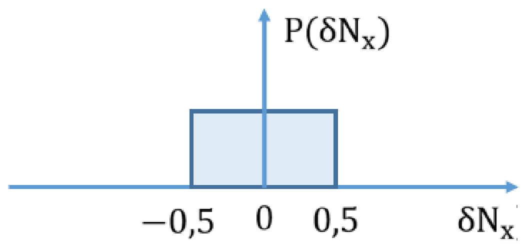
Often, instead of a nonlinear mathematical model of an analog digital converter, the use of which makes it difficult to study an automatic control system (ACS), it is enough to have its linearized model. The essence of linear cutting is to replace a nonlinear transformation with a linear addition operation [5]:

$$N_X(nT) = N_X(nT) + \delta N_X(T), \tag{8}$$

where is the result of scaling;$N_X = X/ q$

δN_X - the error created when selecting the nearest integer from the value , which is called the "noise" of rounding.N_X

When rounding to the nearest integer < 0.5, to assess the impact of rounding "noise" on the quality of the system, consider that it is an uncorrelated random sequence that is distributed over the interval [-0.5; 0.5] according to the uniform law (Fig. 4).δN_X



Rice. 4. distribution law of the probability density of rounding "noise"

$$P(\delta N_x) = \begin{cases} 1, \text{при} |\delta N_x| < 0{,}5; \\ 0, \text{при} |\delta N_x| > 0{,}5. \end{cases} \quad (9)$$

Based on this hypothesis, we obtain the probabilistic characteristics of the rounding "noise":

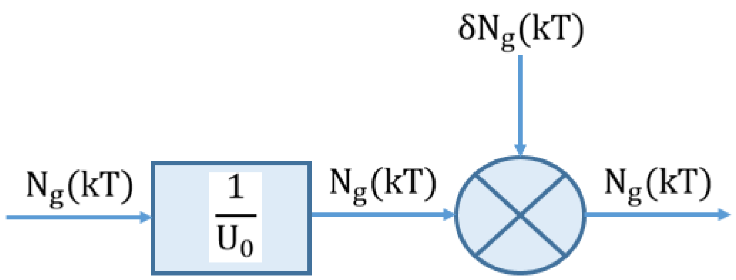
- expected value

$$M\{\delta N_x\} = \int_{-\infty}^{\infty} \delta N_{xp}(\delta N_x)\, d(\delta N_x) = 0, \quad (10)$$

- dispersion

$$D\{\delta N_x\} = \int_{-\infty}^{\infty} \delta^2 N_{xp}(\delta N_x)\, d(\delta N_x) = \frac{1}{12}. \quad \text{(eleven)}$$

Using all the assumptions, we will construct a linearized mathematical model of the voltage-to-code converter (VTC) of the digital automatic range tracking system. The diagram of the mathematical model of the voltage-to-code converter of the digital system for automatic range tracking is shown in fig. 5.



Rice. 5. Scheme of the mathematical model of the FNC of the digital ASD system

3. Scheme of the mathematical model of the digital filter

A digital code converter (DCT), which is sometimes called a digital filter, performs the following tasks:

- converts the sequence of numbers that are fed to its input from the output of the voltage-code converter into a sequence of estimates of the current range [1].$N_g(kT) r(kT)$

- generates a sequence of numbers that controls the operation of the converter code - time delay (PCD) and thereby determines in each period the time shift of the tracking pulses relative to the synchronization pulses.$N_g(kT)$

Due to the fact that the time shift of the tracking pulses must be set before the arrival of the target pulses, when the current range estimate has not yet been received, to form the numbers, it is not the current range estimate that is used, but the range value extrapolated at the moment of time, calculated in the previous cycle of the digital code -converter according to already obtained range estimates , etc., in accordance with the hypothesis embedded in the work program of the digital code converter (DTC) about strengthening the range with the passage of time.$r(kT) N_g(kT)$ $r(kT) kT r(kT) r(kT - T) 2r(kT - T)$

Therefore, in the current cycle of the digital code converter, after receiving the range estimate, the value is calculated - the extrapolated value of the range at the moment of time (the moment of arrival of the next target pulse). The value of the value allows you to determine the number that is required in the next cycle of the ASD to apply to the converter code-time delay in order to obtain the time shift of the tracking pulses. Thus, the ICU in each current cycle of operation calculates the values , and .$r(kT)r(kT+T)(kT+T)r(kT+T)N_k(kT+T)r(kT)r(kT+T)N_k(kT+T)$

The initial values of the ICT in the current cycle of work are:

$r(kT)$, - estimate of the current range;

$$N_k(kT) = S^{-1} \cdot N_k(kT+T) \tag{12}$$

Let's build a diagram of a mathematical model of a digital code converter and assume that the evaluation and extrapolation occurs through linear operations on the input data.

Then you can write:

$$r = K_0(S) \cdot N_g(kT), \tag{13}$$

$$r(kT+T) = K_\varepsilon(S) \cdot r(kT), \tag{14}$$

where and are linear stationary difference estimation and extrapolation operators, respectively.$K_0(S)K_\varepsilon(S)$

It is known that the estimation and extrapolation of the range in the ICT is carried out according to the algorithm, which is represented using linear difference equations [7]:

$$\hat{r}(kT) = r_e(kT) + \frac{1}{K_{gr}} K_1 N_g(kT), \tag{15}$$

$$\hat{V}(kT) = \hat{V}(kT-T) + \frac{1}{K_{gr}} K_2 N_g(kT), \tag{16}$$

$$\hat{r}_e(kT+T) = \hat{r}(kT) + T\hat{V}(kT), \tag{17}$$

where and are the range estimate and its extrapolated value;$\hat{r}\hat{r}_e$

$\hat{V}$-assessment of the target's radial velocity; -output value of the discriminator;N_g

K_1, K_2– algorithm parameters;

K_{gr}- amplification factor with dimension (single bit), which relates the value of the range error, expressed in meters, with the value of the source code of the NCP.

To obtain a range estimation operator, you need to:$K_0(S)$

1. solve equation (13) regarding the estimate of the radial velocity:

$$\hat{V}(kT) = \frac{K_2}{K_{gr}(1-S^{-1})} \cdot N_g(kT) = K_v(S)N_g(kT). \tag{18}$$

2. substitute expression (18) into (19). Present the resulting equation in symbolic form and solve it with respect to:$r(kT)$

$$r_e(kT) = S^{-1}\left[\hat{r}(kT) + \frac{K_r t}{K_{gr}(1-S^{-1})} \cdot N_g(kT)\right] \tag{19}$$

3. substitute into (12) expression (16) for . After that, solve the resulting relation with respect to the range estimate$r(kT)$

$$\hat{r}(kT) = \frac{K_1 + (K_2T - K_1)S^{-1}}{K_{gr}(1-S^{-1})^2} \cdot N_g(kT), \tag{20}$$

Thus:

$$K_0(S) = \frac{K_1 + (K_2T - K_1)S^{-1}}{K_{gr}(1-S^{-1})^2}, \tag{21}$$

or in another way:

$$K_0(S) = \frac{K_1S^2 + (K_2T - K_1)S}{K_{gr}(S-1)^2}, \quad (22)$$

To get the range extrapolation operator, you need to:$K_0(S)$

Solve equation (17) with respect to:$N_g(kT)$

$$N_g(kT) = \frac{1}{K_0(S)} \cdot r(kT) = \frac{K_2(1 - S^{-1})}{K_1t(K_2T - K_1) \cdot S^{-1}} \cdot \hat{r}(kT), \quad (23)$$

Substitute the result in (15):

$$\widehat{V}(kT) = \frac{K_v(S)}{K_0(S)} \cdot \hat{\tau}(kT) = \frac{K_2(1 - S^{-1})}{K_1 + (K_2T \cdot K_1) \cdot S^{-1}} \cdot \hat{\tau}(kT), \quad (24)$$

Substitute the resulting value into expression (17), and then bring it to the form

$$r_e(kT + T)\frac{(K_1 + K_2)S - K_1}{K_1S + K_2T - K} \cdot \hat{r}(kT). \quad (25)$$

Thus:

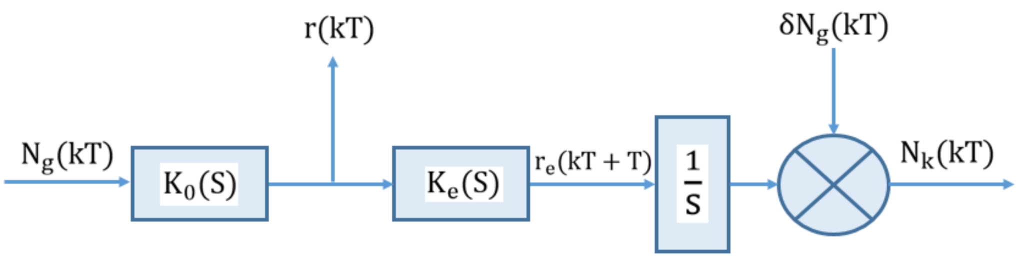
$$K_e(S) = \frac{(K_1 + K_2)S - K_1}{K_1S + K_2T - K_1}, \quad (26)$$

$$\tau_{ci}(kT + T) = \frac{2r_e(kT + T)}{C}, \quad (27)$$

where is the speed of light$C$

In order to obtain selective pulses delayed by time , with an accuracy of at least half of the tracking period of counting pulses, it is necessary to apply an integer to the PCZ, the ratio closest to the value .$kT + TN_g\ {}^{\tau_{ci}}/_{T_i}$

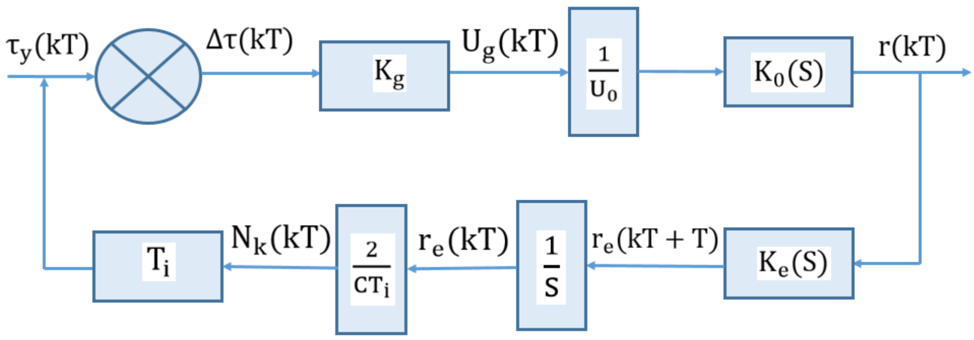
Rounding this number to the nearest integer in the linearized mathematical model is taken into account by introducing an error with zero mathematical expectation and a variance of 12, which is an independent random sequence. Relations (12; 14) define a simplified linearized mathematical model of a digital code converter, which is shown in (Fig. 6).$\delta N_k(kT)$



Rice. 6. Scheme of the mathematical model of the digital filter

4. Schemes of the mathematical model of the digital ASD system

Combining the schemes of mathematical models of the time discriminator, voltage-code converter, digital code converter and code-time delay converter, we obtain a diagram of the mathematical model of a digital system for automatic distance tracking, which is shown in Fig. 7.



Rice. 7. Scheme of the mathematical model of the digital ASD system

To simplify further analysis of ASD, it is necessary to move from the scheme of the mathematical model to an equation that includes the range to the target (12). The transition is carried out by taking into account the relationship between the range to the target$r(kT)$ and the time delay of the signal repulsed from the target

$$\tau(kT) = 2/C\, r(kT), \qquad (28)$$

After that, we exclude from the scheme of the mathematical model the mutually inverse operatorsT_i And$1/T_i$, for which we will transfer the operator with influence through the block with the operator . Then at the input of this block we will have a disturbing equivalent effect:$\delta N_k(kT)\ 2/C \times T_i$

$$\delta r_e(kT) = \frac{C \cdot T_i}{2} \delta N_k(kT), \qquad (29)$$

which has a variance

$$D\{\delta r_e\} = \frac{(C \cdot T_i/2)^2}{1^2}, \qquad \text{(thirty)}$$

after excluding operatorsT_i And$1/T_i$it remains to replace the operators at both inputs of the first adder with one operator inserted at its output. In addition, all interfering influences acting at the input of the system are determined by the relation:$2/C\ 2/C$

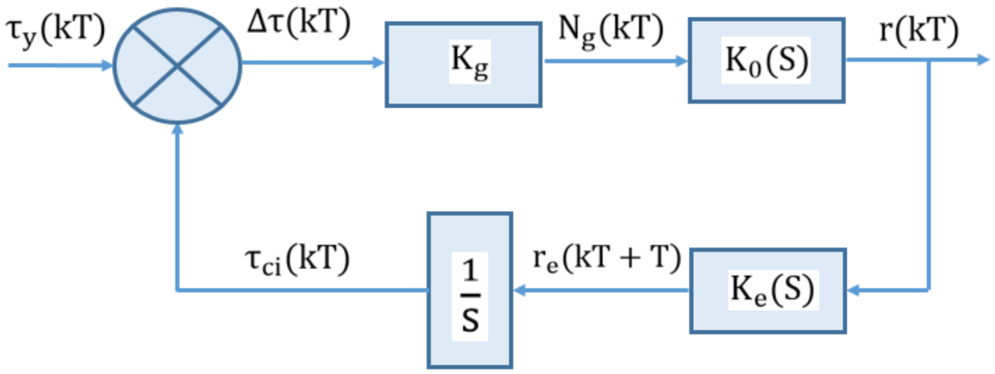
$$S(kT) = \delta r_e(kT) + \frac{CU_0}{2K_g} \delta N_g(kT) + \frac{C}{2K_g} \cdot \varphi(kT), \qquad (31)$$

Due to the fact that is a centered random process, its sign does not matter.(kT)

The dispersion of the equivalent interfering action is equal to:

$$D_f = \frac{\left(C \cdot {}^{T_i}\!/_{2}\right)^2}{12} + \frac{\left(C \cdot {}^{U_0}\!/_{2K_g}\right)^2}{12} + \left(\frac{C}{2K_g}\right)^2 D\varphi, \qquad (32)$$

The finally transformed scheme of the mathematical model of the digital ASD system is shown in fig. 8.



Rice. 8. Simplified diagram of the mathematical model of the digital ASD system (developed by the author)

4. Choice of the estimate of the smallest digit of the FNA

The presence of quantization by the signal level leads to the appearance of an additional effect, which negatively affects the operation of the automatic range tracking system with dispersion [4].

$$D = \left(\frac{CU_0}{2K_Д}\right)^2 \cdot \frac{1}{12} \tag{33}$$

Equating expression (30) to 0.25, we find the maximum value of the price of the smallest digit of the voltage-code converter:

$$U_0 = \frac{\sqrt{3} \cdot 2 \cdot K_Д}{C} = \frac{0{,}69}{3} = 0{,}83 \tag{34}$$

Thus, choosing the price of the smallest digit of the voltage-to-code converter less than 0.83 Volts, one can ignore the influence of instrumental errors on the quality of the automatic tracking system (AS) operation, which are determined by the level of signal quantization in the voltage-to-code converter.

Conclusion.

Based on the results of the study, a mathematical approach is proposed for choosing the optimal parameters for the functioning of the components of a digital system for automatic target tracking in range. With the help of a mathematical model, an analysis of digital and analog systems was carried out, as a result of which the optimal parameters for ensuring stable target tracking were obtained:

- based on the study of the model of the automatic range tracking system, an analysis of the stability and quality of the system was carried out. The allowable areas of the parameters of the algorithm of operation of the digital control device are determined, in which the automatic range tracking system corresponds to its intended purpose.

- based on the analysis of the quality of the automatic range tracking system, the estimate of the least significant digit in the voltage-to-code converter was selected. Choosing the price of the smallest discharge of the voltage-to-code converter less than 0.23 V, one can not take into account the influence of instrumental errors, which are caused by level quantization in the voltage-to-code converter, which affects the quality of the automatic range tracking system.

Thus, according to the simulation results, the requirements for indicators of stability and quality of the automatic range tracking system were met, which fully meet the requirements for such systems.

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Methods for investigating the spatial heterogeneity of electromagnetic pollution of the human environment

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Abstract— **In this article methods for investigating the spatial heterogeneity of electromagnetic pollution of the environment are discussed. Moreover, it provides a general estimation of their use.**

***Keywords*—electromagnetic pollution, sources of electromagnetic radiation, electromagnetic background, monitoring, evaluation, urban area**

I. Introduction

The 20th century was marked by the rapid development of electronics and radio engineering. The widespread use of high voltage power lines, radio electronic devices and means of communication has led to the significant increase in the levels of electromagnetic fields of various frequency ranges and the expansion of the modes of generation of these fields in the environment. It has been established that the electromagnetic field (EMF) poses a serious danger to human life and health and has a negative impact on the functioning of electronic equipment.

The development of the electric power industry and radio electronics began to be restrained by the negative phenomena generated by this technology, its quantitative growth. Further progress in the field of electric power industry and radio electronics requires solving the problem of ensuring safety of human, ecology of the external environment and the joint functioning of various radio and electrical systems.

The intensive development of electrical technology, television technology, computers, mobile communications, electronic household and office equipment has caused the emergence of a large number of artificial sources of the electromagnetic field and has led to “electromagnetic pollution” of the human environment [1].

Clearly expressed electromagnetic pollution is observed near the power lines, heating networks, television stations, cellular communications, etc. Electromagnetic pollution in large cities already exceeds natural levels by thousands of times.

The facts show that the usual level of the low-frequency electromagnetic field of a large city corresponds to the situation of a natural “magnetic storm”. Already today, electromagnetic pollution of the environment, along with chemical pollution, is the most common type of pollution that carries dangerous global consequences and causes great concern for both scientific community and public. The World Health Organization has included the problem of electromagnetic pollution of the environment in the list of priority problems of humanity.

It has become usual to use radio emitters on houses and cars and use of radiotelephone as a mean of radio communication. Power lines and radio transmission centers are ubiquitous in residential areas and in places of human recreation. Currently, sources of electromagnetic radiation are increasingly spreading both at work and in everyday life, therefore the number of people exposed to these radiations is growing. The electric power industry has powerful sources of electromagnetic fields in its arsenal. Dozens of types of modern household appliances are used in the apartments of our citizens, including electric floor heating, microclimate systems, etc., which create a dangerous environment for humans and pets.

Among the registered effects of electromagnetic pollution on humans, the most common is damage to the cardiovascular, nervous, hematopoietic, digestive and reproductive systems of a person, its action leads to oncological diseases [2-7].

The danger of electromagnetic radiation, even weak, lies in the fact that they do not manifest themselves in any way, and the human body does not perceive them in the form of any physical impact. However, their action manifests itself gradually in the form of short-term or long-term ailments, which people attribute to their other causes that have nothing to do with the operation of systems, devices that generate electromagnetic fields of varying intensity. And if the human body is exposed to electromagnetic radiation for a long time, then, unfortunately, very often it leads to the most negative consequences.

These consequences are treated by different methods, but the cause - the electromagnetic field in which the person is constantly located - is not taken into account and cannot be eliminated in any way.

Unfortunately, many sources of electromagnetic radiation are hidden, that is, their location, radiation intensity, time and duration of the work are not known in advance. It most often occurs in residential areas where people spend most of their time. It is these sources that are most dangerous; since they cannot be controlled without special measuring instruments, and it is also impossible to accurately determine their type and location. It is impossible to predict how such sources will behave, what the resulting electromagnetic field they will form within the limits of their action.

Thus, we can draw the following important conclusion that all sources of electromagnetic radiation during their operation must be under strict control. In this case, it is necessary to monitor both location and level.

II. Main Part

Currently, one of the most urgent tasks is to assess the environmental situation in heterogeneous multicomponent environments, which include the majority of anthropogenically modified territories. This requires adequate data on the spatial and temporal variability of environmental factors, the degree of their danger to human health, as well as models of both environment itself and the processes of interaction of human society, under the influence of which the formation of ecological situation of a particular territory takes place.

The key problem in assessing the environment is its impact on human health, up to date, only the consequences of sufficiently strong impacts, many times greater than those encountered in reality, have been investigated properly.

Majority studies of background levels of physical impact by traditional medical and sanitary-epidemiological methods have insufficient static significance, and often results are contradictory and difficult to compare, including for reasons such as the almost complete absence of methods for considering the real spatial heterogeneity of environmental factors, a serious lack of objective data on values of individual/collective exposures (doses), and the lack of common methods for obtaining and analyzing data.

The basic shortcoming of most studies is the prior idea of human environment as a regular or locally homogeneous environment. However, up to date, the level of study of physical phenomena in most cases has revealed a pronounced non-linear nature of their course and a complex irregular spatial structure of pollution. This is especially true for electromagnetic fields of industrial frequency and radio frequency range.

The description of these phenomena, especially when assessing the potential danger for both individual and a group of people, should be deterministic. At the same time, the degree of detailing of the deterministic description of the ecological conditions of the environment should ensure that the spatial heterogeneity of the environment quality is considered within the basic structures of the units of territory and at the same time strive for the maximum possible consideration of highly variant individual sensitivity to environmental factors through monitoring surveys.

The main task of this work is to consider the existing methods for expert evaluation of the spatial heterogeneity of electromagnetic pollution in the conditions of city and residential/public premises, and their characteristic features.

Presently, there are various methods for studying the spatial inhomogeneity of electromagnetic pollution of the environment, but the most commonly used are:

- affirmative method;
- statistical method;
- method of finite-difference solution of Maxwell's equations in the time domain;
- method of parabolic wave equation;
- natural method;
- time-exposure method.

The assessment of the affirmative calculation method is based on:

a) modeling the field by electrodynamic methods near the transmitter antenna, for example, calculating the effective value of the field strength, which is calculated by the formula:

$$E_e = \frac{173\sqrt{P_1 D_1}}{r} * F, mV/m \qquad (1)$$

where: E_e – effective value of the electric field strength of the radio wave at the receiving point, mV/m;

P_1 – radiated antenna power, kW:

D_1 – transmitting antenna directivity factor;

r is the line-of-sight distance between the radiation source and the receiver, km;

F is the signal attenuation factor;

b) Vvedensky interference form, which is designed to calculate fields in ultra-short waves range and is based on the interference pattern of addition a direct (freely propagating in air) beam oscillations and a beam reflected from the Earth's surface and falling into a receiving antenna.

The effective value of the resulting field strength is determined by the following formula

$$E_e = \frac{173\sqrt{P_1 D_1}}{r}\sqrt{1 + 2R\cos\theta + \frac{2\pi}{\lambda}\Delta r + R^2}, \frac{mV}{m} \qquad (2)$$

where:

R – reflection coefficient;

θ – is the reflection loss angle;

λ – is the wavelength;

Δr – is the difference in the path of the rays.

As we can see, this method is based on calculated and statistical indicators, such as the reflection coefficient and the reflection loss angle.

The statistical method only approximately considers the characteristics of the real environment for propagation of radio waves, especially the nature of urban development. When decomposing methods for calculating the spatial distribution of the electromagnetic field, depending on the relative position of the receiver and transmitter, empirical constants and coefficients are used, which must be determined / refined experimentally.

An example is the Okumura-Hata model. Based on the Okumura-Hata model, many measurements are given in the frequency range from 150 to 1920 MHz in Tokyo.

The empirical Okumura-Hata model is often used in calculating the coverage area of a cellular base station (BS), as it is recommended by the International Radio communication Advisory Committee (CCIR) and is quite simple to apply. This model makes it possible to calculate the path loss for a specific BS power and parameters.

The average level of losses on the radio path, following the empirical Okumura-Hata model, is determined as follows [8, 9, 10]:

$$L = 69{,}55 + 26{,}16\lg(f) - 13{,}82\lg(H_{bs}) + [44{,}9 - 6{,}55\lg(H_{bs})]\lg(r) + \alpha(h_{as}) + \alpha(U_r) + \alpha(b) + \alpha(H_{bs}, f)\,, dB \quad (3)$$

where: f – [100:3000] – operating frequency, MHz;

H_{bs} – [3:300] – BS antenna suspension height, m;

r – [1:100] – distance between the base station and the subscriber station, km;

As we can see, it is impossible to calculate the spatial distribution of the electromagnetic field with a high level of detail (less than hundreds of meters) using statistical methods due to the use of averaged characteristics of radio wave distribution medium without considering local features.

The method of finite solution of Maxwell's equations in the time domain is one of the most popular methods of numerical electrodynamics. It is based on the discretization of Maxwell's equations written in differential form and belongs to the general class of grid methods for solving differential equations. The basic algorithm was first proposed by Kane Yee in 1966. However, the very name “Finite-difference time-domain” and the abbreviation FDTD were given Allen Tufflove method in 1980.

Initially, FDTD meant the use of the basic Yee algorithm for the numerical solution of Maxwell's equations. However, now the method includes a wide variety of possibilities, such as modeling media with dispersed and nonlinear properties, the use of various types of grids (and not just Yee's rectangular grid).

In Maxwell's equations, the change in the electric field E depends on distribution of the magnetic field H in space. And the change in the field H, in turn, depends on distribution of the field E. The grids for the electric and magnetic fields are shifted with respect to each other by half a discretization step in each of the spatial variables and in time.

With the help of finite-difference equations, it is possible to determine the fields E and H at the current time step from the values of the fields at the previous one. Thus, under given initial conditions, Yee's algorithm makes it possible to obtain an evolutionary solution in time from the origin with a given time step.

The structure of interaction of electromagnetic waves is displayed in a spatial lattice by assigning the appropriate values of permittivity of each component of the electric field and permeability of each component of the magnetic field.

The FDTD method imposes extremely high requirements on computing resources, which requires to use powerful multiprocessor computers with a large amount of memory, and therefore the practical spatial scales of the calculation are limited to linear dimensions of the order of ten to hundreds of wavelengths. However, this method has a potentially high accuracy in calculating the level of electromagnetic field, even when it interacts with complex three-dimensional structures. [11].

The parabolic wave equation method is characterized by relatively low requirements for the computing platform and high calculation speed compared to the method of finite solution of Maxwell's equations in the time domain. It also allows you to simulate the propagation of radio waves through a medium with inhomogeneous dielectric characteristics. This method is more intended for calculating the problems of radio wave propagation over the relief surface, which leads to an increase in duration of the calculation under conditions of sharp elevation changes (in multi-storey buildings) and requires special preliminary preparation of terrain data [12].

The full-scale method, or sometimes it is called the experimental method, is based on the study of the state of electromagnetic field in a controlled area by means of electronic measuring instruments. The initial data obtained as a result of direct measurements of electromagnetic field strength at controlled observation points using measuring equipment allows you to get a complete picture of the electromagnetic environment, for example, at work or in residential area. The numerical results of measurements of the levels of electromagnetic field strength can be visualized graphically, with a general plan for the placement of sources of electromagnetic radiation [13, 14].

It is important to note the fact that in order to obtain a more complete picture of the state of electromagnetic fields, it is also necessary to analyze its spectral components. This approach is very important, since, as it is known, electromagnetic fields with different generation frequencies affect the human body in different ways [15].

The degree of influence of an electromagnetic field on a person at different frequencies varies significantly: the shorter the wavelength or the higher the operating frequency, the greater the potential energy it has. In this case, the depth of field penetration into the human body decreases, affecting mainly the surface layers of human body.

An example of study results of the spectral components, as well as the registration of short-term interference at the control point of observation, is clearly shown in Fig. 1 and 2.

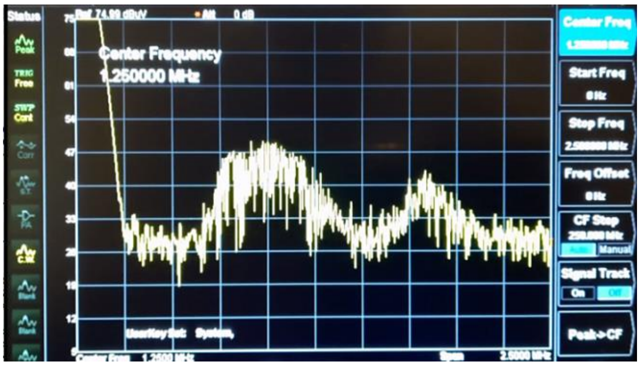

Fig. 1. An example of the study of spectral components of electromagnetic radiation in the frequency band 0...2.5 MHz at the control point of observation

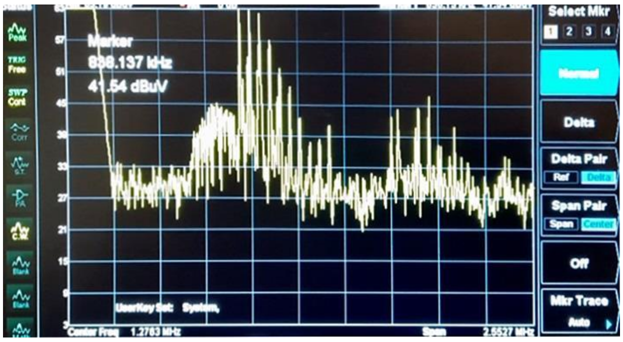

Fig. 2. Example of registration of short-term interference at the control point of observation

Thus, we can obtain additional information about the state of EMF sources at the observation point with the changes and processes present in them.

Regarding *the time-exposure method*, this method is based on determining the allowable time for a person to stay in various areas of a room with sources of electromagnetic radiation in order to assess the state of electromagnetic environment.

The state of the electromagnetic environment is assessed by a spatial picture of electromagnetic hazard, which is a map of the permissible time for a person to stay in various zones of space under study, obtained as a result of identifying the most dangerous EMR components from various sources in frequency range under study and subsequent modeling of EMF on a computer, and displaying the overall picture on the monitor.

Dangerous components of EMR corresponds to the smallest value of the time spent by a person at points of measurement of EMF intensity and density of electromagnetic fields near radiation sources regulated by regulatory documents [16].

Thus, for example, the time spent by people in a magnetic field created by EMP sources, except for a personal electronic computer (PC), at frequencies of 50 Hz can be determined by the formula

$$\mathrm{T}_{Permissible(MF\ 50)} = \frac{1600}{\mathrm{H}_{1\ Actual}}, \tag{4}$$

where: intensity of the magnetic field created by EMP sources, except for a PC, at a frequency of 50 Hz, A/m;

Similarly, it is possible to determine the allowable time of stay in zones of magnetic field action with a frequency of 50 Hz from a PC using the formula

$$\mathrm{T}_{Permissible} = \frac{4}{\mathrm{H}_{2Actual}}, \tag{5}$$

where: $\mathrm{H}_{2\ \mathrm{fact}}$ –the intensity of magnetic field generated by the PC, at a frequency of 50 Hz, A / m;

Taking into account the length of 8 hours shift, calculation formulas for determining the allowable residence time in an electric field can be represented as

$$\mathrm{T}_{Permissible} = 8\left(\frac{\mathrm{E}_{Permissible}}{\mathrm{E}_{\ Actual}}\right)^{2}, \tag{6}$$

where: $\mathrm{E}_{\mathrm{Permissible}}$ – the value of the electric field strength generated by EMP sources in the frequency range of 10 kHz - 30 kHz, A/m;

$\mathrm{T}_{\mathrm{Permissible}}$ – allowable residence time, hours.

Similarly, for the magnetic component

$$\mathrm{T}_{Permissible} = 8\left(\frac{50}{\mathrm{H}_{\ Actual}}\right)^{2}, \tag{7}$$

The method for determining the allowable time in production conditions provides the evaluation and normalization of the EMF by magnitude of the energy exposure (EE), which in the frequency range of 30 kHz - 300 MHz is calculated by the formulas:

$$\mathrm{EE_E} = \mathrm{E}^2 * t, \tag{8}$$

$$\mathrm{EE_H} = \mathrm{H}^2 * t, \tag{9}$$

where: E – electric field strength, V/m;

H is the magnetic field strength, A/m;

t is the time of impact on the shift, hours;

and in the frequency range 300 MHz - 300 GHz

$$\mathrm{EE_{EFD}} = \mathrm{EFD} * t, \tag{10}$$

where: EFD – energy flux density, $\mathrm{W/m^2}$, $\mathrm{mW/cm^2}$

III. Conclusion

Today, the development of human civilization, especially in large cities, is characterized by a significant increase in anthropogenic (primarily man-made) pressure on the environment and humans. At the same time, despite the constant growth of the negative impact, the problem of the impact of physical pollution, including electromagnetic, in the conditions of urbanized territories is increasingly given undeservedly little attention.

In order to take timely measures to reduce the impact of physical pollution, it is necessary to study the spatial heterogeneity of electromagnetic pollution and monitor the human environment, which is currently a very urgent task.

Conducting research and monitoring of urbanized territories involves solving a number of tasks:

- determination of the most dangerous zones of the urbanized territory of electromagnetic pollution;
- development of methods for carrying out full-scale measurements of electromagnetic pollution;
- processing of experimental data and issuance of a conclusion on compliance with regulatory requirements;
- development of measures to reduce the impact of electromagnetic pollution.

The methods we have considered for studying the spatial inhomogeneities of electromagnetic pollution of environment have characteristic features of displaying the state of the electromagnetic environment in human environment.

Solving the problem of electromagnetic pollution of the environment is a complex task that affects the interests of various departments and industrial corporations, and requires the coordination of research work [17, 18].

To conclude, it is important to note the statement of Academician A.I. Berg: “The problem of negative impact on the human body of electromagnetic fields as a factor in the production environment and habitat not only continues to remain relevant, but also acquires special significance as the scientific and technological revolution continues to develop”.

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Development of Software for Speech-to-Text Conversion

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***Abstract*— Overall, speech recognition software has broad relevance in enhancing accessibility, customer service and call centers, improving productivity, enabling hands-free control, medical and legal transcription and automating tasks across various industries and domains. Its applications continue to evolve and expand as the technology advances. This article outlines software that converts speech into text using hidden Markov models.**

***Keywords*— speech signal, speech-to-text, speech recognition, hidden Markov model**

I. Introduction

The development of software that simulates human communication is still important today. The simplest communication model is a database containing questions and answers. In this case, there is a problem of writing the knowledge base and implementing the interpretation software. In real life, it is their language that unites people when communicating. This allows people to converse and understand each other. Language understanding plays a fundamental role in human life, enabling effective communication and facilitating social interaction. Overall, language comprehension is a complex cognitive process that combines linguistic, cognitive, and social factors. This allows for meaningful conversations, sharing ideas, expressing emotions, and building connections with others, and is the basis for effective communication in daily life.

Speech-to-text and speech recognition are now widely used in a variety of consumer use cases, legal and business interpretation, transcription, and more. This article describes the technology that makes speech recognition work. When people communicate with each other, understanding is achieved through a combination of verbal and nonverbal cues, context, shared knowledge, and active engagement. Here are the key elements involved in understanding when people communicate [1]:

Verbal communication: Verbal communication involves the use of words and language. Speakers encode their thoughts and ideas into words, sentences, and stories. Listeners in turn decode and interpret these linguistic signals to derive meaning.

Non-verbal communication: Nonverbal cues such as facial expressions, body language, gestures, and tone of voice play an important role in understanding. These provide additional information and clues about emotion, attitude, intent, and emphasis that complement the verbal message.

Active listening: Active listening means paying full attention to the speaker and actively participating in the conversation. It requires focusing on the speaker's words, paying attention to nonverbal cues, and maintaining an open and receptive mindset. Active listeners provide feedback, demonstrate understanding, and encourage speakers through verbal and nonverbal cues.

Data collection: Training machine learning models for language understanding requires large datasets of human communication examples. This dataset typically consists of text or audio data and annotations or labels that indicate the intended meaning or semantic information.

Efficiency of Speech recognition systems.

Speech recognition enables users to speak instructions or text, greatly accelerating data entering and writing operations. Users may voice information instead of typing it in or manually entering it, which saves time and eases physical strain. This results in better workflow and more production. Rapid data input is made possible by speech recognition technologies, which translate spoken words into written text. Healthcare practitioners that must update patient records, produce reports, or complete paperwork will find this to be very helpful. Information that can be rapidly and precisely dictated promotes efficiency and saves time. Productivity is boosted since users may give instructions, narrate messages, or manage apps without having to physically interact with the device.

Accessibility for those with physical limitations or illnesses that limit their ability to type or utilize conventional input devices is improved by speech recognition technology. These people can connect with computers and other digital devices more successfully by utilizing voice commands, which gives them more freedom and independence when working, communicating, and accessing information. Real-time transcription capabilities are provided by automatic speech recognition (ASR) systems, allowing live speech to be turned into text. This is helpful when it's necessary to have instant access to written information, such as when transcribing meetings, lectures, or interviews. With real-time transcribing, participants may concentrate on the dialogue rather than taking notes, saving time.

Speech to text refers to a broad category of voice recognition software tools that listen to human speech, analyze it against a number of manually compiled voice-to-text databases, and then synthesis it into text.

Fig. 1. Efficiency of speech recognition systems.

The transcribing and documentation procedures may be made quicker and more effective by using speech recognition technologies, which can automatically turn spoken words into written text. This removes the need for manual typing or handwriting, saving a lot of time and effort in a variety of fields like business, law, and healthcare.

In order to provide individualized help, voice recognition systems may learn and adjust to the speech patterns, vocabulary, and preferences of specific users. This improves the accuracy of voice-activated devices and helps them comprehend user orders and requests better [2]. Even while productivity and efficiency of speech recognition systems have significantly improved, it's crucial to remember that these systems may still have limitations and occasionally make mistakes, especially when there is background noise, an accent, or a complicated linguistic context.

In [3], Cinthia Lee has researched the use of speech recognition technology as a way to address the writing problems of students with learning disabilities. The research question addressed whether young children with learning disabilities (LD) can tell stories with better fluency/quantity and/or quality using (a) paper-and-pencil (HW) mode, (b) a normal mode. Speech synthesis technology of speech recognition (SR) software, allowing students to see on screen what they have dictated and modify the dictated text if they wish, or (c) dictation mode is simplified by a digital recorder (DR), their students do not have immediate visual feedback or the ability to edit text.

The research presented in [4] converts real-time speech into corresponding text, then converts it into a corresponding summary using Natural Language Grammar (NLG) and Abstract Semantic Representation (AMR) diagrams, and converts the resulting summary into speech.

II. Hidden Markov Model in Speech Recognition

The hidden Markov model (HMM), used for speech recognition, uses statistical probability to arrange the phonemes in the right sequence. It makes use of three separate layers for this. We must examine the model's acoustic level and the likelihood that the phoneme it identifies is correct in the first layer. As previously stated, a variety of elements, including stress, tempo, emotions, gender, and others, affect how phonemes vary. The second layer of the model looks at nearby phonemes and the likelihood that they are close to one another. As an illustration, if you make a "x" sound, a vowel sound like "h" will follow. The phoneme "n" is less likely to follow the phoneme "st"—at least in English—or it may even be impossible. The model evaluates the word level in the third layer. Whether the words that are close to one another are meaningful or not. By calculating the probability that they are close to one another, it does this. It determines if a sentence contains too many or too few verbs, for instance. Adverbs, subjects, and a number of other sentence elements are also checked. To determine the most uttered text, the model analyses and reexamines all probability. This paradigm works nicely with speech's sequential nature. It is not flexible, though. Additionally, there is a huge range of phonemes and possible combinations, so it is still far from being called flawless.

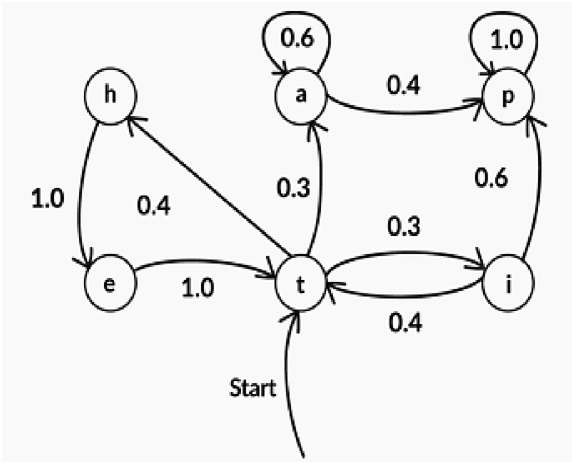

Fig. 2. Probabilistic parameters of a hidden Markov model

The states are represented in the Figure 2 by the letters "a," "p," "i," "t," "e," and "h," while the numbers at the margins denote the likelihood that one state will change into another. For instance, the probability of changing from state "t" to states "i", "a", and "h" is 0.3, 0.3, and 0.4, respectively.

An initial state is a unique condition that symbolizes the start of a process, like the start of a phrase. The modeling of sequential data, such as text and voice, is frequently done using Markov processes [5]. For instance, you may express each word in the phrase as a case if you want to develop a software that anticipates the subsequent word in a sentence. The probability of a transition from one word to the next may be learned from the corpus and is represented by the transition probability. The HMM is a variation of the Markov process, which is used to simulate phenomena in which the latent or hidden states emit observations. For instance, the states represent the actual text words to forecast in a voice recognition system like a speech-to-text converter, but they are concealed from view (i.e., the states). Instead, you must use the observations to infer the states from the speech (audio) signals that correlate to each word.

In a procedure known as feature extraction, the voice wave input from the microphone is transformed into a fixed size series of acoustic vectors $y_1, y_2, \ldots, y_t$. The decoder then looks for the sequence of words w_1, w_2, ..., w_t that are most likely to have resulted in Y [6]:

$$\hat{w} = arg_w max\{P(w|Y)\} \quad (1)$$

Due to the possibility that there will always be further observation sequences, (1) cannot be computed directly, instead the Bayes 1 rule is applied to create the following equation:

$$\hat{w} = arg_w max\{p(Y|w)P(w)\} \quad (2)$$

where Y is the sound signal as a source of observation, w is a word order that has the highest probability spoken, $P(w)$ is the probability that the string word w will be pronounced, $P(Y|w)$ is the probability that when the phrase string w is pronounced, acoustic Y will be observed.

III. Development of Speech-to-Text Software in Python

In this study, software that uses HMMs to translate speech into text is presented. This software is developed in Python programming language.

Software structure

A voice translation program that uses speech recognition can be broken down into many parts and levels. Here is a high-level breakdown of how such an application's usual software structure looks:

User Interface (UI) Layer: The components of the command-line interface (CLI) or graphical user interface (GUI) that enable users to interact with the program are included in this layer. Users may choose languages, enter their voice, and start translating thanks to this tool.

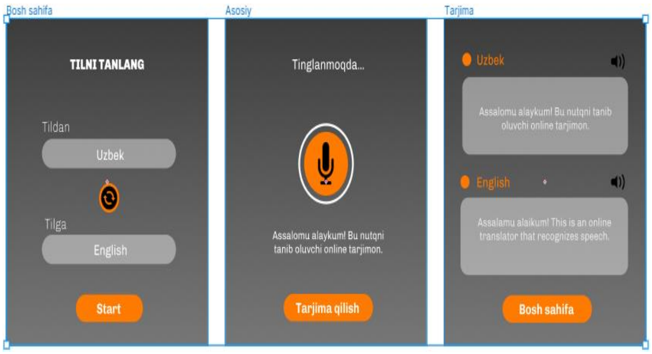

Fig. 3. Main window of the software.

Speech Input Layer: This layer converts the user's spoken words into text using speech recognition software or libraries. It decodes the audio input, analyzes it, and then converts it to text.

Audio Processing: This component handles audio input, capturing and preprocessing the user's voice before passing it to the speech recognition system [7].

Language Processing Layer: This component identifies the language spoken by the user. It analyzes the text output from the speech recognition system and determines the source language.

Text Preprocessing: This component cleans and preprocesses the transcribed text, removing noise, punctuation, and handling language-specific nuances.

Language Translation: This component utilizes translation libraries or APIs to perform the actual translation of the preprocessed text from the source language to the target language.

Speech Output Layer: Text-to-Speech (TTS): This layer converts the translated text into synthesized speech output. It utilizes text-to-speech technologies or libraries to generate natural-sounding audio from the translated text.

Audio Processing: Similar to the speech input layer, this component handles audio output, processing and delivering the synthesized speech to the user [8].

Integration and Communication Layer: API Integration: This layer facilitates communication with external services or APIs for speech recognition, language identification, translation, and text-to-speech.

Data Exchange: This component manages the flow of data between the various layers and components of the application, ensuring proper input/output handling and data synchronization.

Logging and Analytics: These components capture and record relevant data, such as user interactions, translations performed, and application usage statistics. This information can be used for debugging, analysis, and improvement purposes.

It's crucial to note that the particular implementation and selection of libraries, frameworks, and APIs may change based on the application's needs and technological stack. In addition, depending on the requirements of the program, factors like user identification, user preferences, and persistence of translations could also be included in the software structure.

A broad foundation for creating a voice translator application based on speech recognition is provided by the structure mentioned above. To enable users to communicate successfully across several languages, the components work together to process the user's voice input, identify the language, execute translation, and provide speech output.

Main parts of application. UI and UX

The main parts of an application that incorporates speech recognition can be broadly categorized into two areas: the speech recognition component itself and the user interface/user experience (UI/UX) components. Let's explore each of these areas in more detail:

Speech Recognition Component:

- Audio Input: This part involves capturing audio input from the user, either through a microphone or a pre-recorded audio file.

- Audio Preprocessing: The captured audio may need to be preprocessed to enhance its quality, remove background noise, or normalize the volume.

- Feature Extraction: Speech features such as Mel-frequency cepstral coefficients (MFCCs) or spectrograms are extracted from the preprocessed audio. These features provide representations of the speech signal that can be used for further processing.

- Acoustic Modeling: Acoustic models, often based on machine learning techniques like HMMs or deep neural networks (DNNs), are used to recognize speech patterns and convert the audio features into text [9].

- Language Modeling: Language models are employed to improve the accuracy of recognizing spoken words or phrases based on the context and grammar of the spoken language.

- Decoding: The speech recognition system utilizes algorithms to decode the most likely sequence of words or phrases based on the acoustic and language models. This decoded text output is then passed to the UI/UX components.

User Interface/User Experience (UI/UX) Components:

- Input Methods: The application should provide a means for the user to initiate speech recognition, such as a button or voice command.

- Feedback Mechanisms: Real-time feedback to indicate that speech is being recorded or recognized is crucial to provide a responsive user experience. This can include visual cues like waveform animations, progress indicators, or spoken prompts.

- Error Handling: Clear error messages or notifications should be implemented to inform the user in case of any issues or failures during speech recognition.

- Language Support: The UI should allow users to select the desired language for speech recognition and provide appropriate language models and feedback in that language.

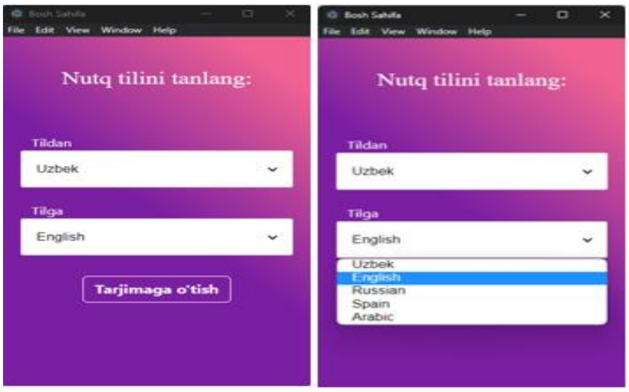

Fig. 4. Selecting the desired language.

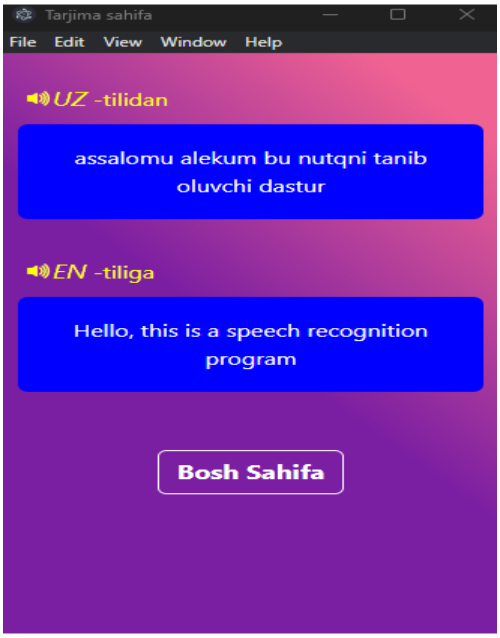

Fig. 5. Audio and text representation of translated speech.

- Integration with Application Features: The UI/UX should be designed to seamlessly integrate with other features of the application. For example, if the speech recognition is used for voice commands, the UI should reflect the available commands and respond accordingly.

These are some of the main parts of an application incorporating speech recognition, including both the technical speech recognition component and the UI/UX components that enable a user-friendly experience.

IV. Conclusion

In general, speech recognition software is extremely important in many fields and provides several advantages. By eliminating the need for manual typing, the speech recognition software presented in this article enables users to enter text and complete activities more quickly and effectively. It enables hands-free operation, multitasking, and workflow simplification, which boosts productivity.

The majority of us speak different languages because we find it challenging to communicate with one another when we travel between other countries or when visitors from different countries visit our country. Then this software can solve this problem.

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Development of a Novel Model for Single Image Super Resolution using Deep Neural Network

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***Abstract* —In this paper, we develop a Deep Neural Network (DNN)-based model for single image super resolution. The proposed model was compared with image interpolation methods such as cubic, area, nearest neighbour, lanczos4 and linear and image super resolution methods such as SelfExSR, and SRCNN using the set14 dataset. The comparison is based on evaluation metrics such as Mean Squared Error (MSE), Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM). The comparison results show that the proposed method outperforms its counterparts considered in this work.**

Keywords—single image super resolution (SISR), DNN, SSIM, RMSE, PSNR, MSE

I. INTRODUCTION

Super-resolution techniques in image processing are a set of algorithms that aim to enhance the resolution of an image beyond its original resolution, either by increasing the number of pixels or by reconstructing the high-frequency details that were lost during image acquisition. There are several super-resolution techniques available, including single-image super-resolution (SISR), multi-image super-resolution (MISR), and deep learning-based super-resolution (DL-SR).

The effectiveness of these techniques largely depends on the specific application and the quality of the original image. In general, super-resolution techniques can help improve the visual quality of images, especially when dealing with low-resolution images that lack sharpness and detail. For example, super-resolution techniques can be used in medical imaging to enhance the resolution of MRI or CT images, making it easier for doctors to diagnose and treat diseases.

SISR techniques are particularly useful for improving the resolution of a single image. These techniques use various algorithms, such as interpolation, edge detection, and statistical modelling, to reconstruct the high-frequency details of an image. However, SISR techniques may not be as effective as MISR techniques when dealing with images that contain noise or artefacts.

MISR techniques, on the other hand, are more effective when dealing with images that contain multiple low-resolution images of the same scene. These techniques use various algorithms, such as image registration and fusion, to combine the information from multiple images and create a single high-resolution image. MISR techniques can produce better results than SISR techniques when dealing with images that contain noise or artefacts.

DL-SR techniques are based on deep neural networks that are trained to learn the map-ping between low-resolution and high-resolution images. These techniques can produce high-quality images with sharp edges and fine details. DL-SR techniques are particularly effective when dealing with images that contain complex structures or textures, such as natural scenes or artwork.

A number of important studies on image interpolation and image super resolution methods have been carried out in the last few decades.

In [1], it is developed an adaptive interpolation technique based on the Newtonian forward difference. In [2], it is developed an adaptive image interpolation technique based on a cubic trigonometric B-spline representation. In [3], it is considered the metric objective quality assessment of compressed TV images based on the prediction error values of sums of pixels of the original and decoded images. In [4], it is developed an artificial neural network (ANN)-based method for image resizing. In [5], it is presented an efficiency estimation of digital image resizing using various image interpolation methods. In [6], it is presented the adaptive image resizing using edge contrasting concept. In [7], it is developed single image super-resolution method based on transformed self-exemplars. Finally, in [8], it is developed a deep learning method for single image super-resolution.

The rest of the paper is organized as follows. Section 2 is dedicated to the development of the proposed model. Section

3 focuses on the implementation of training and dataset. Section 4 focuses on the implementation of the concept and discussion of the results achieved. Concluding remarks are formulated in Section 5.

II. The Proposed Model

This section is devoted to model development for single image super resolution. In developing this model, various technologies widely used in the field of artificial intelligence were used. The figure below shows the residual block-based model for the single image super resolution.

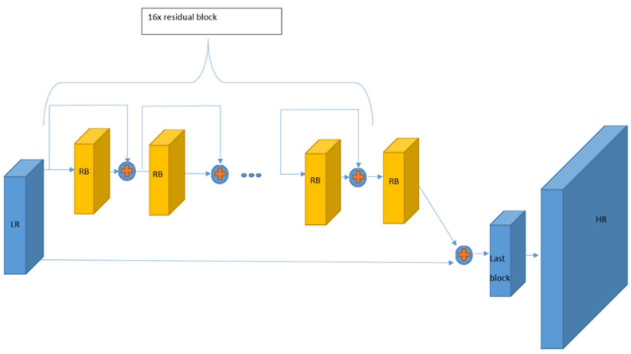

Fig. 1. Residual block-based model for the single image super resolution

It can be seen from Figure 1 that 16 residual blocks were used in the development of residual block based model for single image super resolution. One last block is also used. According to Figure 1, a low resolution image is initially entered as an incoming image. The input image passes through 16 residual blocks and then is inserted into the last block in the state added to the original input image (input low resolution image). After that, a high-resolution image is created, which is larger and has a higher quality level compared to the original input image.

Below is detailed information about each component used in the development of the residual block based model for single image super resolution.

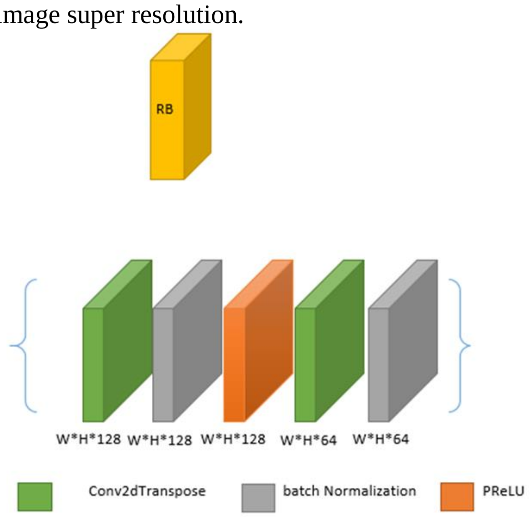

Fig. 2. Residual block and its layers

First, detailed information about the residual block itself will be given.

A residual block is a set of layers arranged in such a way that the output of a layer is removed and added to another layer in the block. The nonlinearity is then applied in the main path after adding together with the output of the matching layer. This bypass connection is known as a shortcut or skip connection.

According to Figure 1, in the development of the residual block based model for single image super resolution, residual blocks were used and their number was set to 16. It can be seen from Figure 2 that each residual block in the developed model consists of the following layers:

• Conv2DTranspose layer (shown in green in Figure 2 and taken as layers 1 and 4 of the residual block);

• Batch normalization layer (shown in gray in Figure 2 and taken as layers 2 and 5 of the residual block);

• Parametric ReLU (PReLU) layer (shown in green in Figure 2 and taken as layer 3 of the residual block).

In the development of the residual block based model for single image super resolution, a total of 2 Conv2DTranspose and Batch normalization layers and 1 PReLU layer were used for each residual block.

Below is a detailed description of the Conv2DTranspose layer and its implementation.

A. *Conv2DTranspose layer*

The transposed convolution layer is sometimes called deconvolution.

When using this layer as the first layer in the model, the input_shape argument keyword is used. For example, input_shape=(128, 128, 3) for 128x128 RGB images in data_format="channels_last".

According to Figure 2, the height, width and 128 features of the input image are taken as input_shape in the developed model.

B. *Batch normalization layer*

Batch normalization is the process of adding more layers to a deep neural network to make it faster and more reliable. The preceding layer's input is subjected to standardization and normalizing operations by the subsequent layer.

C. *PReLU layer*

ReLU is one of the keys to recent advances in deep learning. Its use led to better solutions than the sigmoid activation function. This is partly due to the disappearance of the gradient when the sigmoid function is activated. However, there is still a need for further improvement of ReLU. A LeakyReLU of the ReLU type was developed, this activation function does not make negative inputs zero like ReLU. Instead, it multiplies the negative input by a small value (e.g. 0.02) and leaves the positive input as it was.

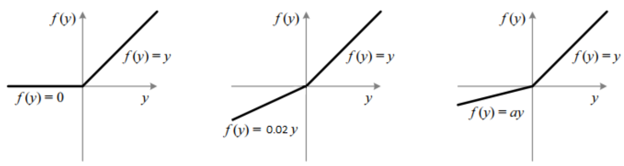

Fig. 3. Activation functions: ReLU (on the left), LeakyReLU (in the middle) and PReLU (on the right) [9]

It can be seen from Figure 1, one last block was used in the development of residual block based model for single image super resolution. The figure below (see Figure 4) provides detailed information about each component (layers) of the last block used in the development of residual block based model for single image super resolution.

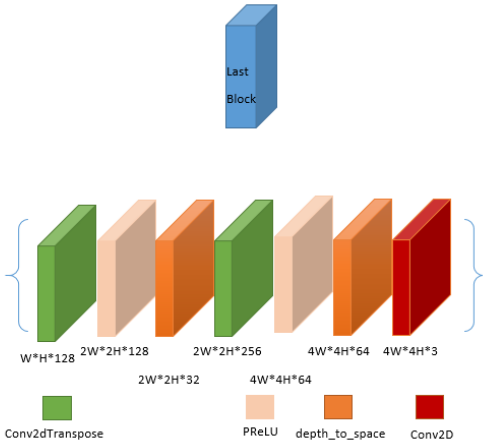

Fig. 4. Last block and its layers

It can be seen from Figure 4 that the developed last block consists of 7 layers. Of these seven layers, two are Conv2DTranspose layers, two are PReLU layers, and two are depth_to_space layers, and the remaining one is a Conv2D layer.

The Conv2DTranspose layer is taken as the first and fourth layers of the last block designed, which is marked in green in Figure 4. The first Conv2DTranspose layer (the first layer of the last block) receives the input image's Weight (W) and Height (H) and 128 features. In the second Conv2DTranspose layer (the fourth layer of the last block), two times the Weight (W) and Height (H) of the input image and 256 features were obtained as input data.

The PReLU layer is taken as the second and fifth layers of the last block developed, and it is marked in yellow in Figure 4. In the first PReLU layer (the second layer of the last block), two times the Weight (W) and Height (H) of the input image and 128 features are received as input data. In the second PReLU layer (the fifth layer of the last block), the Weight (W) and Height (H) of the input image are enlarged four times and 64 features are obtained as input data.

The depth_to_space layer is taken as the third and sixth layers of the last block developed and is marked in orange in Figure 4. In the first depth_to_space layer (the third layer of the last block), two times the weight (W) and height (H) of the input image and 32 features are obtained as input data. In the second depth_to_space layer (sixth layer of the last block) four times the Weight (W) and Height (H) of the input image and 64 features are obtained as input data.

III. Training and Dataset

This section provides information about the training process of the developed residual block based model for single image super resolution. The Div2K dataset was used to train the image resizing and reconstruction neural network. Below is a description of this dataset.

Div2K (or DIVerse 2K) is a high-resolution image dataset (data set) used for testing and benchmarking image processing and computer vision algorithms. Dataset

Contains 2000 high-quality images in 2K (2048 x 1080) or 4K (4096 x 2160) resolution. The images are collected from a variety of sources and cover a variety of views and image types, including natural images, indoor and outdoor views, still images and videos.

The Div2K dataset is often used for tasks such as image super-resolution, image denoising, and image compression. It has become the standard benchmark dataset in these fields, and many state-of-the-art algorithms are evaluated and compared on this dataset. The dataset is open for research purposes and can be downloaded from the official website. Below are examples of images from the Div2K dataset.

Fig. 5. Sample images from Div2K dataset

In the training process of the developed residual block based model for single image super resolution, a computer with the following technical specifications was used.

TABLE I. Implementation Environment of the Training Process of the Developed Residual Block Based Model for Single Image Super Resolution

Implementation environment		
Hardware	CPU	Intel CoreTM i9-11900 2.5 GHz 8C
	RAM	128GB DDR4-3200 nECC (4x32GB)
	GPU	NVIDIA RTX A5000 24GB Graphics
Software	OS	Windows 10
	Programming language	Python

IV. Performance Evaluation

For the evaluation of the proposed Deep Neural Network (DNN)-based model for single image super resolution, experimental results are evaluated using Mean Squared Error (MSE), Root Mean Square Error (RMSE), Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) evaluation metrics and set14 dataset.

The Set14 dataset is a standard image dataset widely used for testing image processing algorithms, especially for image denoising and high-resolution imaging tasks.

A. *Mean Square Error (MSE)*

Mean Square Error (MSE) is a commonly used metric for the evaluation of the image quality. The better image quality is obtained for MSE values closed to zero.

Mean Squared Error (MSE) between two images, say g (x,y) and ĝ (x,y) is defined in equation (1) (see also Ref. [10]) to assess the absolute error.

$$MSE = \frac{1}{MN}\sum_{n=0}^{M}\sum_{m=1}^{N}[\hat{g}(n,m - g(n,m)]^2 \qquad (1)$$

B. *Root-mean-square error (RMSE)*

The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) is used to measure the differences between values (e.g., sample values/data) predicted by our model and the values observed. This leads to the measurement of the accuracy used to attribute the differences in the prediction errors of different predictors to the exact variable [11].

If it is assumed that the estimated parameter given in θ can be a predictor with respect to θ, then the mean square error is actually the square root of the mean square error.

The determination of RMSE is expressed by the following equation:

$$\mathrm{RMSE}(\hat{\theta}) = \sqrt{\mathrm{MSE}(\hat{\theta})} \tag{2}$$

C. *Peak signal-to-noise ratio (PSNR)*

PSNR is used to calculate the ratio between the maximum possible signal power and the power of the distorting noise that affects the quality of its representation. This ratio between two images is computed in decibel form [12].

$$\mathrm{PSNR} = 10\log_{10}\frac{\mathrm{peakval}^2}{\mathrm{MSE}} \tag{3}$$

D. *Structural similarity index measure (SSIM)*

The structural similarity index method is a model based on this perception. The term structural data refers to interconnected pixels or spatially closed pixels. This interconnected resolution points to a number of important information about objects in the field of images. Lighting masking is a term where the distorted part of the image is less visible at the edges of the image. Contrasting masking, on the other hand, is a term that these distortions are less visible in the image structure.

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \text{ x } 100 \tag{4}$$

Comparison of interpolation methods such as Nearest, Linear, Area, Cubic, and image super resolution methods SelfExSR [7], SRCNN [8] and the proposed model based on MSE (for 4 upscaling). The comparison to MSE is shown in Figure 6.

Fig. 6. Comparison (based on MSE) of experimental results of set14 dataset

Figure 6 shows the comparison (based on the MSE) of selected estimation methods. The worst result is obtained with the nearest interpolation method. The best result is obtained by the model proposed in this work.

Fig. 7. Comparison (based on MSE) of experimental results of set14 dataset

As shown in Figure 7, the best two average PSNR values are belong to SelfExSR [7] and the proposed model.

Based on the SSIM metric, the proposed method and its counterparts are applied to the set14 dataset images and the obtained results are compared and presented in Figure 8.

Fig. 8. Comparison of experimental results of local images based on SSIM

As shown in Figure 8, the best two average SSIM values are belong to SelfExSR [7] and the proposed model.

The results of comparison of set14 dataset images between the proposed method and their counterparts based on MSE, RMSE, PSNR and SSIM are presented in Figure 9.

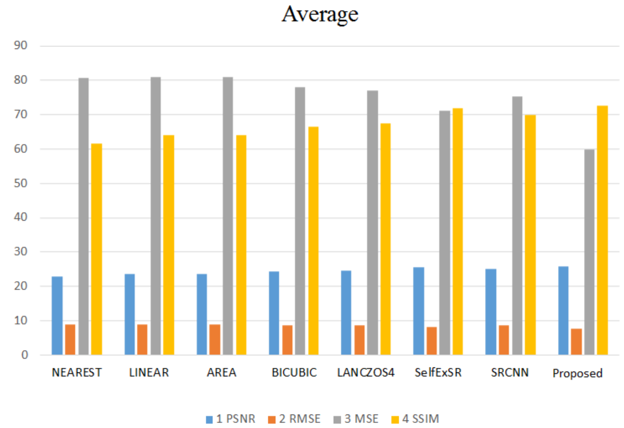

Fig. 9. Comparison of experimental results of local images based on PSNR, RMSE, MSE and SSIM

As shown in Figure 9, the average values of the metrics, namely PSNR, RMSE, MSE and SSIM, are each evaluated using different methods. The result of the evaluation has led to the following values: 22.98, 8.88, 80.81 and 61.56 using the Nearest method; 23.71, 8.86, 80.83 and 63.95 using the Linear method; 23.71, 8.86, 80.83 and 63.95 using the Area method; 24.25, 8.7, 78.06, 66.44 using Bicubic method; 24.51, 8.65, 77.12 and 67.43 using the Lancsoz4 method; 25.63, 8.26, 71.02, 71.82 using SelfExSR [7] method; 25.16, 8.54, 75.26, 69.86 using SRCNN [8] method; 25.93, 7.74, 59.92, 72.62 using proposed method. These results clearly show that for each of the four metrics used for comparison, the proposed method outperforms each of its seven other counterparts used for the benchmark.

V. Conclusion

In this paper, we developed a novel model for single image super resolution using Deep Neural Network (DNN). Based on selected evaluation metrics, namely MSE, RMSE, PSNR and SSIM, the developed method was compared to image interpolation methods like Cubic, Area, Nearest Neighbor, Lanczos4, Linear and image super-resolution methods SelfExSR and SRCNN. The comparison clearly showed that the proposed method outperforms each of its counterparts.

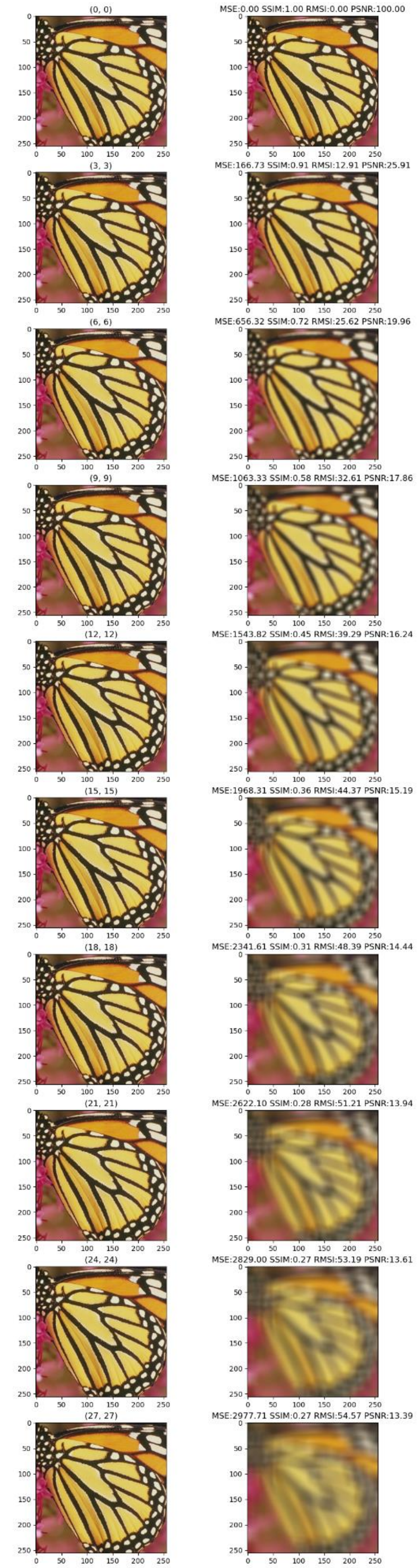

Fig. 10. Example of image upscaling process based on evaluation metrics

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Correction Of Detected Values Of Distorted Image Points Based On Truncated Matrix Filters

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***Abstract*—Scientific and methodological bases for identifying the signal characteristics of technological parameters of production with mechanisms for selecting local areas of objects, tracking, detecting, and correcting distorted points, filtering, segmentation, signal recovery under conditions of a priori insufficiency, parametric uncertainty, low reliability of data processing have been developed. Mechanisms have been developed for determining and using the optimal frequency, the step of tracking and correcting the values of discrete samples of signal characteristics, highlighting objects of interest, and the optimal value of the selected parameter. A technique for determining the probability of detecting distorted points in the interval of an object under the influence of interference of various natures is implemented based on the use of wavelet decomposition with truncated, cyclic, and extended filtering matrices, determining the detailing coefficients. The processes of parametric identification of signal characteristics are modeled taking into account the noise component and the use of its statistical parameters. A software package for identifying the signal characteristics of technological parameters for visualization, recognition, and classification of objects of interest has been developed, which has been tested under conditions of a priori insufficiency, parametric uncertainty, and low reliability of information.**

Keywords—signal characteristics, technological parameters, identification, correction, software package

I. Introduction

In control systems for production and technological complexes, various methods, models, algorithms for identifying a large number of technological parameters and factors are implemented [1, 2, 3, 4]. It is necessary to solve the problem, which is characterized by a significant decrease in the quality of identification of images with signal characteristics (frequency, amplitude, phase), which are distorted at the stages of input, transmission, storage, processing of information. In addition, the violation of the quality of image restoration occurs due to the presence of interference, blurring at points, and other defects [5, 6, 7, 8]. This study is devoted to the development of scientific and methodological foundations for identifying images of technological parameters of production based on the principles of using structural information components. Methods, models and mechanisms for tracking, detecting and correcting distorted points, filtering, segmentation, transformation, image identification under conditions of a priori insufficiency, parametric uncertainty, and low reliability of data processing have been developed.

II. Main Part

A. Identification mechanism based on combining discrete wavelet analysis with matrix image filtering

A generalized mechanism for optimizing the recovery of signal characteristics of technological parameters of production using a model of discrete wavelet analysis (DWA) and matrix filtering is proposed. The zero time component of the signal is limited at one or both ends. When the signal is restored, the mechanism includes three full and one truncated copies of filters with a size of $l \times h$. Matrix W_{tmf} has $c = n_x$ columns and $r = [n_{x/2}]$ rows. The filter consists of both full and partial copies with low-frequency (LF) l and high-frequency (HF) h components. Matrix multiplication is performed by single-level wavelet decomposition in j cycles. Signal Z is recovered using inverse recovery matrices. In this case, the signal is restored at the level of the Daubechies 4 wavelet, which are divided into l - approximating and h - detailing components. When the signal is restored at the decomposition level k, high-frequency coefficients h_i are selected, a threshold is set, its zero value:

$$\xi\{H\} = \{if \left| {}_1^k h_i \right| \geq 0,\ {}_1^k h_i = {}_1^k\ h_i\ ; \tag{1}$$

$$\xi\{X\} = \begin{cases} if \quad {}_1^k h_i \geq D\{X\} \cdot 3,\ {}_1^k h_i = {}_1^k\ h_i; \\ if \quad {}_1^k h_i < D\{X\} \cdot 3,\ {}_1^k h_i = 0, \end{cases} \tag{2}$$

where $\xi\{X\}$ - threshold value; $D\{X\}$ – dispersion signal.

The function of the error of restoring the signal characteristics of the technological parameter by the mechanism using the software "MatLab" was studied. It has been established that the proposed mechanism provides an acceptable signal recovery accuracy within the bit grid. Mechanism when using a truncated matrix filter [9, 10, 11]:

$$W_{tmf}\{l,h\} = \begin{bmatrix} l_0 & l_1 & l_2 & l_3 & 0 & 0 & 0 & 0 \\ h_0 & h_1 & h_2 & h_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & l_0 & l_1 & l_2 & l_3 & 0 & 0 \\ 0 & 0 & h_0 & h_1 & h_2 & h_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & l_0 & l_1 & l_2 & l_3 \\ 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 \\ 0 & 0 & 0 & 0 & 0 & 0 & l_0 & l_1 \\ 0 & 0 & 0 & 0 & 0 & 0 & h_0 & h_1 \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix}. \tag{3}$$

The modified mechanism presents the results as deviations of the wavelet - detailing $h*$ and fitting $l*$ coefficients from the true h and l based on the use of model training sample $Z = \{51,25,70,82,78\}$. Moreover, the values of the coefficients $h*$ and $l*$ show the result of applying the inverse wavelet - transform $W^{-1} = \{l,h\}$ on the sample $Z*$. The experimental value of the mean square error is $r_\sigma = 22{,}6$. The expansion coefficients of the inverse DWA are determined by the values of the error obtained due to the presence of the boundary effect. In addition, the boundary effect shows unreliable readings of the signal characteristics at the beginning and end of the time interval along the abscissa. And the root-mean-square error r_σ depends on the size of the matrix filter n_w, the value of which decreases with an increase in the decomposition level j of the DWA model. A signal of arbitrary duration, not limited by the level $n_x \neq 2^j$, has been investigated. It is determined that an increase in the duration of the signal n_x leads to a decrease in the value of the mean square error. The proposed mechanism is modified with the use of cyclic matrix filters. It is assumed that the signal recovery accuracy is achieved with the periodization mechanism. At the same time, the signal of the DWA model is limited in time, supplemented by periodic copies of itself and from both sides. The filters are truncated along the length and they are used as finite cyclic matrix filters (CMF). CMF is represented as [12, 13, 14, 15]:

$$W_{\mathrm{cmf}}\{L_1,H_1\} = \begin{bmatrix} l_2 & l_3 & 0 & 0 & 0 & 0 & l_0 & l_1 \\ h_2 & h_3 & 0 & 0 & 0 & 0 & h_0 & h_1 \\ l_0 & l_1 & l_2 & l_3 & 0 & 0 & 0 & 0 \\ h_0 & h_1 & h_2 & h_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & l_0 & l_1 & l_2 & l_3 & 0 & 0 \\ 0 & 0 & h_0 & h_1 & h_2 & h_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & l_0 & l_1 & l_2 & l_3 \\ 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{bmatrix}. \quad (4)$$

The matrix contains 4 ordinary and 2 cyclic copies of the filter f, and W_{cmf} has the same dimension as W_{tmf}. It is determined that if signal $N/2$ takes an even value, then its minimum length is equal to $n_{\min} = (N/2) - 1$ - even. If the value is odd, then its minimum length is $n_{\min} = (N/2) - 2$ - odd. When inequality $L_{cmf} L_{cmf}^T \neq I \neq H_{cmf} H_{cmf}^T$ is satisfied, then condition $n_x > n_{\min}$ is true. When equality $L_{cmf} L_{cmf}^T = I = H_{cmf} H_{cmf}^T$ is true, then condition $n_x = n_{\min}$ is true.

Therefore, the use of CMF is fully justified. As a result, a reduction in the signal reconstruction error is achieved, in contrast to the mechanism using a truncated matrix filter (TMF). Reconstruction of the signal based on the direct DWA model reduces the number of expansion coefficients d_1^3, and on the basis of the inverse DWA model $W^{-1}\{l,h\}$ reduces the number of coefficients d_{13}^3.

The effect obtained from the periodization procedure in the mechanism is demonstrated by the example when the value of the coefficient is $\hat{x} = d_k^j$. It has been established that the mechanism with the use of TMF and CMF requires the same number of expansion coefficients of the DWA model. In this case, the value of parameter b remains unchanged. The numbers of detailing and approximating coefficients are obtained using the wavelet convolution operator. The root-mean-square error r_σ for the TMF is comparable in value to the CMF for the boundary effect. The signal recovery error with the considered mechanism changes during the transition from the beginning to the end, or from the end to the beginning of the time interval.

B. Mechanisms for identification of signal characteristics based on the dwa model with an extended matrix filter

A mechanism for the extended use of a matrix filter with additional expansion coefficients $n_{\hat{x}}$ of the DWA model that exceeds the length of the input signal n_x is proposed. In this case, the DWA model is implemented without the use of the periodization operator is implemented. The restriction on the signal time interval is taken into account. It is required that the wavelet decomposition procedure is always performed with non-zero coefficients [16, 17, 18].

The matrix filter contains more truncated copies than the TMF or CMF.

$$W_{\mathrm{amf}}\{L_1,H_1\} = \begin{bmatrix} l_3 & l_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ h_3 & h_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ l_0 & l_1 & l_2 & l_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ h_0 & h_1 & h_2 & h_3 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & l_0 & l_1 & l_2 & l_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & h_0 & h_1 & h_2 & h_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & l_0 & l_1 & l_2 & l_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & l_0 & l_1 & l_2 & l_3 \\ 0 & 0 & 0 & 0 & 0 & 0 & h_0 & h_1 & h_2 & h_3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & l_0 & l_1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & h_0 & h_1 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \\ x_0 \\ x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ 0 \\ 0 \end{bmatrix}. \quad (5)$$

The peculiarity of the application of the proposed operator of "extended matrix filters" (EMF) is that the output of the convolution procedure based on the DWA model yields non-zero coefficients for all points $i = 1,\ldots,n_x$. The mechanism of image identification with EMF has been studied. Let the matrix contain 4 full and 2 truncated copies on each side of signal f. A W_{amf} has $c = n_x$ columns and $r = [(n_x + N - 1)]$ rows. Filter W_{amf} has more rows and, as a result, more coefficients than TMF and CMF filters.

Inequality $L_{emf} L_{emf}^T \neq I \neq H_{emf} H_{emf}^T$ and the condition for restoring signal characteristics $L_{emf}^T L_{emf} + H_{emf}^T H_{emf} = I$ are satisfied for all n_x. The signal reconstruction accuracy is proved using procedure $W^1\{l,h\}$. In contrast to the use of simple truncated filters, the recovery errors when using the EMF do not exceed their values. Moreover, when there is no periodization operator, the DWA model with cyclic filtering gives similar results to matrix filtering. However, they have an advantage in computational efficiency than truncated filters, associated with the use of an excessive number of decomposition coefficients for detailing and approximating signal characteristics components. It is determined that when applying the EMF, a different number of expansion coefficients is obtained with the same signal length . Excess coefficients require an additional $n_x = 129$ samples when they are equal to $n_x = 103$ for TMF and CMF. It is proved that in the case of the sliding DWA model, the influence of the boundary effect can be neglected. This eliminates the introduction of some time delay. The mechanism for detecting and correcting distorted points based on the sliding DWA model is implemented in two stages. In the first stage, the DWA model is decomposed into signal levels into frequency components. The mechanism for detecting distorted dots in images of signal characteristics uses their properties. At the second stage, the DWA model ensures the removal of the high and low frequency components of the signal. The mechanism for detecting distorted points is optimized by adjusting the values of the amplitude, width, location of signal points in time. The algorithm for detecting distorted image dots is set in the following steps.

Step 1. At the input, the signal characteristics are presented as a row $Z = \left| z_0, z_{1,} z_{2,...,} z_N \right|$ matrix.

Step 2. The basic DWA model is decomposed into row matrices of approximating $V = \left| v_0, v_{1,} v_{2,...,} v_v \right|$ and detailing $D = \left| d_0, d_{1,} d_{2,...,} d_v \right|$ coefficients and the number of coefficients is determined.

Step 3. The operator of convolution of the matrix of row Z with matrices of rows $-\psi\{Z,V\} = L_1$ and $\varphi\{Z,D\} = H_1$ is executed. The wavelet decomposition is formed in the form of the current sample:

$$W\{Z_l\} = \begin{Bmatrix} L_1 & H_1 \\ L_2 & H_2 \\ \dots & \\ L_r & H_r \end{Bmatrix}, \qquad (6)$$

where r – number of decomposition levels.

Step 3.1. It is restored in the form:

$$W^{-1}\{W\{Z_l{*}\}\} = \begin{Bmatrix} L_r & H_r \\ L_{r-1} & H_{r-1} \\ \dots & \\ L_1 & H_1 \end{Bmatrix}, \qquad (7)$$

where $Z_l{*}$ – reconstructed matrix row.

Step 4. The signal sampling step is determined based on the analysis of a priori data. The probability of detecting distorted image points is estimated. The expansion coefficients for the first level of the DWA model are calculated. It is required to provide a reliable procedure for filtering signal characteristics at minimal cost.

Step 5. Obtaining detailing and approximating coefficients for the levels of decomposition of the DWA model. Determining the number of necessary addition and multiplication operations in a sample of N

$$O_r = 2v(\dots(((((N-v)/2+1)_1 - v)/2+1)_2 \cdot \dots - v)/2+1)_r \quad (8)$$

Step 5.1. To obtain minimum errors, taking into account the boundary effect, the number of points is set equal to half $v/2 = 7$ and the sample length. Recalculation in progress: 7–1=6, 12+14=26, 26–1=25, 50+14=64, 64–1=63, 126+14=140, 140–1=139, 278+14=292. 7 values of the coefficients were obtained at the decomposition level 4 on the sample $N = 292$. Number of addition and multiplication operations $O_{rp} = 2 \times 14(140 + 64 + 26 + 7) = 6636$.

Step 6. To minimize the error of the boundary effect, the mechanism of overlapping windows is used to control the parameters of the DWA model.

C. Image identification mechanism based on the cascade algorithm of the DWA sliding model

The use of a sliding DWA model is proposed, which is synthesized with algorithms for preprocessing signal characteristics of images and tracking, detecting and correcting distorted values of current discrete samples $Z(i\Delta t_{ls})$. The execution results are presented in a rolling matrix of row $Z_i(t_i)$. If the index of samples in the sequence is even, then the algorithm proceeds to consider the next sample based on the prediction of their values. If not, then only the expansion coefficients of the DWA models for a specific level are calculated. The number of expansion coefficients h_{ki} and l_{ri} come in the form of current sliding matrices of rows DWA, the sizes of which correspond to the decomposition levels. The number of expansion coefficients is used in the algorithm for detecting and correcting distorted points [19, 20, 21, 22].

Detailed decomposition coefficients $h_{ki} \to H_{ik}(t_k)$ are determined and their values are compared with the pre-execution threshold $h_{ki} > \zeta_k$. If the value of the detail coefficient exceeds the threshold, then it is considered to be included in the current sample.

The current values of the matrix of rows $H_{ik}(t_k)$ and $H_{ik}(t_k)$ are approximated. The values of the following signal parameters are determined: A_{Z*} - amplitude; T_{Z*} - duration; t_{Z*} - appearance time.

The amount of computation of the mechanism based on the sliding DWA model is associated with the calculations of detailing and approximating expansion coefficients and approximating functions. The number of detailing coefficients is defined as the convolution of the current values of the measured signal at the first level or the current values of the detailing coefficients at the corresponding levels in the form $h_{ki} = \varphi\{Z_i(\Delta t_k), D\}$, where k – wavelet-decomposition level; $\Delta t_k = 2^k \cdot \Delta t_{ls}$ – sampling step at k -th level; $D = i \cdot \Delta t_{ls}$ – number of readings; i - reference index in the sequence of tracking distorted points.

The number of approximating coefficients is determined by a similar function $l_{ki} = \psi\{Z_i(\Delta t_k), V\}$. The maximum number of restoration, expansion, addition and multiplication operations with detailing and approximating coefficients at level r, in a time interval of $2 \cdot \Delta t_{ls}$, according to the DWA sliding model, with the procedure for thinning out distorted and non-informative points, is calculated as:

Number of decomposition operation	***Number of recovery operations***	***Number of addition operation***
$O_{rp} = 2vr$	$O_{rp} = 2v\sum_{k=1}^{r} 2^k$	$O_{rcc} = v\sum_{k=1}^{r} 2^{r-k+1}$

It has been determined that algorithms based on the sliding DWA model require a much smaller amount of calculations. Time is spent on performing the procedures for decomposing the signal into frequency-time components, performing identification, tracking, detection, and correcting distorted information in real time. The reduced amount of calculations is determined by decomposing the signal by $O_{rp} = -v(r-l)$, restoring by $O_{re} = -v\sum_{k=1}^{r-1} 2^k$. A conditional example is considered, for which the values $O_{rp} = 42$, $O_{rp} = 196$. It is determined that 112 multiplication operations performed are reduced to 70, and with decomposition, 840 operations performed are reduced to 644. The DWA model contributes to a significant reduction in the frequency range of real-time signal analysis. Implementations of the DWA model with the optimal tracking step and sampling rate for detecting distorted points were tested. Implementations of the DWA model at nine levels are considered. The range of signal characteristics analysis is divided into levels: 1–3; 4–6; 7–9. For the indicated levels, the steps for tracking the distorted values of the samples correspond, which are defined as: $\Delta t_I = \Delta t_{ls}$, $\Delta t_2 = 2^3 \Delta t_{ls}$, $\Delta t_3 = 2^6 \Delta t_{ls}$.

With analysis range $v = 14$, level $r = 3$, the amount of calculations is determined by the values

$$O_{rp} = 2vr = 2 \times 14 \times 3 = 84,$$

$$O_{re} = 2 \times 14 \times (2+4+8) = 28 \times 14 = 392, \tag{9}$$

$$O_{rcc} = 14 \times (8+4+2) = 14 \times 14 = 169.$$

And for the highest level of decomposition, the amount of calculations is reduced to 56, and upon restoration, to 308. Due to the use of the sliding DWA model for all considered ranges of analysis of signal characteristics, the volume of calculations is reduced three times, and upon restoration, up to 22 times. The mechanism using the cascade identification algorithm analyzes the signal characteristics in a larger range of their values [23, 24, 25].

D. Mechanism for identification of signal characteristics based on synchronization of decomposition modules

Let $X_i = \{..., x_i, ...\}$` input signal be given with the optimal sampling rate. For the current value, x_i is considered $i = 0$, which is important for ensuring synchronization of the decomposition modules of the DWA model. For decomposition, the input signal is represented by a row matrix $X_i = \{.x_0, x_1, x_2, x_3, ...\}$`, which is folded based on the DWA model. Let L_{2i}, H_{2i}, L_{2i+1}, H_{2i+1} be the row matrices of approximating and detailing, even and odd coefficients of the first level of decomposition of the DWA model; $L_{2(i2)}$, $H_{2(i2)}$, …, $L_{2(i2+1)+1}$, $H_{2(i2+1)+1}$ – are row matrices of approximating and detailing, even and odd coefficients of the second level of decomposition of the DWA model; $L_{2(i2)2}$, …, $H_{(2(i2+1)2+1)2+1}$ are row matrices of the third level of decomposition of the DWA model. The indices indicate the location of the synchronization of the decomposition of the DWA model and the initial sequence of measurement results of the magnitude of the signal characteristic X_i. The mechanism generates one of the values of the approximating and detailing coefficients of the upper-level DWA model. For three decomposition levels, after considering 8 readings, all coefficients of the upper level are calculated. At the same time, after each reading, it is necessary to perform the same amount of calculations, equal to the maximum amount required when using the basic implementations of the DWA model. The algorithm is presented in the following steps [26, 27].

Step 1. Based on a priori data, the generatrix frequency and sampling step are determined.

Step 2. The signal/noise value is set, threshold values are assigned for each decomposition and recovery level αv, where v is the decomposition level number. For the third decomposition level, a threshold is set, which determines the strategy for detecting distorted points.

Step 3. The DWA Daubechies 4 sliding model is implemented.

Step 4. The expansion coefficients are calculated at each level.

Step 5. At the third level, the calculated value of the detail coefficient is analyzed for exceeding the detection threshold.

Step 6. If the excess is detected, and if it is the first in the current interval, then the matrix line "signal detection" is formed. If not, then the value is added to the existing ones. Go to step 8.

Step 7. If the excess is not detected, and the matrix line "signal detection" is formed, then go to step 8. Otherwise, go to step 3.

Step 8. If the row matrix "signal detection" has 8 elements, then go to step 9. Otherwise, go to step 3.

Step 9. The values of the elements of the matrix of the line "signal detection" are analyzed. The maximum value of the matrix element is determined, the detailing and approximating coefficients of "signal detection" are formed, which provides the most accurate signal recovery. Restoration of the detected distorted points is performed by the algorithm in the following steps.

Step 10. Using the detailing and approximating "signal detection" coefficients, taking into account the threshold αv, the algorithm for restoring the filtered signal is implemented.

Step 11. The signal amplitude value is restored - A_{ls} with a minimum error of $\delta = 2\%$.

Step 12. The value of the signal duration is restored - T_{ls} with a minimum error of $\delta = 4\%$.

Step 13. The value of the signal position is restored - $M_{лс}$ with a minimum error of $\pm\Delta t$.

Step 14. Calculation results with the required accuracy are provided to the user.

The efficiency of the mechanism for detecting and correcting distorted points was studied according to the criterion of labor intensity of information processing $E = \min_{M,L} T$, where T is the algorithm execution time; M, L - respectively, the sizes of the window for identification and correction of distorted points. The study was also carried out according to the criterion of the minimum probability of undetected errors. The reliability of information is checked by comparing the characteristics of the input signal with its reference characteristics. A point on a signal is considered reliable if the following condition is met:

$$x_e = \begin{cases} 1, & x(i,j) \in G \text{ - sure event;} \\ 0, & x(i,j) \notin G - \text{unreliable event,} \end{cases} \tag{10}$$

where G - reliable reference area of the signal description point.

The values of the parameters obtained to ensure the effectiveness of the mechanism are presented in Table. 1.

TABLE I. FINDING THE EFFECTIVE VALUES OF MECHANISM PARAMETERS

MxM	**Threshold, h**				
	10.28	10.24	10.20	10.16	10.12
1x1	0.104	0.157	0.35	0.200	0.240
3x3	0.019	0.014	0.019	0.16	0.125
5x5	0.079	0.046	0.015	0.023	0.063

The dimensions of the matrix M and the threshold value h are determined. Moreover, the regulation of the values of these parameters makes it possible to assess the reliability of information with a certain probability of undetected errors or by the minimum value of the root-mean-square identification error. When testing the signal characteristics for six technological parameters, pseudo-random errors are introduced, which are set with an error probability of $\overline{P}_{н} = 10^{-4}$. Effective values of performance indicators are achieved with a 3×5 matrix.

CONCLUSION

Scientific and methodological foundations for the application of wavelet-analysis DWA, on the example of Daubechies 4 with matrix and sliding mechanisms of decomposition, filtering, restoration, approximation, object selection, tracking, detection and correction of distortions.

Methods for calculating the volume of computational operations of addition and multiplication required for the implementation of the developed mechanisms are determined. The effectiveness of the developed mechanisms was studied according to the criteria of the complexity of information processing and the minimum root-mean-square error in identifying the signal characteristics of technological parameters. A mechanism has been implemented with parallel execution of the identification operation based on the sliding DWA model for detecting and correcting distorted points of the selected object, as well as optimizing the signal parameters in real time and in a wide range of values.

An approach has been implemented aimed at splitting frequency ranges into 7 detailing and 1 approximating levels. It has been determined that the decomposition of the signal into frequency ranges using the DWA model allows one to reduce the number of calculations spent on detecting and correcting distorted points on the signal object by a factor of two. The mechanism of threshold tracking of the detected object is applied for each of the set of coefficients. It is determined that the mechanism eliminates the noise component and distorted points on the signal characteristics up to 95%.

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Calculation of costs for the development of a software product for automation of a manufacturing enterprise

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***Abstract*— This study uses various methods to calculate the cost of creating an automation program for a manufacturing enterprise. It also calculates the approximate payback time of the product when implemented. In order to calculate the payback, all the calculated costs were analyzed and the approximate payback time of 7 months was found. Calculation of development costs is carried out using various mathematical methods such as function points, early function points, use-case points and others.**

***Keywords*— automation, cost calculation, development, mathematical models, labor intensity of development.**

I. INTRODUCTION

Software products have a peculiarity both in terms of their development and in terms of their consumption (use). [1, 2] There is no production part in the process of creation of software products in comparison with the creation of traditional goods due to the "electronic representation" of computer programs and data. [3, 4] A software product is ready when the "starting sample" is ready. [5] If at the creation of conventional goods at this stage the material production of its copies only begins, then for software products it is replaced by replication, which does not affect the characteristics of the product itself in any way (here we can only talk about the quality of the information carrier with the recorded product). [6-8]

Consumer behavior here also differs from consumer behavior in the markets of traditional goods. [9] Software elements belong to durable products, besides, due to their "intangible nature" computer programs are subject only to moral wear and tear. [10, 11] Therefore, a software product is bought only once, it cannot be sold to the same customer a second time, only updated and (presumably) improved versions are sold. [12] Sometimes a manufacturer can sell one copy of a product and separately - "licenses" for the required number of additional users of the product. Software can also be distributed through data networks. This capability eliminates the dependence of commerce on the geographic location of the seller and buyer and allows for instant delivery of the product to the consumer. [13-16]

This study will analyze the cost of developing a software tool to automate a manufacturing enterprise, using the following methods: calculation of capital (one-time) costs, calculation of operating (current) costs, project approach to assessing the cost of development, function Points and others. [17, 18] The approximate payback time of the software product at the enterprise and labor costs for its development are also calculated. [19]

The advantage of the developed product over competitors is that the cost of capital expenditures for development and implementation will be significantly lower than analogs on the market. [20, 21] Also, the functionality of the program will be reduced to the solution of the minimum range of tasks for production optimization. [22, 23] The method itself and its computer implementation will reduce the time to conduct the experiment. The user interface will be intuitive, and the worker will not need any programming knowledge at all. [24, 25]

Certain functionality of the identification program and its target orientation, undoubtedly, narrow the range of consumers of this software product, but at the same time fully allow a particular user to solve his specific problems. [26] The software is designed for small-sized enterprises specializing in production. [27]

The initial version of the software can be distributed free of charge via the Internet. For testing the idea and further development of the product, there is a test production enterprise engaged in furniture manufacturing. [28] And in the future, it is planned to distribute as commercial software. The cost calculation requires a separate detailed consideration. [29]

II. CALCULATION OF CAPITAL (ONE-TIME) COSTS FOR DEVELOPMENT AND IMPLEMENTATION OF THE SOFTWARE PRODUCT

The value of capital (one-time) costs for the creation of a data processing system (DPS) can be determined as follows:

$$K = K_{sd} + K_{eq} + K_{aux} + K_r + K_{ict}, \qquad (1)$$

where: K_{sd} - system design costs, rubles; K_{eq} - costs of main equipment, rubles; K_{aux} - costs of auxiliary equipment, rubles; K_r - costs of construction and reconstruction of premises, rubles; K_{ict} - costs associated with the installation, adjustment and transportation of equipment, rubles.

When creating and operating systems related to information processing, the composition of capital expenditures is calculated according to the following formula:

$$K = WF + IP + RP + RE + MC + El + S + In + ME, \quad (2)$$

where WF - programmer's labor remuneration fund; IP - value of insurance contributions to PFR, FSS, federal and territorial MHIFs; RP - cost of premises rent; RE - cost of equipment rent; MC - material costs; El - cost of electricity; S - cost of software; In - cost of using the Internet; ME - cost of main equipment.

The programmer's payroll can be calculated as follows:

$$WF = BS + Aw, \quad (3)$$

where BS - basic salary; Aw - bonuses and additional payments to the tariff salary.

Let's assume that the creation of a software product took 3 months. Bonus to the salary is taken as 20% of the basic salary, district coefficient for the city of Krasnoyarsk = 20%, Also, incentive bonus is applied = 40%. Calculation of the Salary Fund is presented in Table 1.

TABLE I. PAYROLL CALCULATION

Title	Total, rub.
Salary	70000
Bonus for timely completion of work	14000
Incentive allowance	28000
District coefficient	14000
Salary with all allowances	126000
Total payroll for 3 months	378000

The amount of insurance contributions to the funds is calculated as follows:

$$IP = WF * IP, \quad (4)$$

where IP is the rate of insurance premiums equal to 30% of the wage fund.

IP = 378000 * 0,3 = 113400 rub.

Costs for equipment and premises are assumed to be 0, since the programmer was working remotely.

Material costs include the costs of consumables required during development and implementation, these are summarized in Table 2.

TABLE II. MATERIAL COSTS

Title	Amount
Paper	316
Printer toner	520
Chancery	250
Total	1086

Electricity costs are calculated as the sum of the cost of electricity consumed by the computer as a whole, the printer, and the electricity used for lighting the room. Electricity consumption is presented in Table 3.

TABLE III. ПОТРЕБЛЯЕМАЯ ЭНЕРГИЯ

Name	Consumption for the whole period, kWh
System unit	250
Monitor	19
Printer	168
Lighting	120
Total	557

Thus, the payment for electricity will be as follows:

Ex_{el} = 557kW * 2,09rub. = 1164,13 rub.

Acquisition of additional software for development and implementation is not required, therefore, it will amount to 0 rubles.

When implementing the software, one computer (system unit + mouse and keyboard, monitor) will be required, total cost 50000 rubles.

Also during the development and implementation was used Internet connection costing 500 rubles/month, therefore, for 3 stages of development cost is 1500 rubles.

Thus, the total cost of capital expenditures for creation and implementation of the software will be approximately 545150.13 rubles.

III. CALCULATION OF OPERATING (CURRENT) COSTS OF THE PROGRAM PRODUCT

The operating (running) costs of the system are determined for a year and consist mainly of three components, which are calculated for a year:

- Wages and salaries of key production personnel;
- Salary costs of administrative and managerial personnel (AMS);
- General production costs;

$$Ex = Ex_b + Ex_{ams} + Ex_{am} + Ex_{pc} + Ex_{tc}, \quad (5)$$

where: Ex_b - salary of the main production personnel, rubles; Ex_{ams} - salary of AMS, rubles; (it is recommended that it does not exceed AMS); Ex_{am} - amortization of fixed assets and intangible assets; Ex_{pc} - general production expenses; Ex_{tc} - other expenses.

In our case, operating costs for the year are determined by the following formula:

$$Ex = Ex_s + Ex_g + Ex_d + Ex_{oex}, \quad (6)$$

where Ex_s - salary costs of software maintenance personnel, including insurance premiums; Ex_g - general production costs, which include: electricity costs (depending on the amount of equipment, the consumed capacity and electricity tariffs); materials costs; costs associated with equipment repair; costs associated with the purchase of spare parts for repair; costs to pay for the lease of communication channels; Ex_d - amortization of fixed assets and intangible assets; Ex_{oex} - other costs.

Software acquired on the basis of an author's contract or a sales agreement is not recognized as an intangible asset and is not subject to amortization, since the acquiring organization does not have exclusive rights to it. Accounting of expenses for the acquisition of this software is recognized as other expenses on a straight-line basis over its useful life. Software created by the organization itself is recognized as an intangible asset and is subject to amortization.

It is assumed that the software product will be used for 56 hours per week, therefore, the working time rate of the software maintenance employee will be 224 hours per month. One programmer will be required to maintain the software.

If at full-time employment the norm of working time per month is 160 hours, then at 224 hours the tariff rate will be 1.28. Table 4 summarizes the calculations of the programmer's salary fund.

TABLE IV. PROGRAMMER'S PAYROLL

Title	Total, rubles.
Salary	70000
Incentive allowance	28000
District coefficient	14000
Salary with all allowances	112000
Insurance premiums	33600
Salary and wages fund including insurance premiums for the month	145000
Fund Salaries and Wages including insurance premiums for the year	436800

Electricity consumption is presented in Table 5

TABLE V. ELECTRICITY CONSUMPTION

Title	Consumption for the entire period
System unit	250
Monitor	19
Printer	168
Lighting	120
Total	557

Thus, the payment for electricity will be as follows:

Ex_g = 557kW * 2,09 = 1164,13 rub.

Materials required for work include pens, pencils, paper and other stationery, the cost of which will be no more than 1000 rubles per year.

Next, for the personal computer in use, we calculate depreciation. Electronic computer equipment, including personal computers and printing devices to them, belongs to the second depreciation group with a useful life of two to three years. In accordance with the straight-line method of depreciation calculation, the amount of depreciation charged for one month is determined as the product of the original cost of the fixed asset and the corresponding depreciation rate:

$$AE = Eq * DR, \qquad (7)$$

Where AE - depreciation charges, rubles; DR - depreciation rate, %.

The original cost of the equipment is 50000, the depreciation for 12 months will be as follows:

Exae = 50000*((1/36month.)*100%)*12month. = 16666,6 rub.

The operating system Microsoft Windows 10 Professional is not amortized as its cost is included in the cost of purchased computer equipment. Also, software is not amortized, as the institution does not have exclusive rights to this software, and the acquisition costs are recognized in other expenses on a straight-line basis according to the useful life of the software.

The costs of the developer's salary for 3 months and insurance premiums are presented in Table 2 and in total amount to 436800 rubles. Other costs of software design include Internet access costs, material costs amount to 2057 rubles.

Then the cost of creating the software tool will be 438857 rubles.

As a result, the cost of operating expenses will amount to 585523.6 rubles.

IV. FUNCTION POINT METHOD

Input data for calculating FP-metrics are presented in Table 6.

TABLE VI. DATA FOR CALCULATION.

Title	Rank, difficulty, number			
	Low	Medium	High	Total
External inputs	3	0	0	3
External outputs	0	5	0	5
External requests	0	4	0	4
Internal logical files	0	0	15	15
External interface files	0	7	0	7
Total number of ranks	34			

The number of function pointers is calculated by the formula:

$$FP = \text{number of ranks} * (0.65 + 0.01 * \sum Fi) \qquad (8)$$

Thus the number of function pointers = 22.

Next, we recalculate the FP-estimate is recalculated into LOC-estimates V:

$$V = K_{pl} * FP \qquad (7)$$

K_{pl} Python = 48, consequently, V = 48*22 = 1056

To convert the program volume in conditional lines V into labor input T, the intermediate COCOMO model is used, according to which the nominal labor intensity (without taking into account labor input factors, cost factors and complexity) can be calculated by the formula:

$$T = Nl * KSLOC^{N2}, \qquad (8)$$

where KSLOC (thousand lines) = V / 1000, N1 = 3.2 N2 = 1.05

T = 3.2 * 1.056^1.05 = 3.388 persons/month

Development time is calculated by the formula

$$t= 2,5 * T^{N3}, \qquad (9)$$

where N3 = 0,38

Thus, the recommended time for the development of the software product, taking into account the calculated labor costs will be: t = 2.5 * 3.38^0.38 = 3.97 months

V. Практическое применение метода Use-Case Points

A. Determining the technical complexity of the project

Technical Complexity Factor (TCF - Technical Complexity Factor) is calculated taking into account the technical complexity indicators. ti. value is assigned to each indicator in the range from 0 to 5 (0 means no significance of the indicator for the given project, 5 - high significance). The TCF value is calculated by the formula:

$$TCF = 0.6 + (0.01 * (Sum (Ti * Wi)), \quad (10)$$

Where Ti is the complexity indicator and Wi is the weight of the indicator presented in Table 7.

TABLE VII. INDICATORS OF TECHNICAL COMPLEXITY OF THE PROJECT.

Indicator	Description	Weight
T1	Distributed system	2
T2	High performance (throughput)	1
T3	Online end-user experience	1
T4	Complex data processing	1
T5	Code reuse	1
T6	Easy installation	0,5
T7	Ease of use	0,5
T8	tolerance	2
T9	Easy to make changes	1
T10	Parallelism	1
T11	Special safety requirements	1
T12	Direct access to the system by external users	1
T13	Special requirements for user training	1

Thus, TCF = 0.6 + (0.01 * 14) = 0.74

B. Determination of developers' qualification level

EF value is calculated by the formula:

$$EF = 1.4 + (-0.03 * (Sum(Fi * Wi)), \quad (9)$$

Where, Fi is the skill level indicator and Wi is the weight of the indicator. These indicators are presented in Table 8

TABLE VIII. INDICATORS OF DEVELOPERS' QUALIFICATION LEVEL

Indicator	Description	Weight
F1	Familiarization with technology	2
F2	Experience in application development	2
F3	Experience in using the object-oriented approach	3
F4	Availability of a lead analyst	0
F5	Motivation	4
F6	Stability of requirements	1
F7	Part-time employment	5
F8	Complex programming languages	5

Thus, the developer's qualification level should not be lower than: EF = 1.4 + (-0,03 * 22) = 0.74

The final UCP (Use Case Points) value is calculated as follows:

$$USP = UUCP * TCF * EF \quad (10)$$

Consequently, the complexity of the project is: UCP = 48 * 0,74 * 0,74 = 26,28

C. Estimating the labor intensity of the project

It is suggested to use 20 persons/hour per UCP as an initial value. This value can be refined taking into account the experience of developers. Here is an example of a possible Let's consider indicators F1 - F8 and determine how many indicators F1 - F6 have a value less than 3 and how many indicators F7 - F8 have a value greater than 3. The total number is equal to 4, therefore, we will use 28 man-hours per UCP.

Labor intensity = 28 man/hour * 26,28 = 735,84 man/hour

D. Project payback

Project payback = development costs annualized cost difference in AS-IS and TO-BE models

The cost difference from the implementation of the system and redistribution of labor forces is 136 rubles per hour downward in the TO-BE model. 224 - number of working hours per month.

Payback = 136*224*12 = 365568 rubles

Development costs = 545160 rubles

PPb = 545160/365568 = 1.5 years or approximately 18 months

VI. Conclusion

The use of various mathematical models helps to calculate the cost of developing an automation program at the planning stage, but the choice of model and their analysis should be approached with understanding, because each model is aimed at calculating depending on one or another indicator.

In our study, 3 months have been allocated for the project and this is the optimum in calculating the labor cost. According to Function Points methodology, the optimal time for project development is 3.27 months. According to the methodology, the nominal labor intensity = 3.38 man/month. Considering the labor intensity of UCP methodology, the labor intensity is also about 3 months. Also the study calculates the payback period, which is about 18 months, but it is difficult to calculate the real payback period, because it is hard to calculate the benefit of the program on paper, because the real estimate of the real increase in profit from the functionality of the application in the activities of the company has not been calculated. The considered models help to get all the necessary information on costs, which can be further used to build a work plan or other documents attached to the development of a software product.

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Gestational Diabetes Mellitus Risk Assessment Using Artificial Intelligence: A Review

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***Abstract* — In recent years, in the field of healthcare, artificial intelligence has started to take the lead. Research on the application of artificial intelligence technology in the realm of health has received a lot of interest. To effectively predict disease at an early stage using historical healthcare statistics, artificial intelligence and machine learning algorithms are being increasingly used and integrated into healthcare systems. The assessment of the risk of acquiring diabetes, particularly gestational diabetes in early pregnancy, has received a lot of attention recently. Given the foregoing, this paper questions the usage of artificial intelligence models, one of the contemporary technologies that are frequently used in the healthcare industry. This paper reviews software tools and systems developed for assessing the risk of developing gestational diabetes mellitus based on artificial intelligence used worldwide.**

Keywords—Gestational diabetes mellitus, Artificial Intelligence, Machine learning, Software tools

I. INTRODUCTION

In recent years, interest in conducting research in the fields of Artificial Intelligence, Robotics and hardware development has increased in the world, including in Uzbekistan [1-3]. One of the ongoing studies aims to assess the risk of developing gestational diabetes mellitus (GDM) in Uzbek pregnant women with the help of artificial intelligence. It is known that in recent years, the number of people suffering from various cardiovascular diseases and diseases related to body weight is increasing. It can be mentioned diabetes is one of the diseases that millions of people suffer from around the world. Diabetes is a disease caused by insulin deficiency and metabolic disorders in the body. According to the 2019 statistical analysis, the total number of people suffering from diabetes in the world was 463 million, which is 9.3% of the world's adult population (20-79 years old). This number is expected to increase to 578 million (10.2%) in 2030 and 700 million (10.9%) in 2045. In 2019, the prevalence of diabetes was 9.0% in women and 9.6% in men. The increase in the prevalence of diabetes by age group was 19.9% (111.2 million) in people aged 65-79 years [4].

Diabetes can be divided into type 1 diabetes, type 2 diabetes, gestational diabetes and other types.

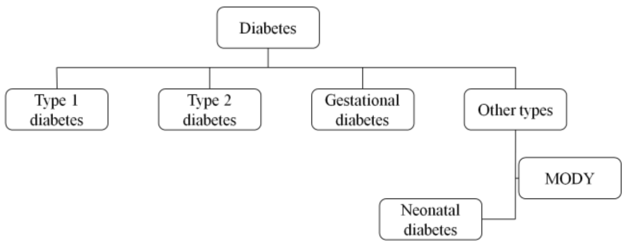

Figure 1. Types of diabetes

Type 1 diabetes is also called insulin-dependent diabetes. It used to be called juvenile diabetes because it often starts in childhood. Type 1 diabetes damages the body's pancreatic cells. The organ is damaged and does not produce insulin.

Type 2 diabetes is adult-onset diabetes. But in the last 20 years, this type of diabetes has become more common in children and adolescents. The main reason for this is the increasing incidence of overweight or obesity among young people.

Gestational diabetes (GD) or Gestational diabetes mellitus (GDM) is a metabolic disorder in pregnant women that is a common problem in endocrinology, obstetrics, and gynecology as well as a social problem.

More than 786,000 new babies are born in Uzbekistan every year. The prevalence of diabetes in pregnancy (GDM) is about 10.5%, which means that about 83,000 pregnant women are diagnosed with this pathology every year. In addition to complications related to pregnancy and childbirth, these women and their children (about 166,000 per year) are at risk of developing obesity, type 2 diabetes, metabolic syndrome, and cardiovascular disease (over the next 5-15 years) at a high level.

The rest of the paper follows this structure: The section "Artificial Intelligence in Diabetes Prediction" is dedicated to the importance of Artificial Intelligence technologies in predicting diabetes (including GDM). The section "Analysis of Studies on GDM Risk Assessment using AI/ML Models" reviewed up-to-date research done in the related field. The section "Results Obtained in the Analyzed Studies" compared the results gained in the analyzed studies. The section "Conclusion" concludes this paper.

II. Artificial Intelligence in Diabetes Prediction

Artificial intelligence (AI) is a rapidly developing field, and its application in the treatment of diabetes, a global pandemic, may revolutionize the approach to the diagnosis and management of this chronic condition.

Machine learning algorithms are used to support predictive models for the risk of developing diabetes or its complications. Digital therapy has proven to be an established intervention for lifestyle therapy in the treatment of diabetes. Patients are increasingly empowered to self-manage their diabetes, and both patients and healthcare professionals benefit from clinical decision support. AI enables continuous and remote monitoring of patient symptoms and biomarkers. In addition, social media and online communities increase patient participation in diabetes care. Technological advances have helped optimize resource utilization in diabetes. Artificial intelligence is changing massive processes in diabetes care, from traditional treatment strategies to creating targeted, data-driven precision care.

Below is a description of the artificial intelligence models that are widely used in the field of medicine to predict diabetes.

A. *Supervised Learning*

Predictive models are constructed with the help of Supervised learning algorithms. A predictive model predicts missing values using other values present in the dataset. A supervised learning algorithm has a set of input data and also a set of output and builds a model to make realistic predictions for the response to a new dataset. Supervised learning includes Decision Tree (DT), Bayesian Method, Artificial Neural Network (ANN), Instance-based learning, and Ensemble Method [5].

B. *Unsupervised Learning*

Unsupervised learning is used to develop Descriptive models. In this model, the set of inputs is known but output is unknown. Unsupervised learning is mostly used on transactional data. This method includes clustering algorithms like k-Means clustering and k-Medians clustering.

C. *Semi-Supervised Learning*

In the Semi-Supervised learning method, it is used both labelled and unlabeled data on a training dataset. Classification and regression techniques come under Semi-Supervised Learning. Logistic regression, Linear Regression are examples of regression techniques.

III. Analysis of Studies on Gestational Diabetes Risk Assessment Using AI/ML models

This section reviews software tools and systems currently in use that have been developed to assess the risk of developing gestational diabetes based on artificial intelligence. In preparation for this review paper, between June and July 2023, Google Scholar, PubMed, Scopus, Science Direct and Web of Science databases were searched for articles with the keywords "gestational, diabetes mellitus, risk assessment, Artificial Intelligence". 2564 articles were found as a result of the search. This review paper included 14 full-text articles conducted between 2017 and 2023.

In [6], it is aimed to develop and validate a gestational diabetes early prediction model using a machine learning algorithm. The study used data collected from 2017 to 2019 from a pregnancy survey in eastern China. Randomly split into a 75% training dataset and a 25% test dataset using the train_test_split function. Based on Python, four classical machine learning algorithms and the New-Stacking algorithm were first trained by the training data set and then tested by the test data set. In the study, Artificial Neural Network (ANN), Logistic Regression (LR), Random Forest (RF), and Support Vector Machine (SVM)—four machine learning models were used. Methods such as sensitivity, specificity, accuracy, and area under the receiver operating characteristic curve (AUC) were used to analyze the performance of the models. The study included valid data from a total of 2,811 pregnant women. The accuracy of the models which gained the highest results is as follows: accuracy 86.91% (RF), sensitivity 81.65% (SVM), specificity 97.53% (RF) and AUC 0.82 (New-Stacking). This study confirms that the New-Stacking model is theoretically successful for its better performance in terms of specificity, accuracy, and AUC.

In [7], it is described an overview (2014–2018) of research on blood glucose prediction used in a blood glucose recommendation system. As a result, 25 studies on blood sugar prediction were selected for recommendations. The results of the study showed that only one research study discussed the hybrid filtering technique in a blood sugar recommendation system for gestational diabetes.

In [8], it is aimed to develop an AI-based prediction model for gestational diabetes in Mexican pregnant women. In the study, data were obtained from 1709 pregnant women. A machine learning-based method was used to select the best predictive variables for the risk of gestational diabetes: age, family history of type 2 diabetes, previous diagnosis of hypertension, pre-pregnancy body mass index, gestational week, parity, birth weight of the last child, and random capillary glucose. An artificial neural network approach was then used to build the model, which achieved high accuracy (70.3%) and sensitivity (83.3%) for identifying women at high risk of developing GDM.

In [9], it is used a machine learning method to predict GDM on retrospective data from 588,622 pregnancies in Israel. The models developed during the study predicted GDM with high accuracy even in early pregnancy. Overall, research-based models may allow for early intervention in high-risk women, as well as a cost-effective screening approach that avoids the need for glucose tolerance testing by identifying women at low risk.

In [10], it is aimed to analyze and compare different machine learning algorithms to determine the best prediction algorithm. In this study, it is also used various evaluation parameters such as accuracy, kappa, precision, recall, sensitivity and specificity. Extensive research has been done on diabetes datasets with algorithms such as Random Forest (RF), SVM, k-NN, CART, and LDA. The results of the study showed that RF provided more accurate predictions than other algorithms.

A data substitution and prediction system was proposed in [11]. The system consists of three layers: 1) Internet of Things (IoT) layer; 2) Fog layer (Fog layer); 3) Cloud layer (Cloud Layer). To evaluate the developed model, data from 16354 pregnant women were obtained from the benchmark data set for intensive care (MIMIC III). Vital signs, demographic data, and laboratory tests were collected for each woman. The results of the forecasting model are among the most up-to-date (ACC = 0.957, AUC = 0.942) and show superiority.

In [12], it is assessed the predictive ability of existing UK NICE guidelines for GDM risk assessment in Singaporean women and used machine learning to develop a non-invasive predictive model. Data from 909 pregnancies were used in the study. The results of the study showed that the UK NICE guidelines showed a poor prediction in Singaporean women [AUC: 0.60 (95% CI 0.51, 0.70)]. In a noninvasive predictive model that included 4 noninvasive factors: first-trimester mean arterial blood pressure, age, ethnicity, and history of previous GDM [AUC: 0.82 (95% CI 0.71, 0.93)].

In [13], it is aimed to identify patients at risk of GDM and develop a clinical diagnostic system to reduce the use of unnecessary oral glucose tolerance test (OGTT) for pregnant women not at risk of GDM using deep learning algorithms. For this purpose, data was obtained from 489 patients between 2019 and 2021. A clinical decision support system for GDM diagnosis was developed using datasets generated by deep learning algorithms and Bayesian optimization methods. As a result, a new successful decision support model was developed using RNN-LSTM with Bayesian optimization method, which provides 95% sensitivity and 99% specificity in the dataset to diagnose patients at risk of GDM by obtaining 98% AUC (95% CI).

In [14], it is presented a machine learning-based discrimination system to identify patients at risk of exhibiting high blood glucose levels based on daily blood glucose measurements and electronic health record data of patients with GDM. In the study, data was collected from 1,148 pregnancies at Oxford University Hospitals NHS Foundation Trust (OUH) for training the model. 709 patients from the Royal Berkshire Hospital NHS Foundation Trust (RBH) were reviewed externally. In the study, it is used linear and non-linear tree-based regression models to predict the proportion of high scores a patient is likely to show in the coming days, and XGBoost achieved the highest performance during internal validation (0.021 [CI 0.019-0.023], 0.482 [0.442] for MSE, R2, MAE, respectively - 0.516] and 0.112 [0.109–0.116]).

In [15], a predictive model for the diagnosis of gestational diabetes using epidemiological data in the United Arab Emirates. In the study, data was collected from a total of 3,858 women to train the developed model. The data used for predictive modelling were derived from self-reported epidemiological data collected during early pregnancy. Three different ML models, random forest (RF), gradient boosting model (GBM), and extreme gradient boosting (XGBoost)—were used in the study to predict GDM. The results obtained using ML models showed that the XGBoost model performed better compared to RF and GBM, achieving an AUC of 0.77.

In [16], it is aimed to develop widely applicable GDM risk prediction models using four different methods in the first trimester. For this purpose, as a result of meta-analysis using 42 studies, score-scaled model, logistic regression model and two more machine learning models (decision tree (DT) and random forest (RF)) were used. A score-scaled model (seven variables) was created based on meta-analysis and data from 1075 Chinese pregnant women from Northwestern Women's and Children's Hospital and showed an AUC of 0.772. The logistic regression model (seven variables) showed an AUC of 0.799 and 0.834 for the training and validation sets, respectively. Two more models were fitted using Decision Tree (DT) and Random Forest (RF) algorithms and showed corresponding AUCs of 0.825 and 0.823 for the training set and 0.816 and 0.827 for the validation set.

In [17], it is developed a pre-conceptional GDM prediction model to enable early intervention. The association of the best predictors with GDM and adverse birth outcomes was also evaluated. The evolutionary algorithm-based automated machine learning (AutoML) model developed in the study was implemented with data from 222 multi-ethnic Asian women in the Singapore Maternal and Child Long-Term Outcomes Pre-Study (S-PRESTO) study. A stacked ensemble model with a gradient boosting classifier and a linear support vector machine classifier (stochastic gradient descent training) was obtained using genetic programming, based on four features (glycated haemoglobin A1c (HbA1c), mean arterial blood pressure, fasting insulin, triglycerides/HDL ratio) and achieved an excellent AUC of 0.93.

In [18], it is investigated whether clinical data at different stages of pregnancy could predict GDM treatment. From a cohort of 30,474 pregnancies with GDM born between 2007 and 2017 at Kaiser Permanente, Northern California, the researchers selected 2007–2016 as the discovery set and 2017 as the interim/prospective study.

In the study, ensemble machine learning prediction methods are used to make these predictions. The least absolute shrinkage and selection operator (LASSO) regression, the super learner, the classification and regression tree (RT), the random forest, and the extreme gradient boosting algorithms have all been compared to estimate the risks of pharmacological treatment in this study.

In [19], an explainable machine learning based clinical decision support system (CDSS) was developed to identify at-risk women in need of targeted pregnancy intervention. The initial phase of the PEARS study used maternal characteristics and blood biomarkers. The models developed during the research are explained with Shapley additive explanations to increase the reliability and acceptability of the system. Researchers developed several models for different use cases: theoretical (AUC PR 0.485, AUC ROC 0.792), GDM screening during antenatal visit (AUC PR 0.208, AUC ROC 0.659) and remote GDM risk assessment (AUC PR 0.199, AUC ROC 0.606).

Below is a Figure (The world map) showing the locations of the countries where the organizations of the authors of the articles analyzed in this review paper.

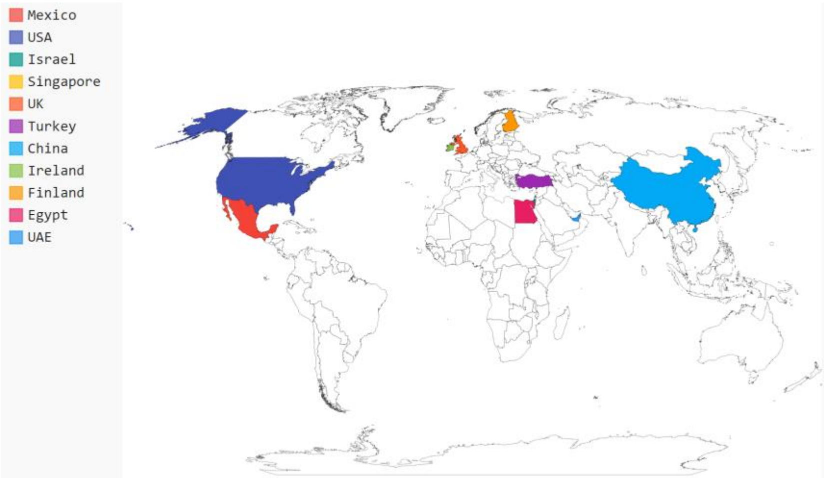

Figure 3. Research on GDM risk assessment using Artificial Intelligence in the world

IV. RESULTS OBTAINED IN THE ANALYZED STUDIES

This section provides information on the results obtained in the articles analyzed in Section 3. The table below shows information about the countries of the organizations of the authors in which GDM risk assessment is being researched, the algorithms/models used/created, the datasets used/created, and the results achieved.

TABLE I. LIST OF STUDIES EVALUATING THE PREDICTION OF GESTATIONAL DIABETES MELLITUS BY MACHINE LEARNING MODELS

Reference	Country	Algorithm/model	No. of participants in dataset	Results achieved (highest)
4	Mexico	ANN	1709 pregnant women	Accuracy (70.3%) and sensitivity (83.3%), AUC = 0.8471
5	Israel	ML	588622 pregnancies	AUC = 0.85
7	Egypt	DNN	16354 pregnant women	ACC = 0.957, AUC = 0.942
8	Singapore, UK and Finland	LR, SVM, Neural Network, and CatBoost	909 pregnancies	AUC = 0.82
9	Turkey	RNN-LSTM with Bayesian optimization	489 patients	sensitivity 95 % and specificity 99 % , AUC = 0.95
10	UK and China	multiple linear regression (MLR), XGBoost, and RF	1148 pregnancies	MSE 0.020 (0.019–0.022)
11	United Arab Emirates	XGBoost, RF, and GBM	3858 women	AUC = 0.77
12	China	Score-scaled, LR, DT and RF	1075 Chinese pregnant women	AUC = 0.772
13	Singapore, UK and Finland	AutoML	222	confidence intervals (CIs) 95 %, AUC = 0.93
14	USA	LASSO regression, RT, RF, and XGBoost	30474 pregnancies	AUC = 0.802
15	Ireland	LR, RF, SVM, adaptive boosting (AdaBoost) and XGBoost	565 women with singleton pregnancy	AUC = 0.792

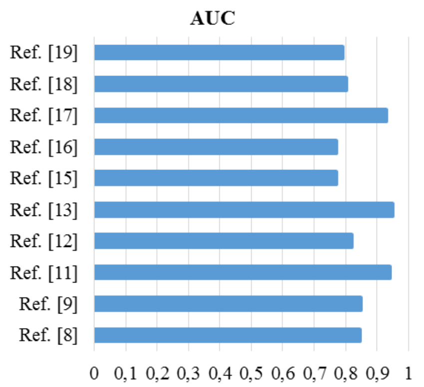

Figure 4. Comparison of analyzed studies based on AUC evaluation metric

It can be seen from Figure 4 that in almost all of the analyzed articles, AUC results were obtained. If we compare the results on AUC with each other, on this Ref. [13] had the highest result and Ref. [15] had the lowest result. The results of Ref. [15] and Ref. [16] are very close to each other. Also, the results of Ref. [8] and Ref. [9] are very close to each other.

Figure 5. Data collected from the pregnant women in the studies

It can be seen from Figure 5 that in each of the analyzed articles, datasets of different sizes were used.

V. Conclusion and Discussions

In this paper, the software tools and systems developed for assessing the risk of developing gestational diabetes based on artificial intelligence in the world were analyzed and the accuracy of artificial intelligence models and machine learning algorithms were evaluated. According to the results of the analysis, it was concluded that the creation of a dataset for the assessment of the risk of developing gestational diabetes is a very important process in order to successfully continue the next stages of scientific research work.

In our future work, we plan to create a gestational diabetes dataset of Uzbek women using the experience gained by studying the remarkable results of the world's leading scientists during the preparation of this review paper.

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Determining the parameters of recognizing operators based on threshold rules built on the basis of feature interconnection models

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***Abstract*—The paper considers the issues of constructing an extremal algorithm within the framework of a family of recognizing algorithms based on threshold rules built on the basis of feature interconnection models. The proposed method is based on the idea of forming a number of subtasks when determining the parameters of recognizing operators, a family of recognizing operators based on threshold rules built on the basis of feature interconnection models. At the same time, the method for determining the parameters, presented as a sequence of computational procedures for solving the corresponding subtasks, the main of which are: 1) determining a set of representative features; 2) determination of a set of models for the interconnection of features; 3) highlighting preferred models of feature interconnection; 4) definition of threshold rules that characterize the proximity between an object and a class. The application of the developed method makes it possible to construct an extremal algorithm within the framework of a family of recognizing operators based on threshold rules built on the basis of feature interconnection models. In order to assess the performance of the proposed method, experimental studies were carried out in solving the model problem of object classification and the problem of diagnosing cotton diseases.**

***Index Terms*—extremal algorithm, threshold rules, feature interconnection models, operators based on threshold**

I. Introduction

One of the promising and most intensively developing areas in the field of applied mathematics and computer science is the methods and algorithms of pattern recognition. This is due to the fact that in recent years pattern recognition has been increasingly used in science, technology, production and everyday life. Therefore, an ever wider circle of specialists pays attention to the problem of pattern recognition, and the number of scientific publications on this topic is constantly growing [3-6].

An analysis of literary sources, in particular [1, 6-29], shows that to date, several fairly well- known models of recognition algorithms have been deeply developed and studied in detail: models based on the use of the separation principle [1, 7, 8]; statistical models [8-10]; models built on the principle of potentials [8, 11-13]; models built on the basis of mathematical logic [1, 14-16]; models based on the calculation of estimates [1, 6, 17-19]. However, an analysis of these models shows that at present, models of recognition algorithms are mainly being developed that are focused on solving problems where objects are described in the space of independent (or weakly dependent) features. In practice, applied problems of pattern recognition defined in a high-dimensional feature space are often encountered. When solving such problems, the assumption of independence of features is often not satisfied [29-31]. Consequently, the issue of creating recognition algorithms that can be used to solve applied problems of diagnosing, predicting and classifying objects in conditions of large dimensions of the feature space and the presence of interconnectedness of features remains insufficiently resolved [29, 31-34].

In [29], a model of recognizing operators was described, based on the assessment of the interconnectedness of features, in the conditions of interconnectedness of features. The main idea of this model of recognizing operators is to find some dependencies between features that characterize objects

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belonging to the same class. For the sake of completeness, we will briefly consider this model, which are determined by setting seven stages:

1) selection of subsets of interrelated features:

$$\mathfrak{G}_B = \{\mathcal{T}_1,\ \mathcal{T}_2, \ldots,\ \mathcal{T}_{n'}\},$$

where $n'$is the parameter of recognizing operators based on threshold rules built on the basis of feature interconnection models;

2) a set of representative features is formed:

$$\mathfrak{R}_X = \left\{x_{i_1}, \ldots,\ x_{i_q}, \ldots,\ x_{i_{n'}}\right\} \tag{1}$$

This set of representative features (1) corresponds to *an n* - dimensional boolean vector $\bar{\mathfrak{r}}$ $(n' = |\bar{\mathfrak{r}}\ |)$:

$\bar{\mathfrak{r}} = (r_1, .., r_i, .., r_n)$;

3) dependency models F_q are defined in each subset $\mathcal{T}_q$ $(q = \overline{1, n'})$ for K_j $(j = \overline{1, l})$:

$$\mathfrak{M} = \left\{F_{i_1}, \ldots,\ F_{i_q}, \ldots,\ F_{i_{n'}}\right\}.$$

Here $F_{i_q}$is the dependency model, for example:

$$x_i = c_1 x_{i_q} + c_0.\ x_i \in \mathcal{T}_q \backslash x_{i_q}.$$

where $c_1, c_0$are the unknown parameters of the dependency model;

4) selection of a set of preferred dependency models:

$$\mathfrak{R}_{\mathfrak{M}} = \left\{F_{j_1}, \ldots,\ F_{j_q}, \ldots,\ F_{j_{n''}}\right\}. \tag{2}$$

This set of preferred dependency models (2) corresponds ton' -dimensional boolean vector $\overline{\omega}$ $(n' = |\overline{\omega}\ |)$:

$$\overline{\omega} = \left(\omega_{i_1}, \ldots, \omega_{i_q}, \ldots, \omega_{i_{n'}}\right);$$

5) the definition of threshold rules that characterize the proximity between the object $S$and the class K_j $(j = \overline{1, l})$. Let the preferred model of the relationship between features x_{i_q} and x_i be given in the following form $(x_{i_q} \in \Omega_q, x_i \in \Omega_q \backslash x_{i_q})$:

$$x_i = F_j\left(\overline{c}, x_{i_q}\right),\ x_i \in \Omega_q \backslash x_{i_q}.$$

Then the threshold rules are defined as follows:

$$\mathfrak{d}_q\left(K_j,\ S\right) = \begin{cases} 1, \text{ if } \left|x_{i_q} - F_j\left(\overline{c}, x_i\right)\right| \le \mathfrak{t}_q; \\ -1, \text{ if } \left|x_{i_q} - F_j\left(\overline{c}, x_i\right)\right| > \mathfrak{t}_q, \end{cases} \tag{3}$$

where $\mathfrak{t}_q$ is the parameter of recognizing operators;

6) definition of a generalized threshold rule, which is set as a measure of the proximity of an object S to a class K_j(3):

$$T\left(K_j,\ S\right) = \begin{cases} 1, \text{ if } \mathfrak{t}(K_j, S) \le \varepsilon; \\ -1, \text{ if } \mathfrak{t}(K_j, S) > \varepsilon, \end{cases}$$

$$\mathfrak{t}(K_j, S) = \sum_{q=1}^{n''} \mathrm{g}_q \theta_q(K_j, S),$$

Where ε - parameter of recognizing operators; g_q $\left(q = \overline{1, n''}\right)$–linear polynomial parameters from threshold rules (3) . The combination of these parameters forms a vector $\overline{\mathrm{g}} = (\mathrm{g}_1, \ldots, \mathrm{g}_q, \ldots, \mathrm{g}_{n''})$.

We have defined a model of recognizing operators of the type of potential functions based on the assessment of the interconnectedness of features. An arbitrary operator B from this model is completely determined by setting a set of parameters $\widetilde{\pi}$ [9]:

$$\widetilde{\pi} = \left(n', \{\widetilde{w}\}, \{\overline{c}\}, \{\widetilde{\omega}\}, \{\lambda_i\}, \xi, \{\gamma_u\}\right). \tag{4}$$

It is known [1] that an arbitrary recognition algorithm Acan be represented as a sequential execution of the operators B(recognition operator) and C (decision rule):

$$A = B \circ C. \tag{5}$$

From (5) it follows that the problems of finding the optimal algorithm A can be considered as the problems of finding the optimal recognizing operator B under the condition of a fixed rule $C(c_1,\ c_2)$.

The purpose of this work is to solve issues related to the calculation of the values of unknown parameters (4) in the construction of extremal recognizing operators based on the principle of potentials under conditions of feature interconnection. In this case, a heuristic approach is used, based on the consistent application of local optimization procedures when searching for parameter values at each stage.

Formal description of the problem of determining parameters $\widetilde{\pi}$ is as follows.

II. Formulation of the problem

A model of recognizing operators based on the principle of potentials is given. Any operator B from this model is completely determined by setting a set of parameters $\widetilde{\pi} = \left(n', \{\widetilde{w}\}, \{\overline{c}\}, \{\widetilde{\omega}\}, \{\lambda_i\}, \xi, \{\gamma_u\}\right)$. The set of all recognizing operators from the proposed model will be denoted by $B(\widetilde{\pi},\ S)$. Then the task construction of extremal recognizing operators based on the principle of potentials can be formulated as a problem of finding an extremal operator $B(\widetilde{\pi}^*,\ S)$among recognizing operators $B(\widetilde{\pi},\ S)$. Here $\widetilde{\pi}$, is the vector of adjustable parameters; $\widetilde{\pi}^*$is the vector of optimal parameters.

We set the recognition quality criterion in the form

$$\varphi_A\left(\widetilde{\pi}\right) = \frac{1}{\left(q \bullet \sum \mathfrak{K}\left\{\|\widetilde{\alpha}\left(S_j\right) - A(\widetilde{\pi}, S_j)\|_{\mathcal{B}}\right\}\right)}, \tag{6}$$

$$\mathfrak{K}(x) = \begin{cases} 0, \text{ if } x = 0; \\ 1, \text{ if } x \ne 1, \end{cases}$$

where $\|\bullet\|_{\mathcal{B}}$ is the norm of the boolean vector.

Then the task of constructing extremal recognizing operators is to find the optimal value of the components of the vector-parameter $\widetilde{\pi}^*$ for a given model of recognizing operators, which ensures the fulfillment of the condition:

$$\widetilde{\pi}^* = \arg\min_{\widetilde{\pi}} \varphi_A\left(\widetilde{\pi}\right).$$

III. Solution method

The formulated problem for its solution is reduced to finding the optimal value at each stage. After each iteration, the value of the quality functional (6) is calculated. If it is less than the specified threshold or the number of iterations is greater than the specified one, then the search procedure stops. Let us consider the procedures for determining the values of the parameters of each stage separately.

1. The procedure for determining subsets of related features. Let $\mathcal{T}_q$ $(q = \overline{1, n'})$- subsets of interrelated features [34]. The proximity measure $\mathfrak{L}(\mathcal{T}_p, \mathcal{T}_q)$between subsets $\mathcal{T}_p$and $\mathcal{T}_q$can be specified in various ways, for example:

$$\mathfrak{L}\left(\mathcal{T}_p, \mathcal{T}_q\right) = \frac{1}{\left(N_p - 1\right)\left(N_q - 1\right)} \sum_{x_i \in \mathcal{T}_p} \sum_{x_j \in \mathcal{T}_q} \sum_{k=1}^{m} \upsilon_k d_k\left(x_i,\ x_j\right),$$

$$N_p = card(\mathcal{T}_p),\ N_q = card(\mathcal{T}_q),$$

where $d_k\left(x_i,\ x_j\right)$is the measure of proximity between features $x_i$and x_j for the th object.

The definition $\mathfrak{G}_B = \{\mathcal{T}_1,\ \mathcal{T}_2, \ldots,\ \mathcal{T}_{n'}\}$is carried out as follows.

Step 1 . The first step assumes that each subset contains only one element. In this case we have n subsets.

$\mathcal{T}_1 = \{x_1\},\ \mathcal{T}_2 = \{x_1\}, \ldots,\ \mathcal{T}_n = \{x_n\}$ $(N_1 = N_2 = \ldots = N_n = 1)$.

Define the initial connection matrix$\left\|\mathfrak{L}_{ij}^1\right\|$ as $\mathfrak{L}_{ij}^1 = \mathfrak{b}_{ij}$ [10]. Next, consider the execution of an arbitrary u-th step (u >1).

Step u. Assume that at the $(u-1)$ th step, u'subsets are defined $\mathcal{T}_1,\ \ldots\ ,\ \mathcal{T}_{u'}$ and the connection matrix is constructed $\left\|\mathfrak{L}_{ij}^{(u-1)}\right\|_{u' \times u'}$, where $u' = (n - u + 1)$.

Then, at the th step, the following operations are performed:

1) union $\mathcal{T}_p$ and $\mathcal{T}_q$into one subset, if $\mathfrak{L}\left(\mathcal{T}_p, \mathcal{T}_q\right) = max\left\|\mathfrak{L}_{ij}^{(u-1)}\right\|_{u' \times u'}$, for $i,\ j \in \left[1,\ 2,\ \ldots\ , u'\right]$ and $i \neq j$;

2) formation of a new communication matrix of the th order: $\left\|\mathfrak{L}_{ij}^{u+1}\right\|$.

The process of combining features continues until n'subsets are obtained (n'- some given number), i.e. n' "independent" feature subsets $\mathcal{T}_1,\ \mathcal{T}_2, \ldots,\ \mathcal{T}_{n'}$, of which each feature is strongly related in its subset.

2. The procedure for determining the representative feature in each subset of interrelated features . At this stage, various methods can be used to select unrelated (representative) features from a subset of related features. The main idea of the choice is to select the most "independent" (or weakly dependent) set of features [31, 34].

Let $\mathcal{T}_q$ $(q = \overline{1, n'})$- subsets of interrelated features. It is assumed that calculated N_q- the number of elements (cardinality) of these subsets:

$$N_q = card(\mathcal{T}_q),\ \left(q = \overline{1, n'}\right).$$

Then the procedure of this stage can be described as follows. At the beginning it is assumed that $u = 0$.

Step 1. Selection of isolated elements of the subset as representative features $\mathcal{T}_q$, which are sharply different from other features. At this step, the following actions are performed:

- the value $u$is increased by one and the condition is checked $u > n'$. If this condition is met, then the algorithm stops;

- if $N_q = 1$, then the element belonging to the subset $\mathcal{T}_q$ belongs to the number of representative features, and the transition to the previous action is performed.

Step 2. Selecting a representative feature, when a subset of related features contains more than two elements (i.e., under the condition $N_q > 2$) perform the following sequence of operations for all elements $\mathcal{T}_q$ except the considered element:

- for each element, $\mathcal{T}_q$calculate the estimate of the proximity of each element to other elements of this subset of features

$$\mu_i = \sum_{j=1}^{i-1} \rho\left(x_i,\ x_j\right) + \sum_{j=i+1}^{N_q} \rho\left(x_i,\ x_j\right),$$

$$\rho\left(x_i,\ x_j\right) = \sum_{k=1}^{m} \upsilon_k d_k\left(x_i,\ x_j\right);$$

- determine the element of the subset $\mathcal{T}_q$that is as close as possible to other elements

$$\mu_j = \max_{i \in [1,\ \ldots\ , N_q]} \mu_i;$$

- select the feature as a representative feature x_j.

Step 3. When $N_q = 2$ the following steps are performed:

- for each element, $\mathcal{T}_q$ calculate an estimate of proximity to the representative elements of other subsets that were selected at the previous stages of selection:

$$\mu_{i_\tau} = \sum_{j=1}^{N_0} \rho\left(x_i,\ x_j\right);\ i_\tau = 1,\ 2,\ \ldots,\ k;\ \tau \in [1, 2],$$

where k is the number of subsets that consist of two elements. N_0- the number of isolated elements and elements selected from subsets with a power of more than two;

- to determine the element of the subset $\mathcal{T}_q$ that differs significantly from other selected representative features

$$\mu_j = \min_{\tau \in [1,2]} \mu_{i_\tau};$$

- select the feature as a representative feature x_j;

- go to step 1.

As a result of the considered actions, an n'-dimensional space of features $\mathbb{X}$ is formed, each of which is a representative of a selected subset of interrelated features:

$$\mathbb{X} = \left(x_{i_1}, \ldots,\ x_{i_q}, \ldots,\ x_{i_{n'}}\right).$$

3. The procedure for determining the models of interconnectedness in each subset of features for the class. Let x_{i_q}be a representative feature belonging to the set $\mathcal{T}_q$. Dependence models between features $x_{i_q}$and x_i $(x_{i_q} \in \mathcal{T}_q, x_i \in \mathcal{T}_q \backslash x_{i_q})$are specified for each class $K_j$in the form

$$x_i = F_j\left(\overline{c}, x_{i_q}\right),\ x_i \in \Omega_q \backslash x_{i_q}, \tag{7}$$

where $\overline{c}$ is the vector of unknown parameters; F_j is some dependency model that belongs to some given class $\{F\}$. It is assumed that the parametric form and the number of parameters are known.

For simplicity, it is assumed that the set $\{F\}$ consists only of linear models. It is assumed that the signx_{i_q} $\left(x_{i_q} \in \mathcal{T}_q\right)$ is the independent variable and the feature $x_i(x_i \in \mathcal{T}_q \backslash x_{i_q})$ is the dependent variable. Then the dependency model takes the form $x_i = c_1 x_{i_q} + c_0$, where c_1, c_0 are the unknown parameters of the dependency model.

To determine the numerical values of these unknown parameters, we use the least squares method [35].

4. Procedure for identifying preferred models of interconnectedness. Let be $\mathcal{J}_0$a training sample, E_1be a set of objects belonging to the class $K_j : E_1 = \mathcal{J}_0 \cap K_j$, and E_2be a set of objects not belonging to the class $K_j : E_2 = \mathcal{J}_0 \backslash E_1$. Consider the selection of an important (hypothetical) dependence model based on the assessment of the dominance of the considered models [8]:

$$T_i = \frac{D_i}{\Delta_i}. \tag{8}$$

Here Δ_i, is the sample error variance calculated for objects belonging to the subset $\widetilde{K}_i$:

$$\Delta_i = \frac{1}{|E_1|} \sum_{S \in E_1} |\zeta_i(S)|,$$

$\zeta_i(S) = y_i(S) - F_j\left(\overline{c}, x_{i_q}(S)\right)$,

where $x_{i_q}$is a representative feature of the th subset ($x_{i_q} \in \mathcal{T}_q$);

y_i- an arbitrary sign, except for representative ($y_i \in \mathcal{T}_q \backslash x_{i_q}$).

D_i– selective error calculated for objects that do not belong to the subset $\widetilde{K}_j$:

$$D_i = \frac{1}{|E_2|} \sum_{S \in E_2} |\zeta_i(S)|.$$

Based on formula (8), we calculate the dominance score for all features that belong to the subset $\mathcal{T}_q \backslash x_{i_q}$. As a result, we get $(N_q - 1)$the values T_i $(i = \overline{1, (N_q - 1)})$. The choice of an important dependency is carried out as follows:

$$T_q^* = \max\left\{T_1, .., T_i, .., T_{(N_q - 1}\right\}$$

Repeating this procedure for all n''subsets, we obtain a set of preferred dependency models for the class K_j. It is assumed that $N_q > 1$. Otherwise, the number of preferred models decreases as much as the number of subsets has only one element.

5. Procedure for determining threshold rules characterizing the proximity between an object S_u and class K_j. Using this procedure, a threshold rule is determined that characterizes a binary measure of the proximity of an object S to the class K_j. In this case, the proximity measure is set on the basis of the dependency model in each subset $\mathfrak{R}_q$ $(q = \overline{1, n''})$for each class K_j.

Given a difference function $d_q(K_j, S)$between objects of a class K_j and an object Sin a subset, $\mathfrak{R}_q$ it can be defined as follows:

$$d_q(K_j, S) = \left|x_i - F_j\left(\overline{c}, x_{i_q}\right)\right|,$$

where x_{iq}, $x_i$is the value $i_q$of the -th and i-th feature corresponding to the object S. It is assumed that the feature x_i($i \neq i_q$) belongs to the subset of interrelated features – $\mathfrak{R}_q$; x_{iq}- the value of the representative featurex_{i_q} $(x_{i_q} \in \mathfrak{R}_q)$

Consider the problem of constructing threshold rules that characterize a binary estimate of the proximity between an object $S$and a class K_j $(j = \overline{1, l})$. Let the admissible deviation between the object $S$and the class be given $K_j$in the subspace of interrelated features:

$\Delta_q(S) = \left|x_i - F_j\left(\overline{c}, x_{i_q}\right)\right|$.

Then the threshold rule can be given as

$$\theta_q(K_j, S) = \begin{cases} 1, & \text{if } \Delta_q(S) \leq \delta_q; \\ -1, & \text{if } \Delta_q(S) > \delta_q, \end{cases}$$

where $\delta_q$is the threshold rule parameter$\theta_q(K_j, S)$ $\left(q = \overline{1, n''}\right)$.

The algorithm for determining δ_q-thresholds consists of the following actions (similarly in [13]).

Step 1 . The difference between a certain dependence $F_j(\overline{c}, x_i)$in a set of strongly related features$\mathcal{T}_q$ $(q = \overline{1, n'})$and the value of the featurex_i denote by

$\Delta_{jq}(S_u) = \left|x_{ui} - F_j\left(\overline{c}, x_{i_q}\right)\right|$, (3)

where , $u = \overline{1, m}$; $j = \overline{1, l}$.

Step 2 . Let's sum the elements of each object.

$$\mathcal{D}_j = \sum_{S_u \in \widetilde{K}_j} \Delta_{jq}(S_u).$$

$$\mathfrak{R}_j = \sum_{S_u \in C\widetilde{K}_j} \Delta_{jq}(S_u)$$

Step *3* Dividing $\mathcal{D}_j$and$\mathfrak{R}_j$ by the number of objects on the training sample, we get the value $\delta_q$of the -threshold for the q -th subset of strongly connected features $\mathcal{T}_q$:

$$\delta_q = \frac{\mathcal{D}_j}{\left|\widetilde{K}_j\right|} + h,$$

where $h = \frac{\left(\frac{\mathfrak{R}_j}{C\widetilde{K}_j} - \frac{\mathcal{D}_j}{\widetilde{K}_j}\right)}{2}$.

***6. Determination procedure generalized threshold rule characterizing the proximity between an object* S *and a class* $\mathbf{K_j}$ ($\mathbf{j = \overline{1, l}}$).** Using this procedure, the parameters of the generalized threshold rule are determined, which characterizes the binary measure of the proximity of an object $S$to the class K_j. In this case, the generalized threshold rule is given as a linear polynomial in the threshold rules:

$$T(K_j, S) = \begin{cases} 1, & \text{if } t(K_j, S) \leq \varepsilon; \\ -1, & \text{if } t(K_j, S) > \varepsilon, \end{cases}$$

Here $t(K_j, S)$it is given as a linear polynomial from the threshold rules:

$$t(K_j, S) = \sum_{q=1}^{n''} g_q \theta_q(K_j, S),$$

where g_q is the parameter of the generalized threshold rule $\left(q = \overline{1, n''}\right)$. The combination of these parameters forms a vector $\overline{g} = (g_1, \ldots, g_q, \ldots, g_{n''})$.

The task is to determine the values unknown parameters $\{g_q : q = \overline{1, n''}\}$ according to the given sets of objects $\widetilde{S}^m$.

For this problem, we introduce a functional that characterizes the importance of $\theta_q(K_j, S)$:

$$R(\overline{g}) = \sum_{q=1}^{n''} g_q \mathfrak{R}_q^1 / \sum_{q=1}^{n''} \}_q \mathfrak{R}_q^2$$

$$\mathfrak{R}_q^1 = \sum_{j=1}^{l} \left(\frac{1}{m_j} \sum_{S \in \widetilde{K}_j} \theta_q(K_j, S) \right),$$

$$\mathfrak{R}_q^2 = \sum_{j=1}^{l} \left(\frac{1}{m - m_j} \sum_{S \in C\widetilde{K}_j} \theta_q(K_j, S) \right).$$

Without loss of generality, we introduce restrictions on the coefficients $(g_1, \ldots, g_q, \ldots, g_(n''))$, in the form

$$\sum_{q=1}^{n''} g_q = 1.$$

Taking into account the introduced restrictions on the components of the vector, we can formulate the problem of determining $\overline{g}$ as follows

$$\overline{g} = \arg \min_{S_u \in \widetilde{S}^m} R(\overline{g}).$$

To find the values of the vector, $\overline{g}$ we construct a Lagrange function of the form:

$$L\left(\overline{\}}, \lambda\right) = \sum_{q=1}^{n''} g_q \mathfrak{R}_q^1 / \sum_{q=1}^{n''} g_q \mathfrak{R}_q^2 - \lambda \left(\sum_{q=1}^{n''} g_q - 1 \right), \quad (9)$$

where λ is the Lagrange multiplier.

We differentiate (9) with respect to $g_i \quad (i = 1, n'')$ and, equating to zero, we obtain the system of the equation

$$\frac{\partial L}{\partial g_i} = \frac{\left(\mathfrak{R}_i^1 - \mathfrak{R}_i^2\right)}{\left(\sum_{i=1}^{n''} g_i \mathfrak{R}_i^2\right)^2} + \lambda g_i. \quad (10)$$

Summing (10) over each derivative of g_i, we find the value λ

$$\lambda = \frac{\sum_{i=1}^{n''} \left(\mathfrak{R}_i^1 - \mathfrak{R}_i^2\right)}{\left(\sum_{i=1}^{n''} g_i \mathfrak{R}_i^2\right)^2}.$$

Substituting λinto (10), we calculate the value $g_i \, (i = \overline{1, n''})$:

$$g_i = \frac{\left(\mathfrak{R}_i^1 - \mathfrak{R}_i^2\right)}{\sum_{i=1}^{n''} \left(\mathfrak{R}_i^1 - \mathfrak{R}_i^2\right)}.$$

By repeating the calculation process for all linear polynomials from the threshold rules, a generalized threshold rule is determined. Note that the parameter $\varepsilon$is defined as a parameter $\mathfrak{t}_q$.

Thus, using the proposed procedures, the values of all parameters of the considered family of recognizing operators are determined.

The following is a description of the experimental studies performed.

IV. Experiments

An experimental study of the performance of the proposed approach in constructing recognition operators was carried out using the example of solving a number of problems, in particular the model problem, the problem of identifying a person based on the geometric features of a photograph, and the problem of diagnosing cotton diseases using leaf images. The following recognition operators were selected as test recognition operators: classical recognition operators of the type of potential functions (B_1) [15], a model of recognition operators based on the calculation of estimates (B_2) [36], and a model of recognition operators based on threshold rules built on the basis of models of interconnectedness of features. In conditions of interconnectedness of features (B_3) [8] (uchirish kerak) . Note that the procedures for determining the values of unknown parameters proposed in this work were used in the construction of an extremal recognition operator within the framework of B_3.

A comparative analysis of recognition operators B_1, B_2 and B_3 when solving the problem considered, was carried out according to the following characteristics: the proportion of correctly recognized objects during the learning process; time spent in the learning process; the proportion of correctly recognized objects during the control process; time spent in the control process. To calculate the specified criteria when solving the problem under consideration, in order to exclude successful (or unsuccessful) splitting of the original sample $\mathfrak{V}$ into two parts $\mathfrak{V}_o$ and $\mathfrak{V}_k$ ($\mathfrak{V} = \mathfrak{V}_o \cup \mathfrak{V}_k, \mathfrak{V}_o$ - sample for training, $\mathfrak{V}_k$- sample for control), the sliding control method is used [5, 37]. After completing the sliding control procedure, all of the listed characteristics were determined as averages for each recognition algorithm.

4.1. Model problem. The initial data of recognized objects for the model task are generated in the space of dependent features. The number of classes in this experiment is two. The volume of the initial sample is 1000 implementations (500 implementations for objects of each class). The number of features in the model example is 200. The number of subsets of interrelated features is 5.

4.2.Problems of diagnostics of cotton diseases. The initial data used in the task of diagnosing cotton diseases using leaf images consists of 200 images. The number of classes in this experiment is two:

1) images of cotton leaves suffering from wilt (K_1); 2) images of cotton leaves that are not affected by wilt (K_2). In this case, the number of images in each class is the same: $|\tilde{K}_1| = |\tilde{K}_2| = 100$.

To identify features characterizing the phytosanitary state of cotton from the original image of leaves , the algorithm described in [38] was used .

V. Results

As noted earlier, all problems were solved using recognition operators B_1, B_2 and B_3. The proportion of correctly recognized objects during the learning process (see formula 3 in Section 3) for the model task and the task of diagnosing cotton diseases is shown in Table. 1.

TABLE I
PROPORTION OF CORRECTLY RECOGNIZED OBJECTS DURING THE TRAINING PROCESS FOR THE MODEL TASK AND DIAGNOSTIC TASK

Family RA	Time, s	Recognition accuracy, %
Model problem		
B_1	7.475	96.4
B_2	9.436	95.6
B_3	14.317	94.1
Diagnostic tasks		
B_1	6.985	93.5
B_2	7.029	94.1
B_3	12.979	92.9

The results of solving the problems under consideration using B_1, B_2 and B_3 during the control process are shown in Table. 2.

TABLE II
PROPORTION OF CORRECTLY RECOGNIZED OBJECTS DURING THE CONTROL PROCESS FOR THE MODEL TASK AND THE DIAGNOSTIC TASK

Family RA	Time, s	Recognition accuracy, %
Model problem		
B_1	0.058	78.83
B_2	0.050	82.79
B_3	0.007	93.08
Diagnostic tasks		
B_1	0.048	77.13
B_2	0.041	80.9
B_3	0.005	89.2

A comparison of these results shows (see Table 1 and Table 2) that recognition operators B_3 made it possible to increase the accuracy of recognition of objects described in the space of interrelated features (more than 6-10 % higher than by B_1 and B_2).

VI. Discussion

The developed procedures are aimed at determining unknown parameters within the framework of recognition operators, which differ from traditional recognition operators B_1 in B_2 that they are based on B_3 an assessment of the interconnectedness of features. Therefore, it is advisable to use these procedures in cases where there is a certain dependence between the characteristics. In this case, it is required that this dependence differ in the interconnectedness of features for objects of each class. This allows you to describe objects of each class with an individual model. If the dependence between the features is weak, then classical recognition operators can be used (for example, those given in [1, 3, 12, 15, 21, 29]). Therefore, the recognition operators discussed in this work are not an alternative to existing recognition operators such as B_1 and B_2, but only complement them. Then , when there is a sufficiently strong dependence between the features for all objects of the same class, then in the process of selecting representative features, the information characterizing the same information is discarded, which ensures the selection of features. The results of an experimental study to assess the performance of the above recognition operators show that the considered recognition operators make it possible to solve the problem of pattern recognition more accurately in conditions of interconnectedness of features. This circumstance is due to the fact that these operators, when recognizing an object, use only preferred models of interconnectedness, which led to an increase in the speed of object recognition. Therefore, these recognition operators can be used in the development of recognition systems operating in real conditions. At the same time, we note that the time spent in the learning process has increased. This circumstance is due to the fact that in the process of constructing an optimal recognition operator, it is necessary to optimize a larger number of parameters than when using the traditional model of recognition operators.

VII. Conclusion

Based on the conducted research, the following main results can be formulated. A method has been developed for constructing an extremal algorithm within the framework of a family of recognition operators focused on solving the problem of pattern recognition in conditions of interconnectedness of features. The main idea of the proposed method is the sequential use of various procedures for calculating parameter values. In this case, at each stage the value of each parameter is determined sequentially. The learning process continues until the proportion of erroneously recognized objects is less than a specified threshold or a specified number of iterations has been completed. Experimental studies in solving a number of problems have shown that the considered method of calculating parameters expands the scope of application of recognition algorithms and improves recognition accuracy in conditions of interconnectedness of features. This family of recognition operators significantly reduces the amount of computational operations when recognizing an object and can be used to create various software systems aimed at solving problems of classifying objects described with high-dimensional features.

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Wireless Signal Modulation Recognition Using 1DCNN with LSTM

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***Abstract*— Recognition and classification of modulation of communication signals, it is very important to distribute the electromagnetic spectrum among citizens, government, and military to increase spectrum efficiency and solve the shortage problem. In recent years, wireless signal modulation recognition issues have become one of the most researched topics in the world. Over the years, it has been offering new modern solutions by applying artificial intelligence to wireless signal modulation recognition. In this paper, we propose deep neural networks for the task of signal modulation recognition in the wireless networks. It is used 11 kinds of communication signals with Gaussian white noise are generated from RML2016 dataset, such as MASK, MPSK, MFSK, OFDM, 16QAM, AM and FM. Additionally, a hybrid deep neural network is introduced to identify various modulation types from the representational data by combining the desirable traits of a convolutional neural network (CNN) and an LSTM network.**

Keywords— Modulation, LSTM, 1DCNN, CNN, SNR, RML2016

I. INTRODUCTION

Thanks to the latest technological developments, artificial intelligence is becoming an integral part of our lives. With the rapid growth of wireless technology in recent years, the number of modulation methods and parameters used in wireless systems is growing rapidly. The problem of precise recognition of modulation methods is therefore becoming more difficult. During the past decades, there has been a lot of interest in the development of effective and more comprehensive methods for wireless signal modulation recognition.

Research on wireless signal modulation recognition includes artificial intelligence-based methods and algorithms. It is developed a novel and efficient SCRNN architecture for automatic modulation classification (AMC) in [1]. Using discrete transforms and mel-frequency cepstral coefficients (MFCCs), [2] proposes an ADMR algorithm for orthogonal frequency division multiplexing and multi-carrier code division multiple access systems. The discrete cosine, discrete sine, or discrete wavelet transforms with MFCCs are used in the proposed algorithm to extract the modulated signal coefficients, and either a support vector machine (SVM) or an artificial neural network (ANN) is used to classify the modulation. According to the simulation results, the proposed algorithm provides higher recognition rates than those obtained in the previous contributions, in addition to superiority of SVM performance compared to ANN performance at low signal-to-noise ratios. A number of deep learning methods and models are discussed in [3] for the recognition and categorization of modulations in wireless communication signals. The study also showed how convolutional neural networks (CNNs) may be utilised with PlutoSDR and USRP, a CNN, to detect and categorise wireless signals using an in-depth analysis (DL) method. A deep learning algorithm is suggested in [9] to detect the modulation schemes used in a variety of sampled broadcasts. The proposed approach uses a deep neural network consisting of many convolutional filters to distinguish specific features that distinguish different modulation classes. According to the results, the proposed approach [9] is superior to the recently proposed Convolutional, Long Short-Term Memory (LSTM), Deep Neural Network (CLDNN) in terms of overall classification accuracy. In addition, the accuracy of the classification obtained under the proposed approach is higher in terms of the signal-to-noise ratio than in the CLDNN algorithm The viability and efficacy of using deep learning algorithms to automatically identify the modulation type of incoming wireless communication signals from subsampled data is investigated in [10]. The paper described a GNU radio-based data set that employs ten different types of modulation and imitates the flaws of a real wireless channel. Additionally, subsampling methods that further shorten training times and open the door to online classification with high SNR are being researched.

Another interesting study found in [11]. In the study, it is proposed a CNN based robust automatic modulation classification (AMC) method. The study considered 15 different types of modulation, and the proposed method could classify the received signal without directly extracting the characteristics, as well as automatically learn the properties of the received signals. It is outlined to explore the suitable architecture of the deep learning method in the domain of communication signal recognition in [12]. Based on the analysis of the architecture of the convolutional neural network, the real signal data generated by the instrument is used as a dataset, and comparable recognition accuracy of the modulation classification is achieved compared to several representative structures. In order to address frequent issues in wireless communication, a deep convolutional neural network-based automatic signal modulation recognition approach is suggested in [13]. The proposed algorithm automatically outputs different features of the image through a deep convolutional neural network of deep learning, instead of the vast engineering of manual design features to accurately recognize the signal and noise under different signal-to-noise ratios. The suggested employs a GPU for image processing to build a VGGNet that can automatically identify 10 different types of modulated signals in MPSK and MQAM. Convolution neural networks (CNN) and gate rate units (GRU) are used to extract spatial data and temporal features, respectively, in the hybrid parallel structure technique presented in [14]. The Additive Margin softmax function, a cosine similarity measure that may simultaneously expand the inter-class distance and compress the intra-class distance, is used as the output metric. The proposed method can achieve outstanding performance on an open-access dataset, according to the simulation findings. Convolutional Neural Networks and Gated Recurrent Units, or CNN-GRU, are the foundation of a modulation technique developed in [15]. By using deep neural networks to complete the problem of radio modulation recognition, the most recent developments in machine learning are reviewed in [16]. An overview of signal recognition techniques is given in [17]. Convolutional neural networks' ability to adapt to the complex-valued temporal radio signal domain has been investigated in [18]. The effectiveness of classifying radio modulations using expert feature-based approaches against naively learnt features is also contrasted. To handle two difficult and fundamental wireless signal recognition tasks, namely signal classification and modulation, [19] suggested a multi-task learning architecture.

Overall, the overview of the previous contribution mentioned above on signal modulation recognition are based on Deep Learning solutions. Our proposed 1DCNN-LSTM network is designed to provide an alternative to fast automated modulation classification. As for the learning techniques, we design the architecture by merging CNN with LSTM. In the architecture, CNN is adopted to extract the spatial features of the signal data, while the LSTM is used to learn the sequential dependence in the time-series radio signals.

II. DATABASE AND 1DCNN-LSTM NETWORK

A. Database

The RadioML2016.10a dataset is a well-known dataset in the fields of machine learning and signal processing, specifically used for studying the classification of radio signals. This dataset contains examples of various digital modulation signals that were captured while in the air using software-defined radios. It was created for the 2016 Radio Machine Learning (RadioML) competition. The dataset is frequently used for tasks including signal categorization, modulation recognition, and the creation of machine learning algorithms.

Following are some of the RadioML2016.10a dataset's salient features:

Signal Formats: Samples from several digital modulation techniques, such as AM-DSB, AM-SSB, BPSK, CPFSK, GFSK, PAM4, QAM16, QAM64, QPSK, WBFM, and 8PSK are included in the dataset.

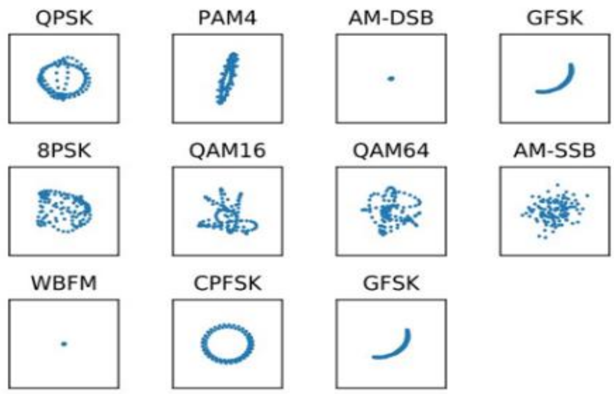

Fig. 1. Illustrative Samples from the RML2016.10a Dataset

Modulation Parameters: Different types of modulation use different modulation parameters, such as symbol rate, carrier frequency, and signal-to-noise ratio (SNR). This gives testers of categorization systems a wide variety of scenarios to choose from.

Data Format: MATLAB format (.mat files) is generally used to distribute the dataset. Information regarding modulation parameters, SNR, and IQ samples (In-phase and Quadrature components) can be found in each file, which corresponds to a particular type of modulation.

Labeling: The dataset labels each sample with the appropriate modulation type. These labels serve as the basis for assessing the effectiveness of algorithms, making them crucial for tasks involving categorization.

Usage: This dataset is frequently used by experts in the field of wireless communication to develop and evaluate algorithms for signal categorization, modulation recognition, and other machine learning tasks. The dataset is used as a standard for assessing how well various strategies work.

Challenges: The goal of the RadioML challenge was to inspire participants to create precise classification algorithms that can tell apart between different types of modulation, particularly in difficult situations with changing SNRs. This feature of the problem drove academics to develop reliable and flexible algorithms.

TABLE I. KEY DETAILS OF RADIOML2016.10A DATASET

Dataset	RadioML2016.10a
Modulations	8 Digital Modulations: BPSK, QPSK, 8PSK, 16QAM, 64QAM, BFSK, CPFSK, and PAM4 3 Analog Modulations: WBFM, AM-SSB, and AM-DSB
Length per sample	128
Signal format	In-phase and quadrature (IQ)
Duration	per sample 128 µs
Sampling frequency	1 MHz
Samples per symbol	8
SNR Range	[-20 dB, -18 dB, -16 dB, . . ., 18 dB]
Total number of samples	220000 vectors

B. Network structure

The strategy we employed for this study project involves a hybrid model consisting of eight layers. It was constructed with great care to ensure its architecture is effective. As shown in Figure 2, these layers include the crucial input and output layers and are supplemented by a trio of 1DConv layers, two

LSTM layers, and one dense layer using the softmax activation function.

The inclusion of the 1DConv layer, a crucial element responsible for data extraction and feature augmentation, lays the groundwork for our network design. A triplet of 1D convolutional layers with 9x1 filters are selectively used within this layer. These filters' use, along with the rectified linear activation function (ReLU), helps to reveal complex structures and patterns in the input data. With this method, localised features can be recognised and captured by the following layers, speeding up the learning process.

The information is then effortlessly channelled into the pair of Long Short-Term Memory (LSTM) layers, which serve as the cognitive hub of our architecture, after having through this convolutional layer processing. Recurrent neural networks (RNNs) use LSTM units as memory reservoirs because of their prowess at handling sequential data. An important feature of LSTM units is that they incorporate a forget gate mechanism, which allows them to acquire and preserve long-range dependencies. This ability is crucial in jobs involving sequential learning, such as voice and handwriting recognition.

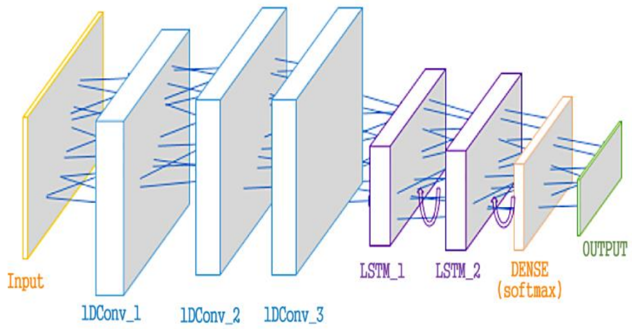

Fig. 2. Architecture of proposed 1DCNN-LSTM model.

The hyperbolic tangent (tanh), the preferred activation function for LSTM units, endows these layers with the ability to produce a complex tapestry of 64 feature maps. These maps are prepared for additional processing and refinement, which will aid in the classification and decision-making processes that follow.

The 'Dense layer,' the supreme judge of classification judgements, is located at the pinnacle of our architectural hierarchy. Here, the softmax activation function assumes a prominent role, expertly directing the categorization procedure. The crucial duty of classifying input signal samples into an array of 11 different modulation types is carried out by this last layer.

Our hybrid model is comprised of a carefully planned series of layers. Each layer has a specific function that contributes towards the ultimate goal of categorizing types of modulation. Our model is capable of identifying intricate patterns, extracting significant characteristics, and eventually making well-informed conclusions in the area of modulation type classification because to the skillful interaction of convolutional, LSTM, and dense layers.

III. Experimental Results

Our study showcases the performance evaluation of our modulation recognition model in Figure 3, which uses varying numbers of filters, namely 32, 64, and 128.. It's interesting to note that the results show that the overall recognition accuracy is highest when using a configuration of 32 filters, especially when the Signal-to-Noise Ratio (SNR) exceeds -4 dB. It is interesting to observe that as we approach an architecture with 128 filters, the model's effectiveness decreases. We relate this to the problem of overfitting, in which the model gets too tailored to the training data. The analysis highlights the fact that 32 filters seem to be the best option for maximising the performance of our suggested model.

As we delve deeper into the study, we see that Table II is crucial in providing a thorough overview of modulation recognition accuracy across different models. These models include the CNN + LSTM setup with an 83% attained accuracy as reported by [17]. Similar to this, [20]'s CNN + LSTM architecture exhibits a high accuracy of 87%. The CNN + Capsule Network model, which is a different strategy, displays a recognition accuracy of 76%.

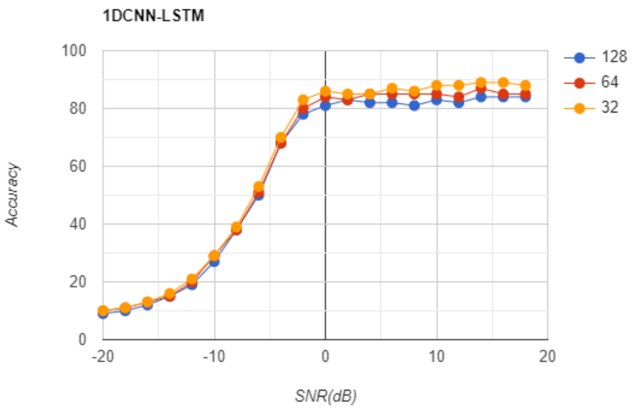

Fig. 3. Proposed model's accuracy for modulation recognition with varying filter counts.

TABLE II. Comparative Modulation Recognition Accuracy of Different Models

Model	Accuracy
CNN + LSTM [17]	83%
CNN + LSTM [20]	87%
CNN + Cap. Net [21]	76%
Proposed 1DCNN + LSTM	89%

Contrastingly, the focus of this study, our novel 1DCNN+LSTM model, stands out as a star performer with an amazing accuracy of 89%. This result demonstrates the effectiveness of our suggested model and supports its superiority to current methodologies. The combination of the Long Short-Term Memory (LSTM) structure and the 1D Convolutional Neural Network (1DCNN) has resulted in a strong collaboration that not only outperforms previous techniques, but also achieves a remarkably high level of accuracy.

To sum up, Table II provides a helpful comparison and Figure 3 presents a clear visual representation that showcase the remarkable capabilities of our recommended 1DCNN + LSTM model in recognizing modulation. The evidence further supports the idea that the careful choice of 32 filters promotes an ideal equilibrium between performance and the risk of over-fitting, bolstering the model's reputation as a leading-edge solution in this field.

IV. Conclusion

In this work, we proposed a hybrid model for the task of signal modulation recognition in the wireless networks. It is used 11 kinds of communication signals from RML2016 dataset. We used 1D Convolutional layers and LSTM layers. 1D Conv and LSTM are efficient in learning long-term dependencies in time series data processing tasks. So, the proposed model can not only extract the spatial features of the signals but also learn the sequential dependence in the time-series signals effectively. The numerical results show that our introduced model outperforms the previously proposed CNN or LSTM approaches in terms of overall classification accuracy and maximum accuracy achieved at the highest SNR level.

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Development of an automated information system for the automation of activities related to digital goods

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***Abstract*—This article discusses the development of an automated information system to improve and increase the efficiency of managing the processes of selling games and programs. This is achieved by automating the process of submitting requests, monitoring the quality and quantity of solutions for such requests. The system is designed to provide access to the list of games or programs provided, its timely updating and optimization; generation of all types of reports; providing the heads of departments of the enterprise with a tool that automates most of the routine work on the registration of the results of the activities of departments and related documents.**

***Keywords*—automated information system, games, digital goods, automation process.**

I. Introduction

Currently, one of the most developed and numerous fields of activity in the field of creation and promotion of entertainment content as in Russia, and around the world, is the sphere of development and subsequent distribution of software (software). In particular, computer games. Every year it becomes more and more independent developers and companies involved in the creation of new games. It becomes obvious that with an increase in their number, the level of internal competition also increases. In order to fixate on leadership the management of these enterprises needs to find non-standard solutions and try new modern approaches to the promotion of their activities [1-3].

The success of the activities of enterprises engaged in software development directly depends on the chosen method of promotion and implementation of their developments. As a rule, modern enterprises choose to conclude an agreement with third-party firms that do not have software of their own development, but are engaged in exclusively by bringing the developments of various individual specialists and companies in general to the end user of their products [4-6].

The problem with this choice lies in the fact that appeals to the services of such enterprises in any case incur certain material losses for the customer company. It is often difficult to predict in advance whether the distribution costs of the developed software will be recouped by the end user demand. Among other things, a situation may arise that such an enterprise may be approached two developers with software of a similar purpose. In this case, developers cannot be sure of the quality of the promotion services provided. Also, in such situations, it is impossible to completely exclude the factor of corruption [7-9].

As a solution to the problem formulated and described above, the majority of enterprises whose activities are focused on the creation of any software (in particular computer games) are proposed to develop automated software distribution system of its own design. In addition to its own software, the system will allow implementation and third-party software. The relevance of the development is associated with an increase in the interest of modern youth in the computer games industry and, accordingly, an increase in the volume of purchased and/or installed software. In this regard, the customer company has expanded its staff, as a result of which the number of software developed by the company has increased. This made it cost-effective to create your own distribution platform, including your own developments [10-13].

Currently, there are no companies on the market, at the same time engaged in the development and distribution of computer games and programs, which means there is no competition. The implementation of the automated system proposed for development will make it possible to assemble products of the most famous manufacturers of various software on one site, as well as provide a stable source of distribution of software developed by the customer company [14-17].

In addition to the above, the automated system proposed for development will allow the company to strengthen its position as a market leader by increasing its fame as the creator of one of the largest sites software implementation and at the same time the creator of a number of programs and computer games a wide range of uses [18-20].

II. Application Structure

A. System Requirements

The AC should be developed in the form of a website based on a three-level architecture. A three - level system means a system of the form:

- client layer

- logic layer
- data layer

A graphical representation of this hardware architecture of the system is presented below in Figure 1.

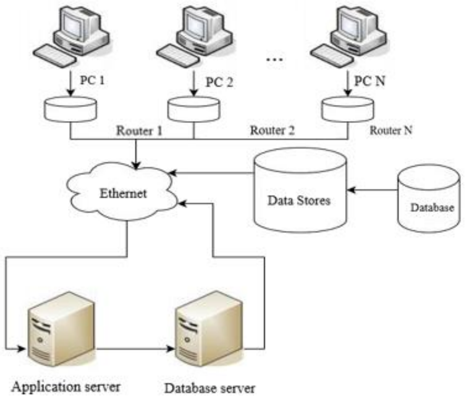

Fig. 1. System architecture

The AS should be implemented using PostgreSQL technology in the form of two subsystems. The architecture of the system (software) is shown in Figure 2.

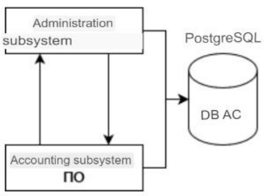

Fig. 2. AIS architecture

The request accounting subsystem is designed to enter registration data about users and downloadable software, as well as information about software translations and implemented promotion tools inside the site. When implementing this subsystem, it is necessary to differentiate access to system functions in accordance with the established levels of data access.

The administration subsystem is designed to register users of the system and assign them rights rights.

B. Functional requirements

The AIS shall implement the functions shown in 3 below.

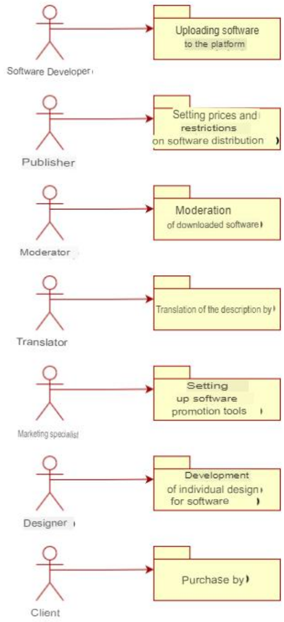

Fig. 3. AIS utilization options

Descriptions of use cases:

1. The developer uploads ready-to-download versions of the developed software to the platform, compatible with various operating systems. It is also possible to fill out a form with a description of the required technical characteristics of the device on which the software will be installed and a description of the downloaded software itself.

2. The developer has provided the final assembly for installation by the user for all operating systems on which the software is planned to be used.

3. The user selects a menu item to upload new software to the platform (the name and form are at the discretion of the system user interface designer), the system launches a form to fill in the characteristics and description of the software. The form should allow you to determine the operating systems with which the software is compatible, the required amount of free memory on the device's hard disk, the amount of RAM, as well as the required characteristics of the video card and processor. In addition, the languages that are available for selection inside the software are set, as well as genres, software rating and name.

4. The software publisher determines software prices depending on the buyer's region, as well as restrictions on its distribution: unavailability in some regions and/or for certain age categories.

5. The user goes to the price settings and restrictions page of the downloaded software and by clicking on the "Add" button, the system opens a form where it is possible to add a price for a specific region (drop-down lists / text fields are at the discretion of the system user interface designer), similarly, the currency in which the customer will pay for the purchase is selected. It is also

possible to select regions and/or age categories for which the software will not be available to purchase (drop-down lists / text fields at the discretion of the designer user interface of the system).

6. The user goes to the software moderation page and marks warnings from the list of standard content descriptors (drop–down lists/checklist at the discretion of the system user interface designer). Next, the user uses the "Passed" / "Not passed" buttons to determine, respectively, the fact of passing moderation / rejection of software for distribution. In the latter case, the user fills in the form where the text field / checklist (at your discretion of the system user interface designer) indicates the reason deviations – non–compliance with the stated rating (indicating conflicting warnings from the list of standard content descriptors) and/or the presence of elements prohibited by the current legislation of the regions where the software will be available for purchase.

III. Results

At the initial stage of system development, during the analysis of the subject area, the following main problem of modern enterprises operating in the field of software development was identified: the lack of their own platform for distribution of their development software increases the risks of material losses due to access to third-party services. As a solution to the problem formulated and described above the development of a system was chosen that automates part of the processes of the daily activity of the enterprise process between the stages of software development before its purchase by the end user [21-23].

The system interface shall conform to the layout shown in Figure 4-6.

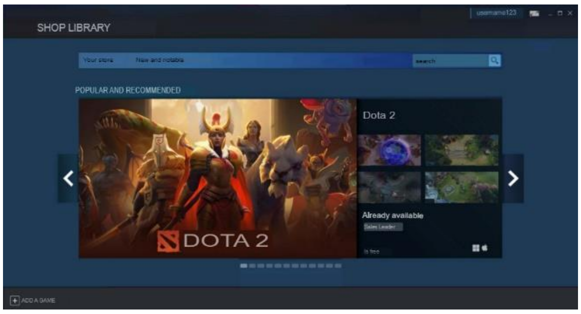

Fig. 4. Layout of the main page interface

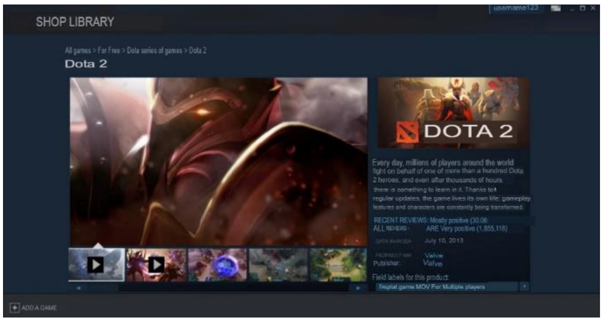

Fig. 5. Layout of the interface of the personal page of the program

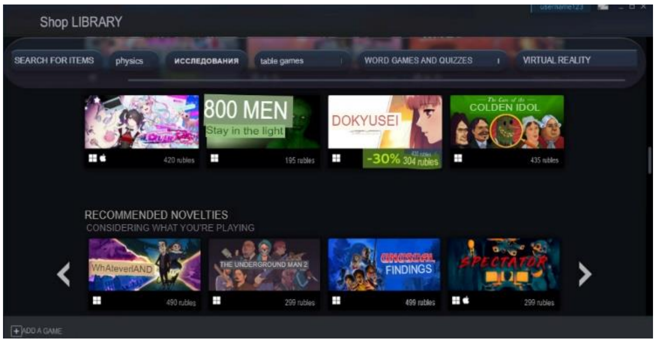

Fig. 6. The layout of the interface of the general page of games of the selected genre

The automated information system will be developed using the algorithm shown in Figure 7 and implemented using the algorithm shown in Figure 8.

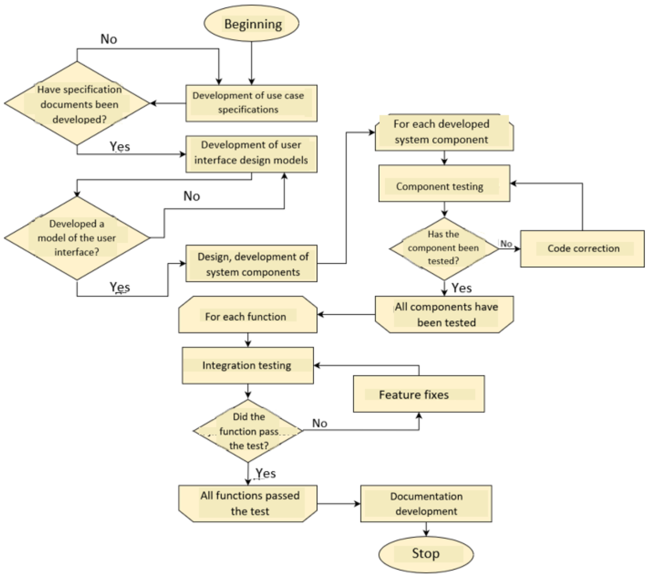

Fig. 7. Algorithm of AIS development

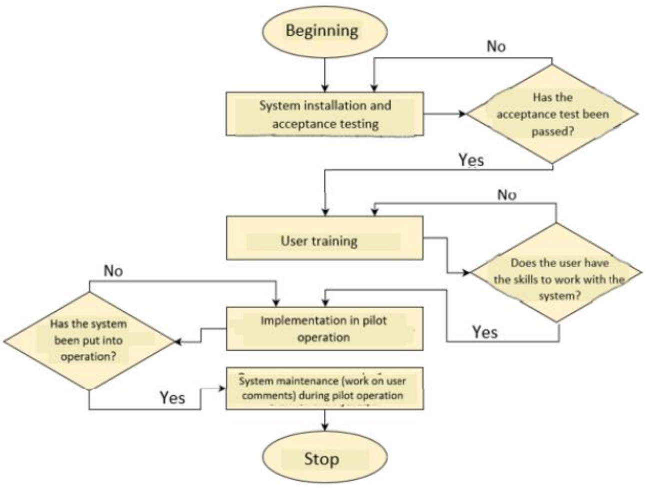

Fig. 8. Algorithm of AIS implementation

IV. Conclusion

At Implementation of the automated system proposed for development allows you to reduce the costs of the enterprise for the implementation of its own software, to identify its target audiences for adapting further releases, as well as to increase the company's profit by providing a distribution platform for other third-party private developers and software development companies [24].

Among other things, the proposed AS will be able to significantly reduce the cost of material and time resources to identify and eliminate factors that hinder the development and improvement of the service by exclusion of third parties (third-party distribution services) from the process of bringing the developed software to the end user [25].

As a result of the development of an automated system, the customer company will be able to increase the volume of services provided, significantly increase the volume of software sales of its own development, analyze the current audience for adapting software being developed in the future, which in turn will help increase the volume of final profit.

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ADVANCES IN POSE ESTIMATION: TECHNIQUES, APPLICATIONS, AND CHALLENGES ACROSS DOMAINS

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***Abstract*— Pose estimation, the process of deducing the spatial orientation of objects or individuals is a vital component of various domains and augmented reality. This paper aims to provide a comprehensive review of the advancements in pose estimation techniques, their diverse applications, and the manifold challenges across multiple domains. The increasing demand for pose estimation in fields such as healthcare, sports, robotics, and computer vision has led to the development of various methods and techniques. We discuss an array of techniques including geometric methods, learning-based methods, and hybrid techniques. A comparative analysis of these techniques is conducted to assess their performance in various scenarios. The results reveal a range of benefits and drawbacks associated with each method, providing valuable insight for future research directions. The findings reveal that deep learning-based techniques have substantially improved the performance of pose estimation, particularly in real-time applications, despite the challenges of occlusions and variations in human poses. Finally, we conclude by identifying key challenges and potential solutions in the field of pose estimation.**

Keywords— Pose Estimation, Computer Vision, Robotics, Augmented Reality, Deep Learning, Challenges.

I. INTRODUCTION

Pose estimation, the task of determining the position and orientation of an object or person, has applications ranging from human-computer interaction to autonomous driving and virtual reality [1]. Pose estimation is a fundamental task in many fields including computer vision, robotics, sports, and healthcare. It involves determining the position and orientation of an object or a person in an image or a sequence of images. Over the years, significant advancements have been made in this field, resulting in a wide variety of techniques with numerous applications. However, pose estimation is a complex problem that presents several challenges, particularly due to variations in lighting conditions, occlusions, and the diversity of poses.

This paper aims to provide a comprehensive review and analysis of the advances in pose estimation, discussing various techniques, their applications, and the challenges faced. Through this comprehensive review, we aim to provide valuable insights for researchers and practitioners in the field of pose estimation. Pose estimation techniques can be broadly categorized into geometric methods, learning-based methods, and hybrid techniques. Geometric methods are traditional techniques that rely on mathematical and geometric principles. Learning-based methods, on the other hand, leverage machine learning algorithms for pose estimation. Hybrid techniques combine the benefits of both geometric and learning-based methods.

Geometric methods, such as Direct Linear Transform (DLT), solve the pose estimation problem mathematically. DLT, for instance, estimates the pose by solving a system of linear equations derived from the correspondences between 2D image points and 3D object points.

Learning-based methods, including Convolutional Neural Networks (CNNs) [2] and Recurrent Neural Networks (RNNs), leverage machine learning algorithms for pose estimation. These methods often provide more accurate results than geometric methods, especially in complex scenarios.

Hybrid techniques combine geometric and learning-based methods to exploit the benefits of both approaches. These methods typically use geometric methods for initial pose estimation and then refine the results using learning-based techniques [3].

II. ADVANCEMENTS IN POSE ESTIMATION TECHNIQUES

Pose estimation techniques can be broadly classified into traditional methods and deep learning methods [4]. Each category has its unique characteristics, advantages, and disadvantages.

A. *Traditional Methods*

Traditional pose estimation techniques mainly revolve around model-based or feature-based methods. These methods typically involve the extraction of feature points, followed by the application of geometric transformation models to estimate the pose. Notable examples include Pictorial Structures and Active Appearance Models [5].

Pictorial Structures are a type of graphical model that represents objects as a collection of parts arranged in a deformable configuration. The parts are localized in the image using a discriminatively trained part detector, and the spatial configuration of the parts is modeled using a tree-structured graphical model [6].

Active Appearance Models (AAMs) are used to match a statistical model of the appearance of an object to a new image. The model is learned from a training set of labeled images, capturing both shape and appearance variations [7].

B. *Deep Learning Methods*

The advent of deep learning has significantly improved the performance of pose estimation techniques. Convolutional Neural Networks (CNNs), such as OpenPose, PoseNet, and AlphaPose, have demonstrated robustness to variations in poses and appearances, making them highly effective [8].

OpenPose is a real-time system for multi-person 2D pose estimation based on CNNs. It uses a novel Part Affinity Fields (PAFs) approach to indicate the degree of association between body parts. This method is robust to occlusions and can handle an arbitrary number of people in an image [8].

PoseNet is a vision model that can be used to estimate a person's pose in real-time. It operates by detecting 17 key points of interest along the body. The model is efficient and works in real-time, making it suitable for mobile devices [9].

AlphaPose is a method for multi-person pose estimation that uses a Region Proposal Network (RPN) to extract features from an image and then applies a Pose Residual Network (PRN) to refine the estimated poses. It can handle crowded scenes and provides high-fidelity pose information [10]. Here’s a comparison table of traditional and deep learning pose estimation methods:

TABLE I. COMPARISON OF TRADITIONAL AND DEEP LEARNING POSE ESTIMATION METHODS

Method	Use Case	Advantages	Disadvantages
Pictorial Structures	Object pose estimation in images	Simple and interpretable model, moderate performance	Struggles with complex poses and occlusions
Active Appearanc e Models	Human face pose estimation in images	Can model both shape and appearance variations	Requires careful initialization and tuning
OpenPose	Real-time multi-person 2D pose estimation	Robust to occlusions, can handle an arbitrary number of people	Requires substantial computational resources
PoseNet	Real-time single-person 2D pose estimation on mobile devices	Efficient, works in real-time, suitable for mobile devices	Less accurate than some other methods
AlphaPose	Multi-person pose estimation	Can handle crowded scenes, provides high-fidelity pose information	Complex architecture, requires large datasets

III. Applications Across Domains

Pose estimation is a computer vision task that aims to detect the orientation or position of an object or a specific part of an object in an image or video. It has a wide range of applications in computer vision, robotics, and augmented reality (AR). Here we delve into the applications of pose estimation in these fields, along with the benefits and drawbacks:

A. *Computer Vision*

In the field of computer vision, pose estimation plays a crucial role in understanding the spatial arrangement and orientation of objects in a scene. It's used in:

- Surveillance systems: Pose estimation helps in identifying abnormal behaviors, tracking individuals, and recognizing actions in surveillance videos.
- Gesture recognition: Pose estimation assists in detecting and recognizing human gestures, enabling more natural human-computer interaction.
- Healthcare applications: In medical imaging, pose estimation can help in identifying the position and orientation of anatomical structures, assisting in diagnosis and treatment planning [11].

B. *Robotics*

Robots use pose estimation for navigation, manipulation, and interaction with their environment [12]:

- Object manipulation: Robots use pose estimation to identify the location and orientation of objects for successful grasping and manipulation.
- Navigation: Autonomous robots and vehicles use pose estimation to understand their position and orientation within their environment, enabling effective navigation [13].

C. *Augmented Reality*

Pose estimation is a key component of AR systems, enabling the fusion of digital content with the real world:

- Interactive gaming: Pose estimation enables the integration of player movements into the game, enhancing the gaming experience.
- Virtual furniture placement: AR apps use pose estimation to virtually place furniture in a room, allowing users to visualize how it would look before making a purchase [14].

TABLE II. COMPARISON OF POSE ESTIMATION APPLICATIONS

Applications	Benefits	Drawbacks
Surveillance systems	Improves security by enabling the tracking of individuals and recognition of abnormal behaviors.	Pose estimation errors can lead to false alarms or missed detections.
Gesture recognition	Enhances human-computer interaction by enabling computers to understand human gestures.	Requires a clear view of the body part performing the gesture, which may not always be available.
Healthcare applications	Assists in medical diagnosis and treatment planning.	Limited by the quality of medical images and the complexity of anatomical structures.
Object manipulation (Robotics)	Enables robots to interact with their environment effectively.	Highly dependent on the accuracy of the pose estimation, which can be affected by lighting conditions and occlusions.
Navigation (Robotics)	Facilitates autonomous navigation in robots and vehicles.	Errors in pose estimation can lead to navigation errors, posing safety risks.
Interactive gaming (AR)	Enhances the gaming experience by integrating player movements into the game.	Requires high processing power and can be affected by lighting conditions and occlusions.
Virtual furniture placement (AR)	Helps users visualize how furniture would look in their space before making a purchase.	The accuracy of the virtual placement depends on the accuracy of the pose estimation, which can be affected by the quality of the camera and the complexity of the environment.

IV. ALGORITHMS OF POSE ESTIMATION

A. Pose Comparison Algorithm

Pose comparison is an important part of pose estimation, allowing the comparison of estimated poses with ground truth data. One common method is using Euclidean distance to measure the difference between corresponding landmark points in two poses.

If we have two poses, $P1$ and $P2$, each with n landmarks, the landmarks of $P1$ are $(x_1[i], y_1[i])$ for i in $[1, n]$, and the landmarks of $P2$ are $(x_2[i], y_2[i])$ for i in $[1, n]$. The Euclidean distance $d[i]$for each landmark i is calculated as:

$$d[i] = \sqrt{((x_1[i] - x_2[i])^2 + (y_1[i] - y_2[i])^2)} \quad (1)$$

The total difference between the two poses can be calculated as the sum of all $d[i]$, or it can be averaged over n.

B. Normalized Landmarks Comparison

Normalization is often applied before comparing landmarks to make the comparison scale invariant. An example of normalization is to translate the pose so that a specific landmark (e.g., the nose in a face pose) is at the origin, and then scale the pose so that the maximum distance from any landmark to the origin is 1.

If we have a pose P with landmarks $(x[i], y[i])$ for i in $[1, n]$, we first calculate the translation as:

$$tx = -x[nose] \quad (2)$$

$$ty = -y[nose] \quad (3)$$

Then apply the translation to all landmarks

$$x[i] = x[i] + tx \quad (4)$$

$$y[i] = y[i] + ty \quad (5)$$

Next, we calculate the scaling factor s as:

$$s = \frac{1}{max}(\sqrt{(x[i]^2 + y[i]^2)} \text{ for } i \text{ in } [1, n]) \quad (6)$$

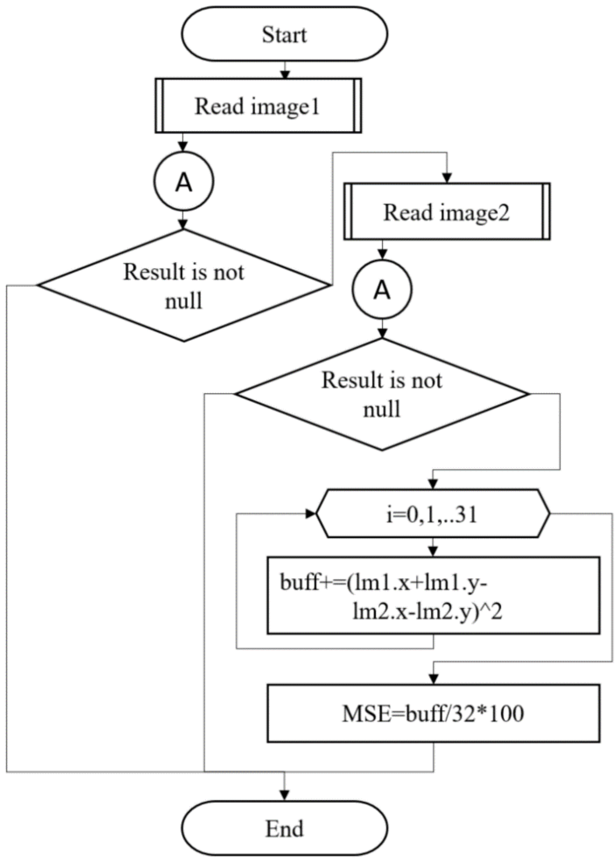
Then apply the scaling to all landmarks:

$$x[i] = x[i] * s \quad (7)$$

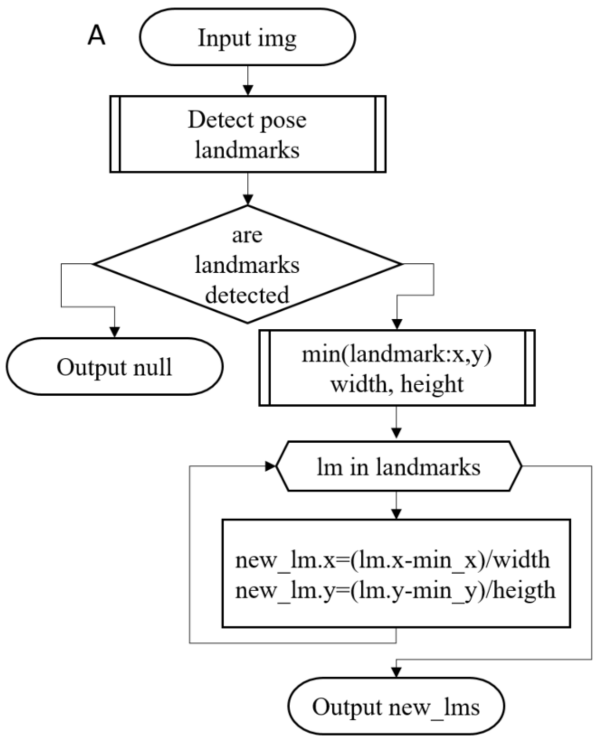
$$y[i] = y[i] * s \quad (8)$$

After these normalization steps, the pose P can be compared with other poses using the Euclidean distance as described in the previous section.

In Figure 1, we proposed the block diagram of the Pose comparison algorithm. As you have seen we calculated and compared different poses of images based on these two diagrams. The main block diagram is a universal diagram which helps to calculate different images and compare results. Also, an additional block diagram of A helps to improve the accuracy of poses in the images.



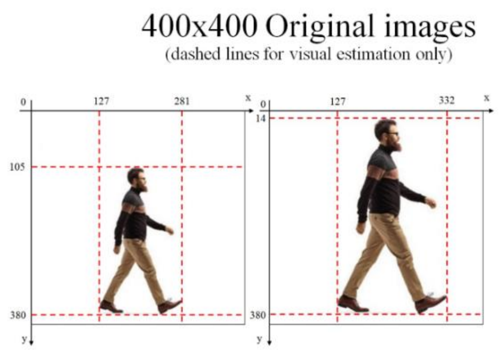
a)



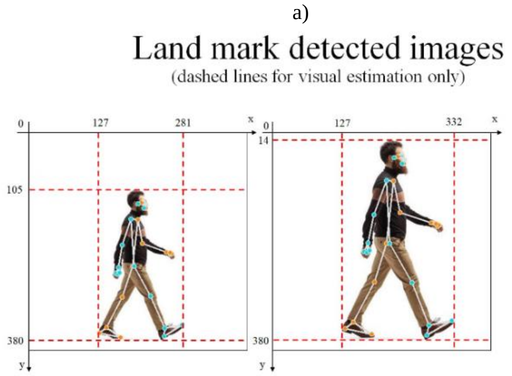
b)

Fig. 1. Block diagrams of Pose comparison algorithm: a) the main block diagram calculation of Pose Estimation; b) additional block diagram for calculation A label.

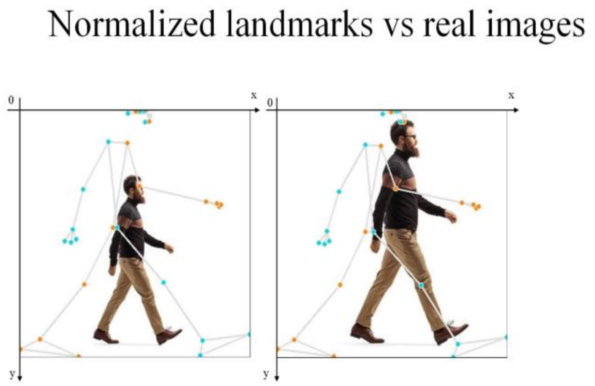
In our research, we calculated Land mark-detected images with normalized landmarks and real images for pose estimation. As you see in Figure 2, we compared two different images, and then calculated Mean Square Error (MSE) based on our block diagram which was described in Figure 1. As a result of our calculation, we took MSE=0.009525% and as a comparison of previous research, we achieved good results in our research of Pose Estimation.



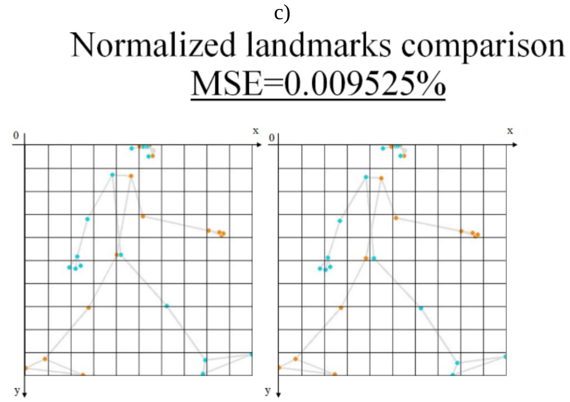
a)



b)



c)



d)

Fig. 2. Normalized landmarks result of Pose estimation: a) 400x400 original image; b) land mark detected images; c) comparison view of normalized landmarks and real images; d) calculation result of MSE for Normalized landmarks.

V. CHALLENGES IN POSE ESTIMATION

In our research, as we have seen while pose estimation has numerous benefits, the accuracy of pose estimation is heavily influenced by factors such as the quality of the images or videos, lighting conditions, occlusions, and the complexity of the objects or scenes. Despite significant advancements, several challenges persist in pose estimation:

- Occlusions: Where a part of the subject is hidden or blocked by another object, pose a significant challenge in accurate pose estimation. In many real-world scenarios, parts of the body may be occluded, making it difficult to predict the positions of hidden joints accurately. This challenge is particularly prevalent in crowded scenes, where multiple individuals may occlude each other [6].
- Variation in Appearance: Pose estimation is also challenged by variations in viewpoint. The appearance of a subject can change drastically when viewed from different angles, which can make it difficult to estimate the pose accurately. This is particularly challenging in 3D pose estimation, where the goal is to estimate the 3D coordinates of the joints, which can be significantly affected by changes in viewpoint [15].
- Lack of Annotated Training Data: The performance of many pose estimation algorithms, particularly those based on deep learning, depends on the availability of large amounts of annotated training

data. However, creating such datasets is a time-consuming and labor-intensive process. The lack of sufficient annotated training data can significantly limit the performance of these algorithms [16].

- Real-time Processing: Real-time pose estimation, where the pose needs to be estimated in real-time as the video is being captured, poses significant challenges in terms of computational resources and processing speed.
- Motion Blur and Image Quality: In video-based pose estimation, motion blur can significantly affect the accuracy of pose estimation. Rapid movements can lead to blurry images, making it difficult to identify the positions of the joints accurately. Similarly, low-quality images or videos, which may have noise or low resolution, can also pose challenges for accurate pose estimation [17].
- Viewpoint Variations: Pose estimation is also challenged by variations in viewpoint. The appearance of a subject can change drastically when viewed from different angles, which can make it difficult to estimate the pose accurately.
- Illumination Changes: Changes in illumination can drastically affect the appearance of a subject, making it challenging to perform accurate pose estimation. Shadows can obscure parts of the body, and strong lighting can lead to overexposed regions, both of which can interfere with the ability to accurately identify body parts and their positions.

Hence, further research and development are required to improve the robustness and accuracy of pose estimation techniques.

VI. Conclusion and discussions

In this paper, we reviewed the methods, applications and challenges of pose estimation and analyzed pose comparison algorithms. The advancements in pose estimation techniques have significantly improved their performance and broadened their applications across various domains. Despite the challenges, such as handling occlusions and variations in appearance the field has shown a positive trajectory of development.

The comparison between traditional and deep learning methods reveals the superiority of the latter in terms of performance and robustness. However, the dependency on large labeled datasets is a significant limitation that future research needs to address.

The applications of pose estimation in computer vision, robotics, and augmented reality highlight its importance in these fields. The ability to accurately deduce the spatial orientation of objects or individuals opens up new possibilities in these domains, contributing to the advancement of technologies like human-computer interaction, autonomous driving, and virtual reality.

Pose estimation plays a critical role in numerous domains. Despite the challenges, the advancements in deep learning have shown immense in improving the accuracy and robustness of pose estimation techniques. As the field continues to evolve, further improvements in these techniques are expected, broadening the range of potential applications.

Future research should focus on addressing the current limitations and exploring innovative ways to leverage pose estimation in various domains. Furthermore, we aim to develop pose estimation technologies in our country, the Republic of Uzbekistan.

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Electronic grade book system

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Abstract *The article describes the structure and processes of a school as an educational institution. It highlights the different phases of schooling, including extracurricular activities, recess, and lessons, which alternate throughout the day. The concept of grades or marks is introduced, where students are assessed using a five-point grading system. The text outlines the periodic assessment of students' performance through final and annual grades, with the possibility of students being held back or moved to a lower grade based on their academic performance. Additionally, the text emphasizes the administrative responsibilities of schools in maintaining records of students' learning outcomes, which can become burdensome for teachers and school administration, especially in larger schools. Overall, the text provides an overview of the educational structure, assessment methods, and administrative challenges within a typical school setting.*

Keywords *automated system, actant, software system architecture, database, use case, software, electronic grade book, school*

I. Introduction

School is an educational institution that enables students to receive compulsory education and general secondary education. Time at school is divided into the following phases: extracurricular activities, recess and lesson. Lesson and recess usually alternate several times. There are four to eight lessons each day at school. In schools there is such a thing as a mark or grade. Grades in schools are given on a five-point system (and have a value from 1 to 5). During schooling, students are given a final grade for the subjects they are studying. Grades are given at the end of each quarter. The annual grade is given at the end of each year. A student may be retained for a second year or transferred to a lower grade if he/she has unsatisfactory annual grades. In the course of work, the educational institution is obliged to keep documents on the final and intermediate results of learning programs. Learning outcomes are reports on students' success in mastering the curriculum for the school year. Depending on the size of the school and the number of students, the number of documents required for the functioning of the school increases rapidly. This puts a heavy burden on teachers and school administration [1,2,3].

II. Relevance of system development

The relevance of the development is related to the increasing workload of teaching staff, the increasing number of children studying, and the introduction of new information technologies. The development of information technologies provides new opportunities for organizing the learning process in a modern school, allowing all participants to interact: school administration, teachers, students and parents. One of the tools of such interaction is the creation and maintenance of electronic school diaries and electronic school journals. The electronic diary is a service that will reduce the load on a general education institution, streamline the process of keeping academic progress logs, and simplify the reporting process for the staff of the educational institution. For teachers, the electronic journal provides an opportunity to place announcements for parents and children, additional information on holidays, contests, Olympiads, and final works in the class news. This will allow all students and their parents to always be aware of events and take an active part in school life. Teachers will be able to edit the electronic journal at the same time. While a paper journal may usually be needed by several teachers at the same time, because of which someone will have to wait to enter the necessary information into the journal, which will slow down the learning process. A paper diary is forgotten, lost, damaged or not filled in at the right moment. To work with an electronic diary, you need only a computer or smartphone with Internet access. No special programs need to be installed. Parents will be able to check their children's grades at any time and contact the teacher in case of any problems. The use of electronic journal and diary allows to unite students, teachers and parents. The program allows the use of new forms of communication and full use of modern information technologies in the educational process. The electronic journal will simplify the learning process for both teachers and students [4,5,6].

III. Purpose and objectives of the establishment

The automated information system is being developed to reduce the load on the general education institution by automating the process of keeping academic progress logs. Providing communication between parents and school, informing parents and children about educational processes related to children [7].

A. The implementation of the electronic logbook system is intended to:

- Providing a way for school staff, parents and students to interact during the learning process.
- Transferring paper documents to an electronic environment.
- Reducing routine work for teachers, reducing the load on teachers during the educational process.
- Reducing the time required to prepare reports related to summarizing learning outcomes.

B. ELL allows solving the following tasks:

- Store student grades in an electronic environment.
- Provide an interface for interaction between school staff, parents and students.
- Provide an interface for viewing schedules of the educational process.
- Generate reports on the results of the educational process.
- Reduce the number of errors that occur when drawing up documents.

C. ELJ is used:

- By teachers to keep a log of students' progress, to compile reports on students' interim progress.
- By class teachers for transmitting organizational information to pupils and their parents, for compiling reports on pupils' interim progress.
- By deputy director for transmitting organizational information to pupils and their parents, for compiling reports on pupils' final progress, for posting schedules of educational events.
- By the headmaster to monitor and check reports on student progress.
- By students to view schedules and their grades.
- By parents of students to view the progress of their children's education.
- Technical support staff to maintain the database and synchronize it with higher institutions.

IV. System requirements

The electronic journal system should be developed in the form of a website based on a three-tier architecture. The system should have two types of client interfaces. The first one is for students and parents to view information about student's progress. The second, for school staff to manage the learning process. The electronic journal system processes confidential information (personal data of the school staff, students and their parents) [8,9,10]. The automated system should implement protection of confidential information. Hardware structure of the system presented in Figure 1.

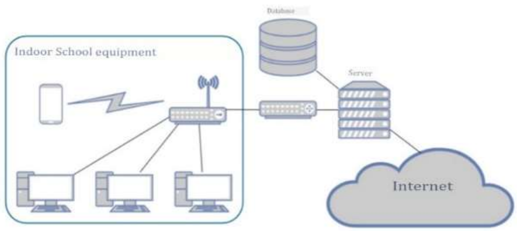

Fig. 1 Hardware structure of the system

The content structure of the system is presented in Figure 2.

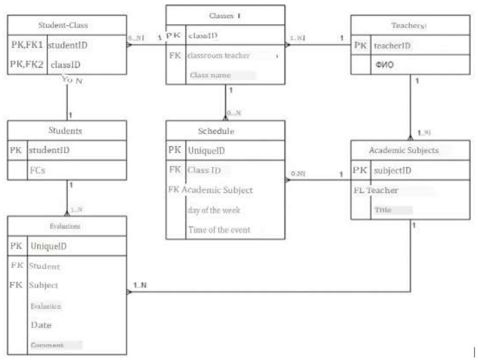

Fig. 2 Database Entity Schema

The functions presented below in the use case diagrams shall be implemented in the ELJ. Each diagram describes functionality of one subsystem. The overall diagram of the use case model, broken down into subsystems, is shown in Figure 3.

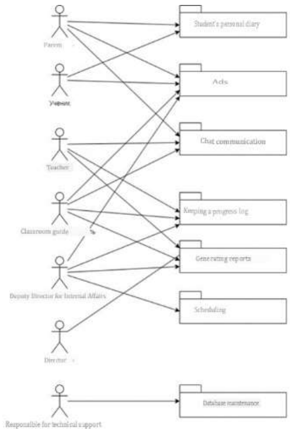

Fig. 3 Subsystems in the use case model

V. Algorithm of system implementation

The director appoints a person responsible for implementation and maintenance of the system. System implementation is carried out when all subsystems are realized. The following are the main processes of putting the system into operation [11,12,13]:

1) Allocation of hardware for database and server application.

2) Installation of database and server application.

3) Entering existing documents into the database.

4) Entering student lists into the database.

5) Installing client applications on the workstations of the institution's employees. Issuing logins and passwords to the employees of the institution.

6) Notifying students and their parents of the transfer of journals to the electronic environment. Issuing logins and passwords to students and their parents.

7) Conducting user training on the system.

8) Conducting tests of the system operation.

Figures 4-5 show the mockups of the interface.

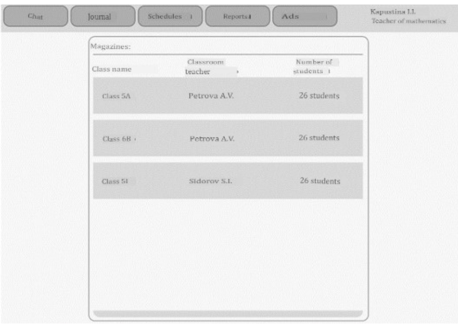

Fig. 4 Layout of the "Learning logs" interface

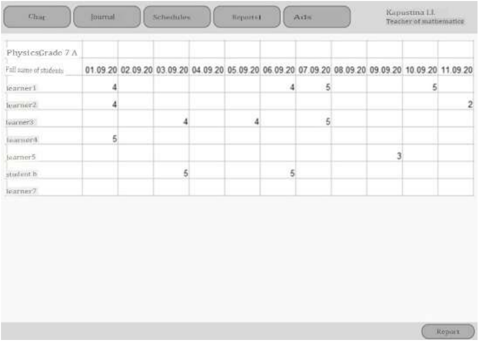

Fig. 5 Layout of the "Report Generation" interface

VI. Conclusion

As a result of the practical work, a part of the terms of reference for the electronic journal system was drafted. Diagrams describing the system structure; specifications of use cases; algorithms for system development and implementation were drawn up. According to the results of the development and implementation of the electronic journal system in operation, it is expected that the system will reduce the amount of routine work that school employees spend on maintaining documents in the educational process. Thanks to the electronic journal system, the organization will be able to solve the problem of increasing the number of documents when the number of children studying increases. The addition of automatic reporting capability will reduce the number of errors in the documents of the organization. So the overall productivity of the employees of the organization will increase. This will allow the educational institution to reduce the cost of record keeping. The introduction of the electronic logbook system will reduce the number of paper documents. Also, storing information on academic progress in electronic form will reduce the organization's expenditures on paper documents. In its turn, it will simplify the process of transferring information on pupils' progress to higher institutions. Electronic journal systems will allow several teachers to make changes to the electronic journal at the same time, which will reduce the time required for teachers to work with the journal. If necessary, teachers will be able to make changes to the journal remotely. The new way of interaction between parents, students and teachers will simplify communication, which will have a positive impact on parents' and children's awareness of school processes and activities. The transfer of timetables and logbooks to electronic form will allow pupils to pay more attention to their studies by eliminating the need to fill in a diary [14,15].

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Automated amusement park information system

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Abstract *Today, information systems simplify and automate the work of a huge number of large and not only companies and enterprises, thanks to which it is possible to obtain a number of advantages, for example, before competitors, or to improve the existing structure of the organization to increase profits or reduce unnecessary costs. Thanks to information systems it is possible to store, process and receive information to several people at the same time, which allows to accelerate the process of work of almost unlimited number of people using this information system. These processes can significantly reduce the time spent on unnecessary, very time-consuming or routine tasks and operations, resulting in improved efficiency in many company processes. A big plus of using information systems for the modern enterprise is that it will require a minimum of cost to collect, store and use data. And it also helps in structuring and displaying only the right data to the employees, which makes their work easier. Also, information system allows you to improve not only internal processes within the company related to employees, but also allows you to improve and facilitate interaction with customers who need to get the maximum benefit from the company's services in the shortest possible time. But as more and more businesses implement information systems every year, it will become increasingly difficult to compete with other companies without an information system.*

Keywords *secure automated system, actant, software system architecture, database, use case, software, efficiency*

I. Introduction

Today, information systems simplify and automate the work of a huge number of large, and not only companies and enterprises, thanks to which it is possible to obtain a number of advantages, for example, over competitors, or to improve the existing structure of the organization to increase profits or reduce unnecessary expenses. Thanks to information systems, it is possible to store, process and receive information to several people at once at the same time, which makes it possible to speed up the work of an almost unlimited number of people using this information system. These processes are capable of significantly reduce the time to perform unnecessary, very long or everyday tasks and operations, which leads to an improvement in the efficiency of many company processes. The big advantage of using information systems for a modern enterprise is that it will require a minimum of costs for data collection, storage and use. And it also helps to structure and display only the necessary data to employees, which makes their work easier. Also, the information system allows you to improve not only the internal processes within the company related to employees, but also allows you to improve and facilitate interaction with customers who need to get the maximum benefit from the company's services in the shortest possible time. But since more and more enterprises are implementing information systems every year, it will become more and more difficult to compete with other companies without an information system.

Also, the information system allows you to control the enterprise much more effectively and manage it with the help of developed and implemented solutions. This is due to pre-known problems enterprises and the development of an information system based on scientific and technological progress. The data received from the information system may be more accurate and operational than without the information system, necessary for making timely management decisions [1,2,3,4,5].

II. System requirements

AIS should be developed in the form of a website for system administration, as well as a mobile application for park visitors. The database server should be created on the basis of object-relational DBMS PostgreSQL. AIS should have three types of client places: the first type is intended for work of the system administrator and is realized in the form of a site; the second type of the park employee should have access to the system both as a site and as an application; the third type is the park visitor who has access to the system through the application.

Programming languages: Java, Swift; operating systems: Windows, Android, iOS; DBMS: PostgreSQL; version control system: Git.

AIS processes confidential information (personal data of park visitors) and is an automated system in a secure design [6,7,8].

The system architecture is presented in Figure 1.

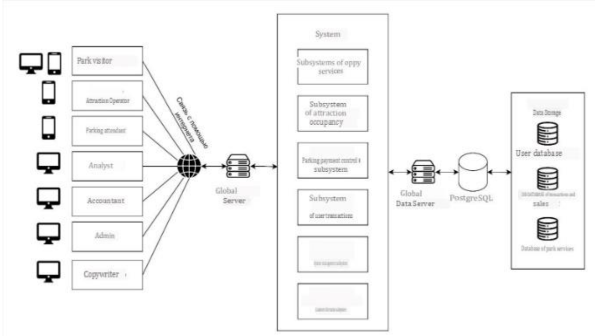

Fig. 1 System architecture

The system management subsystem is intended for editing the information system data, namely: adding, editing and deleting employees in the system; adding, editing and deleting attractions in the system; changing the cost of various services (cost of a ticket for a particular attraction, cost of a parking space). Employee data includes phone number, password, role, full name. Attractions data includes name, description, image, ticket price. Only the system administrator has access to this subsystem [9,10,11,12].

Parking payment control subsystem is designed to check the payment of parking space by park visitors. Only the parking attendant and the analyst have access to this subsystem.

Subsystem of service payment is intended for purchasing tickets for attractions, or for paying for a parking place by park visitors in order not to stand in a queue for a long time.

The subsystem of informing customers is designed to publish informational news related to the amusement park to attract attention and inform people wishing to visit the park. Only the copywriter has access to this subsystem.

The subsystem of visitors' transactions is intended for obtaining necessary data for viewing the statistics of purchases of services offered by the park. Only the accountant and the analyst have access to this subsystem.

Attractions occupancy subsystem is designed to display queues for each attraction at the moment so that visitors can visit as many attractions as possible and thus buy more tickets. To determine the queue, only the attraction operator has access to this subsystem; a park visitor can view the queue at a given time; an analyst can view the statistics for a certain period [13,14,15,16].

III. Requirements for the number and qualifications of personnel

AIS users are:

1) The system administrator;

2) Park visitor

3) Attraction operator (each attraction has its own operator);

4) The parking attendant;

5) Analyst;

6) Copywriter;

7) Accountant;

AIS users should:

a) Have PC skills as a user;

b) know the principles of working with Linux or Windows 2000/XP and higher;

c) have skills in working with smartphones based on Android or iOS;

d) be trained to work with AIS at their workplace within the scope of the user manual.

IV. Functional requirements

The AIS will utilize interfaces to work with the user. Layouts of the interfaces, the realization of which is necessary already in the first version of the system, are presented in Figures 2-9.

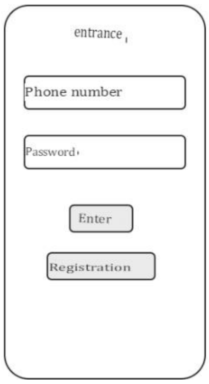

Fig. 2 Interface example

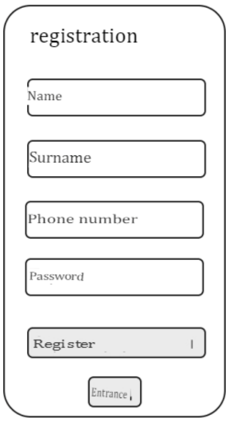

Fig. 3 Interface example

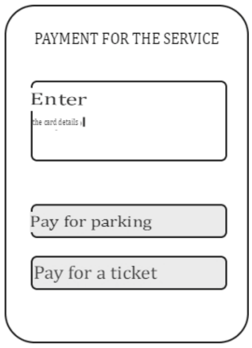

Fig. 4 Interface example

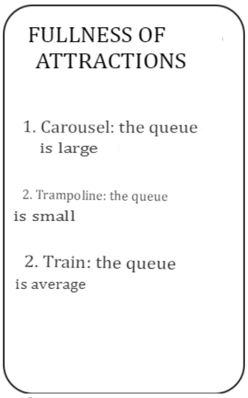

Fig. 5 Interface example

Fig. 6 Interface example

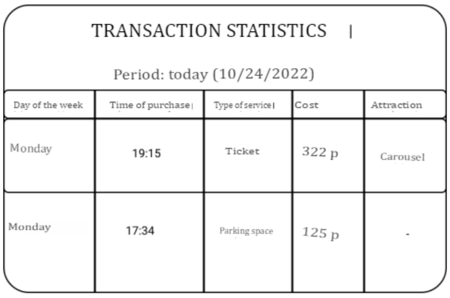

Fig. 7 Interface example

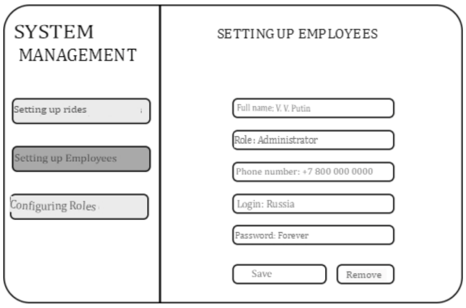

Fig. 8 Interface example

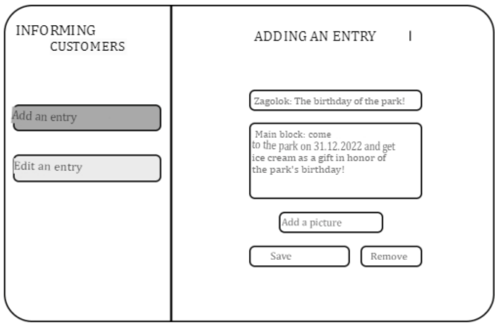

Fig. 9 Interface example

V. COMPOSITION AND CONTENT OF WORKS ON SYSTEM CREATION

System development should be performed on the basis of an architecture-oriented approach. The selected life cycle model should allow for iterative and incremental system development. It is assumed that all the listed works will be repeated at each iteration during realization of subsystem or separate use cases [17,18,19,20].

The list of software development activities in the form of a flowchart is presented in Figure 10.

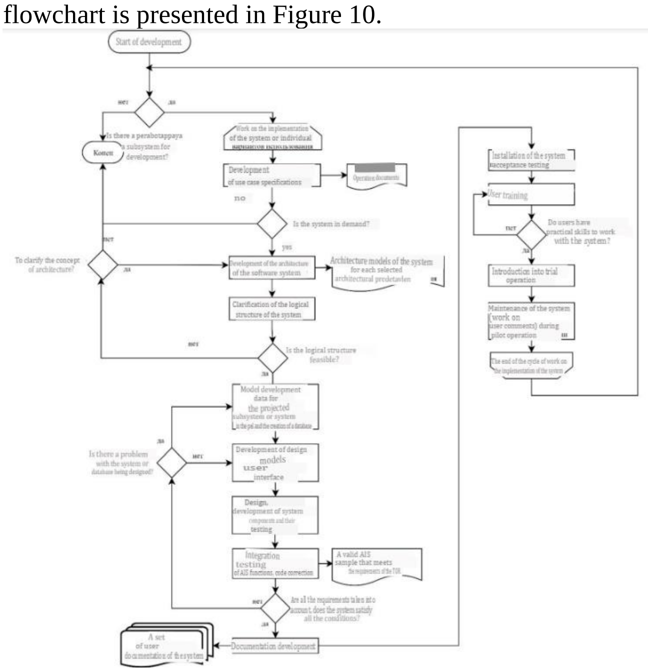

Fig. 10 Block diagram "List of software development works"

VI. CONCLUSION

Thanks to the developed terms of reference, it is possible to develop a well-thought-out AIS for an amusement park, when it is able to benefit not only the customer, but also the visitors of the park. Due to the developed subsystems, the work of certain employees becomes much more efficient and easier, since they do not have to spend a lot of time on everyday tasks and can perform a larger amount of work than before. For example, a park analyst has the opportunity to receive useful and necessary data about the work of the park immediately in a prepared form from the information system [21,22,23,24].

Also, thanks to the developed AIS, visiting the park by customers will become more pleasant and convenient due to the ability to use the park's services in a mobile application without waiting for queues. This allows the company to have even more profit, since park visitors now do not need to waste time in queues and can pay for services anywhere and anytime [25,26,27].

Also, thanks to the developed AIS, it becomes easier to analyze data and predict future revenues of the park by automating the storage of data on transactions of park visitors who they use this information system, and due to this, it will become easier for the park director to make decisions and make future plans for the park.

Also, thanks to the developed AIS, the probability of human error in the work of employees will decrease, since all operations will work according to a strictly specified algorithm. For example, an accountant, thanks to the information system, will count some amounts of money and the income of the park less, since AIS will take over part of the calculations.

Also, thanks to the developed AIS, the storage of big data about the work of employees and purchases of park visitors will become more efficient and easier, since all data will be in one system and access to them will be available at any time for a long time. Thanks to this, it becomes much more effective to control and manage the enterprise with the help of developed and implemented solutions, since the data received from the information system can be more accurate and operational than without an information system, necessary for making timely management decisions.

So, thanks to the developed AIS, it will become easier to convey news and information about life and events taking place inside the park in order to interest new and former park customers to visit it again.

Thus, this AIS is able to simplify many workflows employees of the park and simplify their work in order to increase them efficiency and productivity at some stage of their work. This affects not only some private and minor improvement of the employee's work, but also the improvement of the work of the entire fleet. In addition to simplification the use of the park's services becomes much more accessible and comfortable for customers, which can affect the attraction of new visitors to the park and the retention of old visitors, thereby increasing their own income [28,29,30].

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analysis identifies patients at risk of catheter-associated urinary tract infections in intensive care units: findings from the SPIN-UTI Network
Volume 107, January 2021, Pages 57-63

Analysis of Software Adapted to The Educational Process and Its Capabilities

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***Abstract*— In this article, pedagogical software applications can be considered entertainment or social networking applications, but mobile applications have so far proved to be an educational tool. Over time, the development of a variety of programs has made the preparation of a new generation of e-learning resources more meaningful and user-friendly. All of this allows for the rapid exchange and assimilation of information electronically. It is important that the information provided is relevant to the user. With so much information in the world, choosing the right one is becoming a challenge. In order to avoid such situations, many of our teachers create and use e-learning resources in their subjects, which are as basic as possible and important for students to master. enriched with. Of course, the role of programs that create e-learning resources is important in this process. Over time, the capabilities of such programs have expanded and are being put into practice. Inexpensive, easy-to-use, and high-quality mobile learning resources are taking a variety of forms in the market. In this chapter, we have created a mobile learning resource based on Java technologies and analyzed the different methods of using them to create an optimal teaching methodology.**

Keywords—programming languages, mobile applications, web applications, pedagogical software, software, Hybrid applications

I. Introduction

Nowadays, mobile phones are not only a means of communication but also have a place in all aspects of human life. It is no exaggeration to say that the main reason for this is the applications that form the basis of mobile devices. Until recently, mobile applications were just games. also covers rapid images. One of the forms of education in the field of education today is the result of the active development of these mobile applications by M-s. M-learning is implemented through various mobile web applications. Let's take a look at the concept of mobile applications and mobile web applications and web applications. These concepts are almost no different for most users. But they are not only different in appearance but also in scope.

The simplest mobile applications receive computer applications and transfer them to a mobile device. As mobile applications become more reliable, this technology involves the development of a custom mobile environment that takes into account the limitations and advantages of a more sophisticated approach [1]. For example, applications that use location-based functions were originally designed with a focus on mobile devices, given that the user does not have a concept of location on the computer. In particular, native programs have their advantages and disadvantages.

A. Advantages:

- Geolocation allows companies to adjust loyalty or advertising programs;
- Information about user behavior (or inaction) can be easily collected and analyzed, which helps to evaluate the effectiveness of the entire application or its individual functions;
- native applications usually work better and "feel" better. Sometimes web apps are designed to emulate locals, but they are limited by Internet speed and design capabilities.

B. Disadvantages:

- native applications are expensive to develop;
- native apps need to be approved in every app store, and the process of getting users' attention can be difficult (unless the company has an internal app).

Web page - Uzbek pronunciation of the English word "site". The World Wide Web is a virtual space where specific information can be found and marked with a unique URL. This URL indicates the home page address of the website. The home page, in turn, contains links to other pages on the website or to other sites. Web pages can consist of HTML, ASP, PHP, JSP, graphics, and other files. A browser program is used to open the website. The Website may be personal, commercial, informational, or otherwise [2].

A Web application is a program that is stored on a separate server and delivered to the browser interface via the Internet. According to Web.AppStorm editor Jarel Remik, any component of a website that performs any function for the user is defined as a web application. There is no need to download web applications, as they can be accessed over the network. Users can access the web application through a web browser such as Google Chrome, Mozilla Firefox, or Safari.

Web applications require a web server, a software server, and a database. web servers handle client requests, and the application server performs the required function. The database can be used to store any required data. Web applications provide users with a number of features that can be used by a large number of users at the same time, they can be accessed from different devices with Internet access, they can be accessed using various software tools, the user can download the web application to the user's desktop [3]. The tooth is the most important action on the information in web applications, that is, it allows you to receive, store, process, and transmit information, and so on. Web applications are created differently for different audiences, and there are commercial, educational, entertainment, and social networking applications based on the interests of the audience. Such applications are tracked by the user based on their interests.

C. Some important advantages of web applications:

- Internet-based applications are easier to support and can run on any platform;
- Developers can offer apps without approval from any app store;
- Faster conversion using CSS, HTML, and JavaScript.

D. Disadvantages:

- Web applications do not have access to the user's device;
- Users have to use them over a network, which significantly reduces security management;
- It can be difficult to search for an application because it does not have a directory and an app store with a search function.

E. There are two types of web applications:

- progressive web applications;
- Progressive web Applications offer an alternative way to develop traditional mobile applications by delivering an app store and skipping app installation. PWA is an Internet-based application that uses a variety of browser features, such as offline mode, background launch, and the ability to add a link to the device's home screen, making the application user-friendly;
- Hybrid web applications;
- Hybrid mobile applications are created using standard web technologies such as JavaScript, CSS, and HTML5 and integrated into application installation packages. unlike simple apps, hybrid apps run in a "web container," which provides a bridge to browser time and local device APIs via Apache Cordova;
- A hybrid program is a program written using web technologies and attached to a thin web browser. A hybrid application can be quickly transferred to other platforms that use the same basic code base.

F. Additional advantages of hybrid applications:

- Hybrid applications have the most user-friendly features;
- Developers are not limited to a single platform, instead they can create a hybrid application that runs on multiple platforms (if running as a local application);
- Hybrids are a good choice for programmers who create visually rich applications, such as games (which don't work as well as web applications).

G. The hybrid application has some drawbacks:

- Very complex programs are best done;
- Such an application requires extra time and effort to make the local user look and feel (compared to web applications);
- App stores can reject hybrid apps that run smoothly.

A mobile web application is, for some, an application that runs on the Internet and is designed to display correctly on a mobile device, while for others, it is a program designed specifically for a mobile OT that connects to send and receive data over the Internet [4].

Mobile web applications have a number of conveniences that keep the web page offline and allow the user to use the information provided in the application offline. These types of applications provide quality education to students in educational institutions, including the analysis of textbooks using a mobile device during classes, and the ability to find the necessary knowledge using the device search system, which saves students time. While these types of applications create a culture of effective use of mobile devices by students in the classroom, in addition, in the information age, they develop the ability to search for quality and reliable information and avoid information threats. Increases the readiness of young people studying in higher education institutions for the digital age. Not all students currently studying at the university are equipped with personal computers, but it is easy to set up M-education in educational institutions using mobile web applications, where each student has his or her own mobile device.

The Open University (OU) in Milton Keynes, UK, was the first university in the world to introduce distance learning. Currently, there are leading universities in the world for distance education, including the United Kingdom (Open University), Indira Gandhi Open National University (IGNOU), Center for Distance Education, Institute of Management Technology (IMT) Institute of Distance and Open Education, University of Florida, Charles Sterta University. Forms of education develop with the development of science and technology, based on the needs of society. We can see the evolution of education in the following (Fig. 1.)

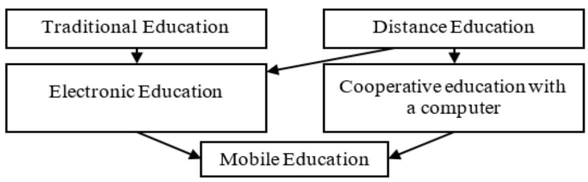

Fig. 1. The evolution of education

Distance learning and mobile learning (Mobile study or M-Learning) is a technology of learning using mobile phones, smartphones and pocket computers. E-Learning, which covers the distance learning system, is the next stage in the development of e-learning technology, which includes a subsystem for access to learning materials and services from various mobile devices, as well as Internet access. takes It's a flexible tool that allows students to learn anywhere, anytime.

“Mobile education is a combination of unique opportunities that create new opportunities for a learning environment where mobile technologies can cover time and space.” Views on the origins of m-learning as a form of education are contradictory. [5] hypothesized that the mobile type of education is part of the e-learning type, i.e., e-learning is a type of distance learning (Fig. 2.).

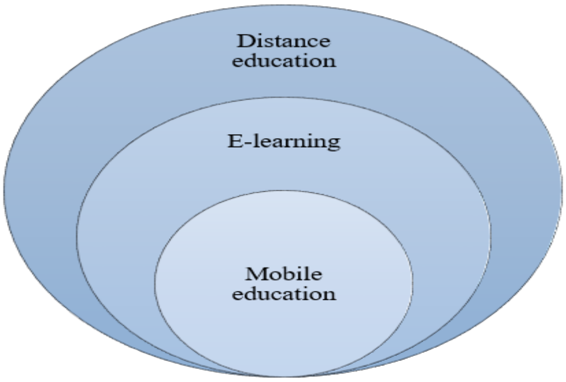

Fig. 2. E-learning system (Giorgiev 2004)

In addition, Kruzov et al. (2012) described distance education as part of “Flexible Learning”. Tik (2006) noted in his work that distance education is becoming e-learning due to achievements and innovations in the field of information and communication, where the mobile type of education consists of elements of distance learning and e-learning noted [6] (Fig. 3.).

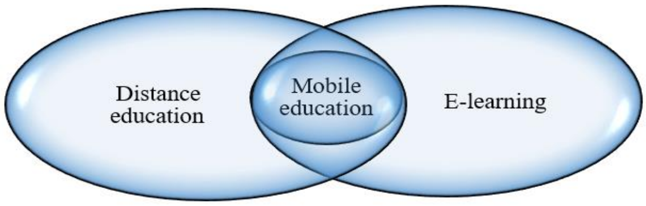

Fig. 3. The relationship between e-learning and m-learning (Tick 2006)

Other experts, such as Eteokleous and Ktoridou (2009), believe that mobile education is the successor to e-learning. They describe e-learning as a form of learning that takes place digitally using electronic means and the media. It can be described as a new tool that expands the distance between learning and teaching, providing access to learning materials using a mobile phone anytime and anywhere [7].

At present, a new stage in the process of mobile education Russian scientist D. Pogulyaev describes mobile learning tools in terms of the tasks they perform (Table 1):

a) Analysis of learning materials using a mobile device, including a mobile electronic textbook or book, a mobile dictionary, multimedia tools for television and video broadcasts, etc.;

b) Student communication tools (mobile chats and conferences, mobile email, mobile forums or blogs);

c) As a knowledge management tool (mobile questionnaires and mobile tests);

d) As a tool for building skills (using mobile research, educational games, and mobile training programs);

e) As a tool to support mobile learning.

TABLE I. ADVANTAGES AND DISADVANTAGES

Evaluation criteria	Mobile app	web-app
View hypertext content	×	✓
View and update video and audio materials	×	✓
Working with multimedia presentations	✓	✓
Work with office applications	✓	✓
Communication with other participants via SMS	×	✓
Complete interactive tasks	✓	✓
Easy opening interface	✓	✓
The minimum value of data transfer	✓	×
Ability to work offline	✓	✓
Completing test tasks	✓	✓
Edit application	✓	✓
Free operating system	×	✓

As can be seen from the table, mobile web applications are the optimal solution for the m-learning form. From this type of mobile web application, the Learning mobile web application includes the following features [8]:

- Save the web page offline and as a result the user will be able to use the information provided in the application offline;
- It will be easier to set up M-learning with the help of mobile web applications;
- Mobile web applications allow students to analyze materials using mobile devices, complete tasks, and master missed lesson materials;
- Able to watch video and audio materials;
- Ability to communicate with other participants via SMS;
- View hypertext content;
- Multimedia presentations are easier to work with;

These mobile web applications not only serve as a single repository of knowledge for the educational institution but also serve as a basis for the formation of a virtual university in the future. Our education system is currently undergoing one of the most revolutionary changes of our time. With the help of mobile learning web applications, students will be able to download almost all information on their smartphones. With the right content for mobile learning applications, the following can be achieved:

- Our university will have a national system of education;
- With the help of these mobile web applications it will be possible to dramatically improve the quality of education;
- The enrollment rate of graduates in higher education in Uzbekistan will increase significantly;

Expands the ability to control the quality of education;

It is known that science was created in response to specific human needs for real, correct knowledge and creation of the world, and in the process of its existence, it has a strong influence on the development of all aspects of social life. The development of science brings various innovations and changes to the life of society. The development of this or that science causes radical changes in various new forms of the educational process [9]. Old forms of education have been rejected, and modern, cheap, high-income alternative methods are now being introduced to the masses. Systematic implementation of the knowledge base allows the student to get quality education remotely at a convenient time and place, and to choose the program of his choice based on the student's personal knowledge and skills. Creating a competitive environment for pedagogues, increasing the quality of science through systematization, as well as providing an opportunity for pedagogues to work on themselves and research. Currently, this type of program is introduced for representatives of all fields, and this type of software is effective in forming the ability of students to study independently and work on themselves, which is the main goal of the qualification requirements. The software offers a variety of applications based on the needs of the independent learner. in this article, the methodology of analyzing pedagogical experiences and conducting it was carried out in the following stages.

II. Material and methods

A group is divided into three (or more) groups according to the level of ability (strong students, medium and weak). In order to organize groups, it is possible to choose other ways (for example, the stability of knowledge interest, reading, new topic and repetition, different aspects of the studied material, practical direction, orientation to the development of various activities, etc.). For each group, the teacher prepares tasks using educational mobile web applications, and representatives of each group work independently with the mobile application for 10 minutes, the main goal of which is to attract the participants to the presented material.

The sequence of tasks for groups can be arranged according to the scheme shown in the table. This sequence can be changed depending on the methodological goals and content of a particular training session (Table II).

TABLE II. A SEQUENCE OF TASKS FOR GROUPS

Lesson stage	Working time	Group 1	Group 2	Group 3
1	3-5 minutes	Organizational moment: lesson setting goals and tasks, updating knowledge in the necessary context		
2	10 minutes	Working with educational mobile web application	Preparing to work with a computer	Consolidation of knowledge
3	10 minutes	Summary Release	Working with educational mobile web application	Preparing to work with a computer
4	10 minutes	Other task forms (testing, developing independent tasks, etc.)	Conclusion	Preparing to work with a computer
5	5 minutes	Activity methods for summarizing and combining the learned material, summarizing the lesson, homework		

After the organizational work, the second stage starts at the same time for everyone. All students of the first group sit at the computers and perform the task assigned to them. Meanwhile, the remaining groups used other sources of information (handouts, notebooks, paper textbooks, etc.). The change of stages is individual for each student. Students of the second and third groups know the sequence of working on a computer. A student of the first group should exchange places with a student of the second group, and then the third. This lesson scheme eliminates the system of mandatory control of knowledge (tests take a lot of time) and also requires accurate organization of work on time. As a control method, you can offer to write in notebooks or give a short handout to students for future lessons. However, this type of lesson is very useful in adapting students to changing activities and mastering different ways of working with information.

III. Result discussion

Teaching based on the integration of the methodology of using educational mobile applications into the educational process made it possible to solve not only the deep learning of educational materials by students but also the issue of conducting lectures and practical lessons together.

Effective use of educational mobile web applications by students of higher education institutions is not only the effective mastering of information technology in education but also the effective mastering of any subject. shows that they can show themselves. Experiments were conducted in order to determine the level of efficiency in the organization of science through the teaching methodology using a mobile web application for educational purposes. For the purpose of statistical analysis of the experiment-test works, a certain amount of data was obtained on the mastery indicators in the experimental and control groups. In order to determine whether such data correspond to the theoretically expected data, we performed a preliminary statistical analysis and calculated the average values and their errors. Student's criterion(s) were used to test hypotheses [10].

Statistical analysis of numerical data, taking into account that this data is relative in nature, that is, it depends not on the grading system, but on the composition of grades, for convenience, “average” is divided into 3, “good” Changed to 4 and “excellent” to 5.

During the pedagogical experiment, we conducted the mathematical-statistical analysis in the following order:

1. The average acquisition for each group was determined by arithmetic means, and their relative and average difference coefficients were compared.

2. In order to further compare the results of mastering, the variability indicators were calculated in the experimental groups and conclusions were made about the averages of the main sets corresponding to each group.

3. Each group drew the polygons of sample distributions and checked the hypothesis about the equality of the average value of the main sets based on Student's two sampling criteria.

4. Appropriate conclusions were drawn from the results of the mathematical-statistical method carried out in the above procedure.

Now we present the results of experiments conducted on the methodology of mixed education and training of the subject "information technologies in education" using educational mobile applications.

In the experimental group of the selected groups, training was carried out based on the use of the mobile application created from the subject "Information technologies in education".

Distance lessons were conducted in the control group based on the teacher's experience.

On the basis of the created mobile web applications for educational purposes, the effect of increasing students' practical skills and knowledge levels with the help of mobile technologies is transferred to the results of the exercises conducted in control groups, the evaluations corresponding to the rating scores. ra is set.

In order to determine the effectiveness of mastering the subject of the proposed educational mobile-web application "Information technologies in education", the results of the control training and summarizing training received from students were analyzed in terms of quality and quantity.

In order to compare the mastery of the experimental and control groups, the average value of the mastery grade in the groups is taken as $X = \frac{\sum x_i m_j}{N}$. where x_i – mastery index (grade value), which are 2, 3, 4, 5; accepts values. mj is the number of repetitions of grades, N is the number of students participating in the experiment.

The average value that evaluates the effectiveness of the educational process is the ratio of the average arithmetic values of the grades of the experimental and control groups, that is, the efficiency coefficient.

$$\eta = \frac{X_T^*}{X_H^*} \quad (1)$$

is calculated by the formula.

Let's get acquainted with the results of university students who participated in the experimental and control groups.

Mid-term control of all departments in "programming technologies" was conducted, the results of which are as follows

24 students from group 201 participated in the experimental group, and 24 students from group 202 participated in the control group. Evaluation work was carried out in these groups as current control and interim control. The assessment was based on a five-point system.

Tashkent state pedagogical university named after Nizami and Tashkent University of Information Technologies named after Muhammad al-Khorazmi conducted experiments and the results were as follows:

TABLE III. RESULTS OF EXPERIMENTAL WORK

Groups	Number of students	Evaluation criteria			
		5	4	3	2
Experimental group	24	8	13	3	0
Control group	24	1	11	12	0

We calculate the average mastery index in relation to these results. Mean value of intermediate control in experimental and control groups

$$\overline{X_T} = \frac{1}{24}\left[8\cdot5+13\cdot4+3\cdot3+0\cdot2\right] = \frac{1}{24}(40+42+9+0) = \frac{91}{24} = 3.79$$

$$\overline{X_H} = \frac{1}{16}\left[1\cdot5+8\cdot4+13\cdot3+2\cdot2\right] = \frac{1}{24}(5+32+39+4) = \frac{80}{24} = 3.33$$

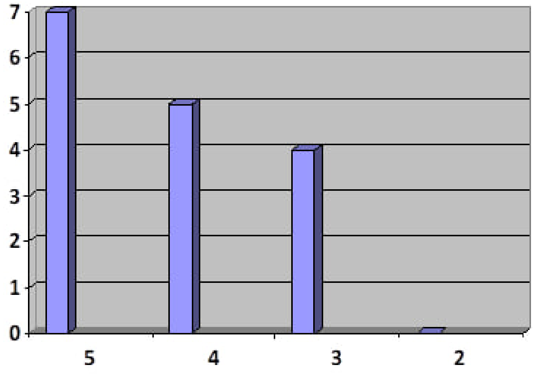

Fig. 4. Intermediate results of training of the experimental group

Efficiency coefficient

$$\eta = \frac{3.79}{3.33} = 1{,}12$$

So, according to the results of theoretical training, the effectiveness of the experimental group is 1.12 times higher. Here is a Fig.5. of these results:

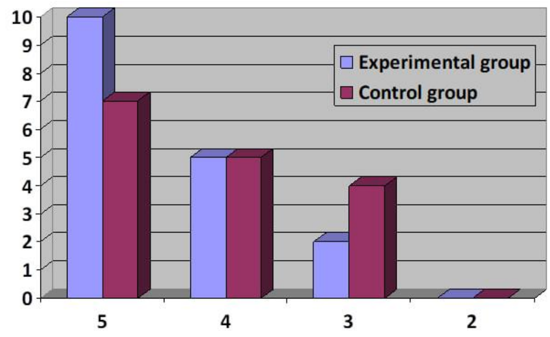

Fig. 5. performance indicator

From the information in the above tables, it can be concluded that conducting lectures, practical classes, and laboratory sessions on the basis of mobile applications in the subject "Information technologies in education" led to students' easy learning of educational materials.

I. CONCLUSIONS

This article discusses the advantages and disadvantages of Java technologies in comparison with other programming languages, explores the possibilities and analyzes the applications of the programming language. The Java programming language was found to be an alternative solution to creating applications for mobile devices. Learning mobile web applications and their types were studied. In the introduction of distance and mixed learning, the possibilities offered by mobile web applications for educational purposes were explored. The types of mobile applications presented in practice were analyzed and the importance of such applications in overcoming the existing problems in the Higher Education System, i.e. in ensuring the quality of education of students, was studied.

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Decision-Making Algorithms Based on Determining the Level of Student Knowledge

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***Abstract*—In this article, we create decision-making algorithms based on determining the level of student knowledge. The developed system is implemented by means of a non-deterministic logic apparatus in the process of summarizing solutions for evaluating the effectiveness of quality control of students' knowledge. We can express it through practical experiences in creating an expert system that makes firm conclusions based on established criteria for evaluating the effectiveness of education. We will consider the issue of using expert systems in the educational process. The widespread use of Internet technologies ensures the development of new forms of education along with new forms of education, including distance systems or "e-learning systems", In this case, the assessment of the effectiveness of education and the control of the quality of the knowledge received by students has become a rather complex multi-criteria issue. It is required to solve it in modern ways. One of these approaches is the application to the training process of an expert system using a non-deterministic logic device.**

Keywords— Participation in the lecture, Activities in seminars, Performance of control works, Completion of homework.

I. Introduction

We will look at the general principles of building a software complex that can comprehensively evaluate the student's learning during the semester, using the principles of rigid logic to classify the level of knowledge of the study group students based on situational analysis. The effectiveness of training can be understood as the level of compliance of the main indicators and values of training with the given criteria. The issue of summarizing the student's mastery is a multi-criteria issue that is difficult to formulate based on the parts of the initial data. If a statistical and mathematical function is used to obtain such an estimate, in the end, it is possible to have a view that is too complex to sufficiently satisfy the necessary requirements.

The application of robust logic allows us to successfully solve the problem with poorly formed initial data. In addition, making and applying rules close to natural language significantly increases the degree of approximation to the required results of inference.

In order to separate the factors of mastery grades, in order to evaluate the activity of the learner during the training course, it is necessary to separate such factors in one way or another, so that these values need to be taken into account when forming the final grades. For this, we define the following main categories in the educational process:

- Participation in the lecture.
- Activities in seminars.
- Performance of control works.
- Completion of homework.

The obtained values of the level of performance for each of these categories are used as initial data for summarizing the resulting assessments of mastery.

The categories determined during the conclusion are combined into groups. Because the grades in the categories of the 1st group should ensure the possibility of consideration at a higher level compared to the other group.

II. Materials and Methods

Participation in the exhibition and activity in the seminar determines the student's activity, and at the same time, the performance of supervision and homework determines his activity and efficiency during the training course. Determining such intermediate levels provides the necessary work in the formation of the knowledge base.

Let's consider the above category "Participation in the lecture" based on non-deterministic sets, see Equation 1:

$\tilde{x}_1$ = "Participation in the lecture"

$$M(\tilde{x}_1) =< M'_{x1}, M'_{x2}, M'_{x3} > \tag{1}$$

where M'_{x1} =low level; M'_{x2} =middle level; M'_{x3} =high lavel.

Let's look at the category "Activities in seminars" in the same way, see Equation 2:

$\tilde{x}_2$ = "Activities in seminars"

$$M(\tilde{x}) =< M''_{x1}, M''_{x2}, M''_{x3} > \tag{2}$$

where M''_{x1} =low level; M''_{x2} =middle level; M''_{x3} =high lavel.

We determine the activity of the learner from the above two categories and evaluate it on three levels, see Equation 3.

F - activity

$$M(F) = < M_F^1, M_F^2, M_F^3 > \quad (3)$$

where M_F^1 =low level; M_F^2 =middle level; M_F^3 =high lavel.

We calculate the values of the elements of the *M(F)*-set in percentage. Now we express the category “Performance of control works” by non-deterministic variables. It is as follows:

$\tilde{y}_1$ =*Execution of control works*

$$M(\tilde{y}_1) = < M'_{y1}, M'_{y2}, M'_{y3} > \quad (4)$$

where M'_{y1} -low level, M'_{y2} -medium level, M'_{y3} -high level.

Let's look at the “Completion of homework” category in the same way:

$\tilde{y}_2$ =Completion of homework

$$M(\tilde{y}_2) = < M''_{y1}, M''_{y2}, M''_{y3} > \quad (4)$$

where M''_{y1} -low level, M''_{y2} -medium level, M''_{y3} -high level.

We determine the effectiveness of the learner's knowledge from the above two categories “Completion of control work”, “Completion of homework” and evaluate it on three levels.

B-efficiency

$$M(B) = < M_B^1, M_B^2, M_B^3 > \quad (5)$$

where M_B^1 -low level, M_B^2 -middle level, M_B^3 -high level.

We calculate the values of the elements of the *M(B)*-set in percentage.

We determine the student's performance in the semester based on the student's activity and knowledge efficiency.

It requires the development of modeling and assessment (decision-making) with non-deterministic logic methods in assessing students' knowledge through learning outcomes. In this case, it will be possible to construct a relevance function based on the distribution of points for “excellent”, “good”, “average”, “satisfactory”, “unsatisfactory” linguistic variables. Fig. 1. avarege grades above.

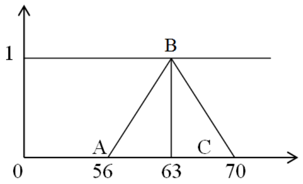

Fig. 1. “Average” grade relevance function.

According to the picture, A(56;0); B(63;1); It can be taken as C(70;0).

$$AB: \frac{x-56}{63-56} = \frac{y-0}{1-0}, \mu_{AB}\ \frac{x-56}{7} = \mu_{AB}(56) = 0, \mu_{AB}(63) = 1$$

$$CB: \frac{x-70}{63-70} = \frac{y-0}{1-0}, \mu_{CB} = \frac{70-x}{7}, \mu_{CB}(70) = 0, \mu_{CB}(63) = 1$$

$U_1 = \{56, 70\}$:

U1: Medium grade={“loosely based”=a_1, “moderately based”=a_2, “strongly based”=a_3}. The weighted values of the linguistic variable “loosely based”=a_1 are μ_{AB}={0, 0.1, 0.2, 0.4, 0.5}. “moderately based” = weighted values of a_2 linguistic variable μ_{AB}, μ_{CB} ={0.6, 0.7, 0.8, 0.9, 1} “strongly based”=weighted values of a_3 linguistic variable μ_{CB}={0, 0.1, 0.2, 0.3, 0.4, 0.5}.

x = 62, $\mu_{AB} = \frac{62-56}{7} = \frac{6}{7} \approx 0.9$ 0.9 we can see that this result holds for a_2. x=67, $\mu_{CB} = \frac{70-67}{7} = \frac{3}{7} \approx 0.4$, 0.4 we can see that this result belongs to a_3.

So we cannot go directly from a_1 to a_3. Therefore, we perform the step $a_1 \rightarrow a_2 \rightarrow a_3$ and develop the following solutions:

- a1→a2: {repetition, simple calculations, getting advice, understanding the essence of science, acquiring skills };
- a2→a3: {working on oneself, practical and theoretical training, receiving advice, learning methods available in science, gaining qualifications}.

So the result was equal to . Here, “mean-based” is a weighted linguistic variable value.

Linguistic variables and solutions for Excellent and Good grades are presented in the same way as the linguistic variables and solutions for medium grades above (Fig. 2. and Fig. 3.).

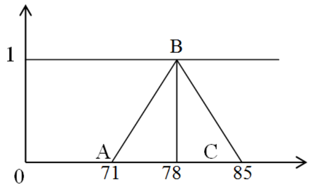

Fig. 2. “Good” grade relevance function.

$$AB: \frac{x-71}{78-71} = \frac{y-0}{1-0}, \mu_{AB}\ \frac{x-71}{7} = \mu_{AB}(71) = 0, \mu_{AB}(78) = 1$$

$$CB: \frac{x-85}{78-85} = \frac{y-0}{1-0}, \mu_{CB} = \frac{85-x}{7}, \mu_{CB}(85) = 0, \mu_{CB}(78) = 1$$

good grade $U_2 = \{71, 85\}$:

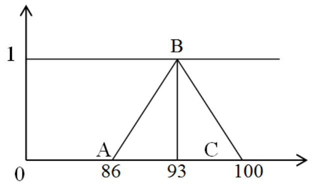

Fig. 3. "Excellent" grade relevance function.

$$AB: \frac{x-86}{93-86} = \frac{y-0}{1-0}, \mu_{AB} \frac{x-86}{7} = \mu_{AB}(86) = 0, \mu_{AB}(93) = 1$$

$$CB: \frac{x-85}{93-100} = \frac{y-0}{1-0}, \mu_{CB} = \frac{100-x}{7}, \mu_{CB}(100) = 0, \mu_{CB}(93) = 1$$

excelent grade $U_3 = \{86,100\}$:

When creating decision-making algorithms based on classified data, decision-making algorithms based on classified data are presented in Fig. 4. below, a general scheme of learner's mastery ratings. In this approach, 3 strict supervisors are used, each of them defines their knowledge system in their work [3].

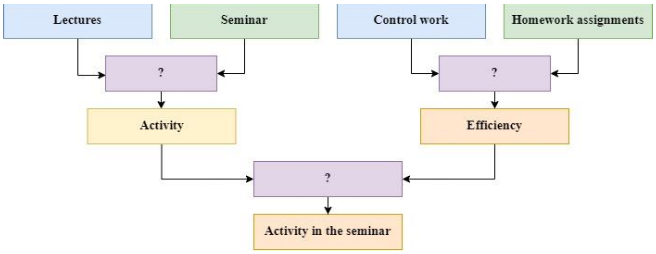

Fig. 4. General rating scheme.

Calculation of statistical estimates. In order to express the idea expressed above in the assessment of mastery, the values given to the input of the inference mechanism, especially the level of performance for each of the specified categories, should be determined in one way or another. During the analysis of the subject area, the following principles of obtaining data values were formed.

Attending a lecture. The arithmetic average of all available attendances can be calculated when evaluating attendance at a lecture [1]:

$$M = \frac{\sum_{i=1}^{n_m} m_i}{n_m} \tag{6}$$

Here n_m -is the number of reports; The price of participation in the m_i- i-report.

Activities in seminars. Evaluation of activities in seminars is carried out in an analogous form [2]:

$$M = \frac{\sum_{i=1}^{n_S} S_i}{n_S} \tag{7}$$

Here n_s-the number of seminars; s_i-i-seminar performance assessment.

Performance of control works. Evaluation of the performance of control works is carried out taking into account the coefficient of complexity determined for each work. These values are significant relative to the weighting factor and are intended to set a higher level when considering the performance of complex tasks than simple ones [3].

$$M = \frac{\sum_{i=1}^{n_t} t_i * c_i^t}{\sum_{i=1}^{n_t} c_i^t} \tag{8}$$

Here n_t - is the number of control works; t_i-i-job completion price, c_i^t-i-job complexity coefficient.

Completion of homework. Completion of homework assignments will be evaluated in the same way [4].

$$M = \frac{\sum_{i=1}^{n_h} h_i * c_i^j}{\sum_{i=1}^{n_h} c_i^h} \tag{9}$$

Here n_h -is the number of homework assignments; h_i-i-job evaluation, c_i^h-i-task complexity coefficient.

Linguistic variables. To evaluate the learner's learning, we include linguistic variables such as "attended lectures, worked in seminars, completed supervision work, completed homework". We express the characteristics of variables with concepts such as "activity", "efficiency" and "grade".

III. PROGRAMMING OF CLASSIFICATION AND DECISION-MAKING ALGORITHMS

In this article, as statistical information, a pilot test is conducted among students of Tashkent University of Information Technologies and Tashkent State Pedagogical University named after Nizami in a multivariate method [5].

We implement programming based on decision-making algorithms based on classified data. Programming is based on the above algorithms. Linguistic variables and variable characteristics can be observed through the Membership Function Editor function in the Fuzzy Logic Toolbox package of the MatLab system. First, we observe the linguistic variable of student exposure in the Membership Function Editor. In this picture, we express the participation of students in the exposure by <occasionally>, <constantly> variables:

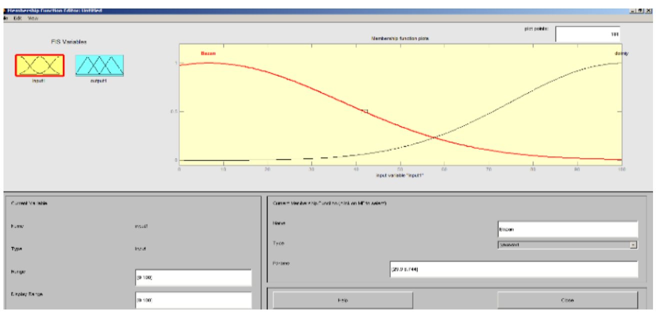

Fig. 5. Representing student exposure in the Membership Function Editor.

Now we monitor the linguistic variable of the students' activity in the seminars in the Membership Function Editor.

We express the activity of students in seminars by <very slow>,<periodic>and<very active> variables:

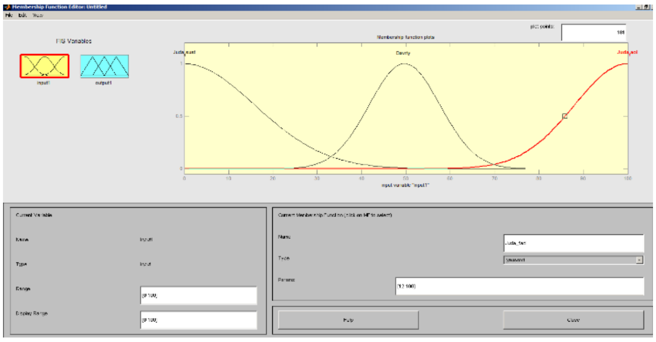

Fig. 6. Representation of students' activities in seminars in the Membership Function Editor.

We monitor the linguistic variable of students' performance of control work in the Membership Function Editor. We express the performance of students in seminars by <bad>, <medium> and <good> variables:

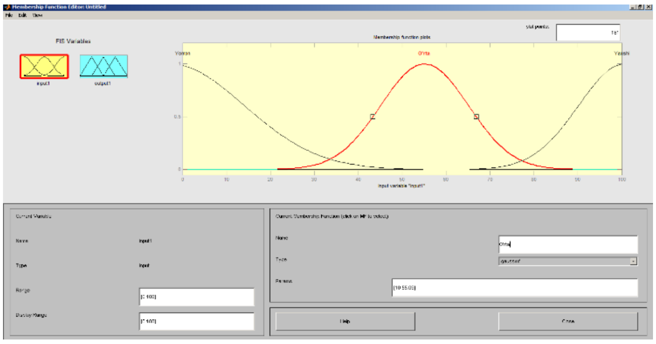

Fig. 7. Representation of students' control work in the Membership Function Editor.

We track the linguistic variable of students' homework completion in the Membership Function Editor. We can represent the students' homework as well as the students' performance in the seminars by the discrete variables <bad>, <average> and <good>. In this case, the student with the <bad> variable did very poorly on homework. A student with a variable <average> did average homework. A student with a <good> variable is considered to have done homework very well. We express the students' homework by the above function as persistent variables <bad>, <medium> and <good>:

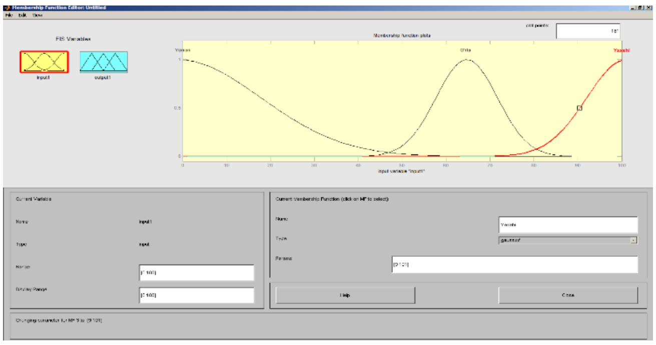

Fig. 8. Representing student homework in the Membership Function Editor.

We observe the characteristics of the linguistic variable of student activity in the Membership Function Editor. We express the activity of students by <low>, <medium> and <high> non-deterministic variables:

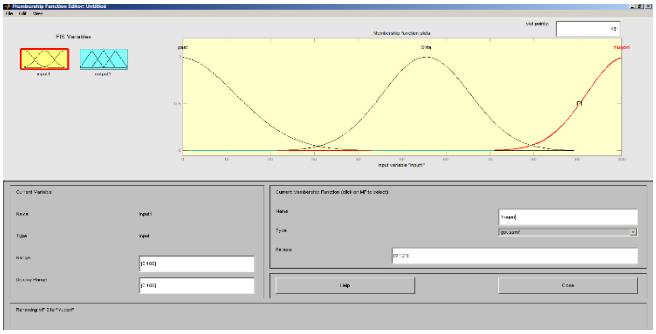

Fig. 9. Representing student activity in the Membership Function Editor.

We observe the characteristics of the linguistic variable of the effectiveness of student knowledge in the Membership Function Editor. We also express the effectiveness of students' knowledge through the variables <bad>, <medium>, <good> and <very good>:

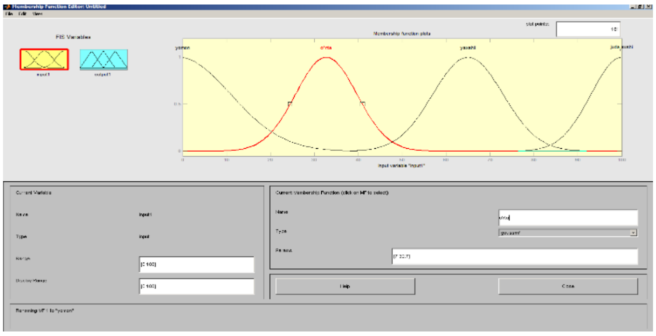

Fig. 10. Expressing the effectiveness of student knowledge in the Membership Function Editor.

We observe the characteristics of the linguistic variable of students' grades in the Membership Function Editor. We also express the grade of students by <bad>, <satisfactory>, <good>, <very good> and <excellent> variables:

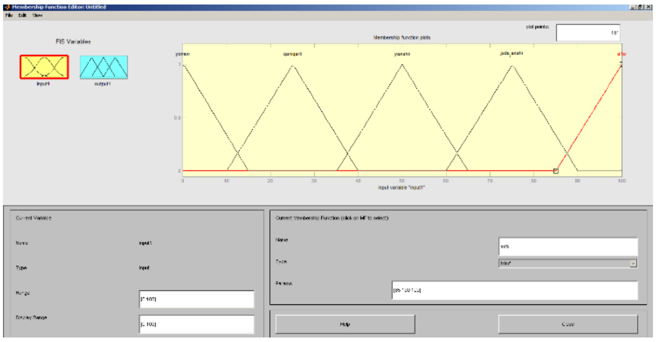

Fig. 11. Representing student grades in the Membership Function Editor.

Now we will look at the rules of operation of persistent controllers (controllers) in the form of a table.

TABLE I. DETERMINING STUDENT ENGAGEMENT THROUGH LINGUISTIC VARIABLES OF STUDENT EXPOSURE AND ACTIVITY IN SEMINARS.

Activity		**Participation in the report**	
		sometimes	**usually**
Activities in seminars	very slow	slow	middle
	periodic	middle	middle
	very active	middle	high

TABLE II. DETERMINING THE EFFECTIVENESS OF THE STUDENT'S KNOWLEDGE THROUGH THE LINGUISTIC VARIABLES OF THE STUDENT'S PERFORMANCE OF CONTROL WORK AND THE COMPLETION OF HOMEWORK.

Efficiency		**Performance of control works**		
		bad	middle	good
Completion of homework	bad	bad	bad	middle
	middle	bad	middle	good
	good	bad	middle	very good

TABLE III. DETERMINATION OF THE STUDENT'S ASSESSMENT BY THE CHARACTERISTICS OF THE LINGUISTIC VARIABLE OF THE EFFICIENCY AND ACTIVITY OF THE STUDENT'S KNOWLEDGE

Grade		**Efficiency**			
		bad	middle	good	very good
Activity	low	bad	bad	satisfactory	very good
	middle	bad	middle	good	excellent
	middle	bad	middle	very good	excellent

One of the main steps in achieving the goal of decision-making based on the Fuzzy Logic Toolbox model is the correlation between the group's students' mastery indicators and the values of significant linguistic variables. To build the Fuzzy Logic Toolbox model, we first create a .dat file based on the values in the columns of student acquisition scores and weighted linguistic variable values. We upload our created .dat file to the Matlab environment based on the antisemite command. (Fig. 12.)

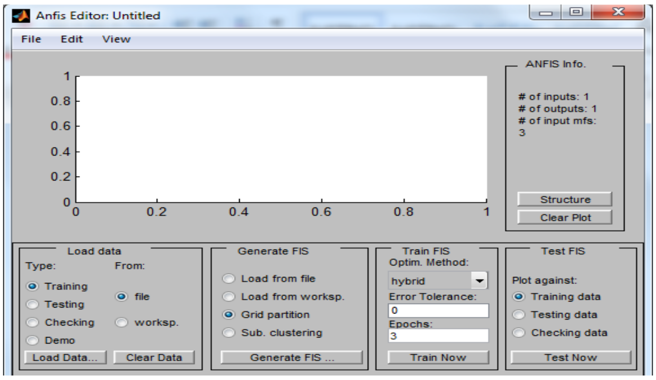

Fig. 12. Representation of students' control work in the Membership Function Editor.

To work in this window, we perform the following steps:

Fig. 13. Representation of students' control work in the Membership Function Editor.

In the image below we can see the rules between incoming and outgoing values.

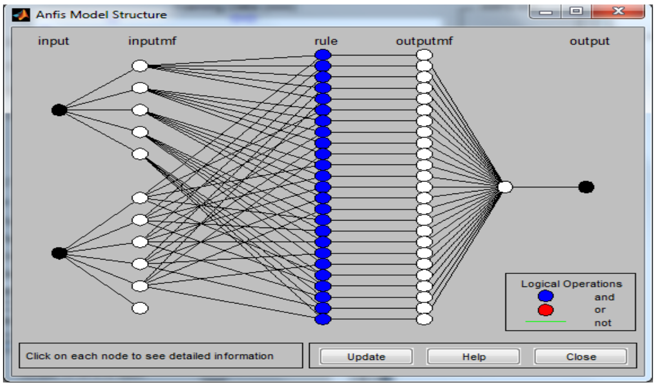

Fig. 14. Representation of students' control work in the Membership Function Editor.

When we give the test now command in the Anfis editor window, we get the following result. (Fig. 3.5) In this picture, the data is represented graphically based on the values in the columns of students' order number, mastery indicators and important linguistic variable values.

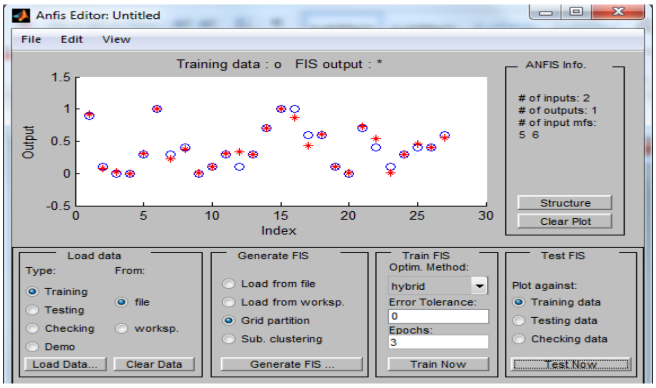

Fig. 15. Representation of students' control work in the Membership Function Editor.

Now, we will model the data using the surface function based on the values in the columns of students' order number, mastery indicators, and weighted linguistic variable values. (Fig. 16.)

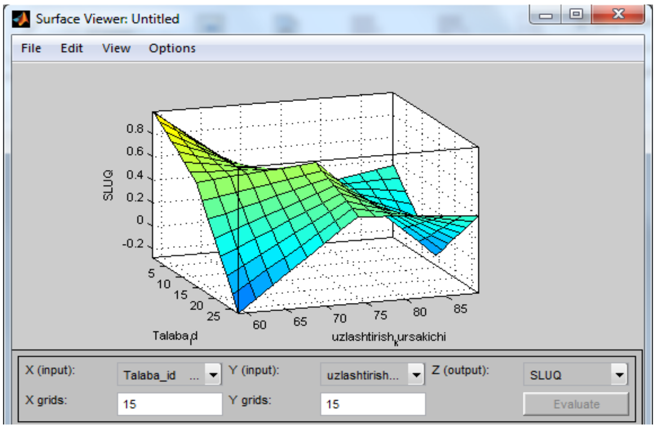

Fig. 16. Representation of students' control work in the Membership Function Editor.

In this model, the number of students, i.e. "Student ID" is 27 students, the learning indicators are min {59 points}, max {89 points} and the weighted linguistic variable values are in the range [0;1] was calculated.

Conclusion

The practical application of the intellectual system for evaluating students' knowledge (as an example of teaching computer architecture) was supported. For this, the goal, content and assessment criteria of computer architecture science were introduced. Statistical information about the marks of the group that mastered this subject, the mastery rate and the rating score in the semester was collected and analyzed. As a statistical reference, the rating record of the students of the Tashkent University of Information Technologies and Tashkent state pedagogical university named after Nizami in the subject “Computer Architecture” for 1 semester was used as a practical application. The values of the linguistic variable were determined based on the student's scores during the semester, and the formula for calculating the weighted linguistic variable value was used. The stages of modeling and conducting experiments on the basis of the Fuzzy Logic Toolbox package of the level of correlation between the mastering indicators of the students of the group and the values of important linguistic variables were considered.

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Optimization of Recognition and Classification of Micro-Objects with Adaptive Image Filtering Mechanisms

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***Abstract*— Scientific and methodological foundations have been developed for the optimal identification of non-stationary objects of complex structure with mechanisms for using statistical, dynamic, specific characteristics of information, as well as predictive and approximating abilities of neural networks (NN) for recognition and classification of images of micro-objects, in particular, pollen grains, unicellular organisms in the composition blood, fingerprints, useful minerals in the rock mass. Mechanisms for visualization, identification based on statistical, dynamic models and neural networks, learning, modeling, algorithmization, extracting useful knowledge, hidden properties and searching for patterns in data are proposed. Two models of recognition of microobjects are investigated. The first is the search for "double borders" of "Snake"; the second is "Paradise", which recognizes with the help of NN with classification mechanisms based on the similarity of images to the characteristics of modal examples. Mechanisms have been developed to control the error in image identification by thresholds, increments, errors in the prediction of RTS elements based on the use of statistical information redundancy. Optimization of the error control was carried out according to the standard deviation criterion, using the mechanisms of gradient optimization, least squares, heuristic search with annealing, and prohibitions. A software package has been developed and implemented, which is specified by the number of neurons in the input layer, hidden layer, an output layer, the value of the bias threshold, the same learning step, and learning algorithms with forward and back propagation of errors at each start of the network.**

Keywords—identification, random time series, optimization, regulation, statistical, dynamic, neural network models, mechanisms, error control.

I. Introduction

The development of computer vision systems (CVS) of images of micro-objects based on the technology of neural networks (NN), including the mechanisms of visualization, learning, modeling, algorithmization, recognition, classification, extraction of useful knowledge, hidden properties of data, analysis, search for patterns, are in great demand and represent an urgent research topic [1, 2, 3, 4].

The importance of solving the problems of recognition and classification of micro-objects, in particular, pollen grains, unicellular organisms in the composition of blood, fingerprints, symbols, and letters of texts, and useful minerals in the composition of the rock mass increases, even more, when the adaptation mechanisms of variables are connected in real conditions of a priori insufficiency, uncertainty, non-stationarity of processes [5, 6, 7, 8].

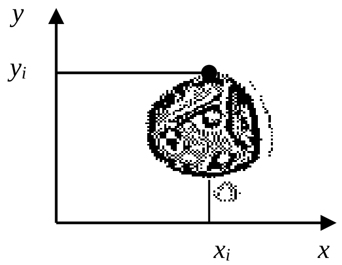
Achievement of the set goal and the required efficiency of the CVS is ensured through the mechanisms of using the unique properties of the NN, which allows you to design tools for identification, approximation, and optimization, and most importantly, unlike statistical, dynamic models, perform a programmed sequence of actions on a specific training set, analyze the incoming information, adapts to the properties of non-stationarity of processes [9, 10, 12, 13, 14].

The present study is devoted to the development of mechanisms for optimal identification of micro-objects with mechanisms for extracting and using generalized characteristics, specific properties, adequate models, statistical, dynamic, specific characteristics of images, as well as predictive and approximating abilities of the NN.

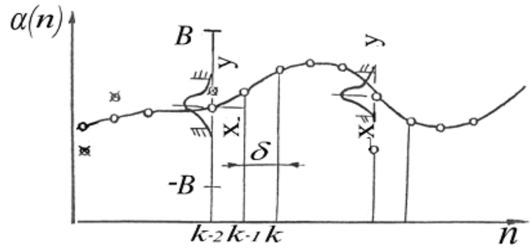
II. Main Part

A. *Basic approaches and principles of identification of micro-objects*

For visualization, recognition, and classification of micro-objects, images are pre-processed, its contour is selected and segmented, which is represented by a sequence of readings (points) of the coordinate grid $x_{11}, x_{12,} \ldots, x_{1n}, x_{21,} \ldots, x_{2n}, \ldots, x_{mn}$, x_{ij} - an element of the reading matrix located at the intersection of the i -th row and j -th column; m is the number of matrix rows corresponding to the number of elements in a row; n is the number of matrix columns corresponding to the number of elements in the column. In fig. 1 a) and b) as a typical example, the principle of sampling the contour of the pollen grain image, determining and controlling the spread of the quantized coordinates of the micro-object presented for recognition is illustrated. To solve the problem of recognition of micro-objects, information about the dynamic process is presented, which is due to interference, noise, or information errors, as well as non-stationarity of processes.



a)



b)

Fig. 1. Representation of the micro-object (a) and the principle of controlling the coordinates of the image contour points (b).

The best recognition of micro-objects requires the development and implementation of mechanisms aimed at improving the efficiency of image restoration [15, 16, 17, 18, 19].

Conceptual principles, methods, models, and technologies for improving the accuracy of identification of micro-objects are proposed, in which statistical, dynamic, and specific characteristics are supposed to be used. The study was carried out according to the criterion of the rootmean-square error of image identification [20, 21, 22, 23, 24].

The problems of binarization, detection, segmentation of curved contours of the main parts of the image, extraction of characteristics, calculation of invariant features, and complex data preprocessing have been solved. The image is destructed into parts that are used to extract the internal features of micro-objects. The calculated characteristics are displayed on a grayscale, which is used to detect contour curves.

The extracted features allow, in turn, to compare unknown micro-objects with micro-objects in the referring database by a pair of numbers, as well as to explore the obtained sets of different features for each image. Note that there may be some differences between objects of the same class. This means that the characteristics of different objects will never match exactly. In this regard, the compliance of the micro-object is checked according to the criterion of "best fit" to the reference example.

Two methods can be used to recognize micro-objects. The first one is approximate, based on the use of "double boundary" search modules, the "Snake" model [25, 26, 27, 28].

The second method uses NN, which is the «Paradise» recognition model, which allows for effective classification of micro-objects by their similarity with the given features stored in the image database with the characteristics of reference examples. Such features of micro-objects are boundaries, texture, etc.

NN "Paradise" is designed to recognize images of microobjects, static fingerprints, and unicellular microorganisms. In addition, its advantages for recognizing the features of other micro-objects have been proven. Paradise network applied to grayscale images. The model uses a mechanism for creating templates that are designed to recognize important features of a micro-object. Recognition occurs by linking several of these patterns together with a classification mechanism.

The network has a three-layer architecture: recognition of "Features"; the definition of a "Pattern", a classification that consists of a panel. Each panel defines a particular type and feature of the input image. Four panels are used. One for defining horizontal lines, another for vertical lines, and two for two frequencies.

Contour lines are selected from images. Moreover, those lines are selected that carry the greatest amount of information. A set of templates is built from the features that are defined at the previous level. These templates are small. They can also be used to represent parts of recognizable objects when training the "Paradise" network. During the training period of the network, templates are generated automatically, and its structure makes them accessible to small transformations and deformations. When obtaining information about an object, all templates are used. Each class of objects is represented in a classification cell. Information about the object is encoded using links between classification cells. Sliced objects are presented to the network.

Existing classes are examined for having a good presentation. If not, then a new class is created. Network parameters are set, as a rule, on the basis of empirical data and are highly dependent on the nature of the application being created. "Classification thresholds" are set, which are used to determine the similarity score between the input feature and the internal template model. "Classification threshold" reflects the variability of the picture image. The next important task of the study is to filter the image from “noise”, “interference”, “garbage”, “not pollen”, etc.

B. Mechanisms for improving the quality of image restoration of micro objects based on error control

Mechanisms have been developed to control the image identification error by thresholds, increments, and prediction errors of RTS elements, which are based on the use of statistical information redundancy.

Mechanism $A^{II}_{\sigma_n}$. According to this mechanism, the information on the contour of the micro-object image is processed according to the rule

$$\gamma = \begin{cases} \beta, & \text{at} \quad x \le \beta \le y; \\ a_\alpha, & \text{at} \quad \alpha_{\min} = \beta_{\min} \le \beta < x; y < \beta \le \beta_{\max} = \alpha_{\max}, \end{cases} \tag{1}$$

those erroneous β values (contour points) are smoothed out by identifying with the average a_α value of all RTS elements. The possibilities of the mechanism with threshold control of information are expanded on the basis of control by the values of increments and prediction errors based on statistical, dynamic models, and NN.

Mechanism $Б_{\sigma_n}$. Let the initial data be described by a random process $\alpha(t)$ with a two-dimensional probability density function $\omega(\alpha_1, \alpha_2, \tau)$, mathematical expectation a_α, variance σ_α^2, and correlation coefficient $R(\tau)$ (here $\tau = t_k - t_{k-1}$ is the time quantization step). Denote by $\Delta\alpha_k$ the difference (increment) $\alpha_k - \alpha_{k-1}$ between the k-th and ($k-1$)-th discrete levels in the sequence of initial data on the transmitting $(0 \le \Delta\alpha_л \le B)$ and receiving $(0 \le \Delta\beta_л \le B)$ sides. On the axis of the set $\{\Delta\beta\}$, we set the negative $(-\Delta x)$ and positive (Δy) boundaries of the control, which divide the set of $\{\Delta\beta\}$ increments into allowed $\{\Delta\beta_p\}$, where $\{\Delta\beta_p\}$ and forbidden $\{\Delta\beta_3\}$, where $-B \le -\Delta\beta_3 \le -\Delta x$, $\Delta y \le \Delta\beta_3 \le B$ subsets.

The information control principle is as follows: information α_k is considered correct if $\Delta\beta_k \in \{\Delta\beta_p\}$ and erroneous if $\Delta\beta_k \in \{\Delta\beta_3\}$. Erroneous elements of the image contour are corrected according to the rule

$$\gamma_k = \begin{cases} \beta_k, & \text{if } \Delta\beta_k \in \{\beta_\rho\}; \\ \beta_{k-1}, & \text{if } \Delta\beta_k \in \{\beta_3\}, \end{cases} \qquad (2)$$

where γ_k is the processed value of the contour element α_k.

Mechanism $Б_{\sigma_n}$ Information control by this mechanism is carried out similarly to mechanism $Б_{\sigma_n}$. Its difference lies in the fact that in this case, the $\Delta\beta_k^*$ difference between the original and predicted values of the contour elements β_k is checked instead of $\{\Delta\beta_k\}$. The following variants of the mechanism for controlling error with prediction have been studied: $B^1{}_{\sigma_n}$ – with stepwise extrapolation; $B^2{}_{\sigma_n}$, $B^3{}_{\sigma_n}$ - with statistical extrapolation, respectively, for one and two previous points. The predictive mechanism corrects erroneous information according to the rule:

$$\gamma_k = \begin{cases} \beta_k, & \text{if } \Delta\beta_k^* \in \{\beta_\rho^*\}; \\ \beta_k^*, & \text{if } \Delta\beta_k^* \in \{\beta_3^*\}. \end{cases} \qquad (3)$$

The processed γ_k value in error correction is $\beta_k^* = \beta_{k-1}$ for the $B_{\sigma_n}^1$; $\beta_k^* = \beta_k$ algorithm for the $B_{\sigma_n}^2, B_{\sigma_n}^3$ algorithms.

A general solution of the problem is obtained, which consists in determining the expressions for the minimum root-mean-square error for each of the proposed mechanisms and the optimal control limits. Partial solutions of the problem for various laws of distribution of elements of the RTS are also obtained [29, 30, 31, 32, 33].

It has been established that threshold control mechanisms are effective when the error probability $P \ge 10^{-3}$, relative variance $\sigma_\alpha / B \ge 10^{-2}$. The accuracy of the information is increased by one order of magnitude. It is advisable to use incremental information control mechanisms in conditions where $P < 10^{-3}$, $\sigma_\alpha / B < 10^{-2}$, $R(\tau) \ge 0{,}7$, where the accuracy of information control increases to two orders of magnitude.

C. Mechanisms for improving the quality of microobject image restoration based on NN adaptive learning.

A technique is proposed that is aimed at studying the effectiveness of identification error control based on the standard deviation criterion, gradient optimization, least squares, and the use of heuristic search with annealing and prohibitions.

The objective function of least squares identification optimization is given as $E(w) = \frac{1}{2}\sum_{j,p}(y_{j,p}^{(N)} - d_{j,p})^2 \to \min$,

where $y_{j,p}^{(N)}$ is the state of neurons of the j-output layer of the NN when the p-th original image is fed to its input; $d_{j,p}$ is the reference (desired) state of the output neuron.

It is required to adjust the weights of the neurons of the network $\Delta w_{ij}^{(n)} = \eta \frac{\partial E}{\partial w_{ij}}$, w_{ij} is the weight coefficient of synaptic connections connecting the i-th neuron of the $n-1$ layer with the j-th neuron of the n layer; η-learning rates, $0 < \eta < 1$. In the case of hyperbolic tangent, the second factor is defined as $\frac{dy}{ds} = 1 - s^2$, the third factor is equal to the output of the neuron of the previous layer $y_j^{(n-1)}$. The first factor is expanded as follows $\frac{dE}{dy_j} = \sum_k \frac{dE}{dy_k} \cdot \frac{dy_k}{ds_k} \cdot \frac{\partial s_k}{\partial y_k} = \sum_k \frac{\partial E}{\partial y_k} \cdot \frac{dy_k}{ds_k} \cdot w_{jk}^{(n+1)}$. Here summation over k is performed among the neurons of layer $n+1$. We introduce the variable $\partial_j^{(n)} = \frac{\partial E}{\partial y_j} \cdot \frac{dy_j}{ds_j}$ and a recursive formula is obtained for calculating the $\partial_j^{(n)}$ values of the layer n from the values $w_k^{(n+1)}$ of the older layer $n+1$ in the form $\partial_j^{(n)} = \left[\sum_k \partial_k^{(n+1)} \cdot w_{jk}^{(n+1)}\right] \cdot \frac{dy_j}{ds_j}$. For the output layer as $\partial_i^{(N)} = (y_i^{(N)} - d_i) \cdot \frac{dy_i}{ds_i}$. Neuron weights are corrected in the form $\Delta w_{ij}^{(n)} = -\eta \cdot \partial_j^{(n)} \cdot y_i^{(n-1)}$. The target function of the surface when smoothing sharp jumps, moving the contour point, correcting the weights of neurons, is supplemented by the procedure for using the change in the weight of the neuron at the previous iteration $\Delta w_{ij}^{(n)}(t) = \eta \cdot (\mu \cdot \Delta w_{ij}^{(n)}(t-1) + (1-\mu) \cdot \partial_j^{(n)} \cdot y_i^{(n-1)})$, μ is the inertia coefficient, t is the number of the current iteration.

For visualization, recognition, classification of images of micro-objects, a software package (SP) has been developed, which is specified by the following input parameters: the number of neurons in the input layer; the number of neurons in the hidden layer; the number of output layer neurons; the value of the threshold (offset), the same for all neurons; the learning step used in the backpropagation learning algorithm; the number of iterations to run each time training is run. The value of the threshold, the training step, and the number of iterations that are regulated during the training of the formed NN. A comparative analysis of the effectiveness of algorithms based on various principles of combining their capabilities and criteria for evaluating the results of data processing is carried out.

The service modules of the complex include interface blocks: a program editor-constructor, designing the NN architecture, network training, calculating and setting the parameters of working modules, saving and loading data, and outputting results. The editor-designer of programs uses data tables and programs in the internal language. Interaction with the user is carried out through a multi-level menu and buttons on the panels of screen forms.

In fig. 2 describes the functioning of the NN, which reflects the work of five program modules.

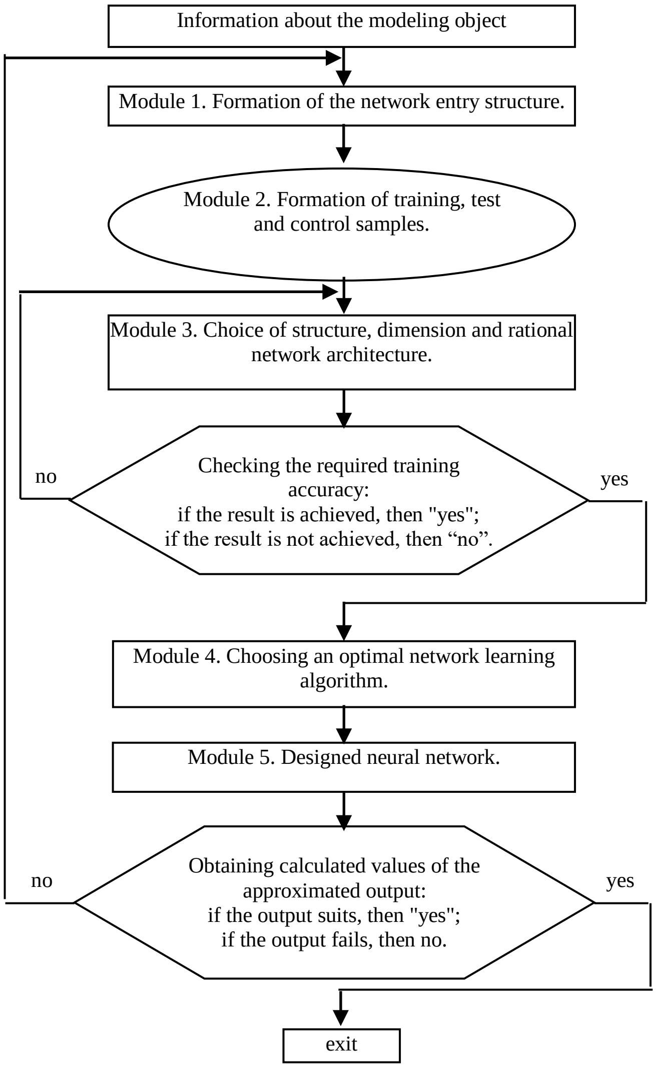


Fig. 2. Diagram of the functioning of the NN.

Thanks to the interface, the complex works in conjunction with the MATLAB 7. In this case, it becomes possible to insert MATLAB inside a program module in the macro language. The NN training module includes one-dimensional optimization procedures; dividing the interval in half; quadratic approximation using derivatives; determining the average value of a point, moving averages; gradient and conjugate-gradient optimization in NN learning.

According to the implemented NN model on the SP control panel, in addition to the windows in which you can change the parameters, there are buttons with which the user can perform the following actions: create a neural network; perform a given number of training iterations using the error backpropagation algorithm ("train"); start the process of image recognition by a trained neural network ("test"); open a form to view the states of the hidden layer of the network; erase the entered image; get information about the program.

After starting and setting the initial conditions, i.e. initial values of the weight coefficients, the number of training samples, the maximum number of iterations, the training parameters of the NN (speed coefficient and error), the values of the input factors are read and normalized. If the number of input factors is more than two and the number of sample values is less than 500, then a three-layer NN is preferred. The number of input neurons is recommended to be taken equal to the amount of input data. The number of output neurons is recommended to be taken equal to the number of predicted variables. The number of neurons in the hidden layer must be at least $(2n+1)$, where n is the number of neurons in the output layer.

The values of the signals at the outputs of the neurons of the output layer are calculated, and then the error is calculated for each training set of samples and the weights of the neurons are adjusted.

D. Optimization of image restoration based on the regulation of the error of the component structure of the NN

It is of interest to study the inherent error of the adder, converter, network branching points when optimizing image recovery. Let the branch point have its own error ε_{tv} and its standard deviation equal to σ_{tv}. The error ε_{tv} is added to each signal of the neuron leaving the branch point.

It is assumed that the error variances of the branch points $D_1, D_2, \ldots, D_k$ are not equal to each other. It is required that the error variance of the signal of the input neuron, taking into account the own error of the branching point, be minimal, i.e. $\min\{D_i\}_{i=1}^{k} - \sigma_{tv}^2$.

The intrinsic error ε_φ of a non-linear transducer is determined by the standard deviation equal to σ_1. The non-linear transducer error ε_φ is added either to the result $\varphi(A+\varepsilon)+\varepsilon_\varphi$ or to the input signal of the non-linear transducer: $\varphi(A+\varepsilon+\varepsilon_\varphi)$. The problem was solved in two versions. When the error ε_φ is added to the result of a nonlinear converter, then its variance is defined as

$$\begin{aligned} D(\varphi(A+\varepsilon)+\varepsilon_\varphi) &= D(\varphi(A+\varepsilon))+ \\ &+D(\varepsilon_\varphi) = \sigma_{own}^2 + \sigma_\varphi^2 = \sigma_1^2. \end{aligned} \quad (4)$$

The dispersion of the output signal of the nonlinear transducer of neurons is equal to $\sigma_{own}^2 = \sigma_1^2 - \sigma_\varphi^2$. The root-mean-square error of the input signal of the nonlinear converter is equal to $\sigma = \sigma_{own} / |\varphi'(A)|$. The error of the input signal is given by the mathematical expectation

$$M_{\varepsilon+\varepsilon_\varphi} \approx \int_{-\infty}^{\infty} (\varepsilon+\varepsilon_\varphi)\cdot \rho_\varepsilon d(\varepsilon+\varepsilon_\varphi) = 0 \quad (5)$$

and dispersion

$$D_{\varepsilon+\varepsilon_\varphi} \approx \int_{-\infty}^{\infty} (\varepsilon+\varepsilon_\varphi - M_{\varepsilon+\varepsilon_\varphi})^2 \rho_\varepsilon d(\varepsilon+\varepsilon_\varphi) = \sigma^2 + \sigma_\varphi^2. \quad (6)$$

Calculation of the mathematical expectation and dispersion of the output signal of a nonlinear converter is carried out according to the linear approximation $\varphi(A+\varepsilon+\varepsilon_\varphi)$ in the form:

$$M_{\varphi(A+\varepsilon+\varepsilon_\varphi)} \approx \int_{-\infty}^{\infty} (\varphi(A) + \varphi'(A)\cdot(\varepsilon+\varepsilon_\varphi))\cdot \rho_\varepsilon d(\varepsilon+\varepsilon_\varphi) = \varphi(A),$$

$$\sigma_1^2 = D_{\varphi(A+\varepsilon+\varepsilon_\varphi)} \approx \int_{-\infty}^{\infty} (\varphi(A) + \varphi'(A)\cdot(\varepsilon+\varepsilon_\varphi) - \\ -\varphi(A))^2 \rho_\varepsilon d(\varepsilon+\varepsilon_\varphi) = \varphi'(A)^2(\sigma^2+\sigma_\varphi^2). \quad (7)$$

From here $(\sigma^2+\sigma_\varphi^2) = \sigma_1^2/\varphi'(A)^2$, i.e. $\sigma = \sqrt{\sigma_1^2/\varphi'(A)^2 - \sigma_\varphi^2}$; $\min\{D_i\}_{i=1}^k - \sigma_{tv}^2$.

It is necessary to calculate the error of the input signals of the adder, the standard deviation of the output signal of the adder σ, the own standard deviation of the errors of the adder σ_Σ.

The intrinsic error of the adder is added either to the output signal of the adder $\sum_{i=1}^n \alpha_i\cdot(x_i+\varepsilon_i)+\varepsilon_\Sigma$ or to each input of the adder $\sum_{i=1}^n \alpha_i\cdot(x_i+\varepsilon_i+\varepsilon_\Sigma^i)$, $\varepsilon_\Sigma^i = \varepsilon_\Sigma/n$.

When the intrinsic error is added to the output signal of the adder, then the standard deviation of the error for the input signals of the adder is calculated as

$$D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_i + \varepsilon_\Sigma) + \sigma^2. \quad (8)$$

When σ_i are equal to each other, then

$$D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_i+\varepsilon_\Sigma) = D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_i) + D(\varepsilon_\Sigma) = \sum_{i=1}^n \alpha_i^2\cdot\sigma_i^2+\sigma_\Sigma^2,$$

that is $\sigma_i = ((\sigma^2-\sigma_\Sigma^2)/\sum_{i=1}^n\alpha_i^2)^{1/2}$.

For the proportional distribution of the standard deviations of the input signals of the adder, we obtain $\sigma^2 = D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_i+\varepsilon_\Sigma) = \sum_{i=1}^n \sigma_i^2+\sigma_\Sigma^2$, that is $\sigma_i = \sqrt{\dfrac{\sigma^2-\sigma_\Sigma^2}{n}}$.

The totalizer's own standard deviation is added to each totalizer input as $\sum_{i=1}^n \alpha_i\cdot(x_i+\varepsilon_i+\varepsilon_\Sigma^i)$.

Let's calculate the variance $D(\sum_{i=1}^n \alpha_i\cdot(\varepsilon_i+\varepsilon_\Sigma^i)) = \sigma^2$.

For a uniform distribution, the variance of the standard deviation can be written as

$$D(\sum_{i=1}^n \alpha_i\cdot(\varepsilon_i+\varepsilon_\Sigma^i)) = D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_i) + D(\sum_{i=1}^n \alpha_i\cdot\varepsilon_\Sigma^i) = \\ = \sum_{i=1}^n \alpha_i^2\cdot\sigma_i^2 + \sum_{i=1}^n \alpha_i^2\cdot(\sigma_\Sigma^i)^2, \quad (9)$$

from here .

In the case of proportional distribution, the standard deviations of the input signals of the adder are calculated as

$$\sigma^2 = D(\sum_{i=1}^n \alpha_i\cdot(\varepsilon_i+\varepsilon_\Sigma^i)) = \sum_{i=1}^n \sigma_i^2 + \sum_{i=1}^n \alpha_i^2\cdot(\sigma_\Sigma^i)^2,$$
$$\sigma_i = (\frac{\sigma^2-(\sigma_\Sigma^i)^2\cdot\sum_{i=1}^n\alpha_i^2}{n})^{1/2}. \quad (10)$$

The standard deviations of errors at the inputs of the adder are calculated using the formula for a uniform distribution of standard deviations:

$$\sigma_1 = \frac{\sigma_{out}}{|\varphi'(A)|} = \frac{0.01}{2/(2+0/32)^2} = 0.03;$$
$$\sigma_2 = \sigma_3 = \frac{0.03}{0.35^2+0.69^2} = \frac{0.03}{0.77} = 0.04;$$
$$\dots$$
$$\sigma_{14} = \frac{3.55}{0.3^2+0.95^2+0.64^2} = \frac{3.55}{1.49} = 2.38;$$
$$\sigma_{15} = \frac{1.43}{0.28^2+0.75^2} = \frac{1.43}{0.8} = 1.79;$$
$$\sigma_{16} = \frac{3.67}{0.54^2+0.41^2+0.28^2} = \frac{3.67}{0.73} = 5.03$$

In fig. 3 illustrates the efficiency graphs of the generalized algorithm estimated by the gain factor *K* in data processing accuracy, which is given as the ratio of the process variance to the RTS smoothing error for various models. *N* is measured along the axis - the amount of information being processed.

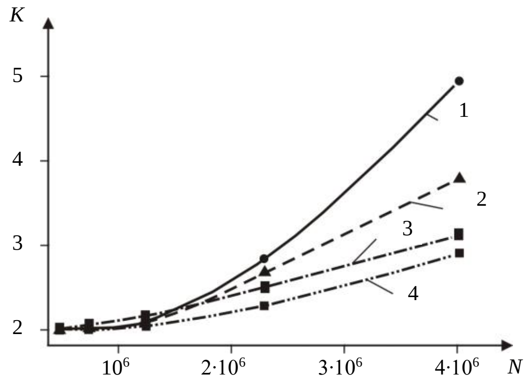


Fig. 3. Graphs of the efficiency of data processing algorithms.

Graph 1 (two dash-dotted line) of the autoregressive model, graph 2 (dash-dotted line), graph 3 (dashed line), graph 4 (solid line) reflect the smoothing of the RTS, respectively, for the three-point, five-point, seven-point cubic spline models with the tools of three-layer NN and cyclic multigrid method.

III. Conclusion

Scientific and methodological foundations for optimal identification for recognition, classification of micro-objects based on mechanisms for extracting statistical, dynamic, specific characteristics of images have been developed. The study was carried out according to the criterion of root-mean-square identification error.

Mechanisms for the optimal identification of micro-objects with the selection of generalized characteristics, the use of specific properties, adequate statistical and dynamic models, predictive and approximating abilities of the NN are proposed.

Optimization of image identification error control is based on the mechanisms of threshold control of contour points coordinates, dynamics increments, with prediction of contour points. Combined statistical, dynamic models, three-layer NN have been researched and implemented.

A general solution of the problems is obtained, aimed at determining the minimum root-mean-square error and optimal control thresholds for various conditions and distribution laws.

The software package is implemented as part of a generalized algorithm, which involves the inclusion of dynamic models (autoregressive, spline functions, three-layer NN). A series of calculations were performed on the basis of a special program written in C++ and implemented in serial mode with one core of a dual-core AMD Athlon 64X2 4800+ processor.

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Applications of quantum cryptography for Internet of Things (IoT) security

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***Abstract*— The Internet of Things (IoT) has brought many benefits to modern society, but it also poses significant security challenges due to the large amount of data generated by IoT devices. One potential solution to these security challenges is quantum cryptography, which uses the principles of quantum mechanics to ensure secure communication. This paper analyzes the application of quantum cryptography in IoT systems, including system problems and solutions, discussions and results, and proposes quantum random number generation (QRNG) and quantum secure direct communication (QSDC) methods as solutions.**

Keywords—Internet of Things (IoT), quantum cryptography, quantum key distribution (QKD), Bennett and Brassard (BB84) protocol, quantum random number generation (QRNG), quantum secure direct communication (QSDC), low-density parity check (LDPC).

I. Introduction

The Internet of Things (IoT) encompasses a cluster of technologies that require various protocols, infrastructures, data storage mechanisms, and information technology (IT) communication methods.

With the development of the Internet of Things (IoT) and the increase in sensitive and confidential information transmitted over these networks, security in this network has become a major concern [1]. One emerging technology that can effectively secure these networks is quantum cryptography. Quantum cryptography is a field of research that employs the principles of quantum mechanics to develop secure communication protocols. In this article, we discuss the use of quantum cryptography in IoT systems, the challenges it presents, and the solutions being developed to address these challenges.

II. Security issues in IoT systems

A. Data breach

IoT applications collect a significant amount of sensitive data from users to function properly and efficiently. Furthermore, most of this data consists of the user's personal information, which must be protected through encryption.

B. Data authentication

Even if the data is successfully encrypted, there is still a possibility of the device itself being compromised. Security is only recognized when the authenticity of data to and from an IoT device cannot be determined by any means.

C. Adjacent channel attacks

These are attacks based on information and data from the system implementation rather than weaknesses in the attack implementation algorithm. Power consumption, electromagnetic leakage, or noise may be sufficient to compromise the system.

D. Lack of updates

There are many IoT devices in the world now, and the number is increasing every year. When developing devices, developers often do not pay much attention to future updates of the device, and therefore a device that was considered secure at the time of manufacture may become insecure within a few years.

E. Malware and ransomware

An example of malware is the Mirai Botnet, which infects IoT devices running Argonaut Reduced Instruction Set Computer Core (ARC) processors. If the default username and password combination for the device is not changed, it is very easy for Mirai to infect the device. Ransomware is a type of malware that tends to lock users out of their devices and threatens to leak users' personal information if a ransom is not paid [2].

We need stronger cryptographic and security algorithms to prevent the abovementioned threats.

III. Quantum cryptography

Cryptography is the process of encrypting and protecting data so that only a person with a specific secret key can access the data. Quantum cryptography differs from traditional cryptographic systems in that it relies on physics rather than mathematics as the main aspect of its security model. Quantum cryptography does not compromise the message without the knowledge of the senders or receivers and provides complete protection. In other words, information encoded in the quantum state cannot be copied or viewed without notifying the sender or receiver [3].

Quantum cryptography uses individual particles of light, or photons, to transmit data over optical fiber. Photons represent binary bits. The security of the system relies on quantum mechanics. These secure features include:

- Particles can exist in multiple places or states simultaneously.
- A quantum property cannot be observed without changing or disturbing it.
- The particles that make up the universe are indeterminate and can exist in multiple places or states of existence simultaneously.
- You can clone some quantum properties of a particle, but not the entire particle.

These properties make it impossible to measure the quantum state of any system without destroying that system.

A. *Quantum key distribution*

One of the main techniques used in quantum cryptography is quantum key distribution (QKD). QKD involves the transmission of a series of photons (light particles) in a state of random polarization. The sender and receiver each measure the polarization of the photons using a device known as a polarizer. Since the polarization of each photon is randomly generated, any attempt to capture or measure the photons necessarily distorts the state of polarization. As a result, an attempt to eavesdrop on the communication is detected immediately [2].

Imagine there are two people named Alice and Bob who want to send each other a secret message. With QKD, Alice sends a series of polarized photons to Bob through a fiber optic cable. This cable does not need to be shielded because the photons have a random quantum state. Alice initiates the message by sending a key to Bob. The key is a stream of photons moving in one direction. Each photon represents one bit of data - 0 or 1. However, in addition to linear movement, these photons oscillate in a certain way (Fig. 1).

Thus, before the sender Alice initiates the message, the photons travel through the polarizer. A polarizer is a filter that allows some photons to pass with the same vibration and others with a different vibrational state. Polarized states can be vertical (1 bit), horizontal (0 bit), 45 degrees right (1 bit), or 45 degrees left (0 bits). A transmission has one of two polarizations, representing a single bit, 0 or 1, in the circuit it uses.

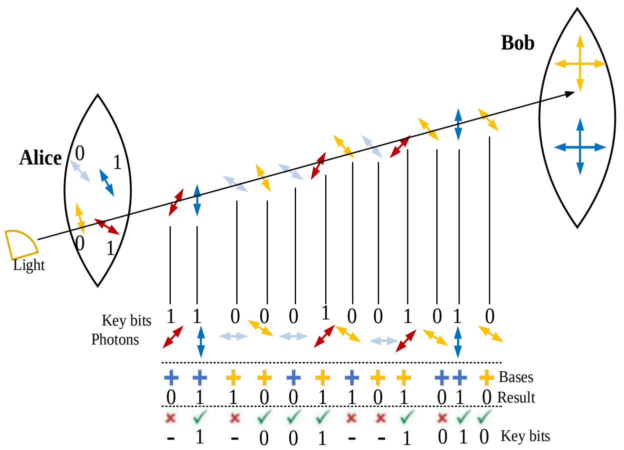

Fig. 1. Implementation of quantum encryption via quantum key distribution (QKD)

The photons now travel along the optical fiber from the polarizer to the receiver, Bob. This process uses a beam splitter that reads the polarization of each photon. When receiving the photon switch, Bob does not know the correct polarization of the photons, so one polarization is chosen at random. Alice now compares what Bob used to polarize the switch and then lets Bob know which polarizer to send each photon from. Bob then confirms that he used the correct polarizer. Photons read with the wrong separator are then discarded, and the rest of the sequence is keyed [4].

If a third party tries to eavesdrop on the conversation, they have to read each photon to access the message. Then, they have to give this photon to Bob. By reading the photon, the third party changes the photon's quantum state, which introduces errors in the quantum key. This alerts Alice and Bob that someone is listening and that the key has been compromised, so they discard the key. Alice needs to send Bob a new uncorrupted key, and then Bob can read the message from that key.

B. *Related works*

In recent years, several studies have been conducted on quantum cryptography. In 2018, Wang et al. proposed a secure communication scheme based on chaotic maps and quantum key distribution. The scheme used chaotic maps to generate a secret key, which was then used in conjunction with QKD to establish a secure communication channel.

In 2019, Zhang et al. proposed a quantum cryptography protocol based on quantum chaotic systems. The protocol used chaotic systems to generate a public secret key, which was then used to encrypt and decrypt messages.

In 2020, Liu et al. proposed a new QKD protocol based on entangled photon pairs. The protocol used two entangled photon pairs to establish a secret key, which was then used for secure communication.

Table 1 below provides an analysis of the scientists who have conducted research using this method to date and their work:

TABLE I. ANALYSIS OF RESEARCH WORK AND RESULTS IN THIS FIELD

Authors	*Approach*	*Method*	*Main result*
Wang et al. (2018)	Chaotic maps and QKD	Generate a secret key using chaotic maps and establish a secure communication channel using QKD	Secure communication is achieved using the proposed scheme
Zhang et al. (2019)	Quantum chaotic systems	Generate a public secret key using chaotic systems and use it to encrypt and decrypt messages	A new quantum cryptography protocol based on chaotic systems has been proposed
Lee et al. (2019)	QKD-based authentication	Improved security compared to traditional methods	A more effective authentication method than traditional methods
Liu et al. (2020)	Conjoined photon pairs	Generate a secret key using two entangled photon pairs and use it for secure communication	A new QKD protocol based on entangled photon pairs has been proposed
Zhou et al. (2021)	Data encryption based on QKD	Improved security and low latency compared to traditional methods	A low-latency encryption method

As the table shows, these studies found that using quantum cryptography in IoT systems can enhance security and reduce communication overhead and latency.

IV. THE IMPACT OF QUANTUM COMPUTING ON THE INTERNET OF THINGS

Quantum computing has various important features that classical computers do not possess, making the security of IoT more vulnerable than before. Although the IoT has encountered numerous threats to date, these security risks may escalate to an unprecedented level if quantum computing is implemented. Organizations relying on real-time IoT applications are coming to realize that quantum computing will become a formidable threat [5].

A. *Key features of post-quantum cryptography*

Post-quantum cryptography is a subfield of cryptography that deals with the design, implementation, and analysis of cryptographic algorithms. More broadly, researchers are striving to enhance information security infrastructure by implementing quantum-resistant primitives known as quantum-safe cryptography. Quantum cryptography is much more efficient than traditional methods due to the following properties:

1) Photon polarization: Used to describe the exact direction of polarization of light or photon particles, counting time plays an important role because these polarized light particles or photons can only be measured at a specific time to determine the correct state of polarization. If no specific photon filter is selected, the photon particle is lost [6].

2) Uncertainty Principle: The German physicist Heisenberg introduced the concept of uncertainty principle related to quantum information, formally known as the Heisenberg Uncertainty Principle [7], which states that it is difficult to measure the state of a particle without perturbing the particle because it has different states with varying probabilities. available in different situations.

3) Non-Clone Theory: In general, cloning refers to the creation of an identical state in another system, i.e., cloning quantum information is the art of producing an identical state in another system [8]. Cloneless quantum theory states that an unknown quantum state cannot be destroyed or cloned because there is currently no machine capable of doing so.

4) Teleportation: Quantum information has its hidden properties because, to measure the classical formation, the sender must calculate the original quantum state that was opened by the sender itself during classical communication, and the remaining information is quantum information. The continuous flow of quantum information, combined with the Heisenberg Uncertainty Principle and photon polarization properties, makes quantum cryptography an ideal choice for ensuring data security and privacy. With these fundamental properties, quantum cryptography enables IoT systems to confront the post-quantum IoT world.

B. *Implementing quantum cryptography for IoT security*

IoT devices have numerous vulnerabilities in terms of user or network security. Additionally, sometimes when there is an attack, where only one device in the entire IoT network may become infected with a virus, other devices trust the infected device and continue to communicate until the infection is detected. A threat may not be detected in time, and during this period, a significant amount of data can be transmitted to any malicious entity [9]. Some viruses can affect systems in such a way that they can only be removed by rebooting the systems, and industrial and corporate systems are not rebooted for extended periods. Thus, there are various points of vulnerability, and IoT systems are highly susceptible to attacks. Here, we explore a potential solution to IoT security through quantum cryptography [10].

A key aspect of quantum cryptography is the quantum key distribution discussed above [11]. The most significant feature of quantum key distribution is the channel's ability to detect the presence of any eavesdropper in the system architecture. This is fundamentally different from classical cryptography algorithms.

In general, the two channels required to establish secure communication in QKD include a quantum channel and a non-quantum (conventional) channel. In the QKD process, messages are not sent directly over the quantum channel. Instead, an initial exchange of random bits containing irrelevant information is performed between two users. The primary purpose of this step is to detect any eavesdropping on the connection. If an eavesdropper is active, they may attempt to intercept the message. Monitoring the conventional channel provides the probability that the connection was tampered with or intercepted during transit. If any tampering is suspected, the connection is reset from the beginning. In another scenario, if the channel is deemed secure, the parties jointly agree to establish the next communication using the quantum bits as a one-time pad.

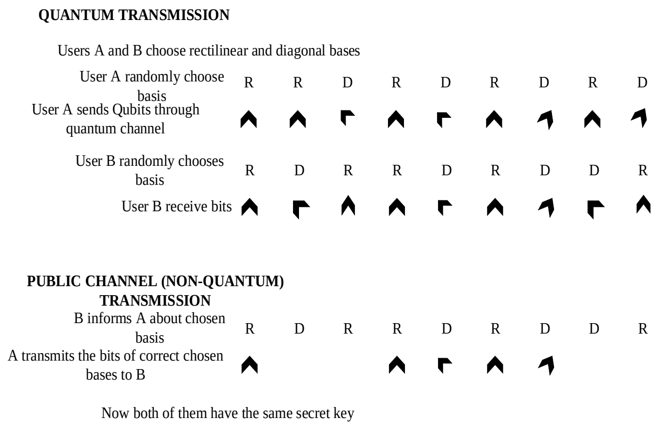

Fig. 2. Illustration of QKD of BB84 protocol

The most widely used protocol for secure key agreement is the Bennett and Brassard (BB84) QKD protocol developed by Charles H. Bennett and Gilles Brassard, as discussed below [12]. Initially, both entities (e.g., users "A" and "B") define the polarization basis, namely Diagonal and Rectilinear. This step is crucial for communication because the agreed-upon basis in this step is used for further communication. Then, one of the two (e.g., user A) randomly selects a basis from which to identify qubits. The selected qubits are then transferred to the other entity through a quantum channel. Next, user A informs user B about the chosen basis over a non-quantum channel, and if the communication is considered secure, they proceed. Finally, user A transmits the qubits chosen by user B to a specific polarization basis, and ultimately, both entities have the same key by applying the BB84 protocol. Figure 2 illustrates the example discussed above using the BB84 protocol. By utilizing quantum state storage and two unitary operations, this protocol modifies the BB84 protocol and ensures that no party can determine the key, but both participating parties can determine the key between themselves [5].

V. Proposed Method and Results

Implicit security is achieved through the use of quantum secure direct communication (QSDC) [13] as a form of quantum communication that utilizes the methods and tools studied above to ensure secure communication between IoT devices. It provides a unique method for direct data transfer and secure communication implementation using quantum random number generation (QRNG), which creates a noise source with a high level of randomness, as we will.

A. *Quantum random number generation (QRNG)*

The main issue in the BB84 quantum cryptographic protocol is the maximum distance that photons can travel. Photons are essentially light particles that can easily be damaged by the environment or natural disasters. In cases where IoT networks span large distances, covering many cities or countries, photons have to travel very long distances. This is where quantum computing falls short. Additionally, quantum devices are bulky and expensive, making them unaffordable for many organizations. The existing quantum key distribution protocol is designed to work with only two devices, which is almost impossible to implement in real IoT systems that integrate hundreds of devices for communication [14].

To address these challenges, a proposed solution combines classical and quantum approaches. The first suggested solution retains current semiconductor chips but uses quantum techniques to generate long and unique cryptographic keys for each device. This can be achieved using QRNG, which creates a noise source with a high degree of randomness. Quantum computing is capable of efficiently and rapidly generating such large numbers. As a result, the keys will be extremely difficult to guess, and each device will have a unique key. The only way to obtain the key is to access the physical device configuration, a task that is very challenging to accomplish without anyone noticing. Therefore, it can be assumed that the key is well-protected, ensuring secure communication [15].

B. *Quantum secure direct communication (QSDC)*

It is also possible to use device-independent quantum cryptography to ensure trust in manufactured devices.

QSDC, considered a form of quantum communication, provides security during direct transmission.

QSDC was first proposed in 2000 to implement direct data transmission without key distribution. Later in 2003, Deng and Long presented all aspects of QSDC and proposed a two-stage QSDC [16]. Recently, QSDC has developed rapidly. In addition, secure direct communication based on continuous variables was presented [17]. Zhang et al. [18] demonstrated QSDC using a two-step QSDC protocol over an optical fiber with a critical distance of 500 m. Later, Qi et al. [19] addressed several key issues and provided a comprehensive security analysis of QSDC for practical application.

Zhou et al. [20] proposed a gauge-independent QSDC that eliminates gauge-related security gaps. Meanwhile, Zhou et al. [21] developed a device-independent QSDC, which represents a relaxation of security assumptions made in conventional protocols and improves communication security. In particular, using modern technologies, a quantum memory-free QSDC protocol has been developed, in which the quantum memory is lost, which solves one of the biggest obstacles to the practical application of QSDC.

A key requirement of QSDC using Wyner's listening channel model is to allow the communication system to operate at a power lower than the privacy capacity of the channel. An efficient quantum coding method using a combination of low-density parity-check (LDPC) codes was presented in the research work (Figure 3). The proposed method can operate in high-loss and high-error modes, which is unique for quantum communication. In this case, the communication distance is about 1.5 km, and the achieved secure data transfer rate is 50 bps, sufficient for text messages and images. Recently, a group at Tsinghua University further extended this practical prototype to a distance of 12.04 km with a communication speed of more than 4 kbps using classical optical fibers. These studies have provided a solid foundation for the practical application of QSDC.

In the coding and decoding layers shown in Figure 3, universal hashing families (UHF) perform the function of secure coding, aimed at ensuring information-theoretic security [22]. In this encoding method, the sender, Alice, first generates a locally random bit sequence of a certain length. Then, it uses reverse UHF (UHF^{-1}) to process the message together with local random numbers and general random numbers, achieving randomization of the secret message and generating a new vector. This vector is encoded with an LDPC code and then mapped to the transmitted codeword. After receiving the codeword, Bob can extract the secret message through the appropriate stages of de-mapping, ECC decoding, and UHF. Eve cannot decipher a secret message if it is a partially stolen transmitted codeword. This secure coding scheme does not require changing the traditional coding structure. Arbitrary error correction codes and anti-loss codes can be used to enhance reliable communication capability.

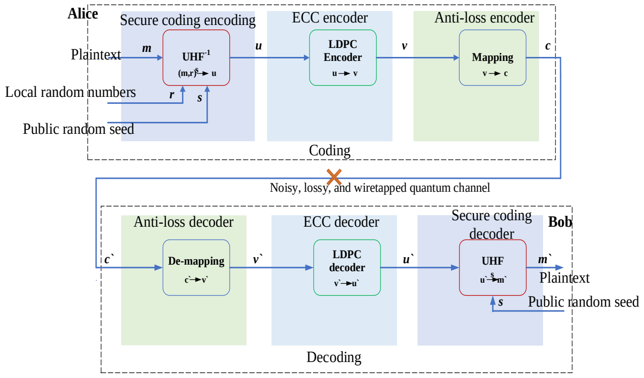

Fig. 3. Encoding and decoding scheme for the QSDC experiment

The single photon source is provided by a strongly attenuated 1550 nm laser with a systematic pulse repetition frequency of 1 MHz. Both communication sides are controlled using field-programmable gate arrays (FPGAs).

As discussed, recent advances in QSDC have accelerated for practical applications. Additionally, as Elsa Kania and John Costello pointed out in their 2018 CNAS report, QSDC enhances communication security, which is typically the value proposition of quantum communication. Furthermore, its direct transmission nature makes it a natural fit with post-quantum cryptography, which finds several important applications in the growing field of quantum networks. It should be noted that, on one hand, QSDC can be used independently for the direct transmission of small amounts of data in the most secure manner. On the other hand, its use can be similar to quantum key distribution, which means it can also be used to distribute a small number of secret keys and then combine them with a standard symmetric cryptography protocol, such as the Advanced Encryption Standard (AES). With the development of classical coding theory and the improvement of quantum devices, the prospects of quantum secure direct communication will be broad and bright.

VI. Conclusion

The advent of IoT has enabled us to communicate with each other using the Internet in our daily lives. However, various problems have arisen following the use of these technologies. Various cryptographic primitives have been developed to address these problems. However, with the emergence of the idea of quantum computing, it became evident that this cryptography was not secure enough. It can be seen that the development of cryptographic solutions that provide the expected level of security in post-quantum IoT networks is required. In this article, we have discussed in detail the IoT-related issues and available countermeasures. In the following sections, a comprehensive description of the concept of quantum cryptography is provided. During this research work, QKD, one of the main methods used in quantum cryptography, and the BB84 protocol used within it, were employed to address the existing problems in the IoT system and ensure secure communication between devices. We utilized the QSDC method to ensure secure communication, and as a result, the encoding and decoding schemes were demonstrated.

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Scientific And Technical Solutions Of Operational Expertise In Emergencies

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***Abstract*—In the process of eliminating emergency situations, state management bodies, local management bodies, organizations, citizens are considered the main element in the prevention of emergency situations, and an operational staff is formed to perform these tasks. In order to carry out expert activities in this headquarters, expertise has its own place, but until now the exact form and place have not been developed and specified. The main task of the employees of the expertise units within the emergency headquarters is to take measures to determine the cause of the emergency situation. In order to fulfill these tasks, the article describes the scientific and technical solutions of operational expertise in emergency situations.**

***Index Terms*—Emergency situation, expertise, model, algorithm, information-analytical decisions.**

I. Introduction

To date, a number of measures to prevent emergency situations are being developed in the direction of determining the causes of emergency incidents in the Republic, conducting expertise, as well as ensuring the safety of the population in emergency and crisis situations. [1-3].

The following must be determined in the event of an emergency or their elimination [4-7]:

- circumstances indicating the cause of the emergency situation, the guilty persons and their level of responsibility;

- presence of people killed and injured as a result of an emergency situation, other specific consequences of an emergency situation;

- emergency fire situation of the organization, object and their cause-and-effect relationship with the emergency situation, as well as the spread and consequences of the emergency situation;

- the reasons and conditions that allowed the emergence and development of the emergency situation.

In the process of determining the cause of emergency situations, the implementation of the following quick measures will consist of stages [8-10]:

1. Identification of the witness of the incident, the managers of the facility;

2. Obtaining and analyzing primary data from witnesses;

3. Determining the cause of the incident by appointing an expert or involving a group of experts.

The above actions will allow you to choose the right direction during the inspection [11-12].

II. Materials and methods

The following processes, in a new sequence, are included in the expertise conducted by the expertise units.

Checking and preparation of the conclusion at the initial stage of C can be symbolically expressed in the following form:

$$S_{xtj} \in (S_x^1, S_x^2, S_x^3 ... S_x^i \, S_y^1, S_y^2, S_y^3 ... S_y^i \, S_z^1, S_z^2, S_z^3 ... S_z^i). \quad (1)$$

Here: S_{xtj} - summary preparation process; S_x^1, S_x^2, S_x^3 conditions for the sequential execution of operations, which are known to the expert in advance and cannot be changed;

S_y^1, S_y^2, S_y^3 solutions to be determined by the expert (the time of the beginning of the situation, the location of the epicenter, the mechanism of the emergence of the emergency situation, the conditions that led to it, the consequences, etc.);

S_z^1, S_z^2, S_z^3 conditions or factors unknown to the expert (interrelationship of the dynamics of the development of the emergency situation with certain conditions and situations, the focus (epicenter), the cause), the right questions were asked to the expert to determine them, the samples for the study were correctly selected, the research was conducted, etc. depends on.

S_x^1, S_y^2, S_z^3 - final stage of a sequence of operations work that the expert knows in advance and cannot be changed, solutions that the expert must determine, conditions or factors that are unknown to the expert in advance.

It shows the time spent from the date of appointment of the expertise to the adoption of the final conclusion.

$$\begin{aligned}\sum \tau_{yx} = \tau_{ethq} + \tau_{tvo} + \tau_{vjk} + \tau_{fvo} + \\ + \tau_{fvtya} + \tau_{adt} + \tau_{maf} + \tau_{teho} + \tau_{lt1,2}\end{aligned} \tag{2}$$

$$\begin{aligned}\partial\tau_{yx} = \tau_{ethq}^{'}(\tau)\,\Delta\tau_{ethq} + \tau_{tvo}^{'}(\tau)\,\Delta\tau_{tvo} + \\ + \tau_{vjk}^{'}(\tau)\,\Delta\tau_{vjk} + \tau_{fvo}^{'}(\tau)\,\Delta\tau_{yo} + \\ + \tau_{fatya}^{'}(\tau)\,\Delta\tau_{fvtya} + \tau_{adt}^{'}(\tau)\,\Delta\tau_{adt} + \\ + \tau_{maf}^{'}(\tau)\,\Delta\tau_{maf} + \\ + \tau_{teho}^{'}(\tau)\,\Delta\tau_{teho} + (\tau)\,\Delta\tau_{lt}.\end{aligned} \tag{3}$$

It was determined that the determination of the time of the examination and taking into account the appearance of the limits is based on the formula under the assessment of the general situation.

$$\begin{aligned}&\tau_{yx}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{etxq}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{tvo}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \\ &+ \tau_{vjk}(\tau)\big|_{\tau_0}^{\tau_{max.}}\ \tau_{fvo}(\tau)\big|_{\tau_0}^{\tau_{max.}} = \\ &= \tau_{fvtya}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{adt}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \ \tau_{maf}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \\ &+ \tau_{teho}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{lt}(\tau)\big|_{\tau_0}^{\tau_{max.}},\end{aligned} \tag{4}$$

$$\begin{aligned}(\tau_{2.ethq} - \tau_{1.ethq}) + (\tau_{2.tvo} - \tau_{1.tvo}) + \\ + (\tau_{2.vjk} + \tau_{1.vjk}) + (\tau_{2.fvo} + \tau_{1.fvo}) + \\ (\tau_{2.ytya} - \tau_{1.ytya}) = (\tau_{2.adt} - \tau_{1.adt}) + \\ + (\tau_{2.maf} + \tau_{1.maf}) + (\tau_{2.teho} + \tau_{1.teho}) + (\tau_{2.lt} + \tau_{1.lt}),\end{aligned} \tag{5}$$

$$\begin{aligned}\tau_{yx} = &\int_{\tau_0}^{\tau_{max.}} \tau_{ethq}(\tau)\,\partial\tau_{ethq} + \int_{\tau_0}^{\tau_{max.}} \tau_{tvo}(\tau)\,\partial\tau_{tvo} + \\ &+ \int_{\tau_0}^{\tau_{max.}} \tau_{vjk}(\tau)\,\partial\tau_{vjk} + \int_{\tau_0}^{\tau_{max.}} \tau_{fvo}(\tau)\,\partial\tau_{fvo} + \\ &+ \int_{\tau_0}^{\tau_{max.}} \tau_{fvtya}(\tau)\,\partial\tau_{fvtya} + \int_{\tau_0}^{\tau_{max.}} \tau_{adt}(\tau)\,\partial\tau_{adt} + \\ &+ \int_{\tau_0}^{\tau_{max.}} \tau_{maf}(\tau)\,\partial\tau_{maf} + \int_{\tau_0}^{\tau_{max.}} \tau_{teho}(\tau)\,\partial\tau_{teho} + \\ &+ \int_{\tau_0}^{\tau_{max.}} \tau_{lt}(\tau)\,\partial\tau_{lt}.\end{aligned} \tag{6}$$

Here: $\sum \tau_{yx}$ - final conclusion;

τ_{ethq} issuance of a decision on the appointment of expertise by the inspector;

τ_{tvo} study of the immediate situation at the scene of the accident;

τ_{vjk} inspect the scene;

τ_{fvo} identification of the emergency situation (through extreme research and interviews with witnesses or special citizens);

τ_{fvtya} determine the ways of spreading of an emergency situation;

τ_{adt} discovery of physical evidence (not limited);

τ_{maf} -use of special literature;

τ_{texo} document submitted by the body conducting the case and evidence studies;

τ_{lt} conducting laboratory research on material evidence (laboratory research is carried out in a special mobile fire technical laboratory or specially equipped laboratory rooms);

$\tau_{lt*1,2}$ is determined using formulas (7)-(11).

Conducting examinations is the stage mentioned in formula (2). And as a result of its implementation in sequences, operative and qualitative examination is achieved. But if any of these steps are not performed by the conducting body or the expert, then the expert opinion will not be perfect.

III. Results

$\tau_{lt*1,2}$ technical evidence in the course of the examination and we will consider the sequence of conducting chemical laboratory research: (7)-formula we will consider the time and sequence for conducting technical examination.

$$\tau_{lt*1} = \tau_{hytl} + \tau_{rt} + \tau_{mmt}, \tag{7}$$

$$\begin{aligned}\partial\tau_{v.f} = \tau_{hytl}^{'}(\tau)\,\Delta\tau_{hytl} + \\ + \tau_{rt}^{'}(\tau)\,\Delta\tau_{rt} + \tau_{mmt}^{'}(\tau)\,\Delta\tau_{mmt}.\end{aligned} \tag{8}$$

To take into account the appearance of time signs and limits, we need to take into account the following conditions,

$$\begin{aligned}\tau_{v.f} = \tau_{hytl1}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{hytl2}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{rt1}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \\ + \tau_{rt2}(\tau)\big|_{\tau_0}^{\tau_{max.}} \quad + \tau_{mmt1}(\tau)\big|_{\tau_0}^{\tau_{max.}} + \tau_{mmt2}(\tau)\big|_{\tau_0}^{\tau_{max.}},\end{aligned} \tag{9}$$

$$(\tau_{2.hytl} - \tau_{1.hytl}) = (\tau_{2.rt} - \tau_{1.rt}) + (\tau_{2.mmt} + \tau_{1.mmt}) \tag{10}$$

$$\begin{aligned}\tau_{lt*1} = &\int_{\tau_0}^{\tau_{max.}} \tau_{hytl}(\tau)\,\partial\tau_{hytl} + \int_{\tau_0}^{\tau_{max.}} \tau_{rt}(\tau)\,\partial\tau_{rt} + \\ &+ \int_{\tau_0}^{\tau_{max.}} \tau_{mmt}(\tau)\,\partial\tau_{mmt}.\end{aligned} \tag{11}$$

Here :

τ_{hytl} conducting operational research in a specially equipped mobile fire technical laboratory;

τ_{rt} - carrying out X-ray phase research in the research of objects;

τ_{mmt} conducting metallographic and morphological research during the research of objects;

From (12) formula (τ_{lt*2}) ake a look at the time and sequence for conducting a chemical examination:

$$\tau_{lt*2} = \tau_{xytl} + \tau_{yta} \tag{12}$$

$$\partial\tau_{v.f} = \tau_{hytl}^{'}(\tau)\,\Delta\tau_{hytl} + \tau_{yta}^{'}(\tau)\,\Delta\tau_{yta}. \tag{13}$$

To take into account the appearance of time signs and limits, we need to take into account the following conditions

$$\tau_{v.f} = \tau_{hytl1}\left(\tau\right)\big|_{\tau_0}^{\tau_{max.}} + \tau_{hytl2}\left(\tau\right)\big|_{\tau_0}^{\tau_{max.}} + \\ + \tau_{yta1}\left(\tau\right)\big|_{\tau_0}^{\tau_{max.}} + \tau_{yta2}\left(\tau\right)\big|_{\tau_0}^{\tau_{max.}} \quad , \tag{14}$$

$$\left(\tau_{2.hytl} - \tau_{1.hytl}\right) = \left(\tau_{2.yta} - \tau_{1.yta}\right) \tag{15}$$

$$\tau_{lt*2} = \int_{\tau_0}^{\tau_{max.}} \tau_{hytl}\left(\tau\right)\partial\tau_{hytl} + \int_{\tau_0}^{\tau_{max.}} \tau_{yta}\left(\tau\right)\partial\tau_{yta} \tag{16}$$

Here : τ_{hytl} conducting operational research in a specially equipped mobile fire technical laboratory;

τ_{yta} conducting a study of identification and classification of ignition initiators in the study of objects.

If both technical and chemical expertise is assigned in the course of the expertise, i.e. in connection with one emergency situation, in addition to the execution of all the sequences specified in formula (2) τ_{lt*1} and τ_{lt*2} are added to each other.

In order for the expert to provide a final and well-founded conclusion, he must conduct a laboratory study of the material evidence provided by the body in charge of the case, as well as examine all of them, not by selecting the objects. This requires complete execution of all sequences given in formula (1) and (2).

Identifying the epicenter of the emergency and it is proposed to reduce the time of examination and optimize the tasks presented in formulas (1) and (2).

Taking into account the experience of expert in order for the experts to independently perform the tasks listed in the (2) and to receive a conclusion is reflected in the following formula.

$$\begin{aligned} r_1 = -\Big(\tau_{\text{tvo}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{tvo2}}}^{1j}\right){\tau_{\text{tvo2}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{tvo2}}}^{1j}\right)} + \\ + \tau_{\text{vjk}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{vjk3}}}^{1j}\right){\tau_{\text{vjk3}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{vjk3}}}^{1j}\right)} + \\ + \tau_{\text{fvo}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{fvo4}}}^{1j}\right){\tau_{\text{fvo4}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{fvo4}}}^{1j}\right)} + \\ + \tau_{\text{fvtya}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{fvtya5}}}^{1j}\right){\tau_{\text{fvtya5}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{fvtya5}}}^{1j}\right)} + \\ + \tau_{\text{adt}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{adt6}}}^{1j}\right){\tau_{\text{adt6}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{adt6}}}^{1j}\right)} + \\ + \tau_{\text{maf}} & \frac{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{maf7}}}^{1j}\right){\tau_{\text{maf7}}}^{1j}}{\sum_{j=1}^{n}\tau_{efy}\left({\tau_{\text{maf7}}}^{1j}\right)}. \end{aligned} \tag{17}$$

Here:
r_1 calculation of expert activity;
τ_{efy} years of activity of the expert.

IV. Discussion

If $\tau_{efy} > 1$ if so, he will have the right to add the expert to the operative staff and receive an independent opinion. A mathematical model for calculating the useful work coefficient for state fire control personnel (F_{sk}) and an algorithm was developed. Mathematical model based on the research conducted on the increase of work quality and efficiency in the activities of the employees of the expertise units of the Ministry of Emergency Situations $(\sum \tau_{yx})$ and an algorithm was developed. According to the results of the conducted research, the coefficient of determining the work efficiency of experts k_s^i -was invited. Useful performance factor when using unmanned aerial vehicles in field conditions $\mathrm{k}_f 2^i - 1,65$ it became known that it will double. When the developed algorithm and mathematical models are checked in practical experience it was determined that tvo should be included in $\tau_{vjk}, \tau_{fvoa}, \tau_{fvtya}, \tau_{uuq}$ and it was possible to increase its efficiency in the examination and to reduce the time spent on obtaining a conclusion by up to 13 percent.

Conclusion.

The analysis showed that leading experts in the field of fire emergency and explosion investigation and expertise are increasingly turning to information computing models to support the conclusions of expert studies. However, experts operating in our republic use calculation methods insufficiently. At the same time, the information models based on the calculations considered and proposed by us cannot solve the problem of obtaining a single correct and complete expert opinion, so there is no reason not to conduct a repeated or additional examination, because experts use calculation models. Some emergency situations receive different results that do not correspond to the data describing the process of initiation and propagation. Air circulation system in the building, wind direction and other factors play a very important role in this.

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Fire Risk Assessment Model

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***Abstract*—Ensuring the fire resistance of objects is a complex and multifunctional mechanism. The occurrence in it of any emergency situation associated with a fire, an accident, etc., leads to a malfunction of a large organism. In order for this failure to be minimal, and the liquidation of the incident to be carried out tactically competently and as soon as possible, it is necessary to create a system of methods and means of intellectual support for fire safety management tasks. The subject of the research is the study of the current situation in the creation and functioning of the means of preparing and processing data, knowledge for the tasks of ensuring fire safety at objects of various functional purposes. The purpose of the work is to develop tools for extracting, formalizing and structuring expert information for the preparation and adoption of managerial decisions on ensuring fire safety, creating a flexible expert diagnostic shell. According to the goal, the objectives of the study are to conduct a systematic analysis of risk characteristics under conditions of uncertainty based on the processing of fuzzy information. Studying the state of development of methods and means of intellectual support for making managerial decisions to ensure fire safety. Development and justification of methods for presenting and processing expert information in the selected subject area. Development of mechanisms for using the concept of probabilities for decision-making models. Creation and approbation of techniques for extracting expert information. The expediency of using the theory of fuzzy sets and neural networks in tasks with incomplete or linguistic information, as well as in tasks that are characterized by intuitive solutions, is revealed. The scientific novelty of the work is the development of a fire risk assessment model. The fire risk assessment model is described using fuzzy inference rules.**

***Index Terms*—Estimation, risk, fire, fuzzy set theory, neural networks, expert information, model, algorithm, decision making.**

I. Introduction

Fire safety issues are considered by specialists as part of the problem of ensuring the safety of complex technical systems [1, 2, 3, 4]. In [4], two areas of activity are distinguished: preventive and operational-tactical. The work is devoted to solving the problem of intellectualization of fire risk management processes and safety improvement. The problems of fire risk management at the design stage were solved using game theory, the main results of such studies are given in [5, 6]. The processes of the appearance of ignition sources, due to the large number of implementation options, are difficult to classify, unlike substances and materials for which standards have been established at the state level. However, preventing the occurrence of just such processes is the most effective in terms of ensuring fire safety. As an indicator of the fire hazard of the actual state of the railway transport object, the probability of a fire, and not the individual fire risk, was chosen.

The probability of a fire as one of the indicators of the effectiveness of fire safety systems. Protected objects must have fire safety systems that ensure the lowest possible probability of a fire. This requirement determined the direction of much future research in the development of methods for assessing the likelihood of a fire and, as a result, fire risks. The results of the fire risk assessment were to ensure the formation of a list of measures to minimize the impact on people of hazardous and harmful fire factors at facilities where the spread of fire can lead to explosions, mass injury to people at these facilities and surrounding areas. Most of all, specialists from the oil and gas industry, owners of hazardous facilities were interested in such studies.

Historically, models describing combustion processes were the first to appear. At the same time, explosion safety was studied and standardized inseparably with fire safety. Already in 1979, the standard GOST 12.0.010-766 established the permissible probability of an explosion: "... the probability of exposure to dangerous explosion factors on people during the year did not exceed 10-6 per person." Perhaps it was this indicator that was transformed into the norm of individual fire risk in 123-FZ. The requirements of GOST 12.0.010-76 apply to production processes. The main factors characterizing the danger of an explosion were: the maximum pressure and temperature of the explosion, the rate of pressure increase during the explosion, the pressure in the front of the shock wave, crushing and high-explosive properties of the explosive environment. Similarly, the factors affecting people during fires were described: shock wave, flame, collapsing structures, harmful substances released during the explosion. Separately, the issues of ensuring fire and explosion safety of industries using gases and liquids [7], electronics enterprises [8], woodworking industry [9] in maritime transport [10, 11] were studied. The systematization of methods for modeling the occurrence and development of a fire was carried out at the St. Petersburg University of the State Service of the Ministry of Emergency Situations of Russia [12]. In this work, 3 groups of mathematical models are distinguished: integral, zone, field. What these models have in common is that they all allow one to calculate the parameters of the medium during the combustion of a gaseous medium or at various stages of a fire inside a room. The accumulated experience in the field of modeling the development of fires and the movement of human flows has led to the fact that, by orders of the Ministry of Emergency Situations, methods for assessing fire risks at production facilities and objects of various functional purposes were approved. The main indicator of fire risk in these methods is the individual fire risk, i.e. the risk of harm to human life and health in case of fire. This indicator allows employees of the Ministry of Emergency Situations to assess the probability of successful evacuation of people in case of fires and manage the factors that affect this probability. It is on these factors that the main emphasis of the methods approved by the Ministry of Emergency Situations is made.

Another important factor - the probability of fire is estimated as the frequency of fires at objects of a certain type based on the total number of fires.

This approach does not allow to rank the factors influencing the occurrence of a fire, and effectively plan corrective actions.

New studies, subject to the priority tasks of the Ministry of Emergency Situations, dealt with such issues as assessing the impact of emergency evacuation equipment on the magnitude of fire risk [13], fire protection systems [14, 15].

II. Materials and methods

The fire risk assessment model is described using fuzzy inference rules:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} \quad -c \quad w_{jp}\right) \rightarrow \\ \rightarrow r = f(x_1, x_2, ..., x_n) \tag{1}$$

Here $a_{i,jp}$ - linguistic term by which a variable is evaluated x_i in line with number jp;

w_{jp} - weight factor of rule with ordinal number jp;

$r = f(x_1, x_2, ..., x_n)$ - fuzzy rule output.

Here:

x_1- changes in the properties of materials that have been thermally affected in a fire as focal signs of a fire (on wood, chipboard, polymeric materials, concrete, brick, metals and alloys, mortars based on cement, paint and varnish coatings, natural building materials).

x_2 type of object, its initial construction and fire-technical characteristics (as a whole and in separate parts), materials and fire resistance limits of structures;

x_3 information about the schemes of the external (from the transformer substation) and internal electrical network; on the types, quantity and locations of lighting fixtures and power electrical equipment, electrical protection devices and switching devices; brand and length of cable products in separate sections;

x_4 characteristics of heating systems, fire protection, burglar alarms, etc..

III. Results

Three types of fire risk assessment model based on fuzzy inference rules have been developed [16-18].

1. Model for assessing the risk of a fire, the output of which is expressed by a linear relationship.

If x_1^1= and x_2^1= and x_3^1= and x_4^1=C

then

$$r_1 = 0,33 - 0,05\frac{\sum_{j=1}^{n}\mu(x_1^{1j})x_1^{1j}}{\sum_{j=1}^{n}\mu(x_1^{1j})} - 0,02\frac{\sum_{j=1}^{n}\mu(x_2^{1j})x_2^{1j}}{\sum_{j=1}^{n}\mu(x_2^{1j})} - \\ - 0,21\frac{\sum_{j=1}^{n}\mu(x_3^{1j})x_3^{1j}}{\sum_{j=1}^{n}\mu(x_3^{1j})} - 0,1\frac{\sum_{j=1}^{n}\mu(x_4^{1j})x_4^{1j}}{\sum_{j=1}^{n}\mu(x_4^{1j})}.$$

If x_1^2= and x_2^2= and x_3^2= and x_4^2=C

Then $r_2 = 0,257 - 0,0393\frac{\sum_{j=1}^{n}\mu(x_1^{2j})x_1^{2j}}{\sum_{j=1}^{n}\mu(x_1^{2j})} - 0,112\frac{\sum_{j=1}^{n}\mu(x_4^{2j})x^{2j}}{\sum_{j=1}^{n}\mu(x_4^{2j})}$

If x_1^3= and x_2^3= and x_3^3= and x_4^3=C

then

$$r_3 = 0,18 - 0,01\frac{\sum_{j=1}^{n}\mu(x_1^{3j})x_1^{3j}}{\sum_{j=1}^{n}\mu(x_1^{3j})} - 0,07\frac{\sum_{j=1}^{n}\mu(x_2^{3j})x_2^{3j}}{\sum_{j=1}^{n}\mu(x_2^{3j})} - \\ - 0,05\frac{\sum_{j=1}^{n}\mu(x_3^{3j})x_3^{3j}}{\sum_{j=1}^{n}\mu(x_3^{3j})} - 0,111\frac{\sum_{j=1}^{n}\mu(x_4^{3j})x_4^{3j}}{\sum_{j=1}^{n}\mu(x_4^{3j})}$$

If x_1^4= and x_2^4= and x_3^4= and x_4^4=C

then

$$r_4 = 0,26 - 0,02\frac{\sum_{j=1}^{n}\mu(x_1^{4j})x_1^{4j}}{\sum_{j=1}^{n}\mu(x_1^{4j})} - 0,05\frac{\sum_{j=1}^{n}\mu(x_2^{4j})x_2^{4j}}{\sum_{j=1}^{n}\mu(x_2^{4j})} - \\ - 0,03\frac{\sum_{j=1}^{n}\mu(x_3^{4j})x_3^{4j}}{\sum_{j=1}^{n}\mu(x_3^{4j})} - 0,134\frac{\sum_{j=1}^{n}\mu(x_4^{4j})x_4^{4j}}{\sum_{j=1}^{n}\mu(x_4^{4j})}.$$

If x_1^5= and x_2^5= and x_3^5= and x_4^5=C

$$r_5 = 0,202 - 0,10\frac{\sum_{j=1}^{n}\mu(x_1^{5j})x_1^{5j}}{\sum_{j=1}^{n}\mu(x_1^{5j})} - 0,08\frac{\sum_{j=1}^{n}\mu(x_2^{5j})x_2^{5j}}{\sum_{j=1}^{n}\mu(x_2^{5j})} -$$

Then

$$-0,04\frac{\sum_{j=1}^{n}\mu(x_3^{5j})x_3^{5j}}{\sum_{j=1}^{n}\mu(x_3^{5j})} - 0,12\frac{\sum_{j=1}^{n}\mu(x_4^{5j})x_4^{5j}}{\sum_{j=1}^{n}\mu(x_4^{5j})}$$

2. A fire risk assessment model whose output is expressed by a fuzzy term. If x_1^1= and x_2^1= and x_3^1= and x_4^1= with weight 0.5

or x_1^1=C and x_2^1= and x_3^1= and x_4^1= with weight 0.5

Then r_1=.

If x_1^2= and x_2^2= and x_3^2= and x_4^2= with weight 0.33
or x_1^2= and x_2^2= and x_3^2= and x_4^2= with weight 0.33
or x_1^2= and x_2^2= and x_3^2= and x_4^2= with weight 0.33

Then r_2=.

If x_1^3= and x_2^3= and x_3^3= and x_4^3= with weight 0.33
or x_1^3= and x_2^3= and x_3^3= and x_4^3= with weight 0.33
or x_1^3= and x_2^3= and x_3^3= and x_4^3= with weight 0.33

Then r_3=.

If x_1^4= and x_2^4= and x_3^4= and x_4^4= with weight 0.5
or x_1^4= and x_2^4= x_3^4= and x_4^4= with weight 0.5

Then r_4=.

If x_1^5= and x_2^5= and x_3^5= and x_4^5= with weight 0.33
or x_1^5= and x_2^5= and x_3^5= and x_4^5= with weight 0.33
or x_1^5= and x_2^5= and x_3^5= and x_4^5= with weight 0.33

Then r_5=.

Here: H - low;
B- high;
C average;
HC below the average;
BC above average.

3. A model for assessing the risk of a fire, the output of which is expressed by a non-linear dependence.

If x_1^1= and x_2^1= and x_3^1= and x_4^1=

$$r_1 = 0,33 - 0,05\frac{\sum_{j=1}^{n}\mu(x_1^{1j})x_1^{1j}}{\sum_{j=1}^{n}\mu(x_1^{1j})} - 0,02\frac{\sum_{j=1}^{n}\mu(x_2^{1j})x_2^{1j}}{\sum_{j=1}^{n}\mu(x_2^{1j})} -$$

Then

$$-0,21\frac{\sum_{j=1}^{n}\mu(x_3^{1j})x_3^{1j}}{\sum_{j=1}^{n}\mu(x_3^{1j})} - 0,1\frac{\sum_{j=1}^{n}\mu(x_4^{1j})x_4^{1j}}{\sum_{j=1}^{n}\mu(x_4^{1j})} +$$

$$+0,003\left[\frac{\sum_{j=1}^{n}\mu(x_1^{1j})x_1^{1j}}{\sum_{j=1}^{n}\mu(x_1^{1j})}\right]^2 - 0,004\left[\frac{\sum_{j=1}^{n}\mu(x_2^{1j})x_2^{1j}}{\sum_{j=1}^{n}\mu(x_2^{1j})}\right]^2 +$$

$$+0,007\left[\frac{\sum_{j=1}^{n}\mu(x_3^{1j})x_3^{1j}}{\sum_{j=1}^{n}\mu(x_3^{1j})}\right]^2 + 0,0011\left[\frac{\sum_{j=1}^{n}\mu(x_4^{1j})x_4^{1j}}{\sum_{j=1}^{n}\mu(x_4^{1j})}\right]^2$$

If x_1^2= x_2^2= and x_3^2= and x_4^2= Then

$$r_2 = 0,184 - 0,007\frac{\sum_{j=1}^{n}\mu(x_1^{2j})x_1^{2j}}{\sum_{j=1}^{n}\mu(x_1^{2j})} - 0,005\frac{\sum_{j=1}^{n}\mu(x_2^{2j})x_2^{2j}}{\sum_{j=1}^{n}\mu(x_2^{2j})} -$$

$$-0,003\frac{\sum_{j=1}^{n}\mu(x_3^{16j})x_3^{2j}}{\sum_{j=1}^{n}\mu(x_3^{2j})} - 0,09\frac{\sum_{j=1}^{n}\mu(x_4^{2j})x_4^{2j}}{\sum_{j=1}^{n}\mu(x_4^{2j})} +$$

$$+0,002\left[\frac{\sum_{j=1}^{n}\mu(x_1^{16j})x_1^{16j}}{\sum_{j=1}^{n}\mu(x_1^{16j})}\right]^2 - 0,0009\left[\frac{\sum_{j=1}^{n}\mu(x_2^{16j})x_2^{16j}}{\sum_{j=1}^{n}\mu(x_2^{16j})}\right]^2 + .$$

$$+0,0005\left[\frac{\sum_{j=1}^{n}\mu(x_3^{16j})x_3^{16j}}{\sum_{j=1}^{n}\mu(x_3^{16j})}\right]^2 + 0,0015\left[\frac{\sum_{j=1}^{n}\mu(x_4^{16j})x_4^{16j}}{\sum_{j=1}^{n}\mu(x_4^{16j})}\right]^2$$

If x_1^{27}= and x_2^{27}= and x_3^{27}= and x_4^{27}= Then

$$r_{27} = 0,17 - 0,003\frac{\sum_{j=1}^{n}\mu(x_1^{27j})x_1^{27j}}{\sum_{j=1}^{n}\mu(x_1^{27j})} - 0,001\frac{\sum_{j=1}^{n}\mu(x_2^{27j})x_2^{27j}}{\sum_{j=1}^{n}\mu(x_2^{27j})} -$$

$$-0,07\frac{\sum_{j=1}^{n}\mu(x_3^{27j})x_3^{27j}}{\sum_{j=1}^{n}\mu(x_3^{27j})} - 0,09\frac{\sum_{j=1}^{n}\mu(x_4^{27j})x_4^{27j}}{\sum_{j=1}^{n}\mu(x_4^{27j})} +$$

$$+0,01\left[\frac{\sum_{j=1}^{n}\mu(x_1^{27j})x_1^{27j}}{\sum_{j=1}^{n}\mu(x_1^{27j})}\right]^2 - 0,0005\left[\frac{\sum_{j=1}^{n}\mu(x_2^{27j})x_2^{27j}}{\sum_{j=1}^{n}\mu(x_2^{27j})}\right]^2 + .$$

$$+0,0002\left[\frac{\sum_{j=1}^{n}\mu(x_3^{27j})x_3^{27j}}{\sum_{j=1}^{n}\mu(x_3^{27j})}\right]^2 + 0,0024\left[\frac{\sum_{j=1}^{n}\mu(x_4^{27j})x_4^{27j}}{\sum_{j=1}^{n}\mu(x_4^{27j})}\right]^2$$

In the proposed models, each input variable has its own membership functions for fuzzy terms (H, HC, C, BC, B), which are used in the equations. The membership function has the following form: $\tilde{\mu}^k(x_i^j) = \frac{1}{1+\left(\frac{x_i^j - b_k^j}{c_k^j}\right)^2}$.

IV. DISCUSSION

Decision-making tasks for risk assessment depending on the conditions of uncertainty are divided into two types:

1) decision-making problems in conditions where the initial data are of a stochastic nature;

2) decision-making problems under conditions when the initial data are of a non-stochastic nature, and the necessary confidence limits for the parameters of the processes under study are unknown or not clearly defined.

In tasks of the second type, risks are manifested to a greater extent than the first, since when solving problems, it is necessary to take into account not only statistical uncertainty, but also linguistic uncertainty. At the same time, risk should be considered as information uncertainty and fuzziness of the system and its individual elements. The measure of this uncertainty determines the degree of danger, possible damage, loss from the implementation of some decision or event. Based on this, it is necessary to single out the main property of risk: risk occurs only in relation to the future and is inextricably linked with forecasting, and hence with making decisions on risk assessment. In this regard, modeling is an essential tool for risk assessment analysis, where fuzzy modeling is preferred.

It should be noted that the development of risk assessment models taking into account uncertainty factors has a number of features.

First, the main difference between the models developed and evaluated taking into account uncertainty is that the conditions for their implementation and the results are considered non-deterministic. In this regard, it is necessary to take into account all possible values of the model parameters. Secondly, the influence of risk factors and uncertainty inevitably leads to the fact that the content and composition of the models change significantly.

This circumstance necessitates the use of new, improved methods, technologies and modeling tools for risk assessment and the resulting fuzzy conclusions.

The advantage of fuzzy logic is the possibility of using expert knowledge about the structure of an object in the form of linguistic statements. However, the apparatus of fuzzy logic does not contain learning mechanisms. Combining fuzzy logic with neural networks gives a fundamentally new quality. The neural fuzzy network obtained as a result of such a combination has the intellectual properties of using knowledge in natural language.

Therefore, the development of risk assessment models and algorithms based on fuzzy inference rules and neural networks is an urgent problem.

CONCLUSION.

A systematic analysis of risk characteristics under conditions of uncertainty based on the processing of fuzzy information was carried out. The expediency of using the theory of fuzzy sets and neural networks in tasks with incomplete or linguistic information, as well as in tasks that are characterized by intuitive solutions, is revealed. The advantage of fuzzy logic is the possibility of using expert knowledge about the structure of an object in the form of linguistic statements. However, the apparatus of fuzzy logic does not contain learning mechanisms. Combining fuzzy logic with neural networks gives a fundamentally new quality. The neural fuzzy network obtained as a result of such a combination has the intellectual properties of using knowledge in natural language. Soft models for assessing fire risks based on fuzzy inference rules and neural networks for training fuzzy knowledge bases have been developed. The essence of learning is to select such parameters of membership functions that minimize the difference between the results of neuro-fuzzy approximation and the real behavior of the object. Algorithms for assessing and predicting the risks of a fire with the help of a neuro-fuzzy approach have been developed. The advantages of the neuro-fuzzy approach become noticeable when the nature of the impact of influencing factors often changes.

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Determination Of The Epicenter Of An Emergency

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***Abstract*—During the study, a computational scientific approach was proposed to solve the problem of information-analytical decision-making support at the initial stage of the emergency investigation, based on the agreement of the calculated values with the actual values. In this, it is shown how the emergency situation starts, develops, spreads and leads to the center of the emergency situation. Therefore, in order to support management decision-making in the social system, an algorithm for determining the epicenter of an emergency situation was proposed in the research.**

***Index Terms*—Contingency, expertise, model, algorithm, decision making, epicenter.**

I. Introduction

At the initial stage of investigation of an emergency situation or emergency situations, it is necessary to determine the following [1-4]:

- the day of the incident;
- the time of the incident;
- place of the accident;
- development and elimination of the incident.

When inspecting the emergency situation, it is necessary to pay special attention to the location of the deformed (fallen) devices in the area. This is sometimes useful in determining the epicenter of an emergency. In particular, if one metal device has collapsed on top of another, it should be noted as a fact that allows to assess the sequence of the collapse or the shape of certain device elements of the building is broken, while paying special attention to the inspection [5-7]. Also, the object is inspected from above or from a distance to determine the deformation of the metal structures or the macrocone (Fig. 1). If the deformation of the building structures is detected, it is appropriate to start the research work from there to determine the cause of the emergency situation. [8-10]. Here: $h_1$and h_2 height of the areas where the temperature reaches the critical point at different distances from the metal device in the emergency room.

Fig. 1. As a result of the emergency situation, the structure of the building changed its shape and the most damaged areas

II. Materials and methods

Time spent on operational expertise at the scene of emergencies τ_{fve} if we express mathematically.

$$\tau_{fve} = \tau_{uua} + \tau_{vkm} + \tau_{omo} + \tau_{mqi} \quad (1)$$

$$d\tau_{fve} = \tau_{uua}(\tau) \vartriangle \tau_{uua} + \tau_{vkm}(\tau) \vartriangle \tau_{vkm} + \\ + \tau_{omo}(\tau) \vartriangle \tau_{omo} + \tau_{mqi}(\tau) \vartriangle \tau_{mqi} \quad (2)$$

To take into account the appearance of signs and limits of times we need to get into the following situation:

$$\tau_{fve} = \tau_{uua}\ (\tau)|_{\tau_0}^{\tau_{\max}} + \tau_{vkm}\ (\tau)|_{\tau_0}^{\tau_{\max}} + \\ + \tau_{omo}\ (\tau)|_{\tau_0}^{\tau_{\max}} + \tau_{mqi}\ (\tau)|_{\tau_0}^{\tau_{\max}} \quad (3)$$

$$(\tau_{2.uua} - \tau_{1.uua}) = (\tau_{2.vkm} - \tau_{1.vkm}) + \\ + (\tau_{2.omo} - \tau_{1.omo}) + (\tau_{2.mqi} - \tau_{1.mqi}) \quad (4)$$

$$
\tau_{vf} = \int_{\tau_0}^{\tau_{\max}} \tau_{uua}(\tau) d\tau_{uua} + \int_{\tau_0}^{\tau_{\max}} \tau_{vkm}(\tau) d\tau_{vkm} + \\
+ \int_{\tau_0}^{\tau_{\max}} \tau_{omo}(\tau) d\tau_{omo} + \int_{\tau_0}^{\tau_{\max}} \tau_{mqi}(\tau) d\tau_{mqi} \tag{5}
$$

Here:

τ_{uua} time to take images through the drone flares;

τ_{vkm} a photo from a rapidly installed video surveillance device

and video recording time;

τ_{omo} online information exchange with operational management headquarters;

τ_{mqi} data processing.

By conducting operational research and expertise at the scene of emergencies using unmanned aerial vehicles (UAVs) as set forth in formula (2):

$\tau_{tvo'}$- study of the immediate situation at the scene of the incident;

τ_{vjk} - inspection of the scene;

$\tau_{fvo'a}$-identification of the emergency situation (through extreme research and interviews with witnesses or special citizens);

τ_{fvtya}-giving an opportunity to significantly save the time spent on determining the ways of the spread of an emergency situation, and all this nitfae - the time spent on conducting operational expertise at the place of emergency situations. This allows to reduce the time spent and increase the quality of the work efficiency of the expert team of military personnel conducting expertise or research at the scene of emergency situations[11-15].

III. Results

Determining the "break height" of vertical lifting devices: A series of vertical lifting devices are inspected to compare the minimum height of each device at which significant deformation begins to occur. When heated by a fire, vertical support structures (such as hangars and other similar structures) at a certain height will "like a fractured shape", resulting in the appearance shown in Figure 2a, including the steel arch. At the same time, the closer the device is to the fire, the h lower the fracture height (Figure 2b). It is known how this situation occurs - the closer the fire source is to the device, the lower the altitude it heats up to its critical temperature with upward convective currents (Fig. 2c). Thus, recording the refraction height of vertical devices allows to reveal a characteristic "macrocone" - a sign of the direction of propagation around the fire.

It is difficult to detect a macrocone by looking closely at the object. The reason for this is that there is a lot of destruction at the emergency site. Therefore, in order to determine the path of the macrocone and the emergency situation and to reduce the time spent on it, the effectiveness of using drones was researched and proposed.

An emergency situation is not a random event, but a certain event and a confluence of circumstances that require its occurrence and development.

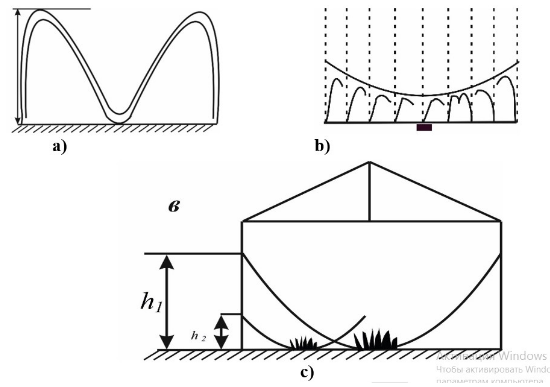

Fig. 2. Deformation of vertical elements of metal devices in case of fire emergency

The causes of a fire emergency are divided into three main groups:

1) carelessness in the use of fire, violation of fire safety rules or failure to comply with them;

2) natural causes and spontaneous combustion (in some cases, spontaneous combustion may occur as a result of violation of safety rules when storing substances, and in some cases as a result of natural events);

3) deliberately creating an emergency situation.

The main or general causes mentioned above include the specific sources of the immediate fire emergency.

The following are the direct causes or methods of an intentional emergency: leaving a burning ember or cigarette residue in a flammable environment, spraying flammable liquids or flammable liquids on objects and lighting them with a match, leaving irons and other electrical appliances connected to electrical networks;

In case of violation of safety rules and careless use of fire, the following can be the direct causes of fire: careless use of an open flame source, use of faulty electrical wiring, improper use of heating devices, improper storage of fire-hazardous materials, throwing burning matches or cigarette residues, burning from the hearth of the heating stove spillage of standing coal, lighting devices (lamps, candles, etc.)

IV. Discussion

In this category of cases, drones can be used very effectively to identify:

- to determine the emergency situation center(s), the place where the emergency situation started;
- identification of traces of intentional emergency;
- determination of ways of spreading emergency situation;
- to identify footprints of people, tracks of vehicles.

At the initial stage of arson examination, depending on the accuracy of the information, simple and complex types of examination situations may arise.

Let's simulate some crime scenes and see where the benefits of using a drone to inspect the crime scene will be maximized.

In the first case, the burning of dry grass led to the burning of several private houses.

In this case, we usually deal with large areas. The use of drones can significantly reduce the time it takes to determine the location of a fire. It is recommended to raise the drone to the maximum height to determine and define the boundaries of the inspected area. When determining the direction of the wind, there will be no difficulty in determining the location of the emergency, the drone will be moved against the wind, and in this case, photo and video recordings will be made.

If the risk of collapse of the structures due to damage poses a threat to the life and health of the expert, a detailed inspection using a drone will be possible.

In the second case. If an emergency situation occurs in a single-family house, but it is found that there is a person inside the house, the roof of the house is completely on fire, and there is a risk of collapse of the structures supporting the house, then the inspection of the scene is complicated by the limited access to the building, which means that the health and life of the expert is at risk. it becomes impossible to examine the corpse without changing its position. In this case, the use of drones is essential. To begin the inspection, the drone is launched into the air and the entire building is captured by the camera. At this stage, photo-video recordings are made, the location of the corpses is determined, and arson devices and other physical evidence are found. Then it is necessary to lower the flight height and move along the zone of interest using horizontal movement. If necessary, the height can be reduced to 0.5 meters for more detailed photo-video recording.

In the third case. Destruction or damage to forest crops by arson.In this case, we are thinking about large areas measured in hectares. The use of unmanned aerial vehicles during the inspection of the scene of the accident helps to determine the boundaries of the area, to find the source of the emergency and the means of its intentional occurrence. To start work, it is recommended to climb horizontally to the maximum height, photo-video recording is carried out to determine the boundaries of the area. When determining the emergency situation, it is necessary to pay attention to the following:

- wind direction. If the inspection is carried out shortly after the elimination of the emergency situation, then it is recommended to move the drone against the wind, since the fire spreads in the direction of air masses;

- special attention should be paid to bonfires, because they can be a source of emergency;

- focus on finding things that can start a fire (containers where fuel and lubricants are stored);

- as well as footprints and vehicle tracks.

CONCLUSION.

In this article, the role of expertise units in the organization of emergency staff work, the mathematical model and algorithm for the personnel investigating emergency situations have been developed. A mathematical model and algorithm were developed in order to ensure speed in the work of the expertise units and the adoption of conclusions. Recommendations were made on the efficiency of using drones during the expertise to determine the epicenter of emergency situations and the procedures for formalizing the results obtained from them. If the conditions for the execution of the event and operation are unknown, it is impossible for us to execute it as successfully as if we had more information. Therefore, any decision made in a situation of uncertainty is worse than a decision made in a well-defined situation. Thus, decision-making based on the results of the investigation is carried out in conditions of uncertainty, because the specific conditions of the dynamics of the risk factors of the occurrence of an emergency situation and the conditions or factors that determine the relationship between cases, as well as the origin of individual events, are not clear.

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Intellectualization Of Fire Risk Management Processes

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***Abstract*—Intellectualization of fire risk management processes through mathematical modeling of processes that lead to a change in the likelihood of a fire will reduce the number of fire cases. Automation of the fire risk management system will provide the possibility of a one-time assessment of many objects and the formation of a list and plan of corrective measures to reduce fire risks. The aim of the work is to reduce the number of hazardous conditions that lead to fires and improve traffic safety by automating the processes of managing fire risks of infrastructure facilities.**

***Index Terms*—Risk, fire, forecast, assessment, management, intelligent systems, fuzzy set theory.**

I. INTRODUCTION

Fire safety issues are considered by specialists as part of the problem of ensuring the safety of complex technical systems [1, 2, 3, 4]. In [4], two areas of activity are distinguished: preventive and operational-tactical. The problems of fire risk management at the design stage were solved using game theory, the main results of such studies are given in [5, 6].

Fire risk assessment is an important tool in risk management. The main objectives of this assessment are:

- obtaining objective information about the state of objects of protection;

- identification of the most potentially dangerous objects of protection and justification of the danger; development of recommendations to reduce the risk of fires and fires and minimize damage from them.

Initially, special assessment methods were not used to study fire safety, but only summary data on event statistics were formed. Later, the simplest statistical methods of analysis began to be used: time series of the consequences of fires were built, and the growth trend was monitored. Studies of this period of time can be divided into two large groups: the first group is models that describe such characteristics as combustion, turbulent flows, heat transfer, and radiation. The second is the movement of human flows during evacuation. Within the framework of this section, it will be established how the simulation results are used, as well as the possibility of using unified models for objects of various types: hazardous production facilities, warehouses, facilities where technological processes of mobile objects are implemented.

Historically, models describing combustion processes were the first to appear. At the same time, explosion safety was studied and standardized inseparably with fire safety. The main factors characterizing the danger of an explosion were: the maximum pressure and temperature of the explosion, the rate of pressure increase during the explosion, the pressure in the front of the shock wave, crushing and high-explosive properties of the explosive environment. Similarly, the factors affecting people during fires were described: shock wave, flame, collapsing structures, harmful substances released during the explosion.

Separately, the issues of ensuring fire and explosion safety of industries using gases and liquids [7], electronics enterprises [8], woodworking industry [9] in maritime transport [10, 11] were studied.

It was noted in [12] that most of the specialists who worked during this period mainly analyzed the risks of hazardous industrial facilities, which did not allow the formation of a holistic concept of the theory of fire risks due to the lack of analysis of complex socio-economic systems. The study [12] introduced the concepts of local and integral risks, which makes it possible to take into account the interest of manufacturing enterprises in assessing fire risks.

New studies, subject to priority tasks, dealt with such issues as assessing the impact of emergency evacuation equipment on the magnitude of fire risk [13], fire protection systems [14, 15]. The theoretical basis of fire risk assessment models is actively developing. To take into account the influence of the behavior of owners or explants of protected objects, the theory of active systems began to be used [16, 17].

The theory of fuzzy sets can be used as a mathematical apparatus that allows this to be done. For objects with similar physical and chemical characteristics, models of the stochastic or probabilistic method for describing processes based on the theory of finite Markov chains began to be used [18]. These models not only make it possible to predict the occurrence of fires, but can also be used to investigate fires, since they make it possible to calculate the most probable fire scenario based on its consequences. However, the use of models of this kind is associated with two factors: the need to form a state graph and the complexity of calculations. In order to minimize calculations, graphs with a minimum number of states are usually used, which significantly reduces the efficiency of modeling. For the effectiveness of planning decisions and the choice of fire extinguishing strategies, game theory was used [5, 6].

To ensure the fire safety of large facilities, various software and hardware systems are combined into a single automated fire safety management system. The work [19] is devoted to the study of the software architecture of security-related systems.

Modern systems should allow not only to effectively extinguish the detected fire, but also to prevent the occurrence of combustion.

Events of fires, accidents with environmental consequences, injuries during work are random.

II. Materials and methods

X complete set of object states, $X = \{X_1, \ldots X_{i,\ldots}, X_N\}$; Classification of the degree of risk. Let us construct a classification of the current value g of the risk degree indicator G as a criterion for dividing this set into subsets (Table 1):

Table1

G valueinterval	Subsetname
0.8 < g < 1	**G_1**- "marginal risk of fire"
0.6 < g< 0.8	**G_2**- "high risk of fire"
0.4 < g< 0.6	**G_3**- "The degree of fire risk is medium"
0.2 < g< 0.4	**G_4**- "lowfirerisk"
0 – 0.2	**G_5**- "the risk of bankruptcy is negligible"

Classification of indicator values. Let us construct a classification of the current values x of indicators X as a criterion for dividing the full set of their values into subsets of the form B (Table 2):

Evaluation of the level of indicators. We will evaluate the current level of indicators and summarize the results in Table 3.

Table 2

Nameofindicator	Subsettingcriterion				
	B_{i1}	B_{i2}	B_{i3}	B_{i4}	B_{i5}
X_1	$x_1<b_{11}$	$b_{11}< x_1<b_{12}$	$b_{12}< x_1<b_{13}$	$b_{13}< x_1<b_{14}$	$b_{14}< x_1$
…	…	…	…	…	…
X_i	$x_i<b_{i1}$	$b_{i1}< x_i<b_{i2}$	$b_{i2}< x_i<b_{i3}$	$b_{i3}< x_i<b_{i4}$	$b_{i4}< x_i$
…	…	…	…	…	…
X_N	$x_N<b_{N1}$	$b_{N1}<x_N<b_{N2}$	$b_{N2}<x_N<b_{N3}$	$b_{N3}<x_N<b_{N4}$	$b_{N4}<x_N$

Table3

Nameofindicator	Current value
X_1	x_1
…	…
X_i	x_i
…	…
X_N	x_N

Classification of the level of indicators. Let's classify the current values of x according to the criteria of table 2. Theresultoftheclassificationistable 4:

Table4

Name of indicator	SubsetClassificationResult				
	B_{i1}	B_{i2}	B_{i3}	B_{i4}	B_{i5}
X_1	λ_{11}	λ_{12}	λ_{13}	λ_{14}	λ_{15}
…	…	…	…	…	…
X_i	λ_{i1}	λ_{i2}	λ_{i3}	λ_{i4}	λ_{i5}
…	…	…	…	…	…
X_N	λ_{N1}	λ_{N2}	λ_{N3}	λ_{N4}	λ_{N5}

Where $\lambda_{ij} = 1,\ if\ b_{i(j-1)} < \ x_i < b_{ij}\ \ ,and\ \ \ \lambda_{ij} = 0$ otherwise (when the value does not fall within the selected classification range).

Risk assessment. Now let's perform formal arithmetic operations to assess the degree of fire risk g:

$$g = \sum_{j=1}^{5} g_j \sum_{i=1}^{N} r_i \lambda_{ij},$$

where

$$g_j = 0.9 - 0.2(j - 1),$$

determined according to table 4.

Linguistic recognition. We classify the obtained value of the degree of risk on the basis of the data in Table 1. Thus, our conclusion about the degree of risk of a fire takes on a linguistic form.

III. ResultsandDiscussion

1. It is required to analyze the degree of fire risk.

2. Solution (item numbers correspond to the numbers of the method steps).

3. We define the sets E, G and B.

For analysis, we build a system X of 6 indicators:

X_1 - lower heat of combustion,

X_2 - specificburnoutrate,

X_3 - smoke-forming ability,

X_4 - oxygen consumption,

X_5 - carbon dioxide release,

X_6 - release of carbon monoxide.

4. We assume that all indicators are equivalent for analysis $(r_i = 1/6)$.

5. Thedegreeofriskisclassifiedaccordingtotheruleof Table 1. Selected indicators on the basis of preliminary expert analysis received the following classification (Table 5):

Table5

Nameofin dicator	Subsettingcriterion				
	B_{i1}	B_{i2}	B_{i3}	B_{i4}	B_{i5}
X_1	x_1<9000	9000< x_1<11000	11000<x_1 <13000	13000<x_1< 14000	14000< x_1
X_2	x_2<0	0<x_2<0.017	0.017<x_2< 0.03	0.03<x_2<0.045	0.045<x_2
X_3	x_3<85	85< x_3<0.95	0.95<x_3<0 1.10	1.10< x_3<1.4	1.4<x_3
X_4	x_3<1,5	1.5<x_4<1.9	1.9<x_4<3.1	3.1< x_4<5.5	5.5<x_4
X_5	x_5<1.1	1.1< x_5<1.4	1.4<x_5<2.35	2.3< x_5<5.5	5.5<x_5
X_6	x_6<0.003	0.003< x_6<0.005	0.005< x_6<0.008	0.008 < x_6<0.03	0.03<x_6

Fireloadcharacteristics (Table 6): 6. Let's classify the current

Table6

Indexcode X_i	Name of indicatorX_i	Value of$X_i$in the I period ($x_{I,i}$)
X_1	netcalorificvalue	14700
X_2	specificburnoutrate	0,015
X_3	smoke-formingability	82
X_4	oxygenconsumption	1,437
X_5	carbondioxiderelease	1,285
X_6	carbonmonoxiderelease	0,0022

values of x according to the criteria of table. 7. The result of the classification is Table 7:

Table 7

Indicator X_i	Value {λ} in the period				
	$\lambda_1(x_{I,i})$	$\lambda_2(x_{I,i})$	$\lambda_3(x_{I,i})$	$\lambda_4(x_{I,i})$	$\lambda_5(x_{I,i})$
X_1	0	0	0	0	1
X_2	0	1	0	0	0
X_3	1	0	0	0	0
X_4	1	0	0	0	0
X_5	0	1	0	0	0
X_6	1	0	0	0	0

8.Assessing the degree of risk of a fire $gives g_I = 0.709$, . Linguistic recognition of g values according to table 1 determines the degree of fire risk as high a.

Conclusion.

The expediency of developing and using algorithms for the intellectualization of diagnostics of object malfunctions leading to an increase in fire risk is substantiated. Analysis of the state of the problem of assessing and managing fire risks at facilities, typesautomated fire risk management systems made it possible to identify the need to develop methods and algorithms,providing the possibility of predicting the probability of a fire based on the technical characteristics of objects. A method for mathematical modeling of fire risk has been developedat the stage of its operation. The method is based on the use of fuzzy set theory. It consists in modeling the development of events leading to a fire.

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The problem of membrane oscillations subjected to impulsive action at fixed times

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Abstract. ***The problem of free oscillation of a membrane is considered in the case when the oscillation process is subjected to the action of an external force of an impulsive nature at fixed points in time. The corresponding mathematical model is a task consisting of the equation of the membrane oscillations in which a mixed task is set, and the presence of impulse action is given by a special condition called the impulse action condition. Under these conditions, a solution to the problem is constructed using the method of separation of variables in the form of a Fourier series in terms of eigenvalues of the boundary value problem for the Helmholtz equation. The solution of the equation of a round membrane with impulsive action at fixed instants of time is constructed.***

Keywords. Differential equations with impulsive action, solutions, impulse effect, boundary conditions, initial conditions, conditions of impulse actions, membrane, oscillations, boundary value problem, eigenvalues, eigenfunctions, rectangular coordinates, polar coordinates, round membrane.

I. INTRODUCTION

Question history. Mathematical description of nonlinear processes using differential equations is an important task both from the point of view of practice and from the point of view of theory. One of the topical directions in the theory of differential equations at present is the theory of differential equations with impulsive action, which is used in the mathematical description of the evolution of various phenomena and processes with short-term disturbances, the duration of which is conveniently neglected when compiling the corresponding mathematical model. In this case, we can assume that these perturbations are of an “instantaneous” nature. Such an idealization leads to the need to study differential equations with impulsive action. In this paper, we consider the problem of constructing a solution to a mixed problem for a wave equation with impulsive action, which describes vibrations of membranes of various shapes[1,9,10].

An elastic membrane with a tightly fixed boundary at rest is identified with a certain region G of a bounded piecewise-smooth Jordan curve Γ in a plane OXY [1]. Let us assume that at fixed moments $t=t_k,\ k=1,2,...$ such a membrane is subjected to short-term perturbations, the duration of which can be neglected when compiling the corresponding mathematical model. In this case, we can assume that these perturbations have an “impulsive” character [2, 3, 4,16,17]. The oscillations of such a membrane are characterized by the solution $u=u(x,y,t)$ of the wave equation

$$\frac{\partial^2 u}{\partial t^2}=a^2\Delta u,\quad \Delta=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2},\quad t\neq t_k, \tag{1}$$

with initial conditions

$$u(x,y,0)=\varphi_0(x,y)$$

$$\left.\frac{\partial u(x,y,t)}{\partial t}\right|_{t=0}=\varphi_1(x,y),\quad (x,y)\in G\ , \tag{2}$$

and conditions of impulse actions

$$\begin{aligned}\Delta\left.\frac{\partial u(x,y,t)}{\partial t}\right|_{t=t_k}&=\frac{\partial u(x,y,t_k+0)}{\partial t}-\\ -\frac{\partial u(x,y,t_k-0)}{\partial t}&=I_k(x,y),\ (x,y)\in G,\ k\in N\end{aligned}\ , \tag{3}$$

where $I_k(x,y)\neq 0,\quad (x,y)\in G,\quad k\in N$ are some real functions, and concerning the values $t_p\ ,\ \ p\in N$, it is assumed that they satisfy the condition $t_m>t_n$ and $t_n\to+\infty$, for $k\to\infty$, as well as the boundary condition

$$u(x,y,t)=0,\ \ t\geq 0,\ (x,y)\in\Gamma \tag{4}$$

The solution to the problem (1)-(4) is a function $u=u(x,y,t)\in C^2_{(x,y),t}\left(G\times\left((0,+\infty)\setminus\{t_k,k\in N\}\right)\right)$ that is continuous on the right t at the points of impulsive actions $t=t_k, k\in N$, satisfies $t=0$ the initial condition (2) and satisfies $t=t_k, k\in N$ the conditions of impulsive actions, and also satisfies the boundary condition (4) at the points (x,y) of the curve Γ .

II. LITERATURE REVIEW

In the 1960s, in the work of Myshkis A.D. and Samoileko A.M. [6], a new approach to the study of differential equations with impulsive action was proposed, which gave a powerful impetus to the development of the mathematical theory of impulsive systems. The main scientific results on the study of the theory of differential equations with impulsive action by the 1990s are given in [2,3] and it should be noted that these results mainly relate to ordinary differential equations with impulsive action, scientific results on the study of differential equations with partial derivatives so far day is relatively small[5,6,8].

Methodological aspects of studying the theory of differential equations (the concept and ways of its implementation, methodological system, applied orientation) are reflected in the research of R.M. Aslanova, G.I. Bavrina, Kh.A. Gerbekova, V.D. Lvova, P.M. Melnikova, B.A. Naimanova, C.B. Plotnikova, G.E. Polekhina, A.G. Savina, G. Treliński and others, but about university students[11,13,14,15].

III. METHODOLOGY

Analysis, synthesis and other scientific research methodologies were used in this scientific work. Also, the

Cauchy problem applied to differential equations can be solved using analytical and numerical methods.

IV. SOLVING THE MIXED PROBLEM POSED FOR THE IMPULSIVE WAVE EQUATION DESCRIBING THE VIBRATIONS OF MEMBRANES OF DIFFERENT SHAPES

Consider the problem of constructing a solution to the problem (1)-(4) using the method of separation of variables, i.e. by the Fourier method [1].

We represent the solutions to the problem (1)-(4) $t \neq t_k, k \in N$ in the form

$$u(x,y,t) = T(t)V(x,y). \quad (5)$$

Then $t \neq t_k, k \in N$, we have

$$\frac{\partial^2 u(x,y,t)}{\partial t^2} = \frac{d^2 T(t)}{dt^2} V(x,y)$$

$$, \frac{\partial^2 u(x,y,t)}{\partial x^2} = T(t) \frac{\partial^2 V(x,y)}{\partial x^2},$$

$$\frac{\partial^2 u(x,y,t)}{\partial y^2} = T(t) \frac{\partial^2 V(x,y)}{\partial y^2} \quad (6)$$

Substituting (6) in places in equation (1), we obtain the equation,

$$T''(t)V(x,y) = a^2 T(t)\Delta V, \quad t \neq t_k. \quad (7)$$

The separation of variables in equation (7), leads to the equality

$$\frac{T''(t)}{a^2 T(t)} = \frac{\Delta V(x,y)}{V(x,y)}, \; t \neq t_k.$$

The left side of the obtained equality does not depend on x y and, and the right side does not depend on t. Consequently, each of the quantities $\frac{T''(t)}{a^2 T(t)}, \; t \neq t_k$ $\frac{\Delta V(x,y)}{V(x,y)}$ does not depend on x, y t and, respectively, i.e., they are permanent. Denoting this constant $-\lambda$, we write the last equality in the form

$$\frac{T''(t)}{a^2 T(t)} = \frac{\Delta V(x,y)}{V(x,y)} = -\lambda,, \; t \neq t_k.$$

It follows that for expression (5) to be a solution to equation (1), the function $T(t)$ must be a solution to the equation

$$T''(t) + a^2 \lambda T(t) = 0, \qquad t \neq t_k, \quad (9)$$

and the function $V(x,y)$ was the solution of the

$$\Delta V(x,y) + \lambda V(x,y) = 0. \quad (10)$$

Further, by substituting expression (5) into boundary condition (4), we have

$$T(t)V(x,y) = 0, \quad (x,y) \in \Gamma, \quad t \geq 0$$

This shows that the boundary condition (4) is equivalent to the boundary condition

$$V(x,y) = 0, \quad (x,y) \in \Gamma \quad (11)$$

for the function $V(x,y)$. It follows from (10) and (11) that the function $V(x,y)$ is a solution to the homogeneous Dirichlet problem for the Helmholtz equation. It is known that for this problem the eigenvalues $\lambda > 0$ and by introducing the notation $\lambda = \mu^2$, where μ is a real number, it is proved that this problem, under sufficiently general conditions set on G, has a countable set of eigenvalues $\mu_1, \mu_2, \cdots, \mu_n, \cdots$ and corresponding eigenfunctions $V_1(x,y), V_2(x,y), \cdots, V_n(x,y), \cdots$.

Then, $t \neq t_k, k \in N$ for each eigenvalue μ_n of the problem (10), (11), the solution $T_n(t)$ of equation (9) corresponds, taking this into account, we write equation (9) in the form

$$T_n''(t) + (a\mu_n)^2 T_n(t) = 0, \;\; t \neq t_k. \quad (12)$$

Then the solution of problem (1)-(4) corresponding to the eigenvalue μ_n, according to (5) can be written in the form $u_n = T_n(t)V_n(x,y), n = 1, 2, \cdots$ and due to the linearity of equation (1) the sum of these solutions is also a solution to this problem, i.e. solution of problem (1)-(4) can be represented as a series

$$u(x,y,t) = \sum_{n=1}^{\infty} T_n(t) V_n(x,y). \quad (13)$$

To find, $T_n(t)$ we find the form of the initial conditions and the conditions of impulse actions for equation (12). For this purpose, by substituting (13) into (2) and (3) we have,

$$u(x,y,0) = \sum_{n=1}^{\infty} V_n(x,y) T_n(0) = \varphi_0(x,y)$$

$$\left.\frac{\partial u(x,y,t)}{\partial t}\right|_{t=0} = \sum_{n=1}^{\infty} V_n(x,y) T_n'(0) = \varphi_1(x,y)$$

$$\Delta \left.\frac{\partial u(x,y,t)}{\partial t}\right|_{t=t_k} = \sum_{n=1}^{\infty} \left[T_n'(t_k+0) - T_n'(t_k-0)\right] V_n(x,y) =$$

$$= \sum_{n=1}^{\infty} \left(\Delta T_n'(t)\Big|_{t=t_k} \right) V_n(x,y)$$

Now, multiplying both parts of these equalities by $V_k(x,y)$ and integrating over the domain G, taking into account the orthogonality property of the eigenfunctions of problems (10), (11), we have

$$T_n(0) = \frac{1}{N^2(V_n)} \int_G \varphi_0(x,y) V_n(x,y) dxdy, \quad (14)$$

$$T_n'(0) = \frac{1}{N^2(V_n)} \int_G \varphi_1(x,y) V_n(x,y) dxdy, \quad (15)$$

$$\Delta T_n'(t)\Big|_{t=t_k} = \frac{1}{N^2(V_n)} \int_G I_k(x,y) V_n(x,y) dxdy \quad (16)$$

Where $N(V_n)=\left(\int_G V^2{}_n(x,y)dxdy\right)^{1/2}$ is the norm of the function $V_n(x,y)$? Therefore, $T_n(t)$ we can find both solutions of equation (12) with impulsive action (16) under initial conditions (14), (15).

The Cauchy problem for an equation of the form (12) with impulsive action at fixed times were studied in detail in [5,6], where it was proved that the solution to such problems on a half-interval $[0,t)$ can be represented as

$$T_n(t)=T_n(0)\cos a\mu_n t-\frac{T_n'(0)}{a\mu_n}\sin a\mu_n t+\sum_{0<\gamma_k\le t}\frac{\gamma_k}{a\mu_n}\sin a\mu_n(t-t_k), \tag{17}$$

where, $T_n(0)$ $T_n'(0)$ and $\gamma_k=\Delta T_n'(t)\big|_{t=t_k}$ are defined by formulas (14), (15), (16), respectively, and under the conditions

$$\sum_{p=1}^{m}\gamma_p\cos a\mu_n t_p=\sum_{p=1}^{m}\gamma_p\sin a\mu_n t_p,\ a\mu_n T=2\pi q_0 ,$$

$$\gamma_{p+m}=\gamma_p,\ t_{p+m}=t_p+T,$$

where q_0, m are some natural numbers, this solution is periodic with some period T .Substituting (17) into (13) we obtain the solution of the mixed problem (1)-(4) in the form of a Fourier series

$$u=\sum_{n=1}^{\infty}\left[\begin{array}{l}T_n(0)\cos a\mu_n t-\dfrac{T_n'(0)}{a\mu_n}\sin a\mu_n t+\\ +\displaystyle\sum_{0<\gamma_k\le t}\frac{\gamma_k}{a\mu_n}\sin a\mu_n(t-t_k)\end{array}\right]V_n(x,y) \tag{18}$$

on eigenfunctions of the homogeneous Dirichlet problem for the Helmholtz equation. It can be seen from (18) that the effect of impulse actions on the process of free vibration of the membrane has the form

$$\sum_{n=1}^{\infty}\sum_{0<\gamma_k\le t}\frac{\gamma_k}{a\mu_n}\sin a\mu_n(t-t_k)V_n(x,y).$$

In particular, when the area G is a rectangle bounded by lines $x=0, x=p, y=0, y=q$ i.e. $G=\{(x,y):0\le x\le p,\ 0\le y\le q\}$ then the boundary conditions (4) can be written as

$$u\big|_{x=0}=0;\ u\big|_{x=p}=0;\ u\big|_{y=0}=0;\ u\big|_{x=q}=0 . \tag{19}$$

In this case, the solution of equation (1) with the initial condition (2) and under the conditions of impulsive action (3) constructed by the method of variables is written in the form of a double Fourier series,

$$\begin{aligned}u(x,y,\mathrm{t})=\sum_{m,n=1}^{\infty}[\alpha_{mn}\cos\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}t+\\+\frac{\beta_{mn}}{\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}}\sin\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}t]\sin\frac{m\pi x}{p}\sin\frac{n\pi y}{q}+\\+\frac{1}{\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}}\sum_{k=1}^{p}\gamma_{mn}(k)\cdot\\ \cdot\sin\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}(t-t_k)]\sin\frac{m\pi x}{p}\sin\frac{n\pi y}{q}\end{aligned} \tag{20}$$

where

$$\alpha_{mn}=\frac{4}{pq}\int_0^p\int_0^q\varphi_0(x,y)sin\frac{m\pi x}{p}sin\frac{n\pi y}{q}dxdy ,$$

$$\beta_{mn}=\frac{4}{apq\mu_{mn}}\int_0^p\int_0^q\varphi_1(x,y)sin\frac{m\pi x}{p}sin\frac{n\pi y}{q}dxdy ,$$

$$\gamma_{mn}(k)=\frac{4}{pq}\int_0^p\int_0^q I_k(x,y)sin\frac{m\pi x}{p}sin\frac{n\pi y}{q}dxdy,\quad k=1,2,... ,$$

by eigenfunctions of the boundary value problem

$$\Delta V(x,y)+\mu^2V(x,y)=0 , \tag{21}$$

$$V\big|_{x=0}=0;\ V\big|_{x=p}=0;\ V\big|_{y=0}=0;\ V\big|_{x=q}=0 , \tag{22}$$

which, in turn, is solved by the method of separation of variables. In formula (20), the term

$$\sum_{m,n=1}^{\infty}\frac{1}{\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}}\sum_{k=1}^{p}\gamma_{mn}(k)\cdot \sin\pi\sqrt{\frac{m^2}{p^2}+\frac{n^2}{q^2}}(t-t_k)]\sin\frac{m\pi x}{p}\sin\frac{n\pi y}{q}$$

means the effect of impulse actions on the process of free vibration of a quadrangular membrane.

A similar problem can be considered in the case when the area G is a circle of radius R centred at the origin of the form $G=\{(x,y):x^2+y^2\le R^2\}$, with a tightly fixed circle, the boundary condition (4) is written as

$$u(x,y,t)\big|_{x^2+y^2=R^2}=0 . \tag{23}$$

In this case, passing from rectangular coordinates x, y to polar coordinates r, θ, we obtain the problem of finding a solution to the equation

$$\frac{\partial^2u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}+\frac{1}{r^2}\frac{\partial^2u}{\partial\theta^2}=\frac{1}{a^2}\frac{\partial^2u}{\partial t^2} ,\quad t\ne t_k \tag{24}$$

with initial conditions

$$u(r,\theta,t)\big|_{t=0}=\varphi_0(r,\theta),\quad \frac{\partial u(r,\theta,t)}{\partial t}\bigg|_{t=0}=\varphi_1(r,\theta) \tag{25}$$

under conditions of impulse action

$$\begin{aligned}\Delta\frac{\partial u(r,\theta,t)}{\partial t}\bigg|_{t=t_k}=\\=\frac{\partial u(r,\theta,t_k+0)}{\partial t}-\frac{\partial u(r,\theta,t_k-0)}{\partial t}=I_k(r,\theta),\quad k\in N\end{aligned} \tag{26}$$

and under the boundary condition

$$u(r,\theta,t)\big|_{r=R}=0 . \tag{27}$$

Separating the variables in equations (24) using the substitute

$$u(r,\theta,t)=V(r,\theta)T(t) ,\ t\ne t_k , \tag{28}$$

and taking into account the boundary condition (27), $V(r,\theta)$ we obtain the boundary value problem

$$V_{rr}+\frac{1}{r}V_r+\frac{1}{r^2}V_\theta=\mu^2 V, \qquad (29)$$

$$V|_{r=R}=0, \qquad (30)$$

and for the function $T(t)$, the second-order ordinary differential equation

$$T''(t)+a^2\mu^2 T(t)=0,\ t\neq t_k. \qquad (31)$$

Solutions to the boundary value problem (29), (30) can be constructed by the method of separation of variables by setting

$$V(r,\theta)=W(r)G(\theta) \qquad (32)$$

Then, to determine the function $W(r)$, we obtain the Bessel equation

$$r^2W''(r)+rW'(r)+(\mu^2r^2-\omega)W(r)=0, \qquad (33)$$

where, due to condition (30), the function $W(r)$ must be equal to zero for $r=R$ and bounded for $r=0$, i.e., must satisfy the boundary conditions of the form

$$W(R)=0\ ,\quad W(0)<\infty. \qquad (34)$$

For the function $G(\theta)$, we get the equation

$$G''(\theta)+\omega G(\theta)=0 \qquad (35)$$

Further, for a unique definition of a function $V(r,\theta)$, we require that the function $G(\theta)$ be single-valued, i.e., 2π periodic $G(\theta+2\pi)=G(\theta)$. Therefore, setting $\omega=n^2$, $0,1,2,\cdots$, we represent the general solution of Eq. (35) as

$$G_n(\theta)=\alpha_n\cos n\theta+\beta_n\sin n\theta,$$

Where α_n β_n and are arbitrary constants. The solution to the Bessel equation (33) $\omega=n^2$ can be represented as

$$W_n(r)=D_nJ_n(\mu r)+E_nY_n(\mu r).$$

It follows from boundary conditions (34) that $E_n=0$ $D_nJ_n(\mu R)=0$ and. Since $D_n\neq 0$, then from the last equality, we have $J_n(\mu R)=0$. It is known that this equation has a countable number of positive solutions $\rho_1^n,\rho_2^n,\cdots$ and these solutions correspond to the values $\mu_{nm}=\frac{\rho_m^{(n)}}{R}$, $m=1,2,\cdots;$ $n=0,1,2,\cdots$ Then the solution of the boundary value problem (33), (34) can be written as $W_{nm}(r)=J_n\left(\frac{\rho_m^{(n)}r}{R}\right)$. Then the eigenvalues $\mu_{nm}^2=\left(\frac{\rho_m^{(n)}r}{R}\right)^2$ of the boundary value problem (29), (30) correspond to two linearly independent eigenfunctions :

$$V_1(r,\theta)=J_n\left(\frac{\rho_m^{(n)}r}{R}\right)\cos n\theta,\ V_2(r,\theta)=J_n\left(\frac{\rho_m^{(n)}r}{R}\right)\sin n\theta,$$

$$m=1,2,\cdots;\ n=0,1,2,\cdots.$$

Therefore, for all $t\in[0,t_1)$ particular solutions of the equation, equation (24) satisfying the boundary condition (27) can be written as

$$u_{nm}(r,\theta,t)=\left[\left(A_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+B_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\cos n\theta+\right.$$

$$\left.+\left(C_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+D_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\sin n\theta\right]J_n\left(\frac{\rho_m^{(n)}r}{R}\right).$$

To satisfy the initial conditions (25), we represent the solution $u_0(x,\theta,t)$ of problem (24)–(27) in the half-interval $[0,t_1)$ as a series

$$u_0(x,\theta,t)=\sum_{n=0}^{\infty}\sum_{m=1}^{\infty}\left[\left(A_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+B_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\cos n\theta+\right.$$

$$\left.+\left(C_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+D_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\sin n\theta\right]J_n\left(\frac{\rho_m^{(n)}r}{R}\right).$$

(36)

For $t=0$ from (36), we have

$$A_{0m}=\frac{1}{\pi R^2J_1^2(\rho_m^{(0)})}\int_0^R\int_0^{2\pi}\varphi(r,\theta)J_0\left(\frac{\rho_m^{(0)}r}{R}\right)rdrd\theta,$$

$$A_{nm}=\frac{2}{\pi R^2J_{n+1}^2(\rho_m^{(n)})}\int_0^R\int_0^{2\pi}\varphi(r,\theta)J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\cos n\theta drd\theta,$$

$$C_{nm}=\frac{2}{\pi R^2J_{n+1}^2(\rho_m^{(n)})}\int_0^R\int_0^{2\pi}\varphi(r,\theta)J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\sin n\theta drd\theta,$$

$$B_{0m}=\frac{1}{\pi a\rho_m^{(0)}RJ_1^2(\rho_m^{(0)})}\int_0^R\int_0^{2\pi}\psi(r,\theta)J_0\left(\frac{\rho_m^{(0)}r}{R}\right)rdrd\theta, \qquad (37)$$

$$B_{nm}=\frac{2}{\pi a\rho_m^{(n)}RJ_{n+1}^2(\rho_m^{(n)})}\int_0^R\psi(r,\theta)J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\cos n\theta drd\theta,$$

$$D_{nm}=\frac{2}{\pi a\rho_m^{(n)}RJ_{n+1}^2(\rho_m^{(n)})}\int_0^R\int_0^{2\pi}\psi(r,\theta)J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\sin n\theta drd\theta.$$

Substituting the found values of the coefficients in series (36), we obtain a solution to the problem of the mixed problem (24)-(27) for all $t\in[0,t_1)$.

To continue the solution $u_0(r,\theta,t)$ to the half-interval $[t_k,t_{k+1})$, $k=1,2,\cdots$ we use the impulsive action condition (26). The solution to the problem of the mixed problem (24)-(27) in half-intervals $[t_k,t_{k+1})$, $k=1,2,\cdots$ we represent as a series

$$u_k(r,\theta,t)=\sum_{n=0}^{\infty}\sum_{m=1}^{\infty}\left[\left(A_{nm}^{(k)}\cos\frac{a\rho_m^{(n)}t}{R}+B_{nm}^{(k)}\sin\frac{a\rho_m^{(n)}t}{R}\right)\cos n\theta+\right.$$

$$\left.+\left(C_{nm}^{(k)}\cos\frac{a\rho_m^{(n)}t}{R}+D_{nm}^{(k)}\sin\frac{a\rho_m^{(n)}t}{R}\right)\sin n\theta\right]J_n\left(\frac{\rho_m^{(n)}r}{R}\right),$$

$$k=1,2,\cdots \qquad (37)$$

respectively. Then, according to the definition of the solution of problem (24)-(27) from the condition of impulse action (26), we have the system

$$\begin{cases}u_1(r,\theta,t_1)=u_0(r,\theta,t_1)\\ \dfrac{\partial u_1(r,\theta,t_1)}{\partial t}=\dfrac{\partial u_0(r,\theta,t_1)}{\partial t}+I_1(r,\theta)\end{cases} \qquad (38)$$

From the second equation of system (38), we note that the coefficients at $\cos n\theta$ and $\sin n\theta$ are the Fourier coefficients in the expansion of a periodic θ function $I_k(r,\theta)$ in the interval $(0,2\pi)$ in the main trigonometric system, i.e.

$$\frac{1}{2\pi}\int_0^{2\pi} I_k(r,\theta)d\theta = \sum_{m=1}^{\infty}\left[\begin{array}{l}(-A_{0m}^{(k)}+A_{0m})\sin\frac{a\rho_m^{(0)}t_k}{R}+\\ +(B_{0m}^{(1)}-B_{0m})\cos\frac{a\rho_m^{(0)}t_k}{R}\end{array}\right]\cdot$$

$$\cdot\frac{a\rho_m^{(0)}}{R}J_0\left(\frac{\rho_m^{(0)}r}{R}\right)$$

$$\frac{1}{\pi}\int_0^{2\pi} I_k(r,\theta)\cos n\theta d\theta =$$

$$=\sum_{m=1}^{\infty}\left[\begin{array}{l}(-A_{nm}^{(k)}+A_{mn})\cdot\\ \cdot\sin\frac{a\rho_m^{(n)}t_k}{R}+(B_{nm}^{(1)}-B_{mn})\cos\frac{a\rho_m^{(n)}t_k}{R}\end{array}\right]\cdot\frac{a\rho_m^{(n)}}{R}J_n\left(\frac{\rho_m^{(n)}r}{R}\right)$$

,

$$\frac{1}{\pi}\int_0^{2\pi} I_k(r,\theta)\sin n\theta d\theta =$$

$$=\sum_{m=1}^{\infty}\left[\begin{array}{l}(-C_{nm}^{(k)}+C_{mn})\cdot\\ \cdot\sin\frac{a\rho_m^{(n)}t_k}{R}+(D_{nm}^{(k)}-D_{mn})\cos\frac{a\rho_m^{(n)}t_k}{R}\end{array}\right]\cdot\frac{a\rho_m^{(n)}}{R}J_n\left(\frac{\rho_m^{(n)}r}{R}\right)$$

.

Hence, taking into account the orthogonality property of the Bessel function system from (38).

V. Result

Substituting these found coefficients into the series (37), we obtain the solution of the mixed problem (24)–(27) in the half-interval $[0,t)$ in the form of a series

$$\begin{aligned}u(r,\theta,t)=&\sum_{n=0}^{\infty}\sum_{m=1}^{\infty}\left[\left(A_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+B_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\cos n\theta+\right.\\ &\left.+\left(C_{nm}\cos\frac{a\rho_m^{(n)}t}{R}+D_{nm}\sin\frac{a\rho_m^{(n)}t}{R}\right)\sin n\theta\right]J_n\left(\frac{\rho_m^{(n)}r}{R}\right)+\\ &+\sum_{m=1}^{\infty}\sum_{0\le t_k<t}\frac{\int_0^R\int_0^{2\pi}I_k(r,\theta)J_0\left(\frac{\rho_m^{(0)}r}{R}\right)rdrd\theta}{a\rho_m^{(0)}RJ_1^2(\rho_m^{(0)})}\sin\frac{a\rho_m^{(0)}(t-t_k)}{R}+\\ &+\sum_{n=1}^{\infty}\sum_{k=1}^{\infty}\sum_{0<t_k<t}\frac{2\sin\frac{a\rho_m^{n}(t-t_k)}{R}}{\pi a\rho_m^{(0)}RJ_{n+1}^2(\rho_m^{(0)})}\left[\int_0^R\int_0^{2\pi}I_k(r,\theta)\cdot\right.\\ &\cdot J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\cos n\theta drd\theta\cos n\theta+ \qquad (38)\\ &\left.+\int_0^R\int_0^{2\pi}I_k(r,\theta)J_n\left(\frac{\rho_m^{(n)}r}{R}\right)r\sin n\theta drd\theta\sin n\theta\right]J_n\left(\frac{\rho_m^{(n)}r}{R}\right).\end{aligned}$$

VI. Conclusion

Thus, the solution to the problem of oscillations of a circular membrane subjected to impulsive action at fixed times is built on the assumption that the series (37) is twice continuously differentiable at $t\neq t_k$, and the functions involved in the initial conditions and the condition of impulsive action can be expanded into rapidly converging Fourier series.

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Calculation of the Time Characteristics of Computing Tools with Considering Device Failure

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Abstract. The article derives analytical relationships for calculating the main temporal characteristics of control computing means-conservators of information, information exchange subsystems in a communication network, taking into account the failure of devices under various modes of operation.

Keywords: processor, Markov process, mode of operation, reliability

I. Introduction

In modern conditions, when developing and creating automated communication networks, it is necessary to take into account the significantly increased volume of incoming and transmitted information. In this regard, the functioning of these communication networks is impossible without a well-developed and reliable information transmission system, which is one of the most important subsystems of the communication network.

II. MAIN PART

In the general case, the information exchange subsystem of a communication network consists of a network of information transmission channels and means of automating the processes of collecting and transmitting information - control computing facilities (CCF) [1]. The purpose of the subsystem is the delivery of information from information sources to information-computing complexes (ICC) of the communication network, ensuring the exchange of information between the ICC and the transfer of information from the ICC to managed objects (or to data recipients). In automated subsystems for the exchange of information in a communication network, three main types of CCF can be distinguished:

- output CCF, which carry out the primary processing of the information received by the ICC and allow the ICC to be unloaded from performing the function of interfacing with data transmission tractors;

- CCF-concentrators of information, providing more efficient use of the bandwidth of information transmission channels;

- CCF-distributors of messages, providing the possibility of building a switched network and automating the management of a network of data transmission channels.

The main characteristics of the considered CCF are the average waiting time for the start of servicing a request $\overline{T}_0$and the average length of the request queue $\overline{Q}$. The query waiting time is a random variable that depends on the number of load sources, the number of processors in the CCF, the duration of the input time, and the CCF parameters.

In [2] A. Scherr proposed a continuous Markov model of a computing complex for estimatingT_0 and some other characteristics. Despite a number of simplifications of the process of interaction of load sources with the system, which were allowed during the construction of the model, experimental verification showed the suitability of this model for assessing the characteristics of the CCF.

However, real CCF do not have absolute reliability, therefore, in order to calculate the characteristics of the considered CCF, it is necessary to determine the influence of the unreliability of the CCF devices on its operation. The above model does not allow for such an estimate. In order to obtain analytical expressions for calculating the temporal characteristics of CCF load concentrators, taking into account the unreliability of the equipment, let us imagine the functioning of the CCF consisting of $\mathcal{V}$ processors and service n load sources (Fig.1), in the form of a continuous Markov model, as was done in [2] for a similar complex consisting of absolutely reliable digital computers.

The system has service devices, a request accumulator with a capacity of. The intensity of requests of a free source is equal to, occupied - zero. The intensity of the device transitions from a good state to a faulty one is equal if the device is free, and if the device is busy. The state scheme of the device is shown in Fig.2. The recovery rate of the device is, and the maintenance rate is. Processor maintenance, recovery, and uptime times are distributed exponentially. The validity of these assumptions is partly confirmed by statistics [3].$\mathcal{V}$ $n\nu$ $j\alpha\beta$ μ

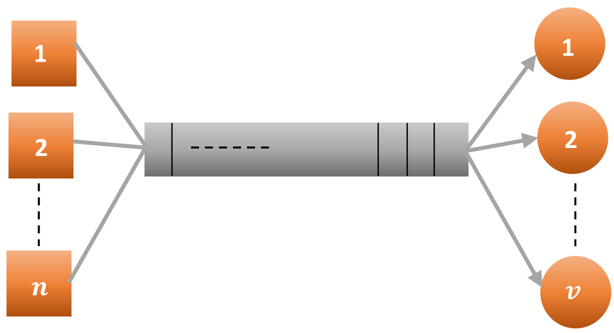

Fig.1. CCF consisting of $\mathcal{V}$ processors and service n load sources

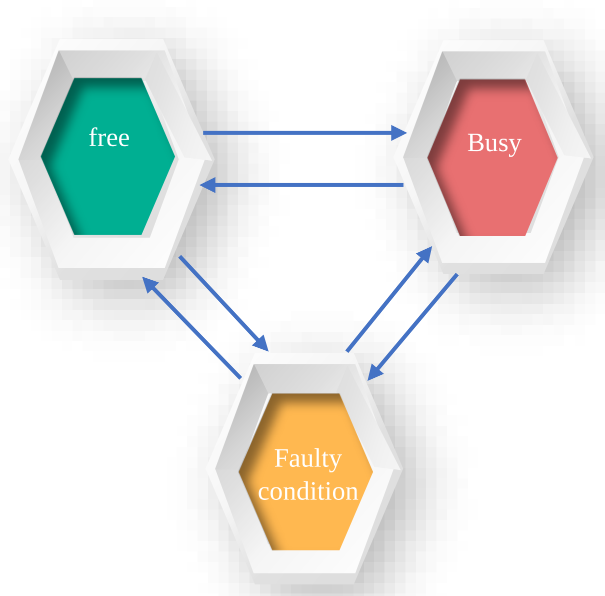

Fig.2. The state scheme of the device

The functioning of the system under consideration can be described by a continuous Markov process x(t) defined in a two-dimensional phase space of states, where is the number of requirements in the system (served and waiting) is the number of faulty devices. Denote $\{i,\ j\} i=\overline{0, \mathcal{V}+n}\quad j=\overline{0, \mathcal{V}}$ P $=(i,\ j)$- state probability - intensity of transitions from state to state. Let us determine the intensities of possible transitions of the Markov process$i, j, \Lambda(K, C\longrightarrow i,\ j)\ i,\ jx(t)$.They look like this:

$$\Lambda(i+1, j\longrightarrow i,\ j)=\mu\min(i+1, V-j);$$

(one)

$$\Lambda(i-1, j\longrightarrow i, j)=v(n-i+1);$$

$$\Lambda(i, j-1, j\longrightarrow i, j)=j(V-i-j+1)u(V-i-j+1)+\alpha\min\,(i, V-j+1);$$

$$\Lambda(i, j+1\longrightarrow i, j)=\beta(j+1).$$

Knowing the intensity of transitions, it is possible in the usual way [4] to compose a system of linear homogeneous algebraic equations describing the stationary regime of the Markov process$x(t)$.The process is a homogeneous transit Markov process and, therefore, has a unique stationary distribution that does not depend on time and initial conditions and characterizes the operation of the system in a stationary mode. Stationary mode of the Markov process$x(t)x(t)$ is described as follows:

$$-[v(n-1)+j(V-i-j)u(V-i-j)+\beta j+(\alpha+\mu)\mu\min(i, V-j)]*$$

$$P(i, j)+\mu\min(i+1, V-j)\,P(i+1, j)+v(n-i+1)P(i-1, j)+\beta(j+1)*$$

$$P(i, j+1)+[j(V-i-j+1)u(V-i-j+1)+\alpha\min(i, V-j+1)]P(i, j-1)=0$$

$$i=\overline{0, n};$$

$$P(i, j)=0\ \text{at} i>n,\ \ i<0\ j>V, j<0\quad (2)$$

$$j=\overline{0, V};$$

System (2) has the order

$$S=(n+1)(V+1)$$

which grows rapidly with an increase in the number of load sources and the number of processes, which can create certain difficulties in solving these systems even on high-performance computers; therefore, it is advisable to consider the possibility of reducing the dimension of the state space and the order of the systems of equations for the stationary probabilities of the system states.

From the theory of Markov processes it is known[5]: in order for the states of the Markov process to be enlarged by means of some partition, it is necessary and sufficient that for any two sets of partitions$A=\{A_0, \dots, A_k\}$

$$A_i=\{A_{i1}, A_{i2}, \dots, A_{ik}\}uA_j=\{A_{j1}, \dots, A_{jm}\}$$

transition intensity meeting the conditions

$$\Lambda(A_{ix}\to A_j)=\Lambda(A_{iy}\to A_j),\text{where}x, y=\overline{0, K};$$

$$\Lambda(A_{j\xi}\to A_i)=\Lambda(A_{j\eta}\to A_i),\text{where}\xi, n=\overline{0, m};\quad (3)$$

These general values of the transition intensities determine the transition intensities of the enlarged Markov process.

In CCF load concentrators, the recovery rate is much less than the maintenance rate. The average time to eliminate the failure of CCF devices significantly exceeds the average interval between receipts of messages processed in the CCF. The functioning of such systems can be represented as an intensive process of receiving and processing requests, which is superimposed by relatively rare, but longer events of device failures [8]. In connection with the above, we can assume. We divide all equations of the system from (2) to. Putting$\mu\gg\beta\mu\gg\alpha\mu\gg\gamma\,\mu$, and,${}^{\beta}/_{\mu}\to 0\ {}^{\alpha}/_{\mu}\to 0\ {}^{\beta\gamma}/_{\mu}\to 0$ it gets

$$-[Z(n-1)+min(i, V-j)]\,P_{i,j}+\min(i+1, V-j)\,P_{i+1}+Z(n-i+1)P_{i-1,j}=0\ (4)$$

where

$$Z={}^{v}/_{\mu}$$

System (4) has solutions:

$$P_{i,j}=\frac{n!\,Z^i}{i!\,(n-i+1)!}P_{0,j}=C_n^iZ^iP_{0,j},\quad i<V-j;$$

$$P_{i,j}=\frac{n!Z^i}{(V-j)!(n-i)!V-j^{i-V+j}}P_{0,j}=P_{0,j},\quad i\geq V-j;$$

(5)

$$P_{i,V}=0, ;i<n$$

$$P_{i,V}=P_V. .i=n$$

where

$P_V=\sum_{i=0}^{n}P_{i,V}$the probability that all devices in the system are faulty.

Expressions (5) allow us to obtain the following expression for the probability of the state "in the system of faulty devices":j

$$P_j = \sum_{i=0}^{n} P_{i,j} = \left[\sum_{i=0}^{V-j-1} C_n^i Z^i + \sum_{i=V-j}^{n} \frac{n!\, Z^i}{(V-j)!\,(n-i)!\, V-j^{i-V+j}} \right] P_{0,j} \qquad (6)$$

From here we obtain expressions for the conditional probability of the state "there are requests in the system, provided that the devices are faulty".ij

$$\mathrm{n}P_{i/j} = \frac{P_{i,j}}{P_j} = \frac{n!Z^i}{\sum_{i=0}^{V-j-1} C_n^i Z^i + \sum_{i=V-j}^{n} \frac{n!Z^i}{(V-j)!(n-i)!V-j^{i-V+j}}}, \quad i < V-j;$$

$$P_{i/j} = \frac{P_{i,j}}{P_j} = \frac{\frac{n!\, Z^i}{(V-j)!\,(n-i)!\, V-j^{i-V+j}}}{\sum_{i=0}^{V-j-1} C_n^i Z^i + \sum_{i=V-j}^{n} \frac{n!\, Z^i}{(V-j)!\,(n-i)!\, V-j^{i-V+j}}}, \quad i \geq V-j. \qquad (7)$$

Let us substitute into system (4) the expression $P_{i,j} = P_{i/j} P_j$.

If, for fixed, adding the equations of the system over all$ji(i = \overline{0,n})$, then after reduction we get a system of equations for determining P_j:

$$-[\theta(j)+1]P_j + \theta(j-1)P_{j-1} + (j+1)P_{j+1} = 0, \qquad (8)$$

where$\theta(j) = \sum_{i=0}^{V-j-1} \left[(V-i-j)\frac{\alpha}{\beta} + i\frac{\alpha}{\beta}\right] P_{i/j} + \sum_{i=V-j}^{n} (V-i-j)\frac{\alpha}{\beta} P_{i/j}$

$\theta(j)\beta$-average intensity of system transitions from state to state.$j + I$

If a,$\alpha = \gamma$then $\theta(j) = (V-j)\frac{\alpha}{\beta}$ (9)

System (8) has a solution

$P_j = \frac{1}{j!} \prod_{K=0}^{J-1} \theta(k)\, P_0$ (10)

The value is determined from the normalization conditions$P_0 \sum_{j=0}^{V} P_j = 1$

$$P_0^{-1} = 1 + \sum_{j=1}^{V} \frac{1}{j!} \prod_{K=0}^{j-1} \theta(k) \qquad (11)$$

Knowing and, we can determine the average length of the request queue $P_j \mathrm{P}_{i/j}$

$$\bar{Q} = \sum_{j=0}^{V} P_j \sum_{i=0}^{n} P_j = P_{i/j} \qquad (12)$$

And the average request timeout

$$\bar{T}_0 = \frac{\bar{Q}}{(n-Q)v} \qquad (13)$$

Representing (9) and (10) in (11), we obtain

$$P_j = \frac{C_V^j g^j}{\sum_{j=0}^{V} C_V^j g^j} = \frac{C_V^j (\frac{1-Ka}{Kg})^j}{\sum_{j=0}^{V} C_V^j (\frac{1-Ka}{Ka})^i}, \qquad (14)$$

Where is the availability factor of the device $Ka = \frac{\beta}{\alpha+\beta}$,

$g = \alpha/\beta$-load on the repair team.

Substituting (7) and (14) into (12), after transformations, we obtain the final expression for the average length of the request queue

$$\bar{Q} = \sum_{j=0}^{V-1} \frac{C_V^j g^j}{\sum_{j=0}^{V} C_V^j g^j} \frac{\sum_{j=0}^{V-j-1} \frac{Z^i}{i!\,(n-i)!} + \sum_{i-V-j}^{n} i \frac{Z^i}{(V-j)!\,(n-i)!\,(V-j)^{i-V+j}}}{\sum_{j=0}^{V-j-1} \frac{Z^i}{i!\,(n-i)!} + \sum_{i=V-j}^{n} i \frac{Z^i}{(V-j)!\,(n-i)!\,(V-j)^{i-V+j}}} \qquad (15)$$

The average waiting time for a response is determined by formula (13) taking into account (15).$\bar{T}_0$

The considered model for the case of absolutely reliable devices was used by A. Sherr to analyze the time-sharing system without taking into account computer failures in a multicomputer complex [2].

Fig. 3 shows the dependence of the relative average request waiting time on the load factor for various values of the availability factor Ka for the CCF with the parameters. Figure 4 shows the dependence of the average length of the request queue on the load factor for various values of the processor availability factor with the parameters, $ZV = 4n = 10ZKa = \frac{\beta}{\alpha+\beta} V = 4n = 10$

Note that in the event of a failure of an individual processor and its recovery, it becomes necessary to redistribute the functions performed in the CCF among the remaining operable processors or among the newly switched on processors. Since the failure and recovery of the processor is a relatively rare event, it is possible to neglect the reaction time of the aircraft to this event or take it into account by slightly increasing the average device repair time.

Consider the models of aircraft operating in autonomous mode (PA).

The normal mode of operation of the duplicated CCF message hub is to operate in the duplicate (D) mode. At the same time, both subsystems of the RCS process request in parallel until the number of requests stored in the buffer storage remains less than a certain predetermined value. As soon as the number of requests stored in the drive exceeds this value, one of the subsystems (processors) interrupts parallel processing, retrieves the first of the stored requests from the drive, and starts processing it independently of the other subsystem (PA mode operation). Operation in this mode takes place whenever the number of requests stored in the drive exceeds the specified value. When the number of stored requests decreases to this value, the CCF switches back to mode D. Thus,

The main characteristics of the WCS in the considered mode are also the average request processing time, the average request waiting time and the average length of the request queue [6].$\bar{T}_0 \bar{T}_0 \bar{Q}$

Let us determine the characteristics for the most interesting from a practical point of view case of a two-processor CCF.

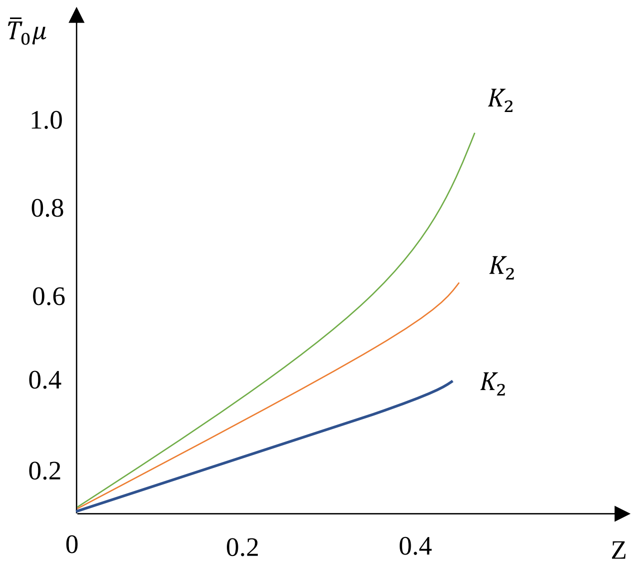

Fig.3. Dependence of the relative average request waiting time on the load factor Z

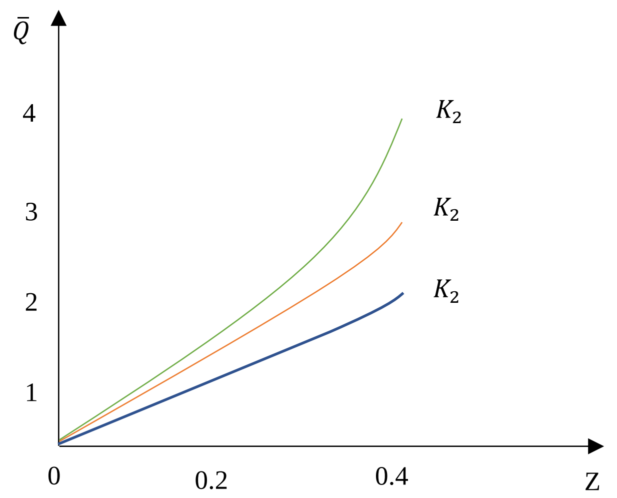

Fig.4. The dependence of the average length of the request queue on the load factor Z

We have a system consisting of two serving devices, the service time in which is distributed according to the exponential law with the parameter. The drive is designed to store requests. Mode D takes place at. The transition to offline mode occurs when. If one of the fixtures finishes service and there are fewer or fewer requests in the queue, a transition to mode D occurs. $\mu Q \leq mQ > mm$

It will consider a Markov system serving load sources, the time interval between requests from the load source is distributed according to an exponential law with parameters. If a request from a source is received for servicing or in a queue, the source stops submitting requests until the end of servicing the incoming request [7] $K(m + n = K - 2)\gamma$.

Denote by the probability of such a state of the system, in which there are requests in it and the system works in mode D. Let us denote by the probability of the state of the system, in which there are requests in it and the system works in offline mode. Let the intensity of the transition of the system from state to state. $P_{j,0}j(j = \overline{0, m+1})P_{m+1,j}m + 1 + j(j = \overline{1, n+1})\Lambda(f, q \to i, j)f, q\ i, j$

The intensities of possible transitions for the system under consideration are described by the following equations:

$$\Lambda(i, 0 \to i + 1, 0) = \gamma(K - i);$$
$$\Lambda(m + 1, i \to m + 1, i + 1) = \gamma(K - m + 1 - i); \quad (16)$$
$$\Lambda(i, 0 \to i - 1, 0) = \mu;$$
$$\Lambda(m + 1, i \to m + 1, i - 1) = 2\mu.$$

With known intensities of transitions, it is possible in the usual way to compose a system of linear homogeneous algebraic equations describing the stationary regime of a Markov system.

The stationary mode is described by the system of equations:

$$-K\gamma P_{0,0} + \mu P_{1,0} = 0;$$
$$-[\gamma(K - i) + \mu]P_{1,0} + \mu P_{i+1} + \gamma(K - i + 1)P_{i-1,0} = 0;$$
$$-[\gamma(K - m - 1) + \mu]P_{m+1,0} + 2\mu P_{m+1,1} + \gamma(K - m)P_{m,0} = 0; \quad (17)$$
$$-[\gamma(K - m - 1 + i) + 2\mu]P_{m+1,i} + 2\mu P_{m+1,i+1} + \gamma(K - m + i)P_{m+1,i-1} = 0;$$
$$-2\mu P_{m+1,n+1} + \gamma P_{m+1,n} = 0.$$

Solving system (17) together with the normalization condition, we obtain $\sum_{(i,j)} P_{i,j} = 1$

$$P_{i,0} = \frac{Z^i \prod_{j=0}^{i-1}(K - j)}{1 + \sum_{g=1}^{m+1} Z^g \prod_{j=0}^{g-1}(K - j) + Z^{m+1} \sum_{g=1}^{n+1} \left(\frac{Z}{2}\right)^g \prod_{j=0}^{m+g}(K - j)};$$

$$P_{m+1,i} = \frac{Z^{m+1} \left(\frac{Z}{2}\right)^2 \prod_{j=0}^{m+1}(K - j)}{1 + \sum_{g=1}^{m+1} Z^g \prod_{j=0}^{g-1}(K - j) + Z^{m+1} \sum_{g=1}^{n+1} (\frac{Z}{2})^g \prod_{j=0}^{m+g}(K - j)}; 18)$$

Where is the load factor of the system by one source $Z = \frac{\gamma}{\mu}$.

Average Request Length

$$\bar{Q} = \sum_{i=0}^{m+1} iP_{i,0} + \sum_{i=1}^{n+1} (m + 1 + i)P_{m+1,i} \quad (19)$$

With known, you can determine the average waiting time for a request in the queue: $\bar{Q}$

$$\bar{T}_0 = \frac{\bar{Q}}{(K - \bar{Q})\gamma} \quad (20)$$

Average request processing time

$$\bar{T} = \bar{T}_0 + \mu \quad (21)$$

The probability of working in the mode D

$$P_D = \sum_{i=0}^{m+1} P_{i,0} \qquad (22)$$

Probability of working in PA mode

$$P_{autonom} = 1 - P_D = \sum_{i=1}^{n+1} P_{m+1,i} \qquad (23)$$

Average intensity of transitions from the mode to the autonomous mode of the PAD

$$\xi = \gamma(K - m - 1)P_{m+1,0} \qquad (24)$$

The resulting expressions are valid for the case when both service devices are operational. The actual characteristics of the CCF will be slightly lower than the characteristics obtained by these formulas, since the duplicated system is in the "one device is faulty" state for a certain part of the time. Let us evaluate the effect of device failures on the characteristics of a duplicated system, based on the assumption that the process of device failures-recoveries has a Markovian character with transition rates much lower than the rates of receipt and servicing of requests. Then the system operation process is a homogeneous Markov process defined in a two-dimensional phase space, where characterizes the process of receiving and processing requests, and is the number of faulty devices.$\{\theta, j\}\theta j$

$$\overline{\Lambda}\,\overline{P} = 0 \qquad (25)$$

where$\overline{\Lambda}$- matrix of intensities of transitions from state to state;

$\overline{P}$-probability matrix of system states.

The above ratios of transition intensities allow us to solve this system by dividing it into systems of algebraic equations that describe the one-dimensional process of servicing requests under the condition of the presence of faulty devices, similarly to how it was done for the system shown in Fig.1.Vj

$$\overline{\Lambda_J}\,\overline{P_J} = 0$$

Where are the conditional probabilities of finding the system from the state $\overline{P_J} = \{P(\theta/j)\}\theta$ with defective devices j.

III. Conclusions

Thus, in order to obtain analytical expressions for calculating the temporal characteristics of CCF-conservative information, taking into account the unreliability of equipment under various operating modes, a model is built in the form of a continuous Markov queuing system with an input stream that is a function of the number of information sources interacting with the system at a given time. Such an assessment of temporal characteristics at the stage of system design of communication networks information exchange subsystems is necessary,

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Development of an automated system to improve the efficiency of the enterprise's operations

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***Abstract*— This paper presents the development of automated information system requirements to improve the efficiency of the enterprise, as well as to improve interaction with customers and personnel tracking. This system will help to increase the speed of information processing and work and documents. the study is accompanied by diagrams of the architecture of the program, as well as models of use cases. These requirements and diagrams will simplify further development of the system.**

Keywords*— *automation, system, development, use case diagrams, AIS.

INTRODUCTION

Today, one of the most developed and numerous spheres of activity of enterprises both in Russia and all over the world is the service sector. [1, 2] Every year, there are more and more companies providing any kind of service, from building materials stores to beauty salons. [3, 4] It is not difficult to draw a parallel between the increasing number of enterprises of this kind and the increasing level of internal competition. In order to remain in the position of market leaders, the management of these enterprises must constantly monitor the level of service, finding and eliminating factors that hinder the development as quickly as possible. [5-8]

The success of activity and efficiency of any enterprise related to the sphere of service provision or, in other words, the sphere of service, can be defined through some qualitative and quantitative indicators. [9] As a rule, modern enterprises are limited to monitoring the volume of profit and periodic so-called "quality surveys" of customers who used the services of this enterprise. [10, 11]

With the increasing interest in service delivery, there has been a need to automate processes to improve the efficiency of businesses. [12-14]

The optimal solution for a company that focuses on the provision of any services is the development of a system that automates part of the processes of the daily activities of the enterprise with the ability to generate both information about the individual performance of each employee, and the overall summary of performance and success of activities. [15, 16]

The relevance of the development in the applied sense is associated with the expansion of the group of companies of the organization - the customer, the increase in the number of employees and, accordingly, the increase in the volume of emerging needs in the provision of services. [17] A new company will appear in the structure of the organization - a separate structural division, fully aimed at providing services both within the company itself and to the employees of all other structural divisions of the organization-customer. [18, 19] Before the separation of a separate company, services were provided by the same employees, concentrated in different business units, which made it much more difficult to collect statistics on emerging requests and problems, as well as control over the performance of employees, because all this was performed within the approximate values by the heads of departments in manual mode. [20] Implementation of the developed automated information system will allow to structure and formalize the list of rendered services, to keep records of labor inputs of specialists, to reveal gaps of the enterprise and to follow the progress of improvement of indicators. [21, 22] The developed automated information system will allow to identify the need for additional functionality and implement it, expanding the scope of its application. [23]

In this study will be developed AIS requirements for automotive service, because enterprises engaged in the field of diagnosis and repair of cars exist in a highly competitive environment. [24] To increase their competitiveness, most enterprises use information systems in the process of their work, as computing technology is able to times accelerate the process of processing information and obtaining results. Fast and effective implementation of collection, processing and storage of huge amounts of information has become the main condition for the successful functioning of modern organizations, institutions and enterprises. [25] The increasing pace of informatization of society increases the importance of computing technology in management processes. [26] Using the capabilities of modern computer technology to automate the process of information processing allows to increase labor productivity, improve the efficiency of work with documents and accelerate the exchange of management information. [27, 28]

The AIS to be developed will allow solving the following tasks:

- Keep records of labor inputs of both individual employees and departments as a whole;

- Quantify the level of volume and quality of services provided to both individual employees and departments as a whole;
- Generate reports on the performance of both individual employees and departments as a whole.
- Improve the efficiency of service delivery process management.

SYSTEM REQUIREMENTS

A. General requirements

AIS should be developed in the form of a website based on a three-layer architecture (client layer - logic layer - data layer). The architecture of the system to be developed is presented in Figure 1.

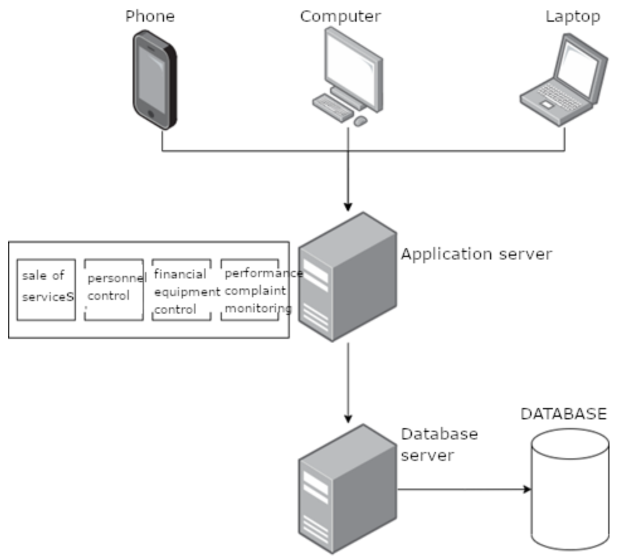

Fig. 1. System Architecture (Hardware)

Database server and application server of AIS should be created on the basis of postrelational DBMS MySQL. Client places for the developed AIS due to the complexity of the realized functions should be developed on the basis of java-technology (applet - servlet) under the J2EE platform. [11]

AIS processes confidential information (personal data of the Group's employees, work-related information not subject to disclosure to third parties) and is an automated system in a secure design. [8]

B. Structural requirements

AIS should be implemented using Cache technology in the form of four subsystems. The architecture of the system is presented in Figure 2.

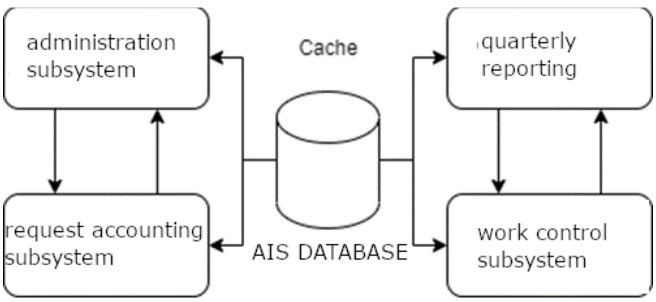

Fig. 2. AIS architecture (Program)

The request accounting subsystem is intended for entering the registration data on employees and performed requests, as well as information on the results of work performed. When implementing this subsystem, it is necessary to differentiate access to requests in accordance with the established levels of access to data.

The quality control subsystem is designed to track: the status of the employee's fulfillment of the individual work plan for a certain number of clients, the level of service and key performance indicators.

The quarterly reporting subsystem is intended for creating reports on quarterly performance results of both each employee individually and the division as a whole.

The administration subsystem is designed to register system users and assign them rights to employees.

C. Functional requirements

The AIS shall implement the functions presented in Figure 3 in the use case diagram.

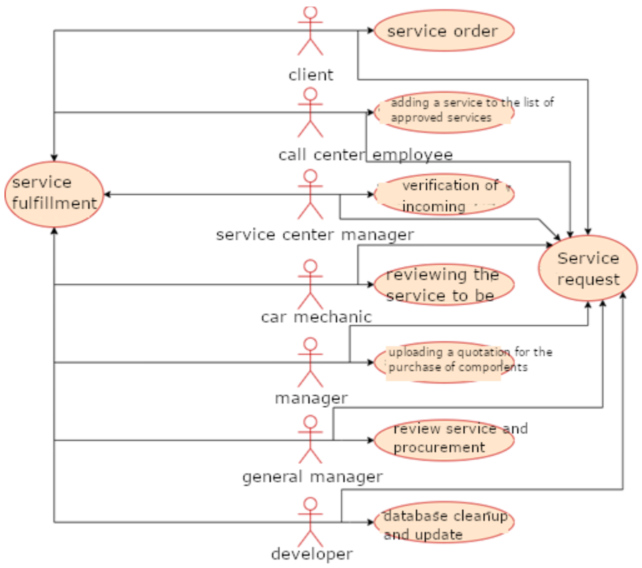

Fig. 3. General model of utilization options

Next, a minimum list of use case specifications should be compiled for each user of the system. Also for each use case it is necessary to prescribe prerequisites and main flow of events. The description of each use case is presented below the diagrams.

The specification for the "Service Ordering" use case is shown in Figure 4.

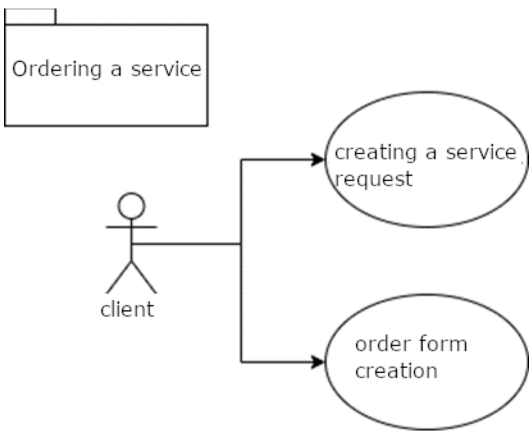

Fig. 4. Option "Ordering a service"

Brief description: service ordering involves adding a service from the general catalog to provide it.

Prerequisites: the site must work and enter services into the base.

The main flow of events: the user clicks the "Service Order" tab at the top of the home page and goes to the corresponding page of the system. When clicking on any service, there is an opportunity to select the item by pressing the button.

On the catalog page, if you click on the button with the "+" sign, the form of adding a new service will appear with the following fields: "Client's name", "Type of service", "Time limits for performing works", "Brief description of the problem". After all fields are filled in, the service is added to the preliminary catalog by pressing the "Add service" button.

The specification for the use case "Adding a service to the list of approved services" is shown in Figure 5.

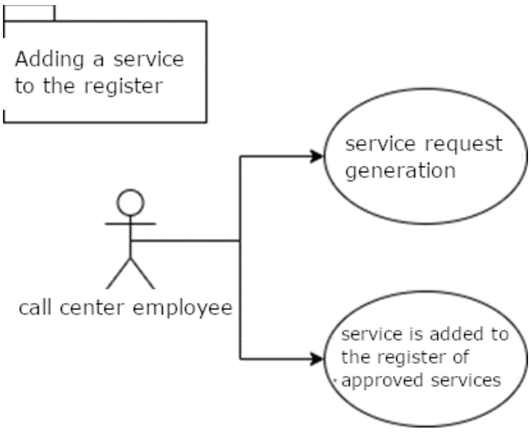

Fig. 5. Option "Adding a service to the list of approved services"

Brief description: In order for a service to be performed, it must be verified and entered into the verified services database.

Prerequisites: the service that will be checked and entered into the register of ordered services must exist in the register of unchecked services.

Main event flow: the user clicks the "Waiting for a decision" tab at the top of the home page and goes to the appropriate page of the system.

The page displays a list of active requests (with links) in the format Client's full name - service for which the request was created. When clicking on the request link, the user goes to the request page with the sections "Client information", "Service", "Description".

The following buttons are available to the user (located at the bottom of the page): "Start coordination" - the request is received in the responsibility of the specialists configured in the route of coordination for the current service, they have available buttons "Agree" - the request is returned to the original responsible persons and "Reject" - a text field appears for free entry of the reason for rejection, the request is closed; "Deny execution" - a text field appears for free entry of the reason for rejection, the request is closed; "Leave a comment" - a text field appears for free entry of the specialist's comment, all comments are displayed in the text field.r.

The specification for the use case "Check incoming services and availability of components" is presented in Figure 6.

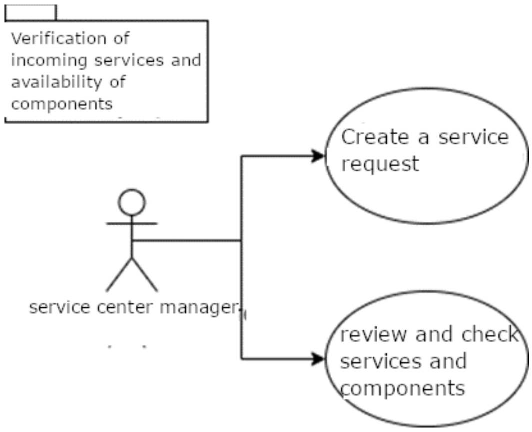

Fig. 6. Option "Verification of incoming services and availability of components"

Brief description: once a service is entered into the Approved Services Registry, it is rechecked for review and to see if the components are available to perform the specific service.

Prerequisites: the service to be audited must exist in a registry of approved services.

The main flow of events: the user clicks the "Service Catalog" tab at the top of the home page and goes to the corresponding page of the system. When clicking on any service, there is an opportunity to select the item "View ordered service" by pressing the button.

On the page of the ordered service, if you click on the "Availability of components for the service" button, a form with the components entered in the database and their quantity in stock appears. If the components are out of stock, the button "Send form for ordering components" appears, which is sent to the manager for complete filling.

The specification for the "View Service to Execute" use case is shown in Figure 7.

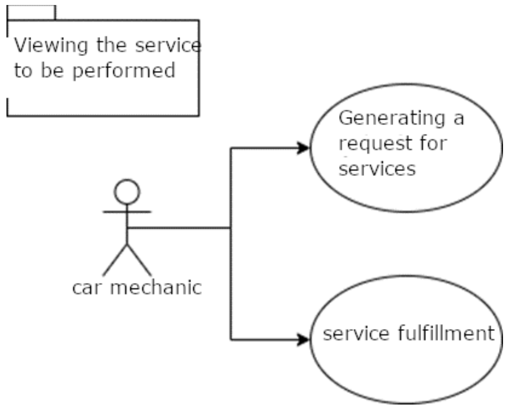

Fig. 7. Option "View service to execute"

Brief description: view the service and components for fulfillment.

Prerequisites: the service to be performed must come in a file to the mail of the service center.

Main flow of events: the user clicks the "Mail" tab at the top of the home page and goes to the corresponding page of the system. When clicking on any service, there is an opportunity to select the "Open for viewing" item by pressing the button.

When clicking on the request link, the user goes to the request page with sections "Recipient Information" (full name, title, contact phone number, e-mail), "Service", "Description" (similar to the one described in the previous specification).

On the page, if you click on the "Accepted for execution" button, the form of adding a coordinator with the fields "Surname", "First name", "Patronymic" and "Position", "Start of execution" appears. After filling in the fields, when you press the "Save" button, the form is fixed by the service of the catalog. Additionally, a button with a "+" icon appears for adding new fields.

The specification for the use case "Loading parts purchase offers into the subsystem" is presented in Figure 8.

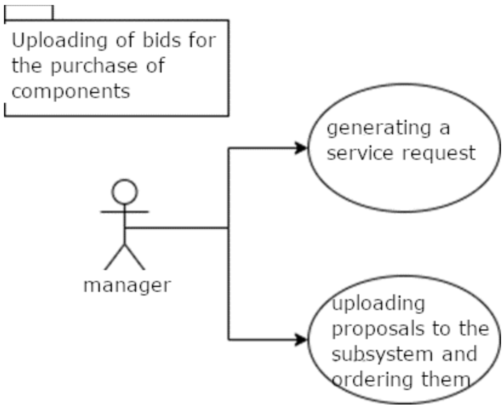

Fig. 8. Option "Loading component purchase offers into the subsystem"

Brief description: when there is a shortage of components, loading and purchasing of goods in the subsystem should take place.

Prerequisites: the service for which components are missing must exist in the current database.

The main flow of events: the user clicks the "Missing components" tab at the top of the main page and goes to the corresponding page of the system. When clicking on any component, there is an opportunity to select "Order a component" by pressing the button.

On the order page, if you click on the button with the "+" sign, the form of adding missing components appears, which contains the fields "Name of component", "Quantity of components", "Tentative delivery terms". After filling in all the fields by pressing the "Save" button the format is saved.

The specification for the "View Services and Procurement" use case is shown in Figure 9.

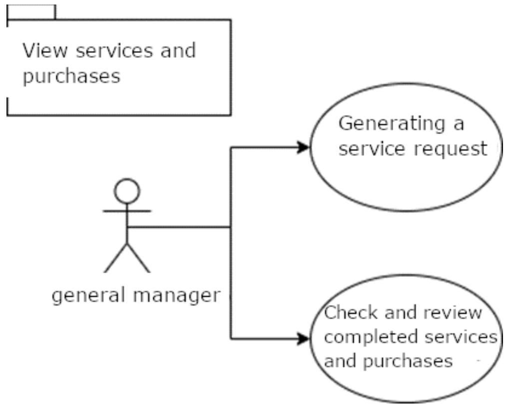

Fig. 9. View Services and Procurement" option

Brief description: To measure the success of an employee and/or department, it is possible to generate a report regarding a service. The forms sent to vendors are reviewed.

Prerequisites: in order to measure the success of an employee and/or department, it is possible to generate a report regarding a service.

Main flow of events: the user clicks the tab "View completed services and purchases" at the top of the main page and goes to the corresponding page of the system. When clicking on any service, there is an opportunity to select the item "Evaluate service and view procurement for this service" by pressing the button.

On the page, if you press the button with the "+" sign, the form of adding a new criterion appears with a drop-down list containing the "Evaluation of success of the performed service" shelf.

The specification for the "Clean and Update Database" use case is shown in Figure 10.

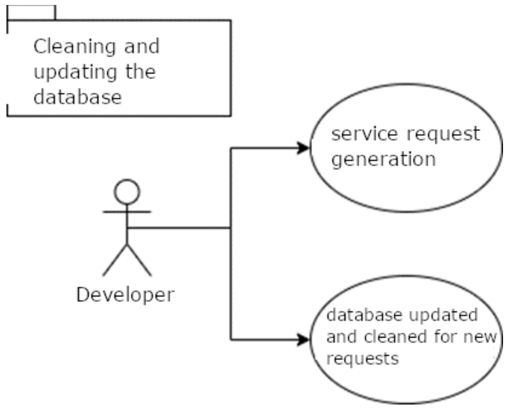

Fig. 10. Option "Cleaning and updating the database"

Brief description: for unapproved services, the database is rechecked, updated and cleared.

Prerequisites: the service to be re-validated must exist in the current database.

The main flow of events: the user clicks the "Unapproved Services Database" tab at the top of the home page and goes to the corresponding page of the system. When clicking on any service, there is an opportunity to select the "View Service" item by pressing the button.

On the page, if you press the "Reject and clear" button, the service is removed from the list; if you press the "Service approved" button, a form with the fields "By whom the service is accepted", "Due date", "Priority of execution" appears.

CONCLUSION

As a solution to the problem of developing a multifunctional system consisting of an Internet service for purchasing services, a subsystem for managing income and expenses, a generator of forms to be sent to employees and suppliers, as well as a service for communication with suppliers, employees and managers of service centers was chosen to develop an AIS that automates part of the processes of daily activities of the enterprise with the ability to generate information about employees and customers for the efficiency of work and success of the activity.

Implementation of the developed automated information system allows structuring and formalizing the list of rendered services, will allow keeping records of labor inputs of specialists, identifying service gaps and monitoring the progress of improvement of indicators. The AIS under development will provide an opportunity to identify the need for additional functionality and implement it, expanding the scope of its application.

As a result of the development of an automated information system, the enterprise-customer will be able to increase the volume of services provided, improve the quality and quantity of work performed, identify and eliminate gaps in the work without increasing the staff and attracting additional specialists, which in turn will help to increase the volume of final production.

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Application of random number generators in solving the problem of user authentication in blockchain systems

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***Abstract* -This article proposes issues of remote user access using authentication technologies in web portals and ensuring information security using an authentication algorithm in interconnected mode. Also, the issue of authentication and key generation in networks and systems based on blockchain technology, deterministic wallets, hierarchical key creation, as well as how it works mathematically and in what cases it is convenient to use in practice are presented. This material deals with security issues related to payment gateways, Bitcoin wallets and other coin storage.**

Keywords Authenticate, protection, info-communication system, internet portal, web portal, Protecting of Information, protection of information resources, generation number, encryption, decryption, attack, and password, blockchain, consensus,* cryptocurrencies, *bitcoin.

I. INTRODUCTION

By modern principles of construction of information infrastructure interaction of state agencies or commercial structure with the citizens (customers), other organizations, including governments, it is advisable to ensure, through produced by the internet news portal, which is a single point of access for all users, resources or to a set of information services[1].

The main objective of creating accessible web portals is to improve information support of the population of other consumers about the activities of federal and regional authorities, socioeconomic development, legislative activities, etc[2].

These problems are solved by using portal technology, including the implementation of e-commerce systems, providing secure access for remote users to corporate resources, etc. Comprehensive protection of Web resources [3,4].

The problem of protection of information resources such as distributed information communication systems using open channels of communication (the Internet) can be solved based on a comprehensive, integrated approach to information security of Internet portals. This is achieved by creating a single design process of information communication system protection of information resources (PIR) portal[5].

Under PIR we mean a set of measures and tools aimed at the identification, reflection, and elimination of security threats specifically Internet portal.

The modern concept of object protection information, including Web portals, involves the implementation of the following sequence of actions:

- Analysis of the functioning of information objects and resources (elements) that require the security of information (the definition of protected objects);
- Identification of possible threats to their ranking in importance and the formation of a list of requirements to ensure the security of information-protected resources;
- Development of adequate information security threats measures, the choice of tools and technologies to protect;
- Agreeing on the choice of information technology (hardware and software, and network resources) in terms of applicability of information security and implementation based on PIR's comprehensive approach to protecting information resources Internet portal.

Please be aware that maintenance is PIR system to the portal. It must include adequate protection for all information technology (IT) to protect critical resources and information to the consumer without compromising the quality of hardware and software info-communication systems [8].

This is achieved through several interrelated organizational and technical protection mechanisms to substantially reduce the probability of the main threats and create a platform for improving the system control and protection of information resources and capacity to secure Internet portal functions[9].

The information provided by users (readers) on public Internet portals is open. Therefore the main task in implementing the security portal is to ensure the integrity and availability of their information resources. In this regard, posing requires, first and foremost, protection against unauthorized access from the Internet[10].

Thus, the most pressing problem is the implementation of strong authentication of authorized users on the portal for access to corporate resources, etc.

- In particular, a key problem for information security is to ensure the OE integrity and reliability of circulating in the system for electronic documents. The presence of such a claim involves the inclusion of PIR portal software and hardware to ensure:

- ➢ Provability of authorship made, modified and deleted records, generating electronic documents, including the placement of the portal content;
- ➢ Authorized the introduction, modification and deletion of records in the portal administrators' databases, etc. The details of these requirements will be described below.

The use of blockchain technology in the implementation of the authentication process leads to effective results[30].

The blockchain uses public-key cryptography (PKC) to encrypt wallets or the places on the blockchain where value or work is securely stored. Blockchain authentication, therefore, raises interesting similarities between the technology itself and securing it. With cryptocurrency wallets being a main feature, identity and access management (IAM) for the blockchain is almost a given, however its user experience (UX) and user interface (UI) are very poor without a modern authentication component such as True Passwordless Security[14].

II. STRUCTURE OF SECURE WEB PORTAL

The structure of a typical secure Internet portal should be designed so that the technologies that have been implemented within the framework of poses, have been involved in all solved problems of information portal (portal administration, management of both public and internal, intended for authenticating user content; portal connection using telecommunications to the Internet, etc.). The block diagram of a typical building PIR secure Internet portal is shown in Figure 1.

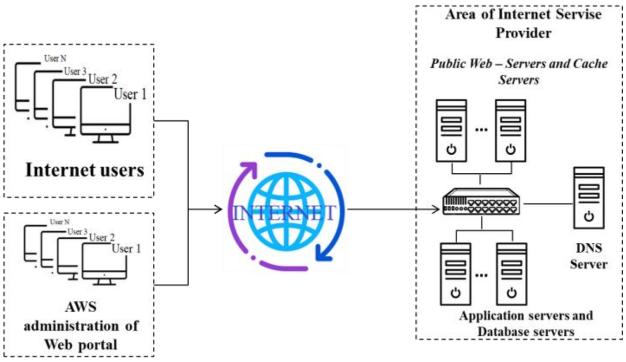

Fig.1.Typical architecture of Web-portal

To ensure comprehensive protection of information resources Internet portal model posing it should implement the following functions and include the corresponding subsystems:

- Protection against unauthorized access;
- Active audit;
- Antivirus protection;
- Cryptographic protection and support of digital signature.

The function of protection against unauthorized access is implemented using:

- protect against unauthorized access portal resources from the Internet and at the level of the protected LAN segments, including the regular means of protection used in the site operating systems (OS) and database management systems (DBMS). This includes the use of certified information security requirements OS and DBMS;
- Administration of protection against unauthorized access;
- System event recording and unauthorized access attempts to protected resources, early warning security administrators about unauthorized access attempts, etc.

III. AUTHENTICATION PROCESS

Systems of authentication and access control are usually implemented as two entirely different things. Although sometimes it makes sense to distinguish between the bolt that holds the door closed and locked, which controls the valve, such things are often integrated into a single mechanism.

In computers, the same authentication process simply sets up the correct user name for future use and access control is carried out separately. Computer systems typically control access by comparing a user with access rules, tied to a particular file or other resource. If the rules allow access to the user with that name, then he gets the opportunity to use the resource. Current authentication systems have evolved as a result of decades of attacks, many of which were successful. This has led to attempts to intercept passwords, which, in turn,- to the emergence of other protective measures (Fig. 2).

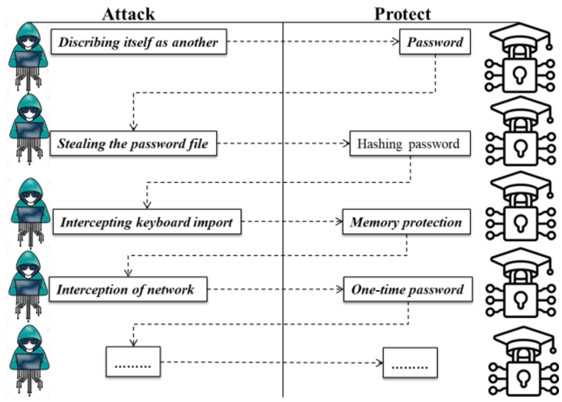

Fig.2.Evolution of the attack and protective measures for authentication.

IV. ALGORITHM OF AUTHENTICATION

Mutual authentication of the user and the network, except for user authentication, provides authenticated network. In the latter case, the object is authenticated network user. The figure shows a five-step scheme of a mutual authentication system (B) and a guest user of the system (A) services to info-communications systems.

Algorithm of authenticate process:

1. $B: R_B \rightarrow A;$ (1)
2. $A: R, R_S \rightarrow T;$ (2)

$$T: C(B) = E_{KTB}(R_S, R, K_S), \& C(A) =$$

3. $= E_{KTA}(R, K_S, C(B));$ (3)

$$T: C(A) \rightarrow A;$$

4. $A: C(B) = D_{KTA}(R, K_S, C(B)) \rightarrow B;$ (4)

$$5. \quad \begin{aligned} &B:(R_S, R, K_S) = D_{KTB}(C_B); \\ &C(A) = K_S(R) \to A; \end{aligned} \tag{5}$$

V. Mechanism of generation number

The generation mechanism has its limitations - it usually requires a computer at each end of the connection, since the dongle must be allowed to receive and send information. A timing diagram allows us to restrict a simple terminal or fax. In this case, users can even enter their password to the phone keypad, when they call in the network for voice mail[12].

Scheme of "challenge-response" scheme gives timings for ease of use. For the logic input timing diagram the user is to simply dial 10 digits. The scheme as a "request-response" may require the user to perform a larger number of manual steps. In some schemes of "challenge-response" the user must enter a secret key and then type on the keyboard obtained using a hardware key, the encrypted word call[13].

In some cases, the user must perform a second logic input to the communication server after authentication.

In the system of comprehensive protection of information resources. Internet portal's essential point is the application of institutional, organizational and technical measures. In particular, when you access the internet portal in action (connecting to the internet) need to develop all the organizational and normative-technical documentation, including a part of information security. You need to assign and prepare the security administrator, to train other staff (content managers and editors) on the basic rules of safety information. Also, to improve access to information resources Internet portal should make full use of technologies and redundancy and duplication (for example, through the use of cluster solutions) designed to maximize backup and recovery, and other measures.

In addition, we present the technology of creating hierarchical keys for deterministic wallets based on blockchain technology, as well as how it works mathematically and in what cases it is used in practice.

VI. Generation of hierarchical keys for crypto wallets based on blockchain technology

First of all, let's define what a deterministic wallet is. When we talk about key generation, we often use the word "wallet" because in the context of cryptocurrencies, the possession of a private key is proof of ownership of the coins, and in this case, the wallet and the key have a similar meaning[13].

A deterministic wallet is a wallet in which all used private keys were generated from a single secret shared by all keys. The peculiarity is that it is possible to generate as many pairs of keys for an electronic signature from one secret. You can use new addresses for each incoming payment and change.

Conveniently, the keys of such a wallet can be easily transferred to another device, backed up and then restored, because fact, only one master secret needs to be backed up. In addition, all private keys generated from the main secret are not related to each other in any way. It is also impossible to trace the connection between the generated addresses (to determine that they all belong to the same user), and having a generated private key, it is impossible to restore the shared secret[14].

A. Master Secret Encoding

Now let's talk about encoding the main secret. There is some standardized approach here that was defined in BIP39. This is the so-called Check Encoding encoding the main secret into a mnemonic phrase - a set of words that is easy to write down on paper and remember if necessary. Checking the checksum at the time of input, that is the error, if any, can be calculated with high probability by the formula (6), (7). The calculation results are presented in Table 1.

$$C = \frac{E}{32} \tag{6}$$

$$W = \frac{(C+E)}{11} \tag{7}$$

Entropy is concatenated with a checksum, which is calculated as a double SHA-256 hash (SHA-2 at 256 bits), after which the required number of bits is cut off. The concatenated data is converted to another number system:

From binary to base 2048 (as you can see, 2048 is 2^{11}) and if you add the length of the Entropy bits and the checksum, you get a number that is a multiple of 11. Thus, we get the number of words in the output mnemonic phrase.

The data is "cut" into 11-bit pieces. There is a dictionary consisting of 2048 words 2^{11}) to which certain requirements are applied. The default language of the dictionary is English, but any language can be used. Words must not exceed a certain length (usually the limit is up to 7 characters). All of them must be encoded in UTF-8 with some normalization of all characters. Mandatory is the uniqueness of each word for the first four characters.

The first four characters uniquely identify a word in the dictionary, and the remaining characters are used to complete that word into a convenient form for reading, remembering, etc. In this way, each piece of data, consisting of 11 bits, receives a one-to-one correspondence in the form of a word from the dictionary. If the Entropy of your secret is 256 bits, then the data to encode will be 264 bits, and your mnemonic phrase will be 24 words long. This is the main BIP39 approach to encoding wallet secrets and is the most commonly used in practice.

To make a backup copy and use it in the future, you are invited to write this phrase to an external medium. Paper that you keep in a safe place is best. This way you can restore full access to all your keys.

B. Types of Deterministic Wallets

Deterministic wallets come in two types. Let's consider their main differences.

The first one is the simplest. The main secret here is concatenated with the index of the child key that we want to get, after which the concatenated data is hashed. This is most often done using the SHA-256 hash function.

The second type is hierarchical deterministic wallets (HD wallets), whose principles are defined in BIP32, and are a very common approach to hierarchical key generation. Consider the differences between these types of wallets in the diagram Fig. 3 and Fig. 4.

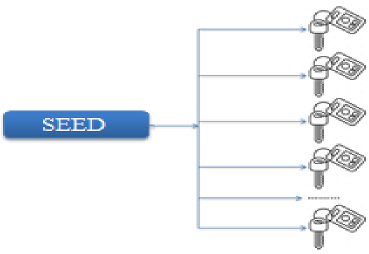

Fig.3. Deterministic wallet

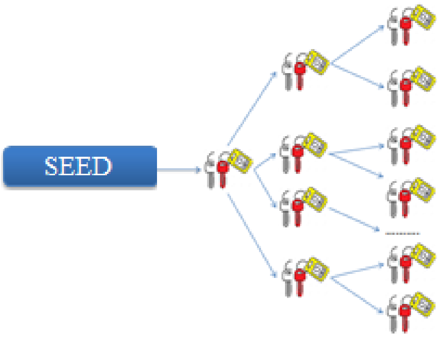

Fig. 4. Hierarchical deterministic wallet

A typical deterministic wallet has some seed from which a huge set of private keys is directly generated. Their number can only be limited by the dimension of the index that is concatenated to the secret before hashing. This is usually 4 bytes, which means that the space of possibilities allows for about 4 billion unique deterministic wallet keys. In practice, this should be enough for any situation.

C. Hierarchical deterministic generation

Let's move on to a hierarchical deterministic wallet, the key unfolding scheme of which is presented in a simplified form so far. There is a seed from which a pair of master keys is directly obtained. If in a regular deterministic wallet, we get a private key, then here we get a key pair. Moreover, there are hierarchical levels, on each of which we calculate an index to generate a child key. We can also build public key branches and private key branches.

Hierarchy levels. Regarding HD wallets, it is worth noting that according to the BIP32 rules, at each level of the hierarchy, the spawn node has three objects: a private key (private key), a public key (public key) and a chain code (chain code), which is used to generate the next level of the hierarchy. Let's take a closer look at the BIP32 key generation scheme Fig. 5.

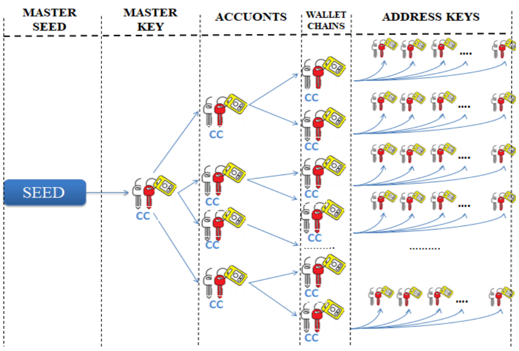

Fig.5. Scheme of hierarchical generation

It all starts with seed, it is also called the master seed, from which the zero level of the hierarchy is calculated - a pair of master keys and chain code[14].

From a pair of master keys, a huge number of pairs of keys with certain indices can be generated. A new level of hierarchy is formed, which is used to generate accounts. Let's say one user has a seed and he wants to create several addresses that will be different from each other. The coins of these addresses will not be mixed, will not be published together, and it will not be possible to find a connection between them in ready-made transactions. These keys will be used completely separately from each other. In one of the accounts, a group of keys will be used for the working budget, in the other - for the personal budget, and in another account - for the black book. Coins will not mix.

The next level of the hierarchy defines different key generation chains. The chains with indexes 0 and 1 are the most commonly used. The chain with index 0 will generate final keys to form an address for incoming payments, and the chain with index 1 will generate wallets that will receive coins sent by the user to himself, that is, change. This is necessary so that the wallet at the program level distinguishes payments sent from outside from change, calculates the changes in the balance of each transaction and compiles a visual list with the history of all payments. This makes it easier to develop a wallet and use it for everyday payments.

D. Hash-based message authentication code

Now let's move on to the mathematical part of the processes of hierarchical key generation. Let's start by looking at the hash-based message authentication code. This is another class for calculating hash functions. It differs in that it takes two values as input, and not one. The first value is the secret key, and the second value is the message itself.

$$HMAC(K,m) = H\left(\left(K^{opad}\right) \| H\left(\left(K^{ipad}\right) \| m\right)\right) \quad (8)$$

K -Key, m -message, iPad - some constant values necessary for the formation of keys that differ from each other at different stages of hashing.

SHA-512 is used as a hash function. The peculiarity is that to use HMAC, you need to own the secret key to get the correct hash value of the message. So, to calculate the hash value by HMAC, the key value is XORed with a constant iPad value, after which the result is hashed. The message is concatenated to this value, after which the XOR of the key with a constant value is calculated, concatenated with the hash value, and then hashed again. As a result, we get 512 bits of the hash value.

Result

Based on the formula (6), (7) above, the calculation results of entropy are given as follows. Table1.

Table 1. Basic Secret Encoding-BIP 39 (Bitcoin Improvement Proposals 39)

Entropy	Checksum	Data	Words
128	4	132	12
160	5	165	15
192	6	198	18
224	7	231	21
256	8	264	24

You have the main secret (Entropy) - the data from which all the private keys of the wallet are deployed. This secret can have different lengths. As for the checksum: for every 32 bits of Entropy, there is 1 bit of checksum, that is, the Checksum formula is calculated as the length of Entropy in bits divided by 32. Fig.6.

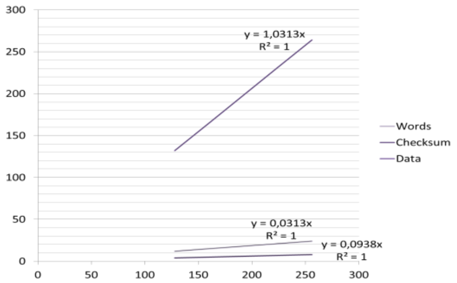

Fig.6. Table1 shows the calculation results and their regression equation

Conclusion

It is proposed to implement complex organizational and technical solutions to ensure the protection of information resources developed and introduced by state and corporate internet portals. Stable operation of the PIR hardware and software and the Internet portal as a whole is achieved by ensuring the necessary level of information security by preventing and blocking certain threats. Analytical ideas on the issue of generating keys using blockchain technology in improving authentication systems were also considered. in this case, the use of blockchain technology was mainly based on cryptocurrencies such as Bitcoin.

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Prospects of application of blockchain technology in the banking

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***Abstract* -This study analyzed the main mechanisms for achieving consensus in distributed ledgers. Different types of distributed ledgers were classified according to the characteristics of who can form data chains and who has access to them. Such important applications of the distributed ledger (blockchain) as smart contracts were examined in detail, the principle of their work was described, and the features of functioning on various platforms were systematized. Most of the work is devoted to a detailed review of the use of blockchain technology in the financial sector. Using the analysis of individual international and domestic practices as an example, the benefits of using the blockchain in the banking sector and payment systems are analyzed.**

***Keywords: Blockchain, consensus, smart contract, credit, loan system*, cryptocurrency, bitcoin, Ethereum, transaction, hash function, distributed ledger, decentralized application, public key, payment.**

I. Introduction

Blockchain technology, in addition to restructuring the securities market, has the potential to at least significantly simplify the procedures for providing certain banking services. In particular, the use of smart contracts in the future can significantly increase the efficiency of certain banking operations in which banks act as intermediaries between counterparties. The advantages of distributed registries and, in particular, blockchain, in terms of security, immutability of entered data and transparency in a distributed network are extremely attractive for the banking sector in some aspects[1].

First of all, this has already been mentioned earlier, it is possible to imagine an interbank exchange system based on distributed ledger technology. With the help of it, banks from different countries will be able to interact with each other more efficiently in terms of cross-border payments, significantly reducing the number of intermediaries (in the form of central banks, for example) and simplifying the movement of capital in the interbank exchange market[2].

Another promising direction for banks in the implementation of blockchain technology is the provision of a system for reliable and secure storage of credit histories of individuals and corporate entities. Today, in all countries there are special institutions, which in Uzbekistan are called credit history bureaus, which aggregate information about all bank loans issued in the country, compiling a single profile of the credit history of a particular organization or individual. At the request of the person or organization itself, as well as interested institutions (for example, other banks), the bureau provides an extract of the person's credit history. In their daily activities, such institutions face several problems that significantly reduce their effectiveness [5].

Firstly, these are long intervals for updating information in the bureau, since usually the provision of information on loans by banks to the bureau is carried out every month, and the complete entry of the received data and their reconciliation with current positions can take up to 7 business days.

Secondly, the problem of identification, which consists of the possible incomplete provision of information about the borrower or a simple mistake in the work of bank tellers - all this can make it impossible to unambiguously compare newly received data with some person or company.

Thirdly, the result of an error may be the inconsistency of information on the same person in different credit bureaus, which may affect the bank's decision to issue a loan to a person when an incomplete or erroneous history provided by one of the credit bureaus is provided as a source of information.

Fourthly, this is the limited activity of such bureaus by certain jurisdictions and countries, which leads to the fact that if a person moves to a new country, then his / her credit history starts from scratch in another country, which, generally speaking, with a possible exchange of information between bureaus different countries could significantly reduce the risks involved. Finally, a significant problem is the possibility of data leakage or unauthorized access to them. In 2017, hackers were able to steal information about the credit histories of 143 million people and the American credit bureau Equifax [3].

The third possible field for the introduction of blockchain in the banking sector is the area of standard banking products and services, such as mortgage lending, escrow accounts and letters of credit. Using the functionality of smart contracts, these operations can be made less risky for the bank (speaking of mortgages), as well as significantly reducing transaction costs from documentary support of transactions, their reconciliation and purely intermediary functions (speaking of escrow accounts and letters of credit). A large number of banks, including those in Uzbekistan, are now actively experimenting with the introduction of blockchain in terms of these service operations[4].

Currently, blockchain technology is widely studied by world scientists. Also, the results of their research are presented to the public in the form of scientific articles, books and monographs. The initial research work on blockchain technology was described in Satoshi Nakamoto's scientific work "Bitcoin: A Peer-to-Peer Electronic Cash

System", the scheme, consensus and other mechanisms of the bitcoin cryptocurrency[1]. In the scientific works of Brown R., distributed databases are studied and guidelines for data storage in blockchain networks are given[2]. In the scientific works of Uzbek scientists Joraev G.U., Aloev R., methods of applying blockchain technology in banking and financial systems and ensuring information security are presented[4,5,6-15].

II. SMART CONTRACT DESIGN FOR BANKING ORGANIZATIONS

In international practice, it is accepted to understand a smart contract as some kind of automatically triggered rule, the correct execution of which is ensured by blockchain technology. A smart contract is built according to the linear “if this then that" (ITT) principle, which means that the implementation of the contract conditions is carried out only if the event requested by the contract has occurred. The main advantage of a smart contract is the absence of a centralized arbiter of the transaction[2].

The idea of a smart contract was described at the end of the 20th century, but it received real practical development only in the 2010s. The explosion of interest in smart contracts as an element of distributed ledger technology began with the practice of using settlements in cryptocurrency, primarily Bitcoin, although it is in the Bitcoin blockchain that the possibilities for implementing smart contracts are very limited. Currently, smart contracts are implemented in distributed registries of many cryptocurrencies (primarily Ethereum, Ripple, NXT, NEO and others), and the most important issues for their future development are, firstly, the potential for expansion of applications in various fields and, secondly, the expediency of national and supranational regulation (Fig. 1)[7].

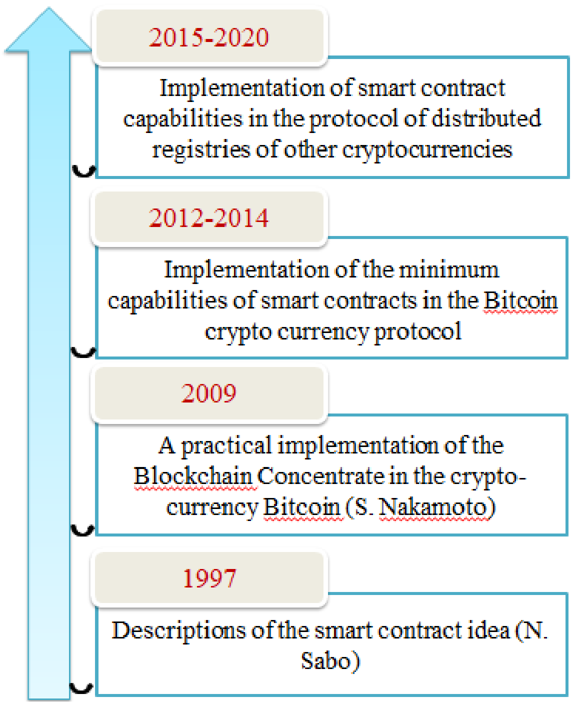

Fig. 1. - Stages of development of smart contract technology on a distributed ledger platform

The standard attributes of a smart contract - subject, subject, conditions, as well as the contract implementation platform - are shown in Fig. 2.

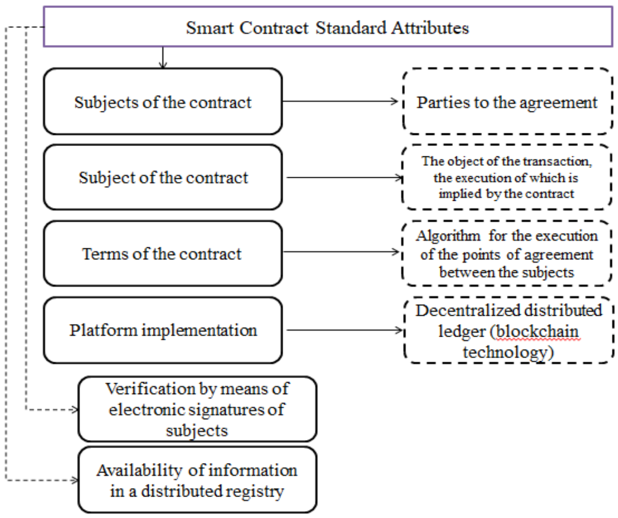

Fig.2 - Attributes of a smart contract

The parties to the contract are the subjects of a smart contract. Confirmation of participation of the parties in the conclusion of the contract and agreement with its terms is carried out through the exchange of electronic signatures. The subject of a smart contract is the object of the transaction between its participants, it can be property rights, cryptocurrency, and more. An important feature is that the subject of the contract can only be the object of the transaction, information about which is already contained in the distributed ledger. The terms of a smart contract are a technically specified algorithm, the execution of which means the execution of the clauses of the contract. Finally, the platform for the implementation of the smart contract is a decentralized blockchain[5].

It is important to note that the possibilities of concluding a smart contract vary greatly for different platforms for their implementation. It is known that the architecture of the Bitcoin blockchain does not imply the technical possibility of creating smart contracts initially. However, since Bitcoin is the most settled and distributed cryptocurrency in the world, alternative smart contract capabilities are being developed for its distributed ledger and blockchain add-ons are being created. Ways to create a smart contract or its equivalent in the Bitcoin distributed ledger include the following: colouring Bitcoin, extending the Bitcoin blockchain protocol, and using an add-on to the Bitcoin blockchain - sidechain (sidechain)[8].

The simplest way to endow Bitcoin with some attributes of a smart contract was developed in 2013 and consists of the so-called colouring of Bitcoin by its purpose for making a transaction with a certain type of asset (stocks, bonds, real estate, gold and other assets). Due to the divisibility of Bitcoin to one millionth (satoshi2), it becomes possible to colour the issue of Bitcoins so that one satoshi corresponds to one colour value. Bitcoin colouring is performed using a special EPOBC protocol, which generates two types of transactions - genesis transactions and transfer transactions [9].

These transactions differ from others in that a 6-bit tag is additionally entered in the information field about them (32-bit number), identifying them as genesis or transfer transactions. As part of the Genesis transaction, coloured bitcoins are issued. A transaction contains information about the number of Bitcoins of a certain colour in an issue, and the hash of this transaction in the distributed ledger is regarded as an indicator of the colour of Bitcoins of this issue. Further, transactions with coloured Bitcoins of the corresponding issue are carried out as part of transfer transactions. Bitcoin colouring is not an absolute substitute for a smart contract, since it only allows you to identify a specific issue of Bitcoins, but does not allow you to include other essential conditions in the transaction code[10].

The second way to extend the functionality of the Bitcoin distributed ledger is to extend its protocol using Merkelized Abstract Syntax Trees (MAST). Currently, the possibility of implementing the MAST functionality in the Bitcoin registry is only being discussed, since it presumably requires a soft fork - a soft change in the rules for recording transactions in a distributed ledger. The MAST functionality combines the technical characteristics of P2SH (Pay to script hash) and Merkle trees and can be schematically represented as shown in Fig. 3.

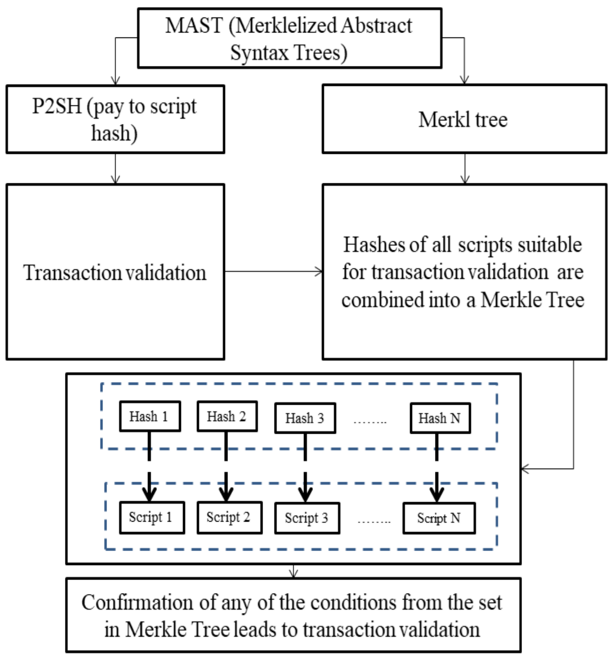

Fig. 3 - MAST Functional Diagram Extending the Creation of Smart Contracts in the Bitcoin Distributed Ledger

The idea of using this functionality is that transaction validation (unblocking Bitcoins from one address and transferring them to another address) is implemented if the P2SH principle is followed - the script of the new transaction must match the hash of the previous one. This idea is supplemented by the idea of multivariance of mutually exclusive transaction validation conditions.

All possible transaction validation conditions are combined into a Merkle tree, a feature of which is the ability to check whether it contains a specific data set (even if not the entire data set of the tree is known). As a result, a transaction is unlocked in one of the cases when the script for the next transaction matches one of the hashes in the Merkle tree. As a result, the MAST functionality provides the ability to predefine the conditions for unlocking a transaction in bitcoins, which can be regarded as a variant of a smart contract.

Finally, the third option for creating a smart contract in the Bitcoin blockchain is to use an add-on for a distributed ledger - the so-called sidechain (sidechain) or its simplified version - dual chain. A sidechain is an additional distributed ledger that integrates with the parent distributed ledger (in this case, the Bitcoin blockchain) and broadcasts information about the transactions made in it[11,12].

Moreover, the sidechain is used not only to discretely import transaction information from an auxiliary ledger to the parent ledger but also to carry out transactions between two ledgers. If the architecture of the auxiliary distributed ledger allows the creation of smart contracts, the sidechain facilitates the appearance of this information in the Bitcoin blockchain. Currently, a dry chain for Rootstock (RSK) is under discussion and development [25]. Rootstock is a centralized two-way-peg system to the Bitcoin blockchain, the platform of which will allow the Bitcoin blockchain to access smart contracts and Ethereum decentralized applications written in the Solidity language. The scheme of interaction between the parent blockchain and the sidechain is shown in Fig. 4.

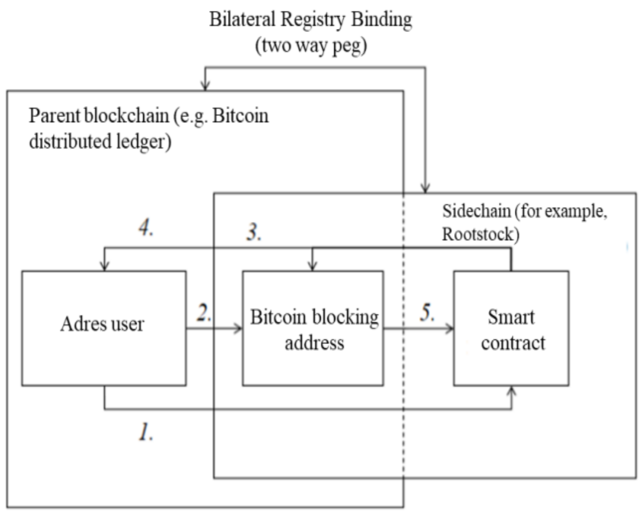

Fig. 4 - Scheme of interaction between the parent blockchain and the sidechain smart contract

1. Request a contract
2. Withholding funds from the user's address to pay for the contract
3. Transaction authentication (multi-signatures)
4. Implementation contract
5. Transfer of contract payment

However, Sidechaining is currently limited, requiring changes to the Bitcoin protocol and hence a soft fork. The problem of sidechain security is also insufficiently studied, since the sidechain receives financial resources (for example, a fee for creating a smart contract) from the parent distributed ledger, and protection through the PoW protocol does not work so effectively for it[13].

As shown above, the creation of smart contracts on the Bitcoin distributed ledger has limitations, while other distributed ledgers offer more opportunities for this. In various distributed registries, smart contracts are created in different languages (special, as in the Ethereum registry, or already existing, as in the NEO registry), with or without restrictions on contract type templates, with varying degrees of complexity, contract profile specialization, with the possibility of automatic calibration errors[14].

The basic platform for the implementation of a smart contract is the Ethereum platform, on which a smart contract is created in the Solidity language without restrictions on the form (template) of the contract. The NEO alternative blockchain platform allows for automatic optimization of the smart contract code before launch, which reduces the speed of contract creation, but increases the efficiency of its use in the future[15].

The currently existing smart contracts have such limitations as the impossibility of correction and the impossibility of importing information from outside the distributed ledger (Figure 5).

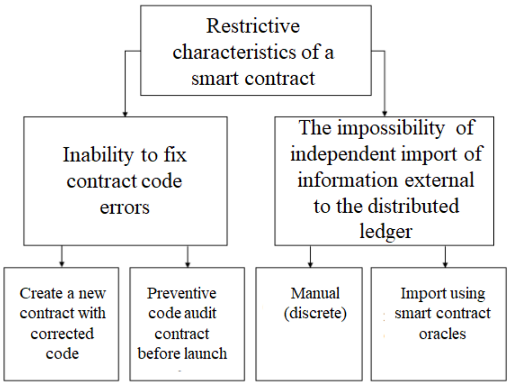

Fig.5.- Restrictive characteristics of smart contracts

The impossibility of changing the smart contract rule means that the detection of errors in the code in the process of using the contract leads to the refusal to use this contract and the creation of a new one. This feature, on the one hand, stimulates the emergence of complex contracts that calculate a large number of probable outcomes; on the other hand, it is the complexity of the contract that increases the risk of coding errors. In this regard, the creation of rich smart contracts is often accompanied by a preliminary audit of the contract by technical professionals.

The second feature of a smart contract - the impossibility of accessing external information - means that only information that has already been previously placed in a distributed ledger, within which the contract exists, is available to the contract. However, the import of the information necessary to fulfil the contract into the distributed ledger can be done manually or using oracles.

A blockchain oracle can be defined as a special infrastructure algorithm that imports information into a distributed registry from a server external to the registry, which in turn sends a request to the provider of the necessary data, as shown in Figure 16. As a result, previously missing information appears in the distributed registry, which is necessary for the smart contract to fulfil the conditions of the code.

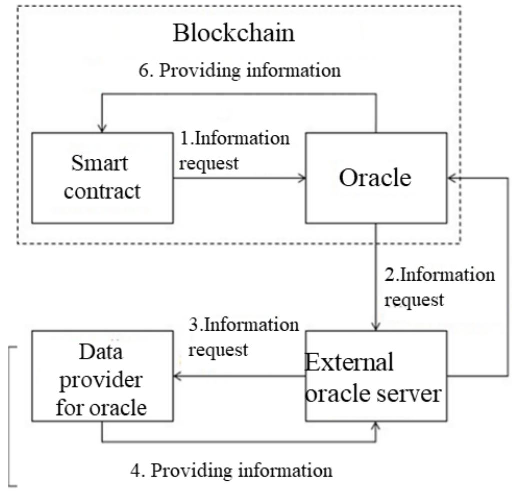

Fig. 6. - Scheme of interaction between an oracle and a smart contract

This algorithm overcomes the limitation caused by the determinism of the distributed ledger: the continuous import of information by the oracle into the distributed ledger allows the smart contract to access this information in real-time and compare the actual conditions with those specified in the contract and lead to a change in the state of the transaction. The scheme of interaction between the oracle and the smart contract includes two main stages: the import by the oracle of information from the outside world and the import of information by the smart contract from the oracle.

CONCLUSION

Finally, a smart contract on the Ethereum platform can be effectively used in transactions with securities and derivative financial instruments. For example, a securities transaction is made between clients using private keys, and the transfer of ownership is confirmed using a public key. At the same time, the smart contract imports information about the issue of securities from the oracle, fixes the transfer of ownership, and manages operations such as the payment of dividends.

Similarly, in transactions with derivative financial instruments, a smart contract imports current information on instruments from the oracle, fixes the obligations of counterparties (for example, the conditions for performing a swap operation), calculates net obligations, closes the transaction and generates a record of its result in the ledger. The use of smart contracts in the field of derivative financial instruments has a high potential since a properly programmed contract can hedge the client's risks in an almost fully automated mode.

As indicated above, the Ethereum platform is the most basic for creating smart contracts, and therefore it is used in the development of nationally distributed registries, smart contracts and applications for them.

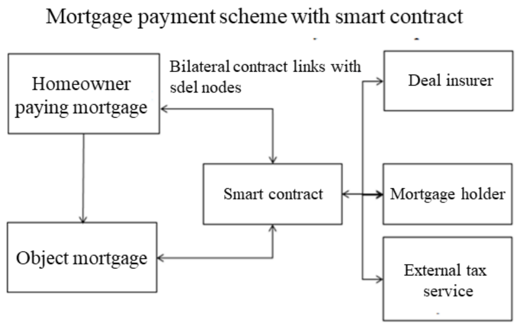

Fig.7. - Scheme of mortgage payments using a smart contract

As indicated above, the Ethereum platform is the most basic for creating smart contracts, and therefore it is used in the development of nationally distributed registries, smart contracts and applications for them.

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IDENTIFICATION OF SHORT CIRCUIT TYPES IN ELECTRICAL SYSTEM ELEMENTS

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Key words: protection and automation devices, management process, fuzzy logic, short circuit.

Summary: in this article, the causes of technological violations in electrical systems are considered, a number of characteristic shortcomings in the protection and automation of electrical system elements are identified. The tendency to reduce the reliability of relay protection associated with the transition from analog to digital types of protection is substantiated. On the basis of the studied examples, the use of fuzzy logic in protection, the feasibility of using fuzzy logic elements in protection devices and automation of electrical systems to identify types of short circuits are substantiated.

Relevance. Today, elements of fuzzy logic are used in various industries, which demonstrate positive qualities [8-11]. The existing protection and automation schemes in relay protection are interconnected by many types of protection, which reduces their speed and reliability in general. Quick performance and reliability, in turn, are the main requirements for relay protection and automation [1].

Based on the results of the analysis of the causes of damage in electrical systems, a number of characteristic shortcomings in the protection and automation of elements of electrical systems can be identified. These are:

- the complexity of implementing the interaction of protections among themselves;
- slowdown in determining the types of short circuits;
- false positives, when the type of short circuit is not correctly determined;
- a large proportion of damage without establishing the cause.

In this regard, the development of an algorithm for identifying types of short circuits in the elements of an electrical system using fuzzy logic elements is relevant.

The advantages of this algorithm:

- will reduce the response time of protection.

Problem Analysis

An analysis of the publication in high-ranking journals was carried out, which made it possible to draw the following conclusions:

- tendencies to reduce the reliability of protection systems built on the basis of increasingly complex microprocessor-based protection devices (MPDs) [2];
- insufficient reliability of the MPD, in particular, that a significant proportion of protection failures occur in microprocessor devices (approximately 23% of all cases), which make up only about 10% of the total number of protection devices. This, of course, is one of the most important factors determining the need to take special measures to improve the reliability of the MPD [2];
- combining many functions in one microprocessor terminal sharply reduces the reliability of protection, since if this terminal fails, too many functions will be lost at once compared to the case when these functions are distributed among several terminals [3];
- the need to limit the number of functions implemented in one MPD terminal was also discussed by scientists at the International Conference "Modern

trends in the development of protection systems and automation of power systems";

- a sharp increase in the level of complexity of the work of personnel serving protection with the transition to MPD, as a cause of severe accidents in power systems;

- the complexity of the software interface and the need to introduce an excessive number of settings when programming the MPD;

- unsatisfactory state of the electromagnetic environment at most of the old substations, which were designed and built for electromechanical protection, and not for microprocessor protection, and the resulting numerous failures in the operation of the MPD [4];

- the lack of universal strict requirements for the MPD hardware and software, and as a result, too much variety of programs and algorithms embedded in the MPD used in one power system, which leads to problems during operation and to an increase in the likelihood of false operation of these devices;

- most of these devices must be installed in heated switchgears, since at temperatures below -25 degrees, the liquid crystal display, which is equipped with microprocessor devices, becomes unreadable. This is a particular disadvantage for the Northern region, since in winter the temperature can drop to -40 degrees, which makes it impossible to use these devices in outdoor-type complex switchgears. The device of microprocessor complexes is more complex and a number of difficulties with their repair are associated with this. If the electromechanical complex can be disassembled and the damaged part replaced, then the microprocessor complex can only be repaired at the factory [5].

It was also noted that the sensitivity to electromagnetic interference of protection devices based on a microprocessor element base is several orders of magnitude higher than that of their traditional electromechanical counterparts, and therefore, in order to ensure electromagnetic compatibility (EMC) of secondary circuits, it is necessary to sharply increase the level of their electromagnetic protection. Without carrying out a set of works to ensure EMC, it is impossible to achieve acceptable MPD reliability characteristics [4,5].

Based on the analysis of the causes of technological disturbances in electrical systems, a number of characteristic shortcomings in the protection and automation of electrical system elements were identified. It is about the following:

1. Decrease in the reliability of protection as the MPD application expands.
2. Continuous complication of MPD and increase in the concentration of protective functions in one terminal.
3. Complication on the MPD of functions unusual for protection, for example, monitoring of electrical equipment.
4. The use of non-deterministic logic in the MPD, causing the danger of loss of control over the actions of the protection.
5. Expansion of the use of freely programmable logic in the MPD, accompanied by a significant increase in the percentage of personnel errors and incorrect actions of protections.
6. Complication of checks of serviceability and general operation of protection as many types of MPDs from different manufacturers are accumulated in one power system, purchased through tenders and differing from each other both in design and software.

All this creates a combination of a number of factors and criteria in the protection of electrical installations, which must be taken into account and the complexity of organizing protection increases with the removal of protection from the consumer and approaching the power source. At the same time, the complex of protections as a whole or separately must meet a number of requirements, and first of all, speed, quality and reliability of operation.

In this regard, a hypothesis has been formulated on the application of the principles of fuzzy logic to protect objects of electric power systems.

Description of the experiment

Currently, fuzzy logic is widely used to solve real-life problems. Fuzzy logic is a set of mathematical principles used to represent knowledge, as opposed to classical binary logic. It is a powerful tool for dealing with uncertainty and was originally introduced to provide reliable and low-cost solutions to real world problems. Fuzzy logic systems can be classified into three main types: 1) simple fuzzy logic systems (pure Fuzzy Logic Systems: Maimo); 2) fuzzy systems Mamdani, Takagi and Sugeno (Takagi and Sugeno); 3) fuzzy logic systems with a fuzzifier and a defuzzifier [11].

Having studied the works of scientists published in high-ranking journals, we can talk about the possibility of implementing the hypothesis of applying the principles of fuzzy logic to protect objects of electric power systems to identify types of short circuits in the elements of electric power networks [8-11]. The proposed method based on fuzzy logic together with the method of symmetrical components can be efficient and effective under various fault conditions. It will also increase the speed of protection.

For the experiment, ES models with and without transformer coupling were created in the Simulink software [7]. On the created models, experiments were carried out on the occurrence of short circuits (single-phase, two-phase, two-phase to ground) at the beginning, in the middle and at the end of the lines in the MatCad system.

Experiment results

As a result of the experiments:

- the values of currents and voltages of three sequences were obtained (Table 1.);

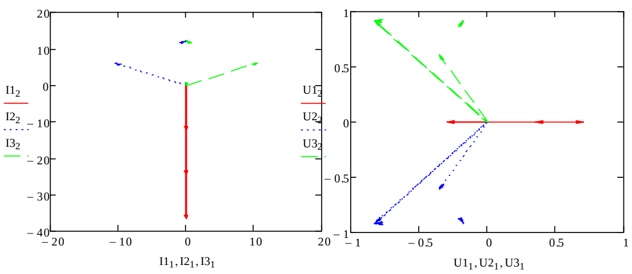
- the degrees between the vectors are determined for the construction of vector diagrams of currents and voltages (Fig. 1.).

Table 1

Values of currents and voltages of direct, reverse, zero sequences in case of single-phase short circuits

Types of damage	Values of currents and voltages of direct, reverse, zero sequences	Regarding reg. regime
$K^{(1)}$	$I_{kA1}=I_{kA2}=I_{k0}=-j12.14$ $I_{kA}=3\ I_{kA1}=-j36.413$ $\mathbf{I_{kB}=0}$ $\mathbf{I_{kC}=0}$	↑ ↓
	$U_{kA1}=-(U_{kA0}+U_{kA2})=0.705$ $U_{kA2}=-0.352$ $U_{k0}=-0.65$ $U_{kA}=-0.295\approx\mathbf{0}$ $U_{kB}=-0.83-j0.92$ $U_{kC}=-0.83+j0.92$	↓ ↑ ↑ ↓ ↑ ↑

Figure 1 shows vector diagrams of currents and voltages built according to the values in table 1.



$I_{kA1}=I_{kA2}=I_{k0}$ $\qquad U_{kA1}=-(U_{k0}+U_{kA2})$

Pic. 1. Vector diagrams of currents and voltages for a single-phase short circuit

This experimental work was carried out in the MatCad system. The calculation methods were based on the existing method of symmetrical components, which makes it possible to determine the values of currents and voltages of different sequences. The calculations were carried out in the system of relative units. The conditions of the boundary conditions coincide with the theory.

During the experiment, asymmetric types of short circuits (single-phase, two-phase, two-phase to earth) were initiated at the beginning, in the middle and at the end of 110 kV power lines. As an example, the results of calculations for a single-phase short circuit were given.

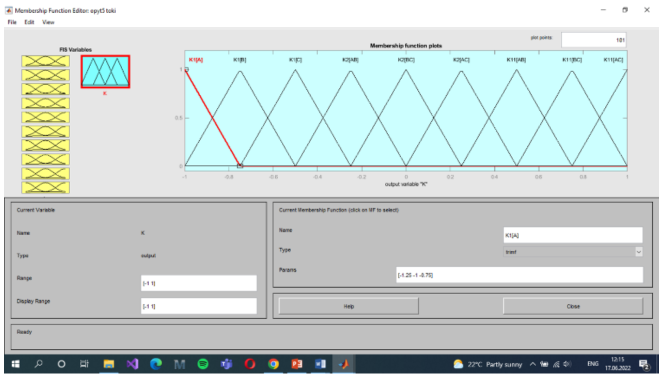
As a result of the experiments:

1. Rules for identifying types of short circuits have been created using the terms “silno uvel”, “silno umen” and “ne izmen” (Table 2.).
2. In the Mamdani fuzzy system, experiments were carried out based on the detection and classification of the type of short circuit in the elements of the ES (Fig. 2.).

Table 2

Rules for identifying types of short circuit

i_A	i_B		
	↗	≈0	↘
↗		$K^{(1)}$	$K^{(1)}$
≈0	$K^{(2)}$, $K^{(1.1)}$ difference at $K^{(2)}$ $I_{k0}=0$		$K^{(2)}$, $K^{(1.1)}$ difference at $K^{(2)}$ $I_{k0}=0$
↘		$K^{(1)}$	$K^{(1)}$



Pic.2. Model for detecting and classifying the type of short circuit in ES elements using fuzzy logic elements.

Work Conclusion

Based on the results of the work done, it can be concluded that it is possible and reliable to use fuzzy logic based on the method of symmetrical components of currents and voltages to identify types of short circuits. This paper proposes real-time detection and classification of faults based on fuzzy logic. For the classification of faults (type of short circuit), current and voltage samples of positive, reverse and zero sequences are taken into account.

It is expected that the proposed logic (method) will identify the types of faults on the ES elements with higher accuracy, and the speed of protection response can be increased and the detection time can be improved.

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ANALYSIS OF THE AVAILABILITY INDICATORS OF THE DATA TRANSMISSION NETWORK WITH PACKET SWITCHING

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***Abstract*—Models and methods for ensuring the availability of data transmission networks with packet switching based on the availability coefficient are discussed in this article. In order to ensure availability, the network availability coefficients were calculated for each packet switching mode by reserving the number of communication channel switching nodes between them. With the help of the obtained results, graphs are described and, on their basis, approximation functions are given that represent the impact on the availability of the entire network by increasing the availability coefficient of each technical facility in the network.**

Keywords— Data transmission network, packet switching, structural availability, availability coefficient, routing protocol, network topology.

I. Introduction

Modern data transmission networks (DTN) are complex geographically distributed technical complexes that perform important tasks for high-quality and reliable data transmission, the provision of which is impossible without ensuring the availability of its constituent elements. The constituent elements of the DTN are understood as a set of technical means: data transmission equipment, switching nodes (switches, routers, etc.), communication channels, control devices, etc. [1-2]. One of the important requirements for DTN s is the requirements to ensure their availability. The requirement for availability means that the network must ensure long-term operation while maintaining all the specified characteristics within the specified limits.

II. Main part

In this regard, solving the problem of ensuring the reliability of the DTN is a complex and knowledge-intensive process that requires constant scientific, methodological and scientific and technical support based on a systematic approach. The system approach suggests that the issues of ensuring the availability of the DTN should be considered at all stages of the life cycle of the DTN, starting with the design.

The availability of DTN is a complex property, it includes such important properties as availability and maintainability, so the availability assessment must be carried out by complex indicators.

These requirements are met by such an indicator as the availability coefficient K_a, the components of which are the mean time between failure, which characterizes the reliability and the mean time to repair, which characterizes the suitability of repairs [4].

$$K_a = T_{mtbf}/(T_{mtbf} + T_{mttr}) \quad (1)$$

where: T_{mtbf} – mean time between failure; T_{mttr} – mean time to repair.

The data transmission network must be efficient, and in its design, appropriate justification and availability calculations must be provided.

The term "availability" refers to the property of the network to keep in time within the established limits the values of all parameters that characterize the ability to perform the required functions in the specified modes and conditions of use [8-9].

Network availability is ensured by the use of reliable equipment and the introduction of redundancy into the network structure to increase network availability, i.e. ensuring its resilience [5].

A comprehensive solution to the problems of ensuring reliability includes two areas: ensuring hardware and structural availability. In the first case, the problem of ensuring the availability of network elements (network equipment), data transmission channels and software is solved.

Hardware availability is a property inherent in an element of a communication system to maintain operability with a quality no worse than the specified one over a certain time interval. The hardware aspect is understood as the problem of ensuring the availability of equipment, individual devices and their elements that form a communication network.

Therefore, one of the important problems in the creation of DTN is the task of analyzing the structure (topology) of a data transmission network and assessing their availability. Structural availability is understood as the property of a communication network to ensure the connectivity of users (elements of the communication network) with a quality no worse than the specified one over a certain time interval [7].

Structural availability provides the network functions associated with data transmission, therefore, to analyze structural availability, the concept of network connectivity is used, which can be violated both by equipment failure in network nodes and by failure of data transmission channels. To ensure network connectivity, fault-tolerant network technologies are used, associated with the introduction of redundancy, the implementation of bypass ways of transmitting information, and the use of protocols that automatically bypass the failed section.

In this regard, in order to create a DTN with given availability characteristics, it is necessary to study the methods of analysis and synthesis of the network topology and their availability indicators.

In this case, the task of analysis is to evaluate the availability indicators of the DTN topology, and the task of synthesis is to select and build a network topology with given availability indicators.

Modern data transmission networks are built using packet switching technology with further packet routing. Since the routing of each packet occurs independently, the solution of routing problems becomes of paramount importance.

The development of packet-switched data transmission networks (DTN with PS) is inextricably linked with the complication of their topology, which leads to the ever-increasing importance of the routing problem, since the quality of the solution to this problem directly affects the performance and efficiency of using the network as a whole.

Routing is the choice of the most rational way of transmitting information, and its solution is one of the main tasks of the network layer. Routing includes two main components [3]:

- determination of efficient routing paths;
- transporting packets across the network;

Routers independently determine traffic routes based on information received via routing protocols (BGP, OSPF, etc.) from neighboring nodes.

Each router uses a routing table that reflects the topology of the network at a given time. The routing table contains the address of the destination network, the address of the next hop on the path to that network, and the route metric [9]. The creation and subsequent updating of the table is carried out using protocols and their corresponding routing algorithms. In packet-switched networks, two classes of packet transmission mechanisms are currently used [2-3]:

- virtual channels;
- datagram transmission;

The mechanism of virtual channels (virtual circuit or virtual channel) creates stable paths for traffic in the network through a packet-switched network. This mechanism takes into account the existence of data flows in the network. When using first-class routing, some particular route between subscribers is chosen during session initialization and maintained throughout the session.

A switched virtual channel is established when a special connection request packet is sent to the network. This packet passes through the switches and lays a virtual circuit. This means that the switches remember the route for this connection and when subsequent packets of this connection arrive, they always send them along the laid route.

If the switch or channel fails on the path of the virtual channel, the connection is broken, and the virtual channel needs to be laid again. An important advantage of this routing method is the preservation of the order of packets during transmission over the network, which is especially important when transmitting audio and video data. Network load is the most important parameter that determines the efficiency of the network, as well as the ability to transmit audio and video data over it.

Unlike packet switching with virtual circuits, the datagram version does not need to establish and release connections. In addition to useful information, each packet (datagram) contains the address of the recipient. Such a packet is processed in routers (switching nodes) individually, without taking into account other packets from the same sender. Therefore, different packets follow different routes through the network, as a result, the receiver may receive packets in a different order than the sender sent them (the order of the packets can be restored at the higher transport layer). The datagram method does not require a connection to be established beforehand and therefore works without delay before transmitting data.

When designing data networks, it is necessary to take into account many criteria and factors in order to build a reliable network infrastructure, taking into account the topology, communication channels, active equipment, and routing protocols. The latter play a key role in the distribution of information flows in communication channels. With short-term failures of some network segments, the use of static routing is not reasonable, due to the lack of operational flexibility.

To date, in DTN with PS, such routing protocols are used, where the route is selected either by the shortest distance (i.e., by the number of intermediate devices when passing a packet), or by an indicator of the nominal bandwidth of communication channels between routers, by their availability and introduced delays [10] .

The structural availability of the network includes various indicators that characterize the fault tolerance of the network to failures of its constituent elements - switching nodes and communication channels.

As the main indicators of the availability of switching nodes and communication channels, the following indicators are used: the probability of failure-free operation, failure rate, availability coefficient, recovery rate. As indicated above, the most important complex indicator of the availability of the DTN with PS is its availability coefficient (K_a), which determines the probability that the network will be in a working state at an arbitrary point in time [11-12].

The availability coefficient in DTN with PS is influenced by the availability coefficient of its nodes and channels. Each of the DTN devices is a device with certain characteristics related to their availability. Since K_a is a probabilistic quantity, the mathematical apparatus of probability theory should be used to calculate K_a DTN. As an indicator of the availability of the network, the availability coefficient is used, which is calculated as the product of the availability coefficient of all network elements, or taking into account their series-parallel connections [13].

One of the methods for calculating K_aDTN of a complex topology is the method of its sequential decomposition into a set of networks with linear topology. The decomposition process is carried out until the remaining structures become parallel-serial. K_a of series-connected devices according to the theorem on the product of the probabilities of independent events is calculated by the following formula (2) [6].

$$K_{a_{\text{serial}}} = K_{a_1} \times K_{a_2} \times \dots \dots \times K_{a_n} \qquad (2)$$

Where $K_{a_1} \dots K_{a_n}$-K_a series connected elements.

K_a of parallel series-connected elements is calculated according to (3) [6].

$$K_{a_{\text{parallel}}} = 1 - (1 - K_{a_1})\left(1 - K_{a_2}\right) \dots (1 - K_{a_n}) \quad (3)$$

hus, K_a of the formalized DTN topology can be represented as a function of K_{a_n} of the network node and $K_{a_{cl}}$ of communication lines (4). The form of the function $K_{a_{DTN}}$ will depend on its topology and will be determined by (2) - (3).

$$K_{a_{DTN}} = f\ (K_{a_n};\ K_{a_{cl}}) \qquad (4)$$

III. Calculation of the Availability Coefficient of DTN with PS (Virtual Channels Mode)

In PS technology, using virtual channels, a logical connection is established, organizing a virtual channel, between the end devices of subscribers, which is used during the entire session. In networks with virtual circuits, the local addresses of packets are used when making a forwarding decision (Fig. 1) [10].

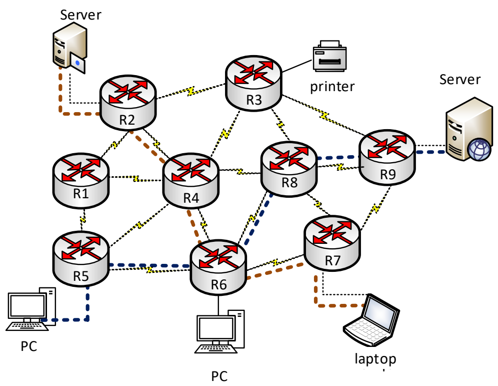

Fig. 1. The principle of operation of the virtual channel

As the model under consideration, a linear topology network of five nodes is used (Fig.2), in which the availability coefficient of the communication line between nodes 1 and 5 is calculated. Internet segments are used as communication lines. Statistical information was processed using the Internet as an information transmission medium.

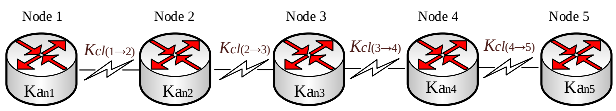

Fig. 2. Formalized topology of the simulated network

The availability coefficient of communication channels between 1 and 5 nodes of the simulated network is calculated by the formula:

$$K_{a_{1\to5}} = K_{a_n}^5 \times K_{a_{cl(i\to j)}}^4 \qquad (5)$$

where K_{a_n} – availability coefficient of the respective nodes;

$K_{a_{cl(i\to j)}}$ – availability coefficient s of communication lines between nodes.

All considered topologies of DTN are reduced to formalized ones, consisting of the same nodes and the same communication channels. K_a of all considered nodes (K_{a_n}) and K_a of all considered channels ($K_{a_{cl}}$) are assumed to be stabilized and equal to each other.

Let's consider the influence of redundancy of communication channels on the effectiveness of the functioning of the (Fig. 3).

To improve the availability of the DTN between communication nodes, redundant links (redundancy of communication lines) are added, which makes it possible to ensure the operation of the DTN in the event of failures of both communication lines and intermediate nodes through which these lines pass.

Backup channels form complex DTN topologies, in which the influence of nodes and communication lines on the availability characteristics of the DTN as a whole is expressed in different ways.

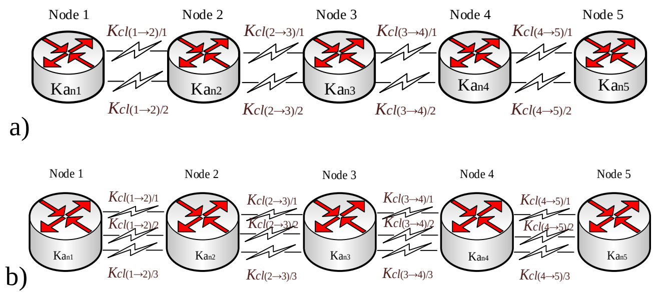

Fig. 3. Formalized topology of a linear network with redundant communication channels

In accordance with (2) and (3) K_a DTN, built on a linear topology with redundant communication lines (2 and 3) (Fig.3-a,b) for the path between nodes 1 and 5 can be written as (6-7).

$$K_{a_{1\to5}}^{with\ reserve\ (2)} = K_{a_n}^5 \times (1 - \left(1 - K_{a_{cl(i\to j)}}\right)^2)^4 \qquad (6)$$

$$K_{a_{1\to5}}^{with\ reserve\ (3)} = K_{a_n}^5 \times (1 - \left(1 - K_{a_{cl(i\to j)}}\right)^3)^4 \qquad (7)$$

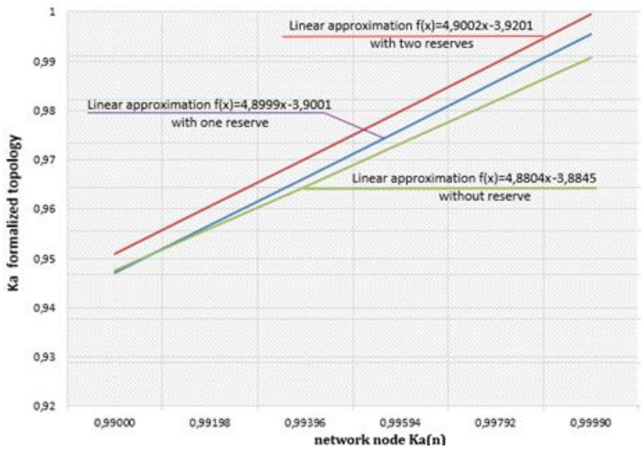

Fig. 4. Graph of the dependence of K_a of formalized DTN topologies on K_{a_n} of a network node

To assess the influence of K_a network elements on K_a DTN as a whole, we construct graphs of the dependence of K_a DTN for each considered topology (Fig.4). Let us construct a dependence graph of K_a for formalized topologies of each type with a stabilized K_a of network channels.

The graph (Fig.4) clearly demonstrates that at low K_a values with a stabilized K_{a_n} K_a value, the linear topologies with all types of redundancy are almost identical.

At the same time, under conditions of low values of K_{a_n}, the largest value of K_a of the DTN segment is achieved when using a linear topology with redundancy.

Together with single-path connections, multipath connections are used in communication practice, based on algorithms for finding several paths to the destination node or the algorithm proposed in [14-17].

In the case of independence of the elements of the paths (no intersections), such a connection has the form shown in Fig.5.

In the case of independence of the path elements in the connections and the absence of intersections, using well-known expressions from the theory of availability, we obtain the total availability coefficient for such a structure of the connection K_a [4]:

$$K_{a\,\mathrm{str}} = 1 - \prod_{j=1}^{J}\left(1 - \prod_{v=1}^{z_j} \mathrm{K}_{a\,v}\right) \quad (8)$$

By (1.9-1.10) we get:

$$K_a^{(\text{double path})} = 1 - \left(1 - \left(K_{a_n}^5 \times K_{a_{ch(i\to j)}}^4\right)\right)^2 \quad (9)$$

$$K_a^{(\text{thrice path})} = 1 - \left(1 - \left(K_{a_n}^5 \times K_{a_{ch(i\to j)}}^4\right)\right)^3 \quad (10)$$

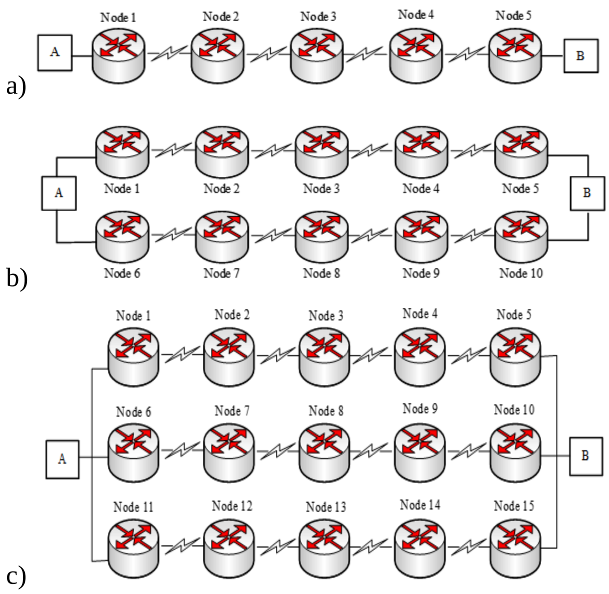

Fig. 5. Connection with parallel-serial connection of elements

Let's build a dependency graph K_a of formalized topologies of each type with a stabilized availability coefficient network channels $K_{a_{cl}}$ of network channels (Fig.6).

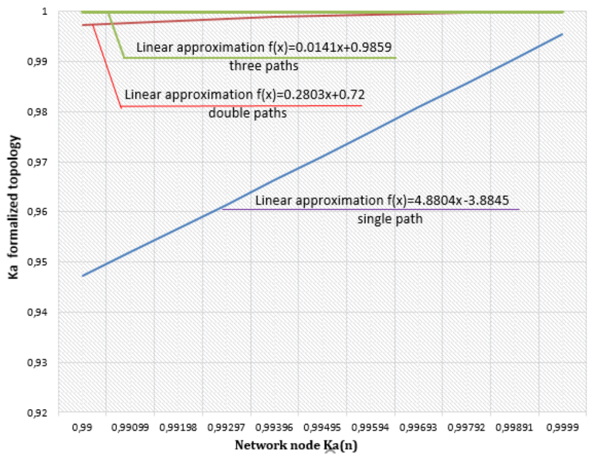

Fig. 6. Graph of the dependence of K_a of formalized topologies of the DTN on K_{a_n} of the network node

IV. Calculation of the Availability Coefficient of DTN with PS (Datagram Mode)

A packet-switched network in datagram mode is a multi-connected network in which each node communicates not with two neighboring nodes, but with many more of them. The network design is based on the following principle: at least three communication lines should come from each network node, since to ensure the high survivability of the system (network), it is necessary to have a large number of nodes [10-11]. Each packet is addressed separately and interpreted as an independent entity with its own control commands. (Fig.7).

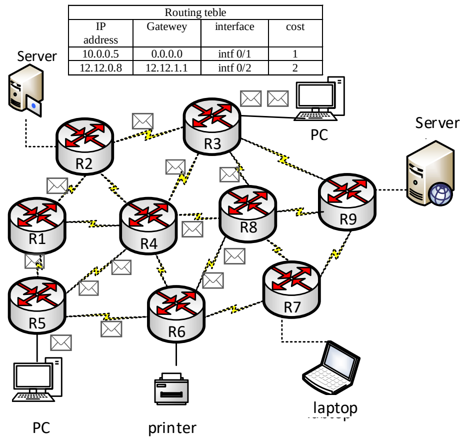

Fig. 7. Datagram principle of packet transmission

When designing modern data transmission systems, mixed or hybrid topologies are used, built on the basis of standard topologies such as "star", "ring", "tree". As the model under consideration, a network of linear topology of five nodes is used (Fig. 8), in which the availability factor of the communication line between nodes 1 and 5 is calculated.

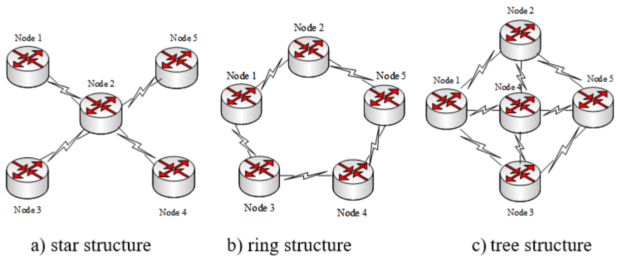

Fig. 8. Structures of analyzed networks

In accordance with (2) and (3), K_a of the DTN built according to the “star”, “ring” and “tree” topology (Fig. 8-a,b,c) for the path between nodes 1 and 5 can be written as (11-13).

$$K^{star}_{a_{1\to5}} = K^3_{a_n} K^2_{a_{ch(i\to j)}} \quad (11)$$

$$K^{ring}_{a_{1\to5}} = K^2_{a_n}\left(1-\left(1-K_{a_n}K^2_{a_{ch(i\to j)}}\right)\left(1-K^2_{a_n}K^3_{a_{ch(i\to j)}}\right)\right) \quad (12)$$

$$K^{tree}_{a_{1\to5}} = K^2_{a_n}(1-\left(1-K_{a_{n4}}K^2_{a_{ch(i\to j)}}\right)^3\left(1-\right.$$

$$\left.-K^2_{a_n}K^3_{a_{ch(i\to j)}}\right)^4\left(1-K^3_{a_n}K^4_{a_{ch(i\to j)}}\right)^2) \quad (13)$$

Let's build a dependency graph K_a of formalized topologies of each type with a stabilized availability coefficient network channels $K_{a_{cl}}$ of network channels (Fig.9).

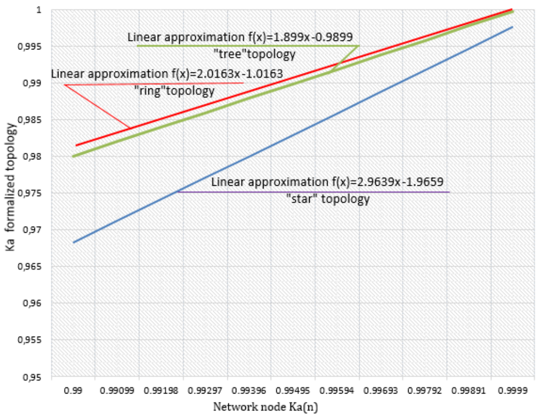

Fig. 9. Graph of the dependence of K_a of formalized topologies of the DTN on K_{a_n} of the network node

V. Conclusion

To assess the availability of the network based on the availability coefficient in data networks, models were created in the virtual channel and datagram modes of the packet switching method, the results were obtained in two different cases. In the first case, three different models were created between the analyzed switching nodes to assess the availability in the virtual channel mode: non-reserved, single and double reserved channels. To assess the availability of these created models, an analytical formula was developed representing the readiness of the coefficient between the considered nodes, and based on the results obtained, approximation functions were created. According to it, the graphs show that the availability factor of a channel with two reserves between nodes is not reserved and does not increase compared to one backup channel, but on the other hand, if any node that forms a virtual channel fails, the network availability coefficient tends to zero.

Therefore, in order to prevent such cases and further increase the availability in the network between the analyzed nodes, two and three-way backup virtual channels were installed and the corresponding analytical formulas were developed. As a result, the availability factor of a three-way virtual channel between nodes increased by 3 and 1.09 times, respectively, compared with one- and two-way backup virtual channels, and corresponds to the value specified in the regulatory document.

In the second case, the availability of the network was analyzed on the basis of star, ring and tree topologies built according to the datagram mode. According to the results of the analysis, the number of nodes in the tree topology increased by 1.65 and 1.12 times, respectively, compared with the star and ring topologies due to the presence of two or more links.

Mathematical models created in datagram mode show that when each node is connected to three "neighboring" nodes, the availability of such a network doubles, and when connected to four, the network will work even if 50% of the nodes are down. The above results make it possible, at the design stage, to quite effectively select an acceptable option for the DTN structure, taking into account the availability of the communication channel and network structure.

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Evaluation of Dynamic Parameter Changes in Fire Safety for Complex Processes

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***Abstract* – This scientific article presents various theoretical data on the assessment and diagnosis of the state of complex processes, the parameters of which change dynamically. Including, the processes of creation, functioning and development of complex natural and artificial systems are accompanied by uncertainty, which is a consequence of blurred goals, incomplete initial information, subjectivity of ideas about future processes and criteria for their assessment. Uncertainty reduction is achieved by foresight and forecasting and, as a consequence, by objectifying subjective decisions. In addition, information is provided on the system of decision support, technological process management, the structure of the task of technical control. The task of studying combinatorial evaluation algorithms and software tools with the ability to generalize is also given.**

Keywords – forecasting, data mining, Data Warehouses, KDD, dynamic system, of technical control, grade, problem solving quality, incorrect algorithm, diagnostics.

I. Introduction

Information uncertainty in the life cycle of complex systems, to which a person belongs, is a determining factor in the process of their existence. The behavior of people, their fate, is mainly associated with decision-making at various stages of the life cycle. It is known that these processes, as a dialectical category, must have a beginning and an end. For the forecasting problem, the beginning is the collection and analysis of a priori information. And although every person makes decisions every day, almost no one thinks about what are the prerequisites for a particular decision, how the time depends on the emergence of an idea or necessity before their implementation on the completeness, nature and form of presentation of the initial data. The processes of creation, functioning and development of complex natural and artificial systems are accompanied by uncertainty, which is a consequence of blurred goals, incomplete initial information, subjectivity of ideas about future processes and criteria for their assessment. Uncertainty reduction is achieved by foresight and forecasting and, as a consequence, by objectifying subjective decisions.

The movement towards the creation of an information society and a knowledge-based society is causing the flourishing of modern automated data mining technologies. This is mainly due to the flow of new ideas in the field of computer science, formed at the intersection of the subject areas of artificial intelligence, statistics and database theory. Elements of automated data processing and analysis are becoming an integral part of electronic data warehouses and have, in this context, depending on the specifics of their application, the names: data mining (obtaining knowledge from data), KDD (knowledge discovery in databases), text mining (obtaining knowledge from word processing, which is especially important in connection with the development of the Internet). Computer decision support systems that implement the indicated areas of data processing are based on two approaches. The first, more traditional one, is that the expert's experience is recorded in the system, and it is used to obtain the optimal solution in a given situation. The second approach is characterized by finding a solution based on the analysis of retrospective data describing the behavior of the object, decisions made in the past, their results, etc. The statistical information that has accumulated during this time is not enough to develop on its basis an effective decision-making strategy using data mining systems. These factors largely establish and shape the trends in the development and application of intelligent information systems [1, 2].

II. Methods

The decision support system used for decision making includes the following analytical methods:

- Regression and dispersion analysis.
- Multivariate and discriminant analysis.
- Time series analysis of survival and prediction.
- Categorical data analysis.
- Structural, spatial and factor analysis.
- Systematize queries and data search tools.

The implementation of multidimensional analysis functions allows you to observe data in dynamics, in different directions and sizes. With the help of reference tools, a link to the database is formed, which is determined by its content and template. Search tools allow the software to quickly search for information across samples, models, and determine the relevance of the data. All this sounds complicated, but in practice it is condemned simply and clearly - you just need to correctly and consistently execute system commands and follow the instructions.

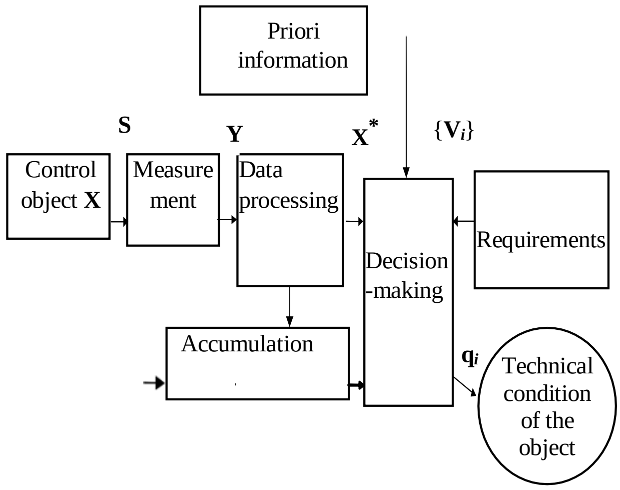
The main concepts that determine the subject of study of the course "Intelligent Information Systems" are: intelligence, artificial intelligence, information. The definition of intelligence in various encyclopedias and reference books allows us to characterize it as an object, method and process. Here are a few of them, in our opinion, the most meaningful. Intellect is the highest way of solving practical and cognitive problems, and this is how it differs from other forms of behavior - instinct and skills. Intelligence is the ability of the brain to solve (intellectual) tasks by acquiring, memorizing and purposefully transforming knowledge in the learning process, based on experience and adaptation to a variety of circumstances. Artificial intelligence is a branch of informatics that studies the algorithmic implementation of ways to solve problems by humans. In other words, within the framework of artificial intelligence, methods of solving computer problems that do not have an explicit algorithmic solution are studied. Artificial intelligence is interpreted as the ability of automatic systems to take over individual functions of human intelligence, namely, to select and make optimized decisions based on previous experience and rational analysis of external influences. Information is a set of symbols (recording on some material medium) for which at least one device exists in nature (man, machine, device), for which this set can be used to achieve a specific goal.

In the practice of using information-measuring and information-control systems, situations are encountered when the state of a complex object is monitored in the absence of a direct effect of one of the significant parameters of its state on the sensors of the measuring system, with incomplete measuring information. The complexity of an object implies its multiparametric description (multidimensionality) and the change over time of the vector of state parameters, the dynamics of the state of the object under external control actions.

In the general case, for technical applications, the task of determining the characteristics of an object is due to measuring signals from the output of a group (often an entire system) of sensors, which indirectly reflect the values of parameters characterizing the current state of the controlled dynamic object. Problems of this type include, for example, the indirect determination of the thrust of a gas turbine engine by a number of its characteristics available for measurement; determination of the parameters of the state of chemical elements, their control and many other tasks solved in the systems of automatic control and technical diagnostics.

Thus, the controlled object, information about which is obtained by means of IS (information system), is a nonlinear dynamic system of discrete time, and it is convenient to describe it in terms of the state space. The DS state space model (dynamic system) defines a set of states that depend on the past behavior of the system and uniquely represent its behavior in the future, provided that a certain sequence of input actions on the system is known. Obtaining information about the entire set of parameters of the state of the analyzed object (despite the paradoxical nature of such a possibility within the framework of the traditional concept of the measurement procedure) is achievable due to the fact that their value at the previous time step is reflected in the current values of the state parameters. This also applies to a condition parameter for which there is no direct effect on the IC sensors. Thus, information about the value of this parameter is reflected with some delay in the set of values of directly measured parameters. This connection of the "unmeasurable" parameter will be shown as a result of a series of transformations of the dynamics equation of the controlled object together with the IS equation that registers the measured parameters of the object state [3, 4, 5].

From the most general point of view, the task of control and monitoring of the technical condition consists in recognizing the current state of an object in conditions of limited information and can be represented in the form of the following components.



X – vector of controlled parameters,

S – vector of measured parameters (signals),

Y – vector of measurement results,

X* – vector of reconstructed controlled parameters,

$\{\mathbf{V}_i\}$ – a set of vectors of restrictions on the controlled parameters for each technical condition,

$\mathbf{q}_i$ – one of the possible technical conditions of the object.

Fig 1. Structure of the technical control task

The object of control is characterized by the vector of controlled parameters $X = (x_1, x_2, \dots, x_{N_x})$, where N_x – is the number of controlled parameters. This includes those parameters, based on the values of which a decision is then made about the current technical condition of the object. In the general case, the controlled parameters are not available for direct measurement, but are determined indirectly based on the vector of measured parameters (signals), available for direct measurement, $S = (s_1, s_2, \dots, s_{N_s})$, where N_s – is the number of measured parameters, while in the general case $N_x \neq N_s$.

The measurement process consists in converting (with the help of sensors, transducers and other components of the measuring channel) the vector of measured parameters S into the vector of measurement results $Y =$

$(y_1, y_2, \dots, y_{N_y})$, where N_y – the number of results, which usually coincides with N_s.

III. Results and Discussion

The analysis of the state of the object is carried out under operating conditions in which it is extremely difficult to obtain complete information. Often it is not possible to make an unambiguous conclusion based on the available information and one has to use special methods. The theoretical foundation for solving the main problem of technical diagnostics is the theory of pattern recognition. This theory, which constitutes an important section of technical cybernetics, deals with the recognition of images of any nature (geometric, sound, etc.), machine recognition of speech, printed and handwritten texts, etc. Technical diagnostics uses recognition algorithms in relation to diagnostic tasks, which are usually can be considered as problems of classification in the multidimensional space of the controlled parameters of the object. Recognition algorithms in technical diagnostics are based on diagnostic models that establish a connection between the states of a technical system and their displays in the space of controlled parameters. Decision rules (decision rules) are an important part of the recognition problem [6, 7 ,8].

Solving a diagnostic problem (classifying a product as serviceable or faulty) is always associated with the risk of a false alarm or missing a target. To make an informed decision, it is advisable to involve the methods of the theory of statistical decisions, developed initially for the needs of radar. The solution of the problems of technical diagnostics is always associated with predicting the reliability for the next period of operation (usually before the next technical inspection). Here, decisions should be based on failure models studied in reliability theory.

The requirements for the control system are largely determined by the methods and algorithms for recognizing the current state used at the decision-making stage, since it is this that primarily determines the requirements for the list of controlled parameters, the requirements for measurements and for processing experimental data. In order to formulate these requirements reasonably, let us consider the formulation of the technical condition recognition problem and the existing methods for its solution.

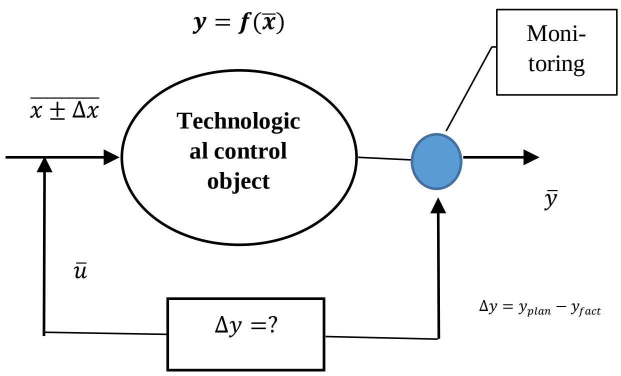


Fig 2. Technological control object

As shown in Figure 2, if the input features (plan) are equal to result $\Delta y = 0$ in relation to the result (fact) or tend to a minimum $\Delta y \to 0 - min$, then the effectiveness of the results in the monitoring system will be higher. The reason is that if the ratio of the planned interval is higher than the actual interval, the expected result cannot be achieved.

The state of an object is described by a set (set) of parameters defining it (monitored parameters, attributes). Of course, the set of defining parameters can be different, first of all, this is determined both by the object of control itself and the task of recognition. Recognizing the state of an object is a procedure for assigning the current state of an object to one of the possible classes (diagnoses). The number of diagnoses (classes, typical conditions, standards) depends on the characteristics of the control task and the objectives of the study. It is often required to select one of two possible diagnoses (differential diagnosis or dichotomy); for example, "good condition" and "bad condition". In most problems of technical diagnostics, diagnoses (classes) are established in advance, and in these conditions the recognition problem is often called a classification problem [9, 10, 11].

The set of generalized estimation algorithms is given as {A}, and its elements are written as $A_q \in \{A\}$. The main task is to determine an extremal algorithm from the set {A}. The solution of this problem depends on the reclassification of the objects of the training sample T_{nml} and the determination of the quality of the algorithm A in each process. Finding an extreme algorithm that correctly determines the class of a recognized object leads to a reduction in the cost of classifying controlled objects. In the process of learning algorithm A, training sample objects T_{nml} can be trained individually, or a part of the training sample (for example, 10%) can be taken as a control sample and implemented by training them.

Each algorithm is assigned to a recognizable object S in the following formal form:

$$A(S) = (\alpha_1^A(S), \alpha_2^A(S), \dots, \alpha_l^A(S)),\ \alpha_u^A(S) \in \{0,1,\Delta\},\quad i = 1,2,\dots,l. \qquad (1)$$

Here, if $\alpha_u^A(S) = 1$, he algorithm puts the object S in the class K_u, if $\alpha_u^A(S) = \Delta$, then the solution of the algorithm S does not belong to the class K_u, when $\alpha_u^A(S) = \Delta$, this algorithm cancels the classification of the object S with respect to the class K_u.

Below is information about the quality function that determines the quality of algorithms and their constituent parameters, as well as a scheme and steps based on determining the parameters of generalized algorithms. The elements $A_q \in \{A\}$ of the set {A} are algorithms, Z is focused on solving the problem. For each algorithm A of the set {A}, there is a function for determining the quality of the solution to problem Z, and it is denoted by $\varphi_A(Z)$, $\varphi_A(Z) \geq 0$.

Finding quantitative φ(A) qualitative functional values of the parametric algorithm A∈{A}, it is necessary to define an algorithm $\varphi(A^*) = \underset{A\in\{A\}}{\text{extr}}\, \varphi(A)$ let the value of the functional reach a minimum [12, 13].

If φ(A) is obtained in relation to the number of errors, then φ(A)→min, if expressed through the quality of training (in percent), then φ(A)→max.

The standard functional quality of pattern recognition is written as

$$\varphi(A) = \frac{1}{nm}\sum_{i=1}^{n}\sum_{j=1}^{m}|\alpha_{ij} - \alpha_{ij}^{A}| \qquad (2)$$

In some publications other methods of its calculation are given.

Also, when solving problem Z, A is considered an incorrect algorithm, but it does not have to be $\alpha_j^A(S_j') = P_j(S_j')$. Algorithms are now considered that negate the calculation of the value $P_j(S_j')$, $1 \le j \le l$ для S_j'. This argument is defined as: $\alpha_j^A(S_j') = \Delta$.

When solving the problem, Z contains in Algorithm A a number of additional requirements for the class of incorrect algorithms. Let the given set of algorithms {A} look like this:

$$A\big(I_0(K_1, \dots, K_l), I(S)\big) = \big(\beta_1^A(S), \dots, \beta_l^A(S)\big),\ \beta_1^A(S) \in \{0, 1, \Delta\}. \qquad (3)$$

In such a set {A} of algorithms, φ(A) is called a quantitative functional - a functional quality or a quality function of algorithm A. The main problem to be clarified (problem Z): from the environment of algorithms defined in (3), it is necessary to find the algorithm A^* as follows :

$$\varphi(A^*) = \sup_{A\in\{A\}} \varphi(A) \qquad (4)$$

Table 1-3 below shows the number of different fires, death tolls, injuries, damage statistics, and number of fires over the years based on the algorithm defined above.

TABLE I.
FORECAST OF POSSIBLE FIRES BY 2025

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Number of fires	1003	1000	999	873	861	856
Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Number of fires	807	769	733	697	661	624

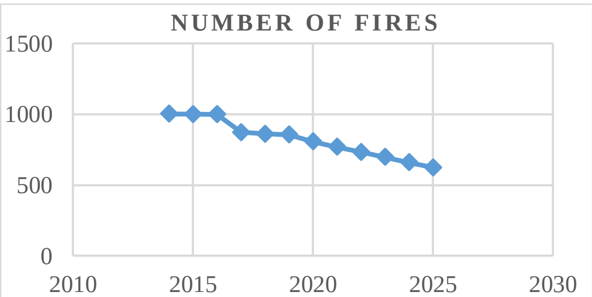


Fig 3. Information about fires is presented in the form of a diagram

TABLE II.
FORECAST OF THE NUMBER OF PEOPLE WHO COULD DIE BY 2025

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Number of dead	17	14	15	11	12	10
Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Number of dead	15	11	10	10	9	9

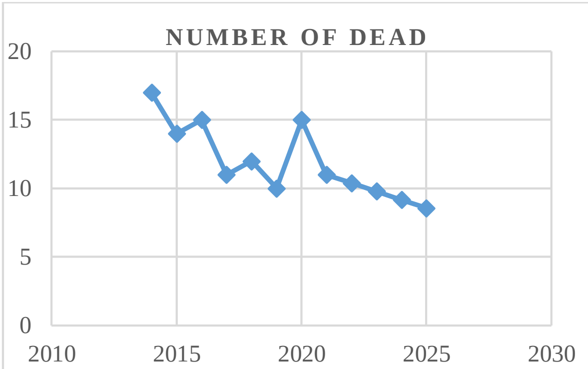


Fig 4. The death toll in the form of a chart

TABLE III.
FORECAST DATA ON THE NUMBER OF PEOPLE WHO MAY BE INJURED UNTIL 2025

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Number of injuries	42	42	40	27	24	22
Year	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Number of injuries	10	8	6	5	4	2

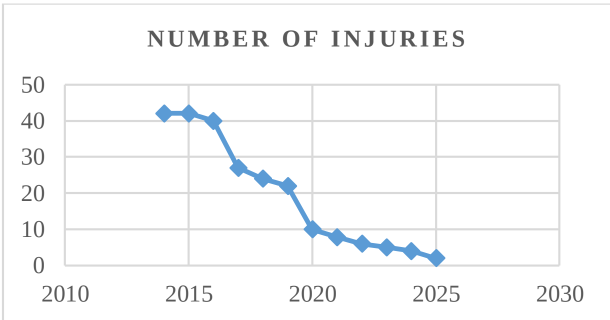


Fig 5. The number of victims in the form of a diagram

This is one of the special cases in the development of pattern recognition algorithms, which allows you to evaluate the ability of algorithms to recognize the process of synthesis of empirical data and solve problems such as process control and statistical analysis. These algorithms are also being developed as a way to generalize functionality to improve the quality of pattern recognition algorithms [14, 15, 16].

IV. Conclusion

In addition, various measurement processes also play an important role in evaluating complex processes. Measuring processes in the tasks of monitoring technical condition are characterized by the following features: condition criteria are often determined using tolerance control of controlled parameters, which can be carried out with not very high requirements for measurement accuracy; some methods of indirect measurement (vibration and acoustic diagnostics, ultrasonic flaw detection, assessment of dynamic and spectral characteristics) require measurement of dynamic processes that are fast in time, which leads to large flows of measurement data and requires sufficient speed of measurement channels in terms of data digitization, storage and transmission to the site processing; when using probabilistic-stochastic control methods, it is required to constantly accumulate large volumes of statistical samples of measured data and find current statistical estimates in real time.

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Non-contact ultrasonic direct method for measuring water level in well and hole

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***Abstract*— The papers relate to ultrasonic measurements and control, and can also be used to determine the water level in wells, boreholes and reservoirs.**

The task was set to increase the distance of non-contact measurement of the liquid level in the well by measuring the time of direct propagation of ultrasound from the emitter to the receiver, which, in contrast to the reflected sound, has a large measurement range, and also increases the accuracy due to the use of a reference-calibration measurement of the channel.

The essence of the work lies in the fact that to develop a device for measuring the water level using a direct sound signal includes the delivery of an sound signal through the mouth of the emitter of an ultrasonic signal, the reception of a direct signal at the receiver, the study of the surface of the water in the depth of the well in a floating position, and the reception of sound on the referent channel in verification receiver, located at a strict distance from the wellhead. In this case, the beginning of the countdown of the time of sound both in the reference and calibration receiver and in the receiver located in the float is carried out due to a radio signal with a frequency of 433 MHz. The idea of measuring is that the speed of sound included is much less from radio signal. Therefore, the propagation time of radio waves can be neglected.

Keywords*— *IoT, sound sensors, radio sensors ISM 433 MHz range, geodesy, geographic information systems (GIS), ultrasound, level gauge, microcontrollers (MCU), radio transceivers

I. INTRODUCTION

The article is devoted to ultrasonic measurement and control can also be used to designed the water level in wells, holes and tanks. The article provides a detailed comparative analysis of existing ultrasonic non-contact methods for measuring the water level in wells and boreholes.

II. ANALYSIS OF ULTRASONIC WATER LEVEL MEASUREMENT METHODS

Traditional methods can ultrasound measure distance and detect the presence of an object without making physical contact. They do so by producing and monitoring an ultrasonic echo. Depending on the sensor and object properties, the effective range in air is between a few centimeters up to several meters. The ultrasonic sensor (or transducer) generates and emits ultrasonic pulses that are reflected back towards the sensor by an object that is within the field of view of the sensor [7],[8].

Known methods and devices for measuring the water level in wells (or a vessel) according to patents in Europe [1], USA [2] and China [3] containing an ultrasonic emitter and a sensor, characterized in that the acoustic transducer is located in the upper [2] or lower part [1] of the pipe (or vessel) and is designed to emit a sound pulse, which is reflected from the surface of the liquid level, also to receive the reflected pulse. But in the ways due to the use of the echo location ultrasonic signal method, non-contact measurement of large depths of the water level is not provided or it requires a large radiation power, which is not allowed for autonomous battery-powered systems, and the correction of the speed of propagation of ultrasound is carried out by measuring the ambient temperature, which does not provide high accuracy measurements.

It is also known a method for measuring [4] the level in hydrogeological wells using a non-contact sonic level gauge, including the supply of an audio signal through the open wellhead, receiving the reflected signal and calculating the time of passage of the signal of the depth of the water surface, in that before using the sonic non-contact level gauge, it is calibrated with a high-precision a level gauge, for example, of a contact type, and correction is carried out by introducing a correction factor, and from the received reflected sound signal, a signal is selected that has the longest transit time with the highest amplitude, and the level depth is calculated using this signal.

The disadvantage of this method is also the need to use the reflected echo signal, which greatly reduces the measurement distance and the need for calibration with a high-precision level gauge each time before measurement.

Close to the proposed are the method and device for the oil and gas industry when determining the level of fluid in wells, as well as hydrodynamic studies of wells [5]. In the well, according to a given program, a sound and electromagnetic wave is simultaneously created, which is the starting point for the time of passage of a sound wave from the liquid level to the wellhead, the time t used for determining the distance using the formula $H = t \times V$, where H is the distance from the mouth to the water level, a, t is the time of passage of a sound wave from the mouth to the level, and V is the speed of sound in a gaseous.

The disadvantage of this method is the complexity of the design of the floating part with the catcher existence, also does not provide high accuracy, since the current temperature of a gaseous medium is not taken into account, where the sound wave propagates, but the speed of depends on the temperature of a gaseous environment. The sound emitter is located in the float part, which limits the measurement distance due to the limited autonomous power supply elements.

Closest to the proposed one is the methods of measurement [6] and control can also be used to determine the depth of the liquid level in wells, wells and reservoirs. The acoustic transducer consists of a transmitter and three receivers - two calibration receivers, made remote with the possibility of lowering and lifting to a given depth, and a measuring one. The method for measuring the liquid level and the degree of gas contamination of the pipe space in the well includes the emission of an acoustic pulse, the registration of signals reflected from the surface of the liquid by the measuring receiver, while the calibration receivers are additionally lowered into the well to different depths and the signal is recorded on them at the moment of passage of the acoustic pulse

The disadvantage of this method is also the need to use the reflected echo signal, which greatly reduces the measurement distance, as well as the need for calibration with two calibration channels, which complicates the design of a stationary meter.

III. DIRECT ACOUSTIC DISTANCE MEASUREMENT METHOD

The objective of the work is to increase the distance and accuracy of non-contact measurement of the water level in wells. To achieve this target, direct acoustic distance measurements are taken as the basis. The essence of which is given in detail below in the article.

The figure 1 shows a diagram of the proposed method.

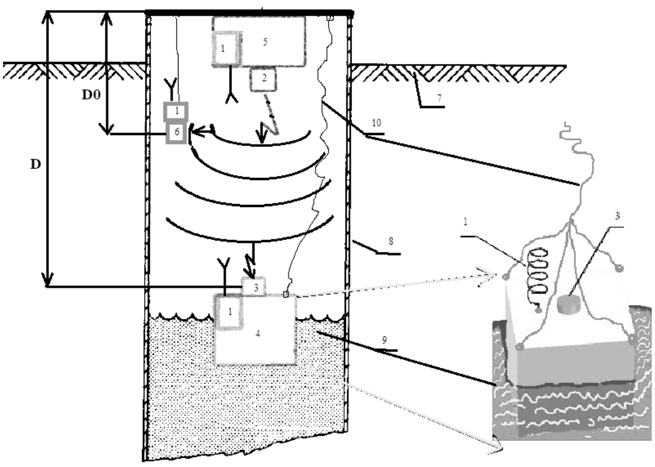

Fig. 1. The structure of the ultrasonic method for measuring the water level in a well or well. 1-transceiver (transceiver of radio waves ISM band of 433 MHz); 2-transmitter of ultrasound; 3- 40 kHz ultrasound receiver head sealed, waterproof; 4- microcontroller control on the surface of the water (float part); 5- microcontroller at the wellhead - main; 6- receiver of ultrasound of the reference-calibration channel, installed at a distance D0=5 meter; 7- soil (ground); 8- well wall; 9 - surface of water at the bottom of the well;10 - centering and holding line.

The target is achieved by simultaneously creating a sound and radio wave in the well, which is the beginning of the countdown of the sound wave propagation time from the wellhead to the water level, measuring the propagation time of the sound wave T, and also determining the transit time of ultrasound Tr to the receiver located at a strictly defined distance D0 from the wellhead. To calculate the distance D from the mouth to the water level in the well, from the beginning, the velocity of propagation of ultrasound in the well is calculated according to the formula:

$$V = D0/Tr, \qquad (1)$$

where D0 is the distance to the calibration channel; Tr- the transit time of ultrasound to based on the data of the calibration (reference) channel.

Then, based on the time T of the passage of a sound wave from the mouth to the surface of the water, the distance is determined by the formula:

$$D = V/T, \qquad (2)$$

where V is the calculation speed to the calibration channel(1); T- the transit time of ultrasound to based on the data of the surface of the water measure channel in float part.

The float part (Fig.1 - 4) is installed at the liquid level (Fig.1 - 9) so that the transceiver (radio wave transceiver) (Fig.1 - 1) and the ultrasound receiver (Fig.1 - 3) installed in it are above the liquid level. In the body of the float (Fig.1 - 4) there is an autonomous control microcontroller, which is initially in a "sleep" - energy-saving mode. A stationary main control microcontroller (Fig.1 - 5) with an emitter of sound vibrations (sound transmitter) (Fig.1 - 2) and its own transceiver (Fig.1 - 1) is also installed at the wellhead, which allows, at certain intervals, for example, one hour, to simultaneously turn on the transmitter of radiowaves (Fig.1 - 1) and the transmitter of sound waves (Fig.1 - 2) for a very short time for the power saver also starts timing T1 on its own high precision timer.

Also, at a strictly defined distance D0 from the wellhead, a reference part consisting of an ultrasound receiver (Fig.1 - 6) and a transceiver (Fig.1 - 1) (optional) is released. A radio wave propagates in a gaseous medium at a speed of 3×10^8 m/s, i.e. almost instantly reaches the radio receiver of transceiver (Fig.1 - 1), while the microcontrollers of the reference-reference (calibration) channel and the float part of the main measuring channel are awakened.

At the same time, the timers of the microcontroller of the calibration channel and the float part are also turned on, and as the sound wave propagates at a speed of 3×10^2 m/s, i.e. 6 orders of speed less than the radio wave, which allows you to take the beginning of the sound propagation with the time of arrival of the radio wave to the radio receiving system of the transceiver (Fig.1 - 1) of the reference channel and the float part, by turning respectively on the timer Tr and T.

The sound wave, reaching the ultrasound receiver (Fig.1 - 6) on the reference channel and on the ultrasound receiver (Fig.1 - 3) located on the surface of the well water, turns respectively off the timers by fixing the time Tr and T. Knowing the time of passage of the sound wave according to the readings of the timers and, the speed of sound (1) is determined in the gaseous medium, thus the distance from the liquid level to the mouth is determined from formula (2).

An approximate design of the float part is drawn in an enlarged form (Fig. 1-4) where a microcontroller with a 433 MHz ISM radio receiver with a screw antenna (Fig. 1-1), an ultrasonic receiver with a 40 kHz sensor (Fig. 1-3) are located.

The float part has an autonomous battery or accumulator supply and can operate in this mode for several years, i.e. the operating time of the float batteries is equal to the overhaul period of the well. For lifting or lowering and holding the float, there is a holding line (10). Thus, the float is lifted and the batteries are replaced.

IV. EXPRIMENTAL PART

It is known that the velocity of an air-coupled ultrasonic sound is influenced by external environmental parameters, such as temperature, humidity, and in-band ambient noise. The sensing range decreases as either temperature increases. Although the sensing rate also decreases as humidity increases, this can often be neglected, as the effects are minimal. The rate of attenuation across temperature and humidity is non-linear[8],[9].

Can calculate the speed of sound in air use the following equation:

$$V(\frac{m}{s}) \approx 331{,}4 + 0{,}6 \times T(in \quad {}^{0}C)(\frac{m}{s}) \qquad (3)$$

As can be seen from equations (1) and (2), in the proposed method the characteristics of the environment (temperature) are not involved in any way, unlike traditional measurement methods where the distance is adjusted depending on the temperature of the environment.

The results of the experiment when measurements are carried out in the traditional way when the speed of sound is determined taking into account temperature and in the new proposed method using a calibration channel are presented in Table 1.

TABLE I. DEPENDENCE OF DISTANCE MEASUREMENT ERROR ON TEMPERATURE

Temperature, ^{0}C	**Measured distance, sm**				
	Valid(real)	***Traditional method***	***error,%***	***Proposed method***	***error, %***
25	500,0	498,5	0,3	499,2	0,16
30	500,0	501,2	-0,24	500,6	-0,12
35	500,0	501,7	-0,34	500,8	-0,16

As the results of a comparison of methods show, the proposed method has twice the accuracy compared to traditional methods for adjusting the speed of sound pagation

V. RESUME

The proposed method, in comparison with the known ones, has a higher distance measurement accuracy, since the propagation velocity of ultrasound in the medium is determined on the basis of a reference channel installed at a strictly defined distance from the wellhead.

The proposed method will find application in the operation of hydrostatic wells and used in water wells.

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PERFORMANCE CHARACTERISTICS OF FIBER-OPTICAL AMPLIFIERS WITH RARE EARTH ELEMENTS

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Abstract— the article considers one of the methods of signal recovery in fiber-optic information transmission systems. Optical amplifiers based on EDFA rare-earth additives are described and their main technical parameters are listed. The reasons for the appearance of noise in them caused by spontaneous electron emission are considered, and the contribution of such noise to the overall gain of the fiber amplifier is estimated. The spectrum of amplified spontaneous emission is analyzed. The results of the development of an EDFA amplifier with a reduced level of intrinsic noise are presented.

Keywords— ***fiber-optic amplifier, erbium dopant, laser pumping, spontaneous emission, ASE noise, nonlinear amplification, saturation, noise power***

I. INTRODUCTION

The most important parameters of an FOA fiber optical amplifier are the noise parameters; they largely determine the specifics of its use in modern fiber-optic transmission systems. Unlike regenerators, optical amplifiers introduce additional noise that must be taken into account. Therefore, along with the gain, one of the important parameters of EDFA is the noise factor [1-2].

For a number of practical applications of FOAs, a low level of intrinsic noise plays an even more important role than achieving a high gain. For such applications, it is necessary to minimize the inherent noise of the optical amplifier, albeit at the expense of some gain reduction. The issue of analysis of the intrinsic noise of the FOA has received relatively little attention in the scientific literature [3–4], so the problem of improving the noise characteristics of the FOA seems to be very relevant.

The reason for the noise in FOA based active fibers doped with ions of rare earth elements is spontaneous radiation generated in the core of the fiber, in which a population inversion has been created. In this case, the power spectral density of spontaneous noise emitted by the element dz of the active medium into each mode of the fiber core is determined by formula (1):

$$dP_v = \gamma(v, P_v)dz \qquad (1)$$

where $\gamma(v, P_v)$ is the amplification factor of the active medium (taking into account saturation). This radiation, propagating in both directions in the fiber core and amplifying, leads to the appearance of amplified spontaneous radiation at the output of the fiber-optic amplifier even in the absence of a signal at the input end of the fiber.

The main parameters characterizing FOA are: gain, noise factor, power of amplified spontaneous emission, saturation power.

II. MAIN PART

The gain of an EDFA FOA can be calculated from a given average input power Pin and average output power Pout. Note that in the expression below, the powers are given relative to the specific wavelength of the signal in question:

$$G_{db} = 10 \log [\{P_{out}(\lambda) - P_{ase}(\lambda)\}/P_{in}(\lambda)], \quad (2)$$

where, P_{ase} - is the power level of amplified spontaneous emission.

Note that the power component ASE is subtracted when calculating the gain G_{db} in expression (2).

The noise performance of an amplifier is one of the most important characteristics for the use of optical fiber amplifiers (FOAs) in optical communication systems. Optical amplifiers distort the signal by adding noise from amplified spontaneous emission, which occurs due to the amplification of light produced by spontaneous emission. When calculating the FOA, the noise parameters are important, because they have a significant effect on the properties of the output signal; when deriving equations, it is necessary to take into account the presence of spontaneous radiation. There are several different ways to quantify the noise characteristics of optical amplifiers. One of them is using the noise factor [5]:

$$N_F = \frac{\left(\frac{P_{sd}}{P_n}\right)_{out}}{\left(\frac{P_{sd}}{P_n}\right)_{in}} \qquad (3)$$

where P_{sd}, P_n- power spectral density of the signal and noise, respectively.

The amplifier noise figure F_n is related to the amplifier gain G and the spontaneous emission factor n_{sp} as follows:

$$F_n = 2n_{sp}(G-1)/G \approx 2n_{sp}, \qquad (4)$$

where,

$$n_{sp} = N_2/(N_2 - N_1), \qquad (5)$$

N1 and N2 are the population inversion of atoms on the amplifying shell in the relaxation and excited states.

Consider expression (4). It is clear from this expression that the signal-to-noise ratio of the amplified signal is degraded by 3 dB even for an ideal amplifier with $n_{sp} = 1$. For most existing amplifiers, the noise figure F_n should exceed 3 dB and can be on the order of 6-8 dB.

The principal source of noise in optical amplifiers is amplified spontaneous emission (ASE). Its spectral density is close to constant and is similar to white or thermal noise. The effect of spontaneous emission is to add fluctuations to the power of the amplified signal, which are converted into current fluctuations in the photodetection process. It turns out that the main contribution to the receiver noise comes from the beats of the spontaneous emission components with the amplified signal. This beat phenomenon is similar to heterodyne detection in that the spontaneously emitted radiation mixes with the amplified signal in the photodetector and forms the heterodyne component of the photocurrent. This beating of the spontaneous emission with the signal creates a noise current.

ASE (amplified spontaneous emission) power. The ASE power in the signal passing through the amplifier can be calculated using the following relationship:

$$N_{out}(\lambda) = (N_{in}(\lambda) \times G) + ASE. \qquad (6)$$

This requires two measurements: 1) the level of the input signal $N_{in}(\lambda)$ and 2) the total noise level of the output signal $N_{out}(\lambda)$.

In saturation, or for a non-linear amplitude response, the ASE contribution is small. Therefore, it can be said that the gain G is nothing but the ratio of output power to input power when ASE is not taken into account.

In the absence of an input signal, EDFA is a source of spontaneous emission of photons. The emission spectrum depends on the shape of the energy band of erbium atoms and on the statistical distribution of the band level populations. The number of spontaneously produced photons propagating along the fiber in the EDFA core is increased, resulting in the creation of secondary photons at the same wavelength, with the same phase, polarization and direction of propagation. The resulting spectrum of spontaneous photons is called enhanced spontaneous emission (Fig. 1). Its power is normalized per 1 Hz and has the dimension of W / Hz. If a signal is applied to the input of the amplifier, then a certain proportion of energy transitions, previously working for amplified spontaneous emission, begins to occur under the action of an optical signal, amplifying the input signal. Thus, not only the useful input signal is amplified, but also the ASE is attenuated (Fig. 1). When a multiplex signal is applied to the input, there is a further outflow of power from the ASE in favor of the amplified multiplex channels. Typically, amplifiers operate in saturation with respect to the output signal.

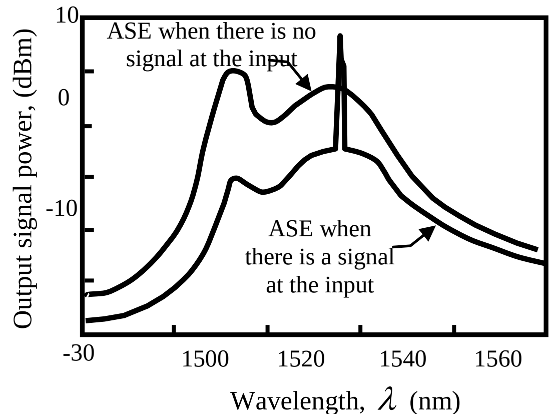

Fig.1. Amplified Spontaneous Emission Spectrum of EDFA

This creates a natural equalization of signal levels in the channels, which is highly desirable, especially for extended lines with a large number of series amplifiers. If the laser preceding the amplifier generates radiation in the spectral window ($\Delta\nu = \frac{c}{\lambda^2}\Delta\lambda$, where is the speed of light), and, accordingly, the filter in the receiving optoelectronic module passes the signal in the same window, then the contribution to the noise power at the output due to amplified spontaneous emission will be equal to $ASE_{\Delta\nu}=ASE\cdot\Delta\nu$. Thus, optical links with an EDFA stage perform better when the multiplex signal is represented by spectrally narrower individual channels. The use of narrow-band filters tuned to the operating wavelength immediately before the receiving optoelectronic module also helps to reduce the noise level from amplified spontaneous emission [6-7].

III. RESEARCH METHODS AND RESULTS

The main problem in the construction of fiber-optic amplifiers is a fundamentally irremovable source of noise—amplified spontaneous emission. The presence of this process leads to the fact that the minimum possible FOC noise figure is at least 3 dB. The fundamental irremovability of this source of noise is explained by the fact that spontaneous emission (noise) already occurs in the fiber in the presence of pumping, and this process does not depend on the signal amplification effect, which requires high pumping levels (the presence of an inverted population), that is, the noise is not equal to zero for any values of the fiber gain.

At a low signal level, the noise gain is equal to the weak signal gain and is the unsaturated gain of the optical amplifier, which should be the maximum possible (30–50 dB for modern designs) to amplify the transmitted optical signal. Therefore, during the time period when the small amplitude optical signal is amplified, the input noise and the ASE noise are amplified at the maximum gain. Most of the proposed technical solutions [8] for low-noise FOAs are based on optimizing the unsaturated FOA gain depending on the average level or other parameters of the amplified signal.

In addition, the FOA, operating in the linear amplification mode, also amplifies the noise components coming from other sources along with the amplified signal, for example, noise due to residual modal, polarization or spectral dispersion, noise of spontaneous emission of a transmitting laser diode, and others.

The original characteristics of the optical signal are not fully restored by the optical amplifier-regenerator.

Thus, it is fundamentally impossible to completely get rid of the noise component associated with the ASE noise of the FOA itself, as well as the noise due to the residual mode, polarization or spectral dispersion, the spontaneous emission noise of the transmitting laser diode, etc.

One of the most important characteristics of any amplifier or regenerator for fiber optic systems is the input-referred noise figure. When considering the operation of FOCL, it should be taken into account that the optical signal in data transmission systems operating at the same frequency is usually a two-level amplitude-modulated signal with a passive pause, that is, after photodetection by the receiver, it is actually a two-level digital signal.

Therefore, such a signal is completely similar in properties to a digital electrical signal (if we do not take into account the modal structure of optical radiation, and the presence of a sinusoidal filling with an optical frequency).

It is known that to improve the quality of a retransmitted digital electrical signal, methods of nonlinear amplification and level shaping (using fixed or adaptive shaping levels) are widely used.

Nonlinear amplification (Fig. 2) is implemented using amplifiers with "hard" signal clipping, and improves the noise properties of the signal in the region of high amplitudes.

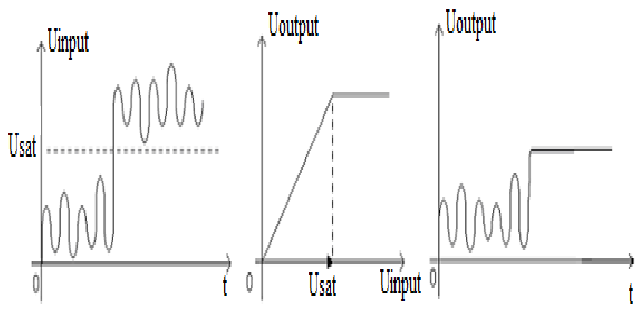

Fig.2. Nonlinear gain with "hard" signal clipping: a) input signal shape, b) non-linear gain transfer characteristic, c) output signal shape

Level shaping (Fig. 3) is implemented using shapers with a “threshold” on thetransfer characteristic and improves noise characteristics at low signal levels.

The developed FOA is built on the principle of amplification-forming a signal in a nonlinear optical amplifier, which has an amplitude characteristic with a “threshold” on the transfer characteristic [9].

The use of such nonlinear processing of an optical signal makes it possible to create a system of quasi-optimal signal regeneration with two-level amplitude modulation (binary signals with a passive pause).

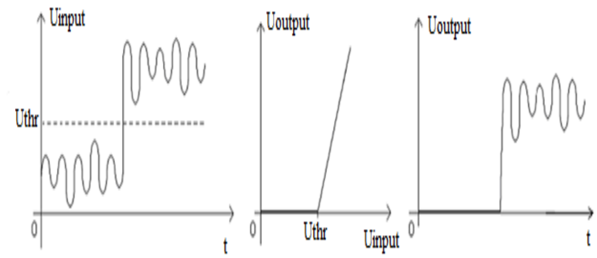

Fig.3. Formation of a signal according to a level with a fixed threshold: a) the shape of the input signal, b) the transfer characteristic of the signal conditioner according to the level with a fixed threshold, c) the shape of the output signal

On figure 4 shows a functional diagram of the developed FOA.

The amplifier consists of a directional coupler 1, a delay line 2, controlled optical modulators (gates) 3 and 4, an FOA on an active fiber 5, a photodetector 6, an electrical signal amplifier 7, a threshold device 8, an input signal 9 is supplied to the input, and a regenerated signal is formed at the output signal 10.

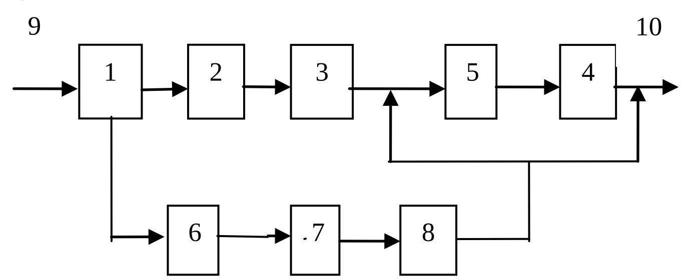

Fig.4.Functional diagram of FOA

In the absence of an optical signal at input 9, the signal of photodetector 6 is small (only the noise component coming to input 9 is detected), while the voltage at the output of electrical signal amplifier 7 is low and threshold device 8 does not pass this signal to optical shutters 3, 4. In this state, the shutters 3,4 are closed, the input noise is not amplified, and the ASE noise of the optical amplifier 5 does not reach the output. This achieves significant noise suppression.

The arrival of the input signal 9 of sufficient amplitude will cause the electrical signal from the amplifier 7 to exceed the threshold level of the threshold device 8 and open the optical shutters 3, 4. In this case, the optical signal is freely amplified by the optical amplifier 5. The operating mode of the FOA 5 is selected so that the input optical signal completely saturates optical amplifier. The delay line is needed to synchronize the input signal and the gate drive signals.

Thus, the distinguishing features of the developed amplifier from the conventional doped optical amplifier EDFA is the choice of the amplifier pumping mode, in which the input optical signal, greater than the threshold, completely saturates the optical amplifier, which leads to a useful effect - noise reduction for a large signal.

IV. CONCLUSION

Thus, an analysis of the FOA noise characteristics shows that the main source of noise in fiber-optic amplifiers is the amplified spontaneous emission generated in the amplifying medium in the fiber core. The amplifying and noise characteristics of a fiber amplifier with an amplifying core are compared. The distinguishing features of the developed amplifier from the conventional doped optical amplifier EDFA is the choice of the amplifier pumping mode, in which the input optical signal, greater than the threshold, completely saturates the optical amplifier, which leads to a useful effect - noise reduction for a large signal. In the case of an input optical signal that is less than the threshold, the reduction in the effect of noise occurs due to the fact that in this state the shutters are closed, the input noise is not amplified, and the ASE noise of the optical amplifier does not enter the output.

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ANALYSIS OF QUALITATIVE INFORMATION SECURITY RISK ASSESSMENT METHODS

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***Abstract*— This article considers the current state and approaches to assessing the information security of telecommunications networks. The main methodological approaches and principles of a qualitative assessment of information security of telecommunications networks are given. The analysis of qualitative methods for assessing information security risks was carried out.**

Keywords— information security, telecommunication networks, information security assessment, information security risks, qualitative risk assessment.

I. INTRODUCTION

International practice shows that solving the problem of assessing information security (IS) of modern telecommunications networks is one of the first and most important problems in the field of IS. The complexity of telecommunications systems and the branching of telecommunications networks further aggravate the situation.

Assessment of the IS of telecommunications networks should be carried out in order to verify the compliance of the achieved level of IS of telecommunications networks with the given level in the technical specifications for the development of these networks. The evaluation of the information security of telecommunication networks is also an important means of ensuring the implementation of the selected information protection tools [2].

The main task of assessing the information security of telecommunication networks is to develop a methodology for setting IS threats for these networks and to determine the losses (damage) of users and operators of these networks due to the implementation of a particular IS threat.

Obtaining an objective assessment of the IS level of telecommunications technologies is an urgent need in order to make informed decisions about the possibility of using certain information protection tools as part of the IS Maintenance System of telecommunications networks. Moreover, these assessments must have the properties of comparability and repeatability in order to be conclusive in the analysis of alternative IS Maintenance System options for telecommunications networks and the assessment of the level of information security at various stages of their life cycle [3].

As mentioned earlier, the first direction of assessing the IS of telecommunications networks is based on the use of a set of strictly defined requirements and properties that telecommunications networks must satisfy (qualitative criteria). Satisfaction of a certain set of requirements and properties determines the compliance of the IS Maintenance System with a certain fixed level of information security of telecommunication networks.

II. ANALYSIS OF THE LEVEL OF RISK

Depending on the information security requirements, two risk analysis options are used: basic and complete. Studies have shown that when using risk analysis methods focused on the base case, the value of information resources is usually considered, but the effectiveness of measures and methods of protection is not evaluated.

The analysis showed that in this case, a simplified approach to risk analysis is used, in which a standard set of the most common security threats is considered without assessing their likelihood, so the basic risk analysis is used in cases where information security is not subject to increased requirements [5].

In case of increased requirements for information security, a full version of risk analysis is used. In this case, it is important to determine the parameters characterizing the level of security, the value of information resources, quantitative assessments of security threats, and vulnerabilities. When conducting a full risk analysis, you need to:

- to define the value of information resources;
- determine the list of threats that are relevant for the object under study and assess the probability of threats;;
- to determine the vulnerability of resources;
- assess the risks of information security;
- choose security measures and methods that provide the necessary level of information security

The methods used to assess the information security risk of telecommunications networks should be based on international standards in the field of practical information security risk analysis, for example, such as BS-77993 (which requires the development of the ISO/IEC 27005 standard), NIST 800-30, ETSI TS 102 165 V.14.1 taking into account the use of risk analysis tools "OCTAVE", "CRAMM", "RiskWatch", as well as the developments of the Russian company "Digital Security" - "Grif", "Condor", "Office 2006"[11].

III. Assessment of the level of risk

In the general case, a risk is presented as the possibility of exploiting a particular vulnerability in the implementation of a particular threat. In information security, the risk of an individual resource (R) is estimated through the value of its assets (AV), vulnerabilities (V), threats that can be realized through these vulnerabilities (T), the probability of threats (P) and the consequences of their impacts (I) in when the threats are realized. Mathematically, risk is a function of the following variables

$$R = f(AV, V, T, P, I) \quad (1)$$

In order for the results of the risk assessment to be considered valid, the process must meet the following criteria:

uniqueness;

objectivity;

reliability;

reproducibility.

The qualitative method does not use the absolute values of the variables, but instead qualitatively evaluates the impact on risk of each variable. When using a qualitative method, it is very important how experienced, qualified and competent the person who performs the risk assessment is. Risk is evaluated qualitatively; however, for easier interpretation of the results obtained, as well as for risk assessment, a quantitative form is used. In contrast to qualitative assessments of the risk level, in this case the numerical values are not absolute, but relative [9].

In addition to subjectivity, which is an inherent problem in the qualitative method of assessing the level of risk, an additional factor that can affect the reliability of the result is the subjective evaluation of the parameters presented in numerical form. The risk assessment needs to analyze the uncertainty and precision of the results by redefining the risk assessment and reinterpreting these numerical values [12]. Assuming that the qualitative variables have been assessed subjectively, it is essential to achieve reproducibility that the outcome of the assessment process be unambiguous. In this case, the same or similar result will be obtained by repeating this process by different experts.

There are a variety of qualitative methods available for risk assessment. Here we will consider four qualitative methods for assessing the level of risk, described in [1].

Each of these methods uses some variables from formula (1). The methods differ in what variables they use and how those variables are quantified.

IV. Method 1: Matrix of predetermined estimates

When using this method, three parameters are used to assess risk: resource value, threats and vulnerability. Each of these parameters is evaluated against possible threats and at the same time, threats are evaluated against vulnerabilities (2). All values are arbitrarily quantifiable

$$R = f(AV_I, V_{I,P}, T_{I,V,P}) \quad (2)$$

In a modification of this method described in [1], numerical values ranging from 0 (low value) to 4 (high value) are used to determine the resource value. For vulnerabilities and quantifying the threat, this method uses value levels from 0 (low) to 2 (high). The level of risk is determined by the sum of parameters:

$$R = AV + V + T \quad (3)$$

Table I shows a matrix of predetermined ratings.

TABLE I. Matrix of predetermined estimates

	The threat	**0**			**1**			**2**		
	Vulnerability	0	1	2	0	1	2	0	1	2
Worth the resource	0	0	1	2	1	2	3	2	3	4
	1	1	2	3	2	3	4	3	4	5
	2	2	3	4	3	4	5	4	5	6
	3	3	4	5	4	5	6	5	6	7
	4	4	5	6	5	6	7	6	7	8

Based on (3) and the ranges of parameters defined in [1], the minimum and maximum estimates of risk value can be calculated by the formulas:

$$R_{MIN} = AV_{MIN} + V_{MIN} + T_{MIN}$$
$$R_{MAX} = AV_{MAX} + V_{MAX} + T_{MAX} = 8 \quad (4)$$

The risk score can be any integer value between R_{MIN} and R_{MAX} inclusive. Figures 1 and 2 show the distribution and cumulative distribution functions of the above risk level estimates (Fig.1).

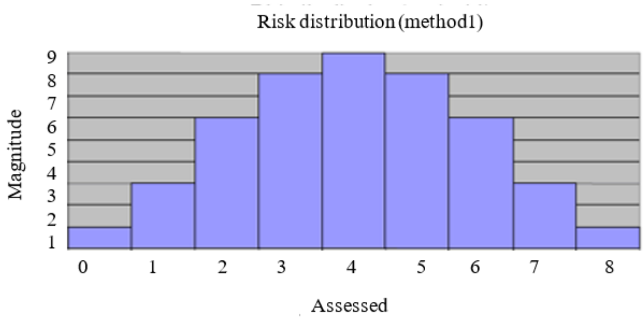

Fig. 1. The distribution function of the risk level assessment (method 1)

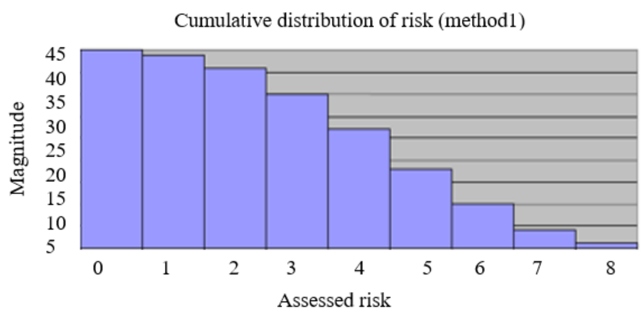

Fig. 2. The cumulative distribution function of the risk level assessment (method 1)

It can be seen that the values of the function for determining the risk level are averaged (Fig.1), while the function of the cumulative distribution of the risk level estimates forms a concave line (Fig. 2).

When using a matrix with predefined estimates, it is possible to arbitrarily estimate the risk, its magnitude during risk treatment and subsequently in the risk management process. Higher risks will not be prioritized due to the use of a distribution function. The inconvenience of this method lies in the fact that when assessing the risk level, the probabilities of the threats and possible consequences are not explicitly taken into account. It is understood that the consequences are taken into account when assessing the value of all parameters, while the probability of the implementation of threats should correspond to the probability of their isolated cases [8-10].

It is also difficult to neutrally assess threats and vulnerabilities in the real world, so estimating the magnitudes of both parameters is quite difficult.

V. Method 2: Risk Assessment by Hazard Classes

This method of assessing the level of risk formally uses only two parameters: the impact on the resource (the value of the resource) and the likelihood of a threat being realized. This implies the assumption that the impact on the resource is equivalent to the value of the resource while the threats are observed in relation to the corresponding vulnerabilities. The risk estimate by this method becomes a function of multiple parameters:

$$R = f(I_{AV,T}, P_{V,T}) \quad (5)$$

A modification of this method uses the same range of magnitudes for the impact (resource value) and the probability of the threats being realized. The possible values are between 1 (low) and 5 (high). The level of risk is calculated by multiplying the two parameters:

$$R = I * P \quad (6)$$

Table II shows the risk assessment matrix containing the values following from the above formula. Threats also have values related to the range defined above.

TABLE II. Risk assessment by hazard class

	exposure (magnitude)	**Likelihood realizations**	**Risk**	**Class the threat**
Worth the resource	5	2	10	2
	2	4	8	3
	3	5	15	1
	1	3	3	5
	4	1	4	4
	2	4	8	3

Based on (6) and the range of values defined in [1], the minimum and maximum values of the risk estimates can be calculated:

$$R_{MIN} = I_{MIN} + P_{MIN}$$
$$R_{MAX} = I_{MAX} + P_{MAX} = 25 \quad (7)$$

The risk score can be any whole number between R_{MIN} and R_{MAX} inclusive. Primes, as well as multiples of primes outside this range, are excluded. Figures 3 and 4 show the distribution and cumulative distribution functions of the risk assessment defined above

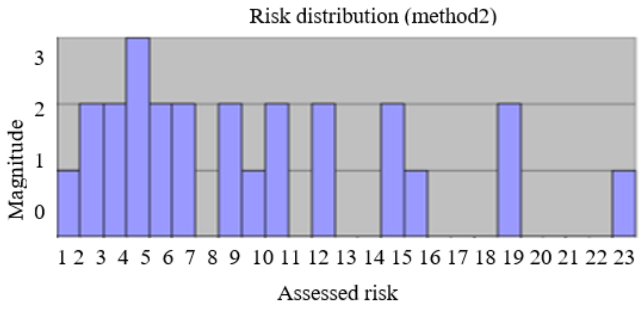

Fig. 3. The distribution function of the risk level assessment (method 2)

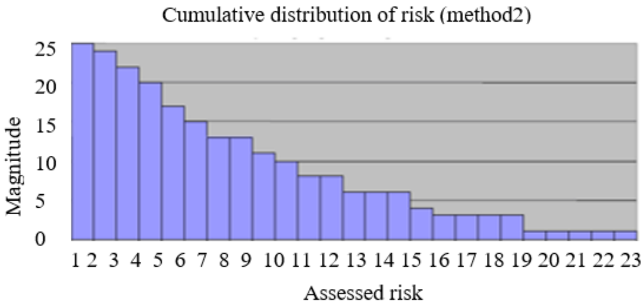

Fig. 4. Cumulative distribution function of risk assessments (method 2)

Figure 3 above shows that the groups of lower values of the risk score function are more distinguished than the higher values. The cumulative distribution graph is convex (Figure 4). Classifying threats by risk assessment allows them to receive priority in the process of subsequent processing (assessment) of risks. The inconvenience of this method lies in the fact that the risk is explicitly assessed only in terms of two parameters, which are implicit functions of a large number of variables. This method uses both the values of the resource and the ability to influence the resource, this method is not correct in all cases.

VI. Method 3: Assessing the Probability of the Threat and Its Consequences

The process of assessing the level of risk when applying this method is more complicated than when using the two methods described above. This method is done in two steps. First, the value of the resource, which is based on the potential consequences of the realized threat, must be determined, and after that the probability of realization is calculated. This likelihood is based on threats and vulnerabilities:

$$R = f(V, T) \quad (8)$$

Finally, the risk score is a combination of the value of the resource and the likelihood of a threat, understood as:

$$R = f(P_{V,T}, AV_{I,T}) \quad (9)$$

Finally, the risk score is a combination of the value of the resource and the likelihood of a threat, realized as: The range between 0 (low) and 2 (high) is used to determine how critical the vulnerability and threat are. The likelihood of occurrence (frequency) can be calculated as the sum of the vulnerability and threat scores:

$$R = V + T \quad (10)$$

The total risk is defined as the sum of the value of the resource and the probability of the threat realizing:

$$R = A * V + P = A * V + V + T \quad (11)$$

Table III shows the probability matrix for the realization of a threat.

TABLE III. PROBABILITY MATRIX FOR A THREAT

Threat	0			1			2		
Vulnerability	0	1	2	0	1	2	0	1	2
Implementation Possibility	0	1	2	1	2	3	2	3	4

Using the matrix shown in Table IV, risk can be assessed by the probability of implementation and the value of the resource.

TABLE IV. MATRIX FOR ASSESSING THE LEVEL OF RISK

Resource value	0	1	2	3	4
Implementation probability					
0	0	1	2	3	4
1	1	2	3	4	5
2	2	3	4	5	6
3	3	4	5	6	7
4	4	5	6	7	8

The minimum and maximum estimated risk values can be calculated from (7), so they can be any integer in the range of R_{MIN} and R_{MAX} inclusive. The distribution and cumulative distribution functions are the same as those in method 1 (Fig.1 and Fig.2). By evaluating the likelihood of implementation and possible consequences (impact), it is possible to arrange the values of risk assessments in the same way as in the matrix of predetermined assessments. Formulas (6) and (11), which are respectively used for risk assessment in method 1 (matrix of predetermined estimates) and in this method, are completely the same. However, method 1 implicitly reflects the likelihood of occurrence (frequency) during the vulnerability and threat assessment process, while method 3 estimates the likelihood of occurrence based on vulnerability and threat assessments. Again, the disadvantage of this method is an independent assessment of the levels of threat and vulnerability.

VII. METHOD 4: RISK SEPARATION INTO ACCEPTABLE AND UNACCEPTABLE

When applying this method, two values are used in risk assessment. Risk may be acceptable (0) or unacceptable (1). The risk assessment methodology can be the same as in the previous method (method 3). The only difference is that the risk assessment matrix is dual (Table V), as is the range of values (296).

TABLE V. MATRIX FOR DIVIDING RISK INTO ACCEPTABLE AND INTOLERABLE

Resource value	0	1	2	3	4
Implementation probability					
0	0	0	0	0	1
1	0	0	0	1	1
2	0	0	1	1	1
3	0	1	1	1	1
4	1	1	1	1	1

$$R_{MIN} = 0$$

$$R_{MAX} = 1 \quad (12)$$

This method is actually a modification of method 3 (estimation of probability of realization and possible consequences) or method 1 (matrix of predetermined estimates), thus it has their advantages and disadvantages.

VIII. CONCLUSION

The use of non-existent values for assessing the level of risk may, but should not, be a disadvantage of the method of qualitative risk assessment. Financial analysis in this case can be carried out later during the process of processing (management) of the risk. The biggest drawback of any qualitative risk assessment method is that it is subjective in estimating the value of a resource, as these values are then used as parameters in the risk assessment process. If fewer parameters are subjectively assessed, then the unreliability of the result is proportionally reduced. Method 2 (risk assessment by threat class), where the risk assessment is based on only two explicit values, can be considered the most reliable.

However, since the parameters used to estimate the level of risk are interrelated (they are implicit functions of other parameters), they actually introduce even more uncertainty into the final result, especially when these functions depend on many other parameters. In addition, the subjective use of functions with many implicit parameters can affect the reproducibility of the risk assessment process if it is carried out repeatedly by independent experts at different times. Both parameters used in method 2 are implicit functions of many parameters and this affects the reliability of the result. This method has the advantage that the risk level is calculated by multiplying the parameters. This allows values to be distributed appropriately and to accurately define acceptable and unacceptable levels of risk, and as a result to accurately prioritize risk management.

When using methods 1 and 3, formally the same results of the risk level assessment are obtained. The fact that method 3's estimate of the likelihood of implementation is based on vulnerabilities and threats can be considered an advantage when comparing method 3 with method 1, which implicitly includes it in the vulnerability and threat level score. Both methods independently assess the level of vulnerabilities and threats, and this was primarily noted as a problem, since it is very difficult in practice to make a reliable assessment of these values. Finally, reducing the range of resulting risk values by using a sum instead of a multiplication can limit the risk assessment process later.

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Development of a model of a cross-platform customer base management system

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***Abstract*—The article discusses how the implementation of a modern and competitive multifunctional cross-platform system will solve the problems associated with the influx of new customers and employees into the organization, which in turn leads to an increase in the workload of employees and supporting technologies. Also, the system can automate some of the customer-employee interaction processes, solve some of the digitalization challenges and help the organization become a strong competitor in the market.**

***Keywords*—economy, enterprises, jobs, productivity, work.**

I. INTRODUCTION

A cross-platform system is one that runs on more than one software platform or operating system [1]. The use of such an approach allows the product to be used by a wider audience of users due to the unlimited use of one platform or operating system. As an example of the application of such a system, the medical orientation will be considered [2].

The sphere of medical services in Russia is very vast. Each medical center must meet the demands of modernity in order to be highly competitive. One of the main tasks for such enterprises, in addition to providing quality medical services, is to attract new clients. As a rule, this is done through advertising or the popularity of a particular clinic due to good customer feedback [3-5].

The success and efficiency of any enterprise related to the medical field can be defined through some qualitative and quantitative indicators [6, 7]. As a rule, modern enterprises are limited to monitoring the volume of profit and periodic surveys of the quality of customers who used the services of this enterprise [8].

In order to increase such indicators, managers of medical organizations take various measures to improve the level of service for clients and working staff of clinics, the effectiveness of which directly affects the reputation and level of the medical enterprise [9, 10]. For example, an organization allocates money for the development of a thematic website, where you can conveniently use some of its services, such as: recording, consultation and so on.

The main disadvantage of such solutions is low awareness of clients and staff about the existence of the developed system and low functionality of such a system [11, 12]. As a consequence, there is little practical use of the system and costs for its maintenance, which are unreasonable [13]. The development of such solutions should be based on the reality that most potential customers have a smartphone with internet access. Mobile applications are a convenient alternative to thematic websites, because mobile applications are oriented to smartphones, and as a consequence carry the most necessary functionality for users [14, 15].

The problem of developing such services is the lack of communication between client applications providing services and the medical system in which the clinic staff works. For more effective coexistence of such systems, it is also necessary to provide the clinic staff with a convenient application that will partially relieve their workload, reduce the number of complex operations, and generally increase the working capacity of each employee of the medical center [16-18].

One of the possible solutions to the formulated problem of user and work services of medical centers is the development of a multifunctional cross-platform application, which is designed to simplify the work of clinic staff, attract new clients by its versatility and convenience, as well as to automate some processes of interaction between the client and the performer in the medical field [19, 20].

The multifunctional system solves the following problems:

- Automation of the process of patients' appointment with doctors;
- Providing a reference for health center services;
- Attracting new customers and retention by having a loyalty program in place;

- Convenient and clear functionality for employees and customers;
- Decrease in the number of appeals on various issues;
- Support communication between patients and physicians for treatment counseling.

The system can be used by potential and registered clients to view the company's services, make appointments, and contact attending physicians with questions; medical center employees in the treatment department to reduce routine and complex operations, view client information, communicate and view appointment schedules, and employees in the technical information department to provide technical support upon request from the user, write news and announcements, enter client registration data into the company database, and approve appointments [21].

II. MATERIALS AND METHOD

A multifunctional cross-platform system should be developed in the form of a mobile application for clients and a desktop application for medical, technical and information departments of the clinic. The architecture of such an application is three-layered: client layer - providing tasks and results understandable to the user; business logic layer - processing of received data, transfer of information to the client layer; data layer - data storage, interaction with the business logic layer through queries.

A schematic of the three-tier application architecture is shown in Figure 1.

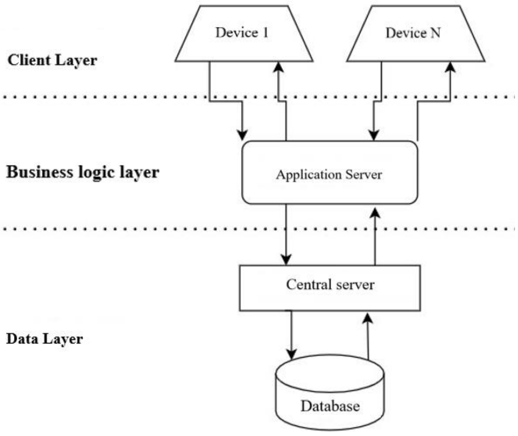

Fig. 1. Schematic of the application architecture

The database server and application server of the multifunctional cross-platform system should be created on the basis of PostgreSQL relational DBMS. Due to the complexity of the implemented functions, the cross-platform application should be developed on the basis of C++ technologies [22].

Multifunctional cross-platform system processes confidential information: personal data of clients and employees of the company, information of working nature, not subject to disclosure to third parties, and is a system in a secure design [23, 24].

The system interface layouts of the system under development are shown in Figures 2-5.

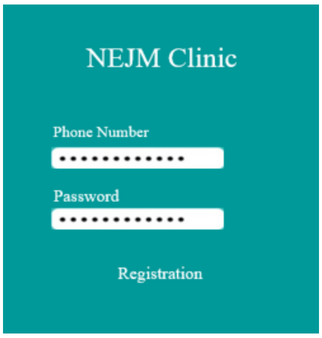

Fig. 2. User Authorization

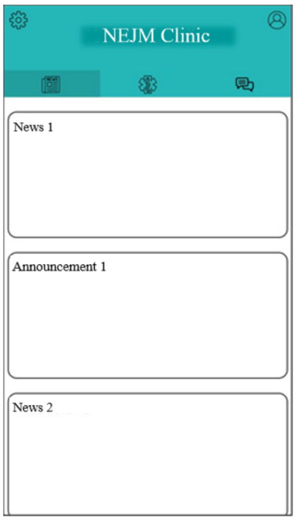

Fig. 3. Viewing the news feed

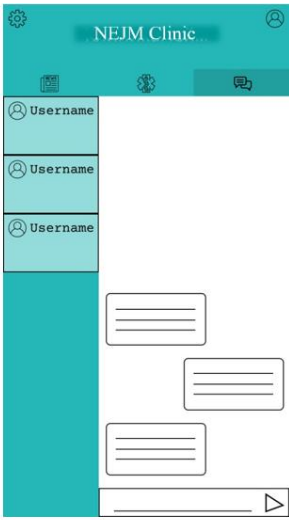

Fig. 4. Chat communication

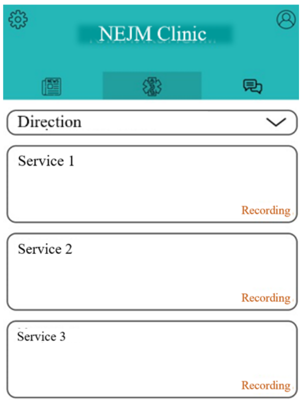

Fig. 5. Selecting a service

The main server of the system is installed indoors and has a permanent white dedicated IP address in the external network. The exact installation location is determined and agreed with the customer during the system development process.

The server is built on the basis of an IBM-compatible computer installed in a server rack and includes: RAM not less than 32 gigabytes; 4 HDD not less than 4 Tbytes; operating system Windows 2012 Server or Windows 8; PostgreSQL.

The network controller shall provide communication with the server via Ethernet channel, as well as be responsible for integration at the relay level with the existing access control and management systembased on Elsys controllers.

A schematic of the implemented hardware is shown in Figure 6.

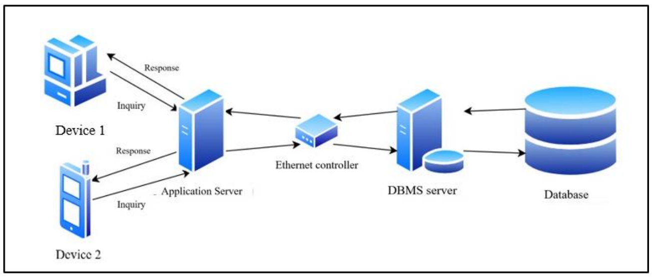

Fig. 6. Hardware schematic

III. Results

A. *Requirements for structure and functionalization*

The cross-platform system is realized as three subsystems. The architecture of the system is presented in Figure 7.

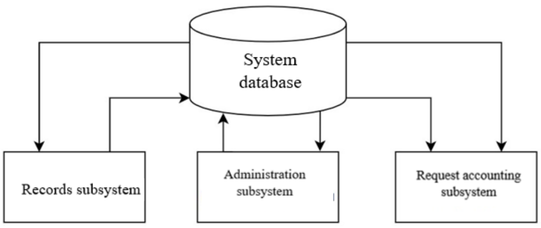

Fig. 7. Multifunctional system architecture

1. The records subsystem is designed to process and aggregate information about future appointments and services. When implementing this system, it is necessary to restrict access to the records table.

2. The subsystem of request accounting is necessary for input of registration data on employees and performed requests, as well as information on the results of performed works.

3. The administration subsystem is designed to register system users and assign them rights.

B. *System utilization options*

The cross-platform system is supposed to implement all the functions presented in the use case diagram (Figure 8). The description of each use case is presented in Figure 8.

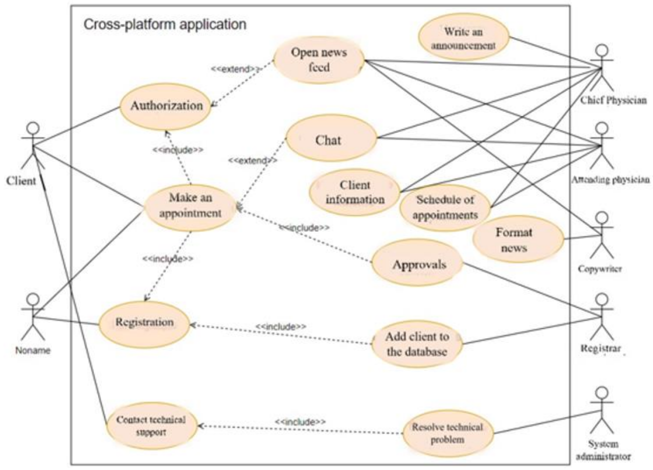

Fig. 8. System utilization options

1. Making an appointment. The client selects one service from the list, presses the record button, confirms his/her action, the system notifies the registrar and sends information about the client. An unregistered user selects a service from the list, the system offers him/her to create an account, the user registers.

2. Authorization. The user starts the application, enters the phone number and password into the authorization panel, the system checks the number for availability in the database and compliance with the password, the user logs in. If the user enters an incorrect password, the system displays a message to re-enter the password or restore it.

3. Contact technical support. The user selects the "contact technical support" option, describes his/her problem in detail in the window, this information is sent to the system administrator. If the user appeals to technical support and solves the problem himself, the user cancels the appeal using a special button.

4. Viewing the news feed. The user opens the news tab in the application, the system gives him the latest news or announcements for a certain period of time.

5. Communication with a doctor or a patient. The user opens the chat tab, selects a possible interlocutor, writes a message to him/her, the system notifies the interlocutor about the beginning of the dialog. If the user blocks the interlocutor, the second one cannot write messages to the first one.

6. Registration. The user starts the application, enters his/her information, phone number and password, confirms registration, the system enters the user into the clinic's client database. User enters information, but does not confirm registration, the registration process is reset.

7. Problem Solving. The system administrator receives in a chat message, accesses certain information about the client, advises the user if possible, and solves the problem.

8. Entering or editing information about the client. The registrar through the interface accesses the database, the system issues information about a particular user, the registrar manipulates the received information, saves the information, the system changes the data in the database.

9. Admission Approval. The registrar receives the request for an appointment, informs the attending physician about the appointment, enters the data into the appointments database; contacts the client or attending physician to clarify the information.

10. News design. The copywriter selects the news design option, types and formats the text in the built-in text editor, confirms the news publication, the system adds the news to the publication feed. The copywriter manually removes the news from the publication feed if necessary.

11. Viewing the schedule of appointments. The doctor opens the tab with future appointments, the system takes information from the database by doctor's name and displays the schedule of appointments for the month in the form of a grid.

12. Viewing client information. The doctor clicks on the client's profile, the system checks if the preconditions are met, the doctor receives information about the client's health and previous appointments. The system may not provide the information to the clinician due to non-compliance with the preconditions, the clinician is notified accordingly.

13. Role issuance. The chief physician selects the role issuance option, the system issues a list of registered users, the chief physician selects a specific user and issues him/her a role from the list, the system updates the user's role and enters it into the employee base. The chief physician opens the list of employees and deletes the user, the system resets the user's role and deletes the user from the employee base.

C. System design and implementation

The basic list of system development activities corresponds to one iteration of the life cycle. It is assumed that all the listed works will be repeated at each iteration of subsystem realization or individual use cases. The block diagram demonstrating the algorithm of the cross-platform system development process is presented in Figure 9.

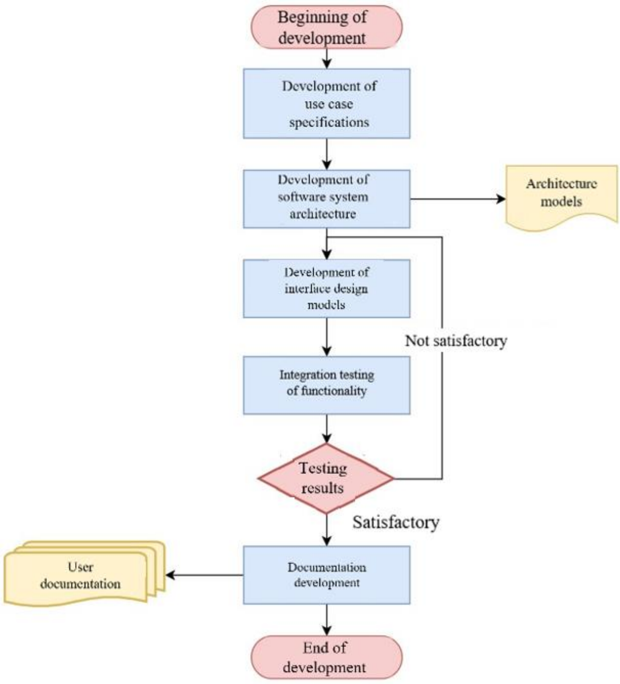

Fig. 9. System development process

Implementation also consists of a list of activities that contribute to the qualitative integration of the system into the workflow of the enterprise and support the operability of the developed software [25, 26]. The flowchart demonstrating the algorithm of implementation into the work of the enterprise is presented in Figure 10.

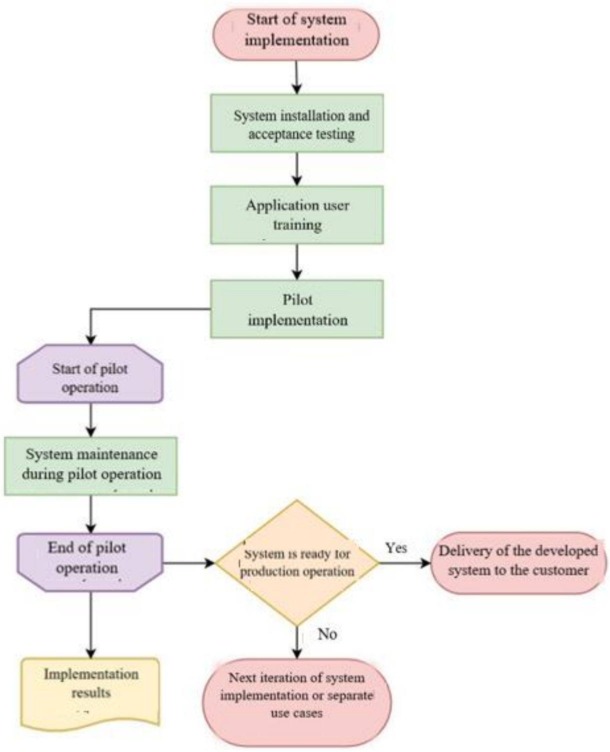

Fig. 10. System implementation process

IV. Conclusion

The optimal solution to the problem posed at the beginning is the development of a cross-platform multifunctional application that combines many useful use cases and simplifies the work of both customers and direct employees [27]. Implementation of the system will increase the inflow of new customers and employees to the organization, and in the long term will increase the turnover of the enterprise, as well as reduce the burden on the employees of the enterprise by automating most routine and time-consuming tasks [28, 29].

On the example of system implementation in the medical sphere, it is obvious to solve some problems of the sphere as a whole, as well as to help in the expansion of the medical center and make the organization a strong competitor in the market of medical services. In addition, the system can significantly reduce the cost of material and time resources to identify and eliminate factors that hinder the development and improvement of service due to the possibility of their local development.

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Temporal Expression Recognition in Low Resource Settings: A Rule-Based Approach for the Uzbek Language

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***Abstract*— This paper introduces a novel algorithm tailored for the recognition of temporal expressions in Uzbek texts, distinctively developed without harnessing machine learning techniques. The primary focus lies in circumventing challenges associated with data scarcity for training and the intricacies encountered when deploying machine learning in the milieu of Turkic languages, particularly Uzbek. The proposed algorithm operates by utilizing morphological analysis and a comprehensive dictionary, demonstrating a commendable efficiency in recognizing temporal entities listed within the lexicon. However, its efficacy wanes when faced with expressions outside the dictionary's scope. An evaluation, based on a corpus of 1000 sentences, evidenced its proficiency in accurately identifying entities in 100% of sentences containing dictionary-listed temporal expressions. Contrarily, its precision dropped to 32% for entities not present in the database. This research underscores the potential benefits and inherent constraints of a rule-based, dictionary-dependent approach, suggesting a direction for future endeavors in enhancing recognition precision through the integration of machine learning or the enrichment of lexical databases.**

Keywords— Temporal expressions, Uzbek language, morphological analysis, rule-based algorithm, data scarcity, Turkic languages, dictionary-dependent approach.

I. Introduction

The advancement of information technology underscores the need for efficient strategies for understanding and processing natural language[1]. A core component of these strategies is the recognition of temporal expressions in text, which holds substantial relevance for several research areas such as event tracking and automated question answering[2]. However, languages such as Uzbek, spoken by an estimated 33 million people, present a unique set of challenges given the scarcity of resources and research in this domain[3].

Historically, Named Entity Recognition (NER) studies focusing on Turkic languages have predominantly addressed the identification and classification of entities like individuals' names, organizations, and geographical locations[4]. Nonetheless, the recognition and normalization of temporal expressions in these languages, particularly in Uzbek, remain largely unexplored[5].

This study seeks to address this gap by proposing a novel algorithm designed to recognize temporal expressions in Uzbek texts. In contrast to many existing methodologies, this algorithm eschews machine learning approaches, instead capitalizing on rule-based methodologies and gazetteer lists[6]. This approach bypasses the need for extensive training datasets, which are often unavailable or inaccessible for low-resource languages such as Uzbek, and offers a simpler alternative to the often complex machine learning implementations.

Focusing on temporal expressions, this study presents a distinctive contribution to the field of Natural Language Processing (NLP) for the Uzbek language, an area that has primarily targeted named entities such as personal names and geographical locations. Additionally, the proposed algorithm offers a viable solution for NLP applications in the context of low-resource languages, harnessing the structure and inherent rules of a language, rather than relying on the availability of large data resources[7].

This research is expected to not only enhance academic understanding of NLP applications for Uzbek and other low-resource languages but also pave the way for the development of advanced NLP technologies, promoting digital inclusivity in Uzbekistan and beyond[8].

II. Dissecting the Components of Uzbek Grammar and Syntax

A profound comprehension of the syntactic features and grammar of the Uzbek language is essential for the development of efficacious rule-based algorithms for NER[9]. As an agglutinative language in the Turkic family, Uzbek demonstrates a distinctive morphological architecture, presenting unique obstacles and advantages for NER[10].

A significant aspect of the Uzbek language is its widespread application of affixes, incorporating both prefixes and suffixes[11]. These are appended to word stems to convey a variety of grammatical attributes, including tense, case, number, and person[12]. With hundreds of potential affix combinations estimated, the NER tasks of stemming and identifying word roots become particularly intricate.

To visualize the concept of word formation in the Uzbek language, let's undertake a morphological analysis[13]. For instance, consider the Uzbek word "bolalarimizga", which translates to " to our children". It is composed of a distinct blend of root and affixes[14].

Highlighting the impact of context on word construction, another example can be analyzed using the same root but within a varied context: "bolamning" in the phrase "bolamning fikri", translating to "my child’s opinion". Here, the morphological dissection is as follows: "bola" signifies "a child", "m" is a singular possessive suffix, and "ning" is a case-ending.

Although one could endlessly modify the forms of this word depending on the sentence context, the key point of these examples is to illustrate the substantial alterations in context and meaning that can transpire via the affix concatenation in the Uzbek language.

In certain complicated verbal and nominal forms, the Uzbek language can append four or more affixes to a word root, substantially altering the word's grammatical function and meaning. Grasping this intricacy is critical for an effective NER implementation[15].

The syntax of the Uzbek language also presents a considerable challenge for NER. Contrary to the frequently observed Subject-Verb-Object (SVO) structure in English, Uzbek primarily adopts a Subject-Object-Verb (SOV) sentence construction[16].

In order to gain deeper insight into the syntax of the Uzbek language, it is advantageous to scrutinize a collection of Uzbek sentences. For instance, the sentence "Men ertaga konsertga boraman " translates to "Tomorrow I will go to concert". The sentence begins with the subject "Men", executing the action, and concludes with the predicate "boraman".

Consider another example with a more intricate sentence structure: “Men uy ishlarini bajardim, endi yakshanba kinoga boraman", which translates to "I have done housework, now I will go to the cinema”. In this sentence, "Men" is the subject, "uy ishlarini" serves as the object, "bajardim" is the predicate, "endi" is an adverbial modifier of time, "yakshanba" is the object again in the second clause, "kinoga" functions as an adverbial modifier of place, and "boraman" is the predicate[17].

III. Related Works

The research presented in [18] delineates a technique for automated extraction of named entities from varied data sources. It leverages the pymorphy2 library coupled with the NLTK module for in-depth morphological text examination, and adopts a random walk approach to emphasize semantically connected keywords. Furthermore, a pre-trained neural network is deployed to identify linguistic patterns containing potential descriptor values of textual named entities. The research culminates in the effective creation of a document-specific ontology through neural network processes and the LIME algorithm to approximate linear models.

However, it's essential to highlight that the methodologies suggested in this work are particularly tailored to Russian and certain Eastern Slavic and Turkic languages, like Karakalpak, due to their unique morphological features. The adaptability of these techniques to the Uzbek language may be constrained, given its particular morphological configurations that may not correspond with the approaches used in this research.

[19] delves into the comprehensive study of automated knowledge extraction mechanisms tailored to bolster decision-making amid the prevalent data deluge. The research encompasses methodologies that encapsulate morphological text assessment, rendering text documents in hypergraphs, and the deployment of the random walk technique to unearth semantically intertwined word pairs. The outcomes are systematically structured into a matrix showcasing word affinity coefficients.

Additionally, the document elaborates on the intricacies of training a neural network assigned the responsibility of gleaning linguistic structures, encapsulating potential descriptor values for named text entities. This neural apparatus has the prowess to procure information predicated on a chosen descriptor, such as geographical indicators, eventually rendering geographical nomenclature as its output.

The research reaches its zenith with the forging of an algorithm geared towards keyword extraction from a cohesive subject text corpus, laying the groundwork for ontology genesis in a specific domain. This aids in precision searching across expansive text corpora. A well-trained neural entity, fortified with a concealed layer, employs these keywords to correlate a specific word cluster with a distinct attribute of the entity portrayed in the content, thereby actualizing the formation of a document-specific ontology.

The methodology broached in this reviewed work could, in theory, be applicable to the Uzbek language, courtesy of its Turkic linguistic heritage. Yet, it's paramount to consider the linguistic intricacies of pronounced synharmonism inherent in Uzbek, which could wield considerable influence over resultant outcomes. Adding layers of complexity is the disproportionate availability of linguistic assets, with languages like Kazakh boasting a rich repository of machine learning datasets, a luxury Uzbek doesn’t partake in. This evident resource scarcity for Uzbek underscores the pressing need to innovate methods independent of voluminous datasets for efficient machine learning algorithm deployment. As a result, this present study introduces a nuanced strategy tailor-made for languages constrained by resources, like Uzbek. The spotlight is on NER sans the mandate of vast data reserves.

The article in reference [20] delves deeply into the nuances of NER as it pertains to NLP, with an emphasis on rapid word detection, classification, understanding textual content, and pinpointing named entities. The researchers delineate techniques for automatically detecting named entities within Uzbek content, showcasing in-depth examples alongside their respective entity classifications. In addition, they outline the functionality of the "Uzbek NER analyzer" software, shedding light on its operating mechanism and encompassed material.

Yet, several shortcomings mar the article. To begin with, while the authors introduce a software solution for NER, they only sparingly discuss its internal structure. It remains unclear which highlighted algorithms and tools have been incorporated, leading to a veil of obscurity around the software's core architecture. Additionally, if there's a reliance on machine learning techniques within the software, there's a noticeable void in clarifying the specific dataset chosen for both training and validation phases. This gap impedes a thorough grasp of the dataset's integrity, representational fidelity, and any inherent biases, which, by extension, affects judgments about the system's resilience and trustworthiness.

Furthermore, the manuscript doesn't offer tangible evidence supporting the proposed methods' efficiency. A lack of well-defined performance metrics, such as precision benchmarks, the total count of Uzbek phrases examined, among other pertinent measures, fosters uncertainty about the real-world applicability of the advocated approach.

Also, it's evident that a significant segment of the discussion on algorithms seems to draw heavily from earlier works [21],[22], and [23]. The article's content largely mirrors prevailing practices, prompting inquiries about its distinctive value within the broader academic discourse in this domain.

IV. Proposed Algorithms

The proposed algorithm primarily hinges on the morphological assessment of word constructs, as elaborated in [24]. Consider the application of this foundational algorithm in a specific operational context.

Task Objective: Pinpoint the city (or cities) present in a stipulated text.

1. The input text provided, for example, is “Men kecha Xorazmdan keldim.” (Translation: I came from Khorezm yesterday).
2. This sentence undergoes segmentation, resulting in an array comprising individual words.
3. Each word in the array is subjected to morphological scrutiny to pinpoint relevant entities (in this scenario, names of cities).
4. The algorithm subsequently generates the output: Khorezm– city.
5. In scenarios where the algorithm stumbles and doesn't spot any relevant entities, the output rendered will be: No entities identified.

A crucial aspect to be emphasized is the efficacy of this methodology. It functions optimally when the gazetteer encompasses pertinent lexemes, such as 'Khorezm', which ought to be cataloged in the root database and duly labeled as a 'city'. Absence of this entry in the gazetteer might impede the algorithm's ability to recognize it. The subsequent section delves into the results derived from the algorithm's execution. Figure 1 provides a visual representation of the algorithm's operational process.

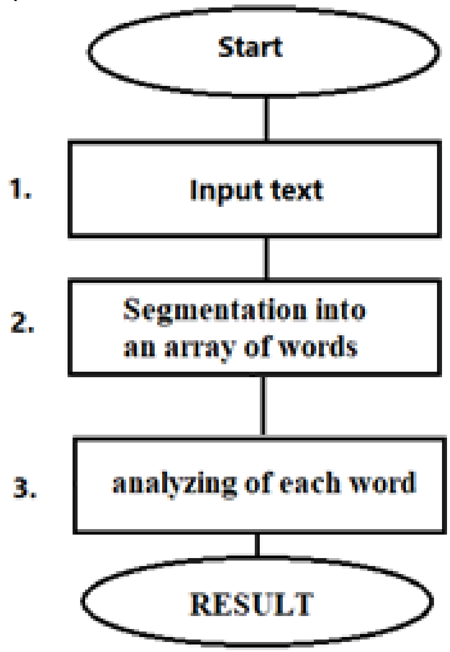

Fig. 1. Scheme of the algorithm’s work.

V. Results of the Algorithms’ Work

The performance of the proposed algorithm meets expectations. For a comprehensive assessment of the algorithm's accuracy, a corpus comprised of 1000 sentences was curated. These were evenly divided into two categories: the first set included sentences with temporal expressions existing in the dictionary, while the latter contained temporal references not cataloged in the database. Each individual sentence was limited to one temporal entity.

Table 1 outlines the algorithm's efficacy. In reviewing the data, the algorithm flawlessly discerned all temporal entities in the first category, amounting to a success rate in 500 out of 500 instances. Contrastingly, for the second category, the algorithm only managed to correctly pinpoint 32% (or 161 out of 500) of the temporal entities.

TABLE I. Results of the First Algorithm

№	Tested Sentences Quantity	% of Sentences, where Location was Found	Quantity of Sentences, where Location was Found
1	**500**	**100**	**500**
2	**500**	**32**	**161**

VI. Conclusion

In the present research, an algorithm for the recognition of temporal expressions in Uzbek texts was introduced, implemented without the utilization of machine learning methodologies. The algorithm showcases a high efficacy in recognizing temporal entities present within the dictionary, underscoring the significance of a comprehensive and accurate database for the method's success.

However, when testing the algorithm on expressions absent from the database, its performance notably diminished. This highlights the inherent limitations of a rule-based and dictionary-dependent approach, especially when confronted with the dynamic and diverse data of real-world scenarios.

The challenge of data scarcity for training and the intricacies of deploying machine learning within the context of Turkic languages, such as Uzbek, remains salient. Nonetheless, the method proposed in this article emphasizes the potential of amalgamating traditional text processing approaches with contemporary innovations for optimal results.

In summation, future research might concentrate on supplementing the current algorithm with machine learning techniques or integrating it with other technologies to enhance recognition precision and adaptability to varied data sources. Additionally, there's an evident need for the expansion and updating of lexical databases to ensure the algorithm can accommodate a broader spectrum of temporal expressions.

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Path planning algorithm for mobile robot exploration using distance parameter.

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Abstract—The new algorithm leverages the concept of frontiers to facilitate efficient navigation and expansion of the robot's exploration area. In each exploration round, the mobile robot employs its sensor range to identify frontiers. By periodically adjusting the sensor range, the algorithm calculates distance parameter of frontiers. The distance of each frontiers and its corresponding rectangle side is calculated, enabling the new algorithm to select a goal point for the robot's navigation.

Experimental results showcase the efficiency and applicability of the new algorithm in terms of exploration time and distance. In comparison to previous algorithms, the new algorithm achieves significant improvements. The path distance required to complete the entire exploration decreases by 15% to 69%, while the time consumption decreases by 12% to 86%. These outcomes underscore the effectiveness of the proposed algorithm in optimizing the exploration process for mobile robots in unknown environments.

Keywords—component, formatting, style, styling, insert (*key words****)***

I. INTRODUCTION

Path planning algorithms play a crucial role in identifying and evaluating potential trajectories to achieve these objectives. In the realm of navigation tasks, robots exhibit various capabilities including environmental modeling, localization, navigation control, frontier detection, obstacle avoidance, and navigating in dynamic contexts. The four primary navigation problems encompass perception, localization, mapping, motion control, and path planning [1-3].

Among these challenges, path planning emerges as the most significant task in mobile robot navigation, encompassing three key aspects. First, the planned path must originate from a specified starting point and terminate at a designated end point. Second, the route must facilitate the robot's movement while avoiding obstacles along the way. Third, among all feasible paths that satisfy the initial two requirements, the path should be optimally determined. Analyzing path planning algorithms involves classifying them based on several criteria. Intelligent technologies allow for the categorization of these algorithms into traditional methods and heuristic methods. In terms of the environment's nature, planning methods can be classified as either static or dynamic (although it should be noted that static environments are rarely encountered in practice). Moreover, planning methods can also be differentiated based on the completeness of information about the environment. Global path planning refers to methods that possess complete information, while local route planning typically involves knowledge limited to the robot's immediate vicinity. Incomplete information about the environment often arises due to its dynamic nature, thus making local path planning more suitable [4].

Multiple approaches exist for path planning, including graph-based and tree-based methods, cell decomposition techniques, potential fields methods, optimization strategies, and intelligent technology-based methods that incorporate behavioral techniques.

Currently, exploration methods in unknown environments, which include tasks such as pathfinding, collision-free path generation, localization, and mapping, can be broadly classified into three types:

- Random-based traversal: This approach involves advancing until an obstacle is encountered and then randomly selecting a turning direction to continue the exploration. However, this method consumes significant amounts of time, energy, and covers long distances [5].
- Pathfinding based on environment models: This type of exploration relies on environmental models such as grid maps and cell decomposition. The environment is divided into regions represented by grids or cells, and path finding for exploration is performed based on these grid or cell reference points [6-8].
- Sensor-based traversal without prior environment data: These approaches utilize algorithms to guide the robot's navigation based on real-time sensor data acquired from laser or camera devices. This enables the robot to explore unknown environments without prior information [9-10].

Over the past three decades, researchers have explored a wide range of methods falling within these three categories, all of which are related to autonomous navigation and exploration in unknown environments. Bruce et al. [11] proposed a path planning algorithm that utilizes rapid exploration of random trees. Their method incorporates a waypoint cache and adaptive cost search path planning. Jadidi et al. [12] proposed a Gaussian process (GP)-based algorithm for online mapping that ensures a continuous uncertainty model map of spatial coordinates. Instead of binary values, the concept of representing geometric boundaries derived from occupancy maps was extended to probability boundary maps, efficiently computed using the GP occupancy map gradient. A greedy research method based on mutual information was also introduced, considering all possible future observations. This multidimensional map inference approach requires a small number of observations, resulting in a rapid decrease in map entropy during the mapping process. Evaluations using available datasets demonstrated the efficiency of the suggested framework for robot mapping and research tasks.

Liu et al. [13] presented an exploration method based on the topology of a grid hybrid map. The method generated target points based on geometry rules and built a topology node. Zhang et al. [14] proposed a topological and semantic grid map-based indoor navigation method, utilizing natural language for goal point selection. This method improved the safety, efficiency, and robustness of mobile robot navigation. Tunggal et al. [15] introduced a pursuit algorithm using the cell decomposition method for robot path planning and a fuzzy inference algorithm for path planning. The researchers claimed that the algorithm finds the minimum path by avoiding obstacles, minimizing the required time to reach the destination. Wang et al. [16] proposed a new autonomous path planning method for exploration in unknown environments using a graph structure. The researchers designed a sampling strategy to obtain random points evenly in the environment of interest to build a roadmap. This roadmap effectively finds a global path from the robot's current location to the target area. The global path is further optimized using a trajectory optimization method, considering the motion restrictions of the robot. The cost estimate of the path is used to select the next best target area using a utility cost function that considers both the path cost and the information obtained from the potential target area. Additionally, a re-targeting mechanism is presented to evaluate the target area and reduce additional path costs.

Cheng et al. [17] introduced a new algorithm for localization and navigation using the construction of a topological map. They developed a progressive Bayesian classifier based on the depth curve obtained with a 3D sensor to directly identify the corridor type. Multiple observations are combined to achieve more reliable characteristics instead of relying on a single observation. They proposed creating a topological map and loop closure methods to build a map of unknown environments. Senarathne et al. [18] proposed a computationally efficient approach that handles locally updated map data to generate safe and reliable boundary information. They addressed two problems: gradually updating the database of frontiers between unknown and mapped cells that are safe for the robot, and determining the achievability of the frontiers in the database. Achieved frontiers are extracted by contours of boundaries. Dugarjev et al. [19] introduced a cell decomposition technique for unknown rectilinear environments using laser sensors for critical edge detection. The algorithm checks the redundancies of the planned path to select a goal point. Lu et al. [20] introduced an RGB-D sensor-based frontier exploration algorithm in unstructured environments. The environment is divided by Octomap, and the best frontier is selected based on a cost function for information acquisition. Jiang et al. [21] presented a laser-based SLAM algorithm, utilizing eight directions of the environment and calculating their path vector probability. Based on the exploration requirements, the robot plans the next goal point.

II. Distance Parameter Based Frontier Selection

The objective of this study is to develop an autonomous path planning approach for mobile robot exploration in challenging indoor environments. The main part of path planning algorithm is a algorithm which should be determined exactly, in our case it is frontier selection. To perform computations for selecting best frontier we propose to determine the parameters of frontier. For this we use distance parameter. Distance parameter - d[n] is distance value between frontiers and its opposite rectangle. The high value of d[n] means more area, where should be explored. The Table 1 contains distance parameters of frontiers. The process of determining distance parameter is shown in Figure 1.

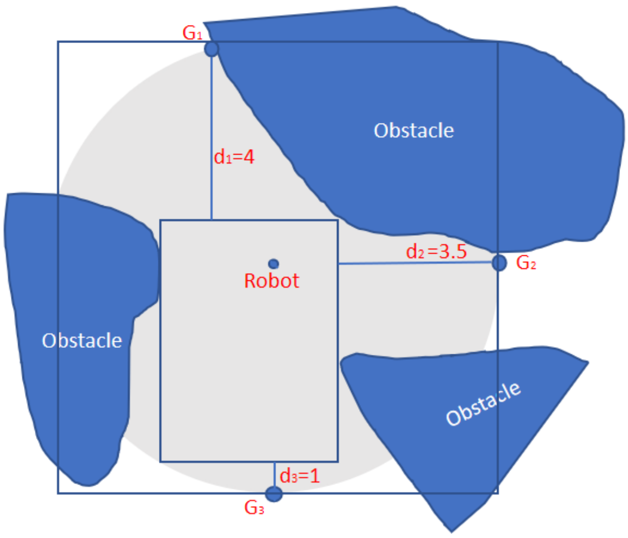

Fig 1. Distance parameter generation

The range of $d-$value is [1, n], where n is quantity of goal points G_n

Table I. Distance parameter values

Goal points	d - value
G1	3
G2	2
G3	1

In each exploration round of algorithm, the robot starts getting the data from rangefinder. On the bases of acquired initial data robot determines the frontiers, F[N], as shown in Figure 1. These frontiers are called are frontiers. After that robot starts processing Rmap algorithms, i.e., using the rectangle tilling algorithm robot generates biggest rectangle among the obstacles [22]. In the next step, algorithm starts determining distance parameters to define which frontier is the best to move forward. Here, algorithm defines the distance parameter d[n], using distance between rectangle side and frontier. In the previous step robot defined frontiers F[N]. Most researchers use outer frontiers to select the best frontier, in our work we calculated distance parameter to estimate more informative frontier. Frontier cost estimation depends on the structure of frontiers, i.e., we make assumption that if frontier with large distance then this frontier has large area where should be explored by robot.

A path planning strategy basing on this movement policy minimizes the exploration path distance and travel time [4].

III. RESULT AND DISCUSSION

To assess the robot's autonomous exploration capabilities, we performed simulated experiments in three different types of environments. The results of an experiment conducted in a non-cyclic environment are presented in Fig. 2. We compared our proposed algorithm with two other exploration algorithms. The first algorithm employed a cost function for selecting the best frontier, as proposed by Gomez [23], while the second algorithm was the Rmap path planning algorithm introduced by Lee [22]. The key distinction between our proposed algorithm and these two strategies lies in the generation and calculation of inner and outer frontiers for path planning in order to select the optimal frontier. All three algorithms were evaluated under identical conditions using a mobile robot.

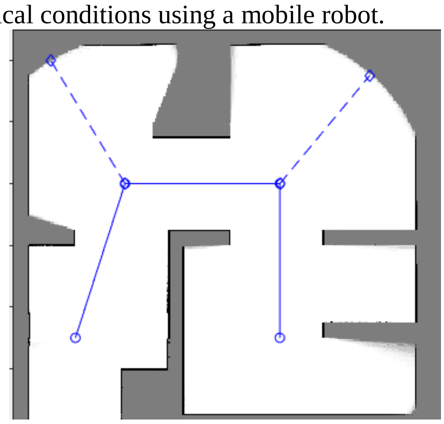

Fig. 2. The path of the robot in a non-cyclic simulated environment.

Table 2 provides a comprehensive overview of the exploration path distance and the number of steps taken, allowing for a clear comparison between the proposed method and the previous methods [22, 23]. It is important to note that all of the strategies have the ability to achieve complete exploration coverage.

Furthermore, Table 2 presents the main metrics in two different environments, including the number of exploration steps, the number of turning points, the traversal distance, and the time consumed. The effectiveness of the proposed path planning method is directly associated with the time consumption and the length of the robot's path. A lower number of steps indicate a simpler navigation process with fewer target points, while the traversal distance reflects the actual distance covered by the robot during exploration.

Additionally, we conducted experiments on the new path planning strategy in a large simulated environment depicted in Fig. 3. The exploration process and the navigation trajectories of the robot using three different path planning algorithms are illustrated in Fig. 3. In Fig. 3a and 3b, the blue lines indicate the robot's path trajectories, while the circled points represent the goal points generated during the exploration. The trajectory followed by Rmap is distinct from new algorithm and the cost function-based frontier algorithms, as depicted in Fig. 11c. Rmap's trajectory is represented using rectangles.

TABLE II. The experimental results of exploration stages and path distances.

Environ ments	**Exploration steps**		
	Rmap+	**Frontier based exploration**	**Rmap algorithm**
Environ ment1	P_1=5	P_1=5	P_1=22
	P_2=5	P_2=5	P_2=11
	P_3=3	P_3=5	P_3=22
	P_4=5	P_4=5	P_4=24
	P_5=10	P_5=5	P_5=11
	P_6=10	P_6=10	P_6=27
		P_7=5	
		P_8=15	
	Total 38m	**Total 55m**	**Total 114m**
Environ ment2	P_1=5	P_1=5	P_1=18
	P_2=5	P_2=5	P_2=17
	P_3=5	P_3=5	P_3=14
	P_4=5	P_4=5	P_4=16
		P_5=8	P_5=15
		P_6=5	P_6=24
		P_7=8	P_7=14
			P_8=22
	Total 20m	**Total 51m**	**Total 140m**

Table 3 presents the results obtained from the simulation experiments. While all three strategies are capable of generating a complete map of the environment, the key metrics for evaluation include exploration time, number of turning points, coverage area, and travel distance. The number of turning points directly impacts the efficiency of the exploration process, as well as the overall navigation distance covered by the robot.

Table 3 illustrates that the proposed algorithm achieves faster exploration and shorter traversal distance in all three types of environments compared to the previous strategies [22, 23]. In a wide environment, new algorithm outperforms the cost function-based frontier algorithm by 15% and the Rmap path planning algorithm by approximately 49%. In a small cyclic environment, proposed algorithm demonstrates a 31% improvement in path distance compared to the cost function-based frontier algorithm and a 66% improvement compared to the Rmap algorithm. In a small non-cyclic environment, our algorithm performs 22% and 69% better than the cost function-based frontier and Rmap algorithms, respectively.

Furthermore, new algorithm minimizes the number of exploration steps, including target points and turning points, resulting in reduced time costs, especially when compared to the previous Rmap algorithm. In the small cyclic environment, new algorithm reduces time consumption by 32% to 71% compared to the cost function-based frontier and Rmap methods. In the wide environment, proposed algorithm outperforms previous exploration algorithms by 12% to 57%.

While the Rmap algorithm achieves maximum coverage area, the proposed algorithm achieves a coverage area comparable to the compared algorithms. Key features of the new algorithm include the selection of optimal frontiers based on inner frontiers generated through iterative calculation. This helps prevent the selection of non-informative areas. Additionally, the algorithm minimizes turning points, thereby reducing exploration time and traversal distance.

TABLE III. The Comparison results in three environments

Types of environ ments	**Algorithm**	**Turning points**	**Explora tion distance**	**Explora toion time**
Wide cyclic environ ment	New algprithm	47	233 m	634 sec
	Cost function based frontiers	51	275 m	722 sec
	Rmap path planning	176	454 m	1480 sec
Small cyclic environ ment	New algorithm	5	38 m	108 sec
	Cost function based frontiers	8	55 m	186 sec
	Rmap path planning	36	114 m	356 sec
Small noncyclic environ ment	New algorithm	9	40 m	56 sec
	Cost function based frontiers	9	51 m	144 sec
	Rmap path planning	42	131 m	407 sec

IV. CONCUSION

In conclusion, this study introduces the algorithm as a new path planning approach for autonomous mobile robots exploring unknown environments. The algorithm, based on a modified frontier-based approach, utilizes LIDAR sensor data to generate inner and outer frontiers. By considering the dimensions of these frontiers, the robot selects the most favorable frontier and plans the shortest traversal path. This algorithm effectively avoids uninformative areas, resulting in improved efficiency in terms of travel time and distance compared to previous path planning methods. The algorithm currently employs the Rmap data structure proposed in previous work for mapping and localization. Future work will involve developing a dedicated data structure for the algorithm and implementing a comprehensive strategy for multiple robots in dynamic environments.

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Application of colored temporary Petri nets for modeling the educational process

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***Abstract*— This article is devoted to the study of methodological approaches used in the system of higher professional education to assess the quality level of vocational training of graduates in the framework of the competence-based approach. With the introduction of the competence-based approach in the system of higher professional education as a means and tool for assessing the progress of graduates, the point-rating system of assessment has been widely used, as an acceptable system of assessment tools in the competence format of education. The authors propose a method for determining the indicator of the degree of professional competence of university graduates, including principles, a system of indicators, the methodology for calculating the integrated indicator of the quality of vocational training of a graduate, expressed in the form of the degree of his professional competence. The complex of characteristics that can be obtained through the use of the proposed methodology reflects the essence of the indicator of the degree of professional competence of a graduate. The results obtained as a result of the application of the methodology reflect the level of professional competence of graduates and make it possible to determine the main directions for improving the quality of professional training of university graduates. The analysis of business processes of mastering the professional competencies of students in a certain discipline. The definition of the educational process as an information object is formulated. Nested colored Petri net, which reflects the logic and features of the course of the educational process at the university.**

Keywords*— competence, assessment, rating, knowledge, skill, practice, productivity, quality, training, teaching methods, intellectual analysis, innovation, graduate, modeling; colored Petri net.

Introduction

When studying at universities, students study many different disciplines. Training courses usually consist of a set of modules, each of which contains theoretical and reference material, tasks for independent work, as well as control questions (often in the form of tests) for self-examination and assessment. This enables students to gain competence, and using these competencies to increase the potential of professionalism. Today, these competencies can also be supplemented with other scientific and educational achievements of the student, such as knowledge of foreign languages, publications, and others. We have proposed criteria for assessing the competence of a graduate, which function non-linearly.

One of the main disadvantages of the traditional assessment system is in student learning - the student does not work actively and rhythmically. In the traditional system, the student's assessment is obvious during the examination session, but this form of assessment does not provide a complete assessment of the student's knowledge. That is, this process aimed at evaluating a result. The society's need for highly qualified specialists requires young personnel capable of solving problems of varying complexity and adapting to changes. Young personnel, ready for self-development and self-knowledge, are becoming a requirement of today.

Formation of quality control of education, control and evaluation of the professional potential of students shows the professional potential of students, as well as what indicators should be emphasizing in improving the quality of education. At the same time, the assessment of the potential level of students leads to an objective assessment of their knowledge, skills and abilities in solving problems in future professional fields.

The paper considers the methodology for creating a model on the example of a complex distributed system - the process of functioning of the professional training of a

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competitive university graduate. This process is one of the examples of non-deterministic dynamic parallel systems, the problem of modeling of which is associated both with the possible randomness of the system and with the need to take into account the dynamics of subsystems.

The learning process is probabilistic in nature, confirmed by both practice and scientific research. For example, Ovakemyan Yu. A. [1], Kovalenko D. S. [2], Ganicheva A. V. [3], Maier R. V. [6], Dorrer G. A. and Rudakova G. M. [4] in their works also suggest the probabilistic nature of the learning process. To predict the course of learning, you can build a mathematical model of the processes that occur during learning. Under certain assumptions, the process can be represented as a graph - a Petri net or a Markov chain.

To describe and analyze such systems, Petri nets [1–3] and their varieties, for example, fuzzy [4], temporal [5–6], colored [7], can be used.

In [4], a model of the educational process in a university using Petri nets is considered. In [5], the use of artificial intelligence technologies for building individual educational trajectories of students is considered.

The paper considers colored temporary Petri nets, which are nets of a higher level and allow, in comparison with ordinary Petri nets, to analyze additional properties of the simulated processes without complicating the network structure.

So, in temporary networks, unlike conventional Petri nets, transitions are triggered with some delay, and markers are in positions for a certain time, which makes it possible to model not only the sequence of events, but also their time reference.

Colored Petri nets allow you to simultaneously simulate several parallel flows of various materials or events during the functioning of complex systems. In similar models based on ordinary Petri nets, one has to artificially introduce additional positions that are not displays of process elements, which serve to streamline the launches of network transitions and separate materials or events, which complicates the spatial structure of the model and makes it difficult to interpret.

The colored temporary Petri nets used in the work combine the advantages of both colored and temporary Petri nets.

In this work, a prototype model for calculating the professional training of a competitive graduate by year for four years is built on the basis of colored time Petri nets.

Definition of the educational process

The concept of a process implies a change in the state of an object over time. The concept of the educational process can be imagine if the object is a student of university. The educational process consists of educational processes and the process of personality development within the framework of the task to build a mathematical model, the authors proposed the definition of an information object - the educational process, reflecting its formalized structure [1].

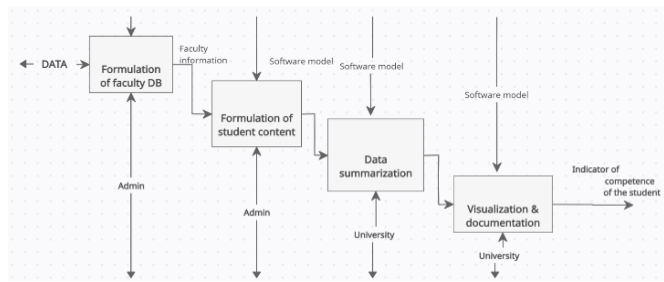

Fig.1. Model for determining the coefficient of student knowledge

The figure shows how the competencies of students are determined. In this model, it is proposed to consider the definition of competence as an integral system that includes several criteria. The software can to summarize and to visualize necessary information.

If students receive competence from the intersection of knowledge, skills and competencies when assessing professional competence, then the overall coefficient of competence is found by assessing the knowledge, skills and competence of each student separately (finding the coefficient indicator), and then summing up each indicator.

In the process of studying at the university, students develop specific and related competencies based on each discipline. Restrictions only to them are not enough to assess the professional competence of a student. For this reason, in addition to knowledge, skills and qualifications. Based on this we offered to add indicators of personal characteristics and motivation to the profession.

As shown in the figure 2, the competencies that students can acquire in each subject will entered into the system by an expert as input. The number of competencies may vary. At the same time, all competencies that a student can acquire during training will formed in the database. In order to determine the student's mastery of these competencies, each student will asked to determine the level of competence. These requests lead to the prevention of uniformity in the calculation of student’s knowledge. That is, in general, the student’s knowledge in one subject will evaluated the assessment serves as a general indicator that includes knowledge, competencies and skills.

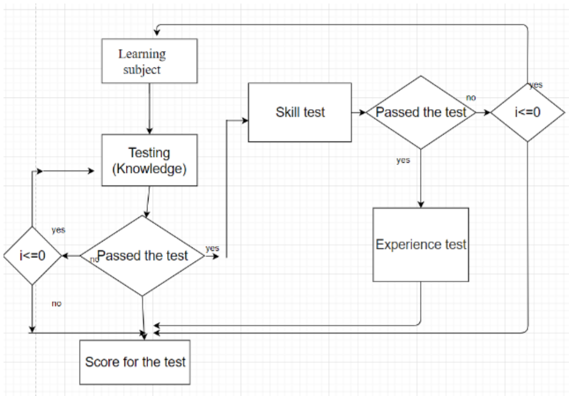

Fig.2. Block diagram of the process of determining the competence of one student

It should be noted that the acquisition of skills does not necessarily indicate a complete mastery of the subject, for which the application of skills requires the development of competence in the student. Qualification, in turn, shows that the student is able to put into practice the acquired knowledge in this subject. It can be said that a student who has formed a qualification has fully mastered the subject and applied it in practice.

A skill is a person's ability to perform a particular activity or action based on previous experience. Skills are a component of activity associated with practical activities, the ability to apply knowledge in practice. Skills are ways to successfully perform an action in accordance with the purpose and circumstances of the activity. It is always based on knowledge, it is the basis of skill (qualification). According to the content, skills are divided into practical (physical) and mental, simple and complex types. Practical skills are directed to the implementation of labor activity, intellectual skills - to the acquisition of knowledge and their development [4].

Skills should not be confused with knowledge, since knowledge is expressed in judgments (judgments) that accurately reflect reality. And skills are more embodied in mental and physical actions.

Qualifications vary by discipline. In the system we propose, professors and teachers who are well versed in the subject enter qualifications into the database of the system. At the next stage, a survey is conducted to determine the competence of students.

The learner will abstractly represented as an automaton with a certain finite set of states that depend on external influences. However, in an abstract automaton, only successive transitions from state to state consider. This model is not quite suitable for describing the student's learning process, since several disciplines studies simultaneously. For each discipline, the student receives knowledge, skills and abilities, and the totality of these indicators shows the level of competence in a particular discipline.

Methods for setting and rules for the functioning of Petri nets.

Another possibility is to describe a color set based on already declared color sets using the built-in color set constructor. To form new colors, it is possible to use constructions such as product, record, union, list and subset, which can be arbitrarily nested.

Therefore, to simulate the learning process, it was decided to use the Petri net. Each position of the network will correspond to a certain state of the learning process, the chip is a student, the transition is the study or mastery of competence, the operation of the transition is the successful completion of the study of the discipline. Adding a color to each chip - this attribute will store information about how well the competencies are mastered in subjects (according to the competency criteria). At the same time, the maximum and minimum intervals are determined by the criteria of each competence for the courses. These indicators make it possible to visually determine the level of students' competence in courses separately. A transition will be considered enabled only if the number of tokens in its input position matches the number of input arcs, and the colors of the tokens match the colors of the arcs.

When the transition is triggered, a token with the “learned” state is removed from the position, at the same time a token with the “studied” state is placed in the position (the “studied” state stores scores or grades). A token with the state "under study" is placed in the position corresponding to the next section of the discipline being studied.

The Petri net has two types of nodes. Our chips will follow the instructions and move around the network.

The diamonds and rectangles of the flowchart are the network transitions, and the arcs of the flowchart are the positions of the tokens (one arc, one position). In this way, a logical sequence of events will be reflected, which will make it possible to trace the flows of information.

Formally, the model of the learning process is described by a tuple of the form:

$PN_c = (P, T, C, \hat{R}^-, \hat{R}^+, \hat{\mu}_0)$, where: (1)

– $P = \{p_1, p_2, \ldots, p_n\}$ — finite non-empty set of positions, p_n- each of the positions corresponds to the stage of the learning process;

– $T = \{t_1, t_2, \ldots, t_m\}$ — finite non-empty set of transitions (the sets P and T do not intersect: $P \cap T = \emptyset$) the transition corresponds to a certain control task, the operation of the transition is interpreted as the execution of the task, m - the number of transitions;

– $C = \{c_1, c_2, \ldots, c_d\}$ — the set of colors c_d of the Petri net, d – is the number of colors;

– R^- — incidence matrix of arcs included in transitions;

– R^+ — incidence matrix of arcs emerging from transitions;

– $\mu_0 = \{\mu_1, \mu_2, \ldots, \mu_n\}$ — petri net initial marking vector.

$S = P * C^{()}$ - the set of all possible markings of a Petri net.

$C_d = Stu_{stud}, Mark, Num_{group}, Cod_{discipl};$ (2)

where $Situ_{stud} = \{ital$ Learning $ital$ Learned$\}$ – state of knowledge;

Ball={1,…,100} – color component that identifies the score obtained when studying a section of a topic or subject. The model in figure 3 describes the behavior of one student while studying the course of the discipline.

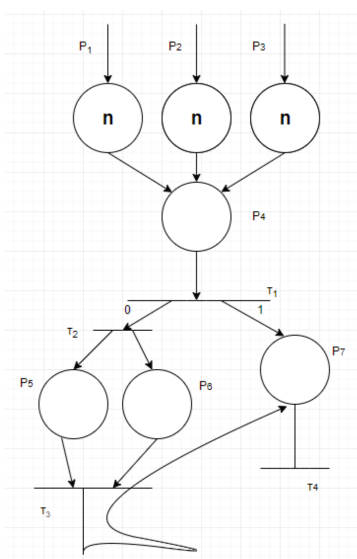

Fig. 3. Colored Petri net (net C), simulating the passage of a training course by each student.

To improve the functionality of the net, the authors suggest using a nested Petri net (Nested Petri Nets – NPN). Structurally, such a network consists of the main EC network and a set of networks - chips (subnets) Ci, where i = 1 ,…, en (subnet drawing - Fig. 3). At the same time, a connection must be established between some transitions of the main network and transitions of networks - chips, allowing only their joint operation. Such transitions will be called labeled. The nested network EC is shown in Figure 4. Each token of the EC network contains n colored subnets that model the behavior of each student during training.

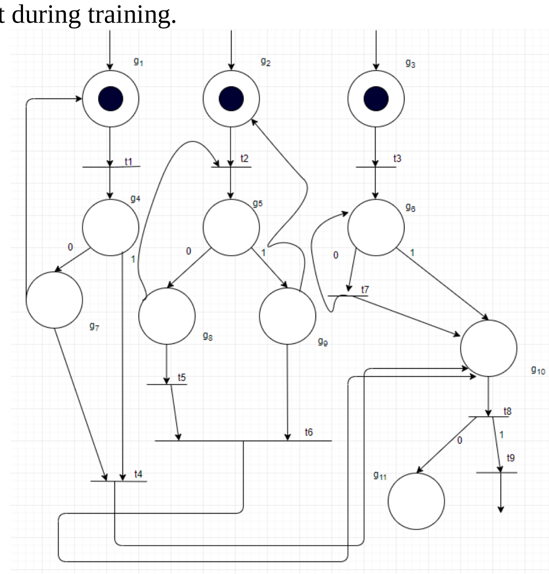

Fig. 4. Nested EC network

With all the necessary resources in NPN, the following four types of trigger steps are distinguished:

• an autonomous step, which corresponds to the triggering of an unlabeled transition in the main network;

• under the system autonomous step, which corresponds to the triggering of an unlabeled transition in the network - the Ci token;

• horizontal synchronization, at which transitions in networks - chips Ci, marked with the same labels, are triggered simultaneously;

• vertical synchronization, when transitions in the main network EC and networks-tokens Ci having the same labels are triggered simultaneously.

Consider only vertical sync. Positions p1, p2, p3, p7 in Figure 3 coincide in meaning with positions g1, g2, g3, g10 in Figure 4. Transitions f4, f6, f7 and t1 must fire simultaneously.

This means synchronizing the following actions:

the arrival of a student in the system generates in the EU network subnet C in the form of a token s, which belongs to the STUDENT color set;

completion of the process of studying theoretical material and passing the test - triggering transitions f1;

• Completion of the testing process and transition to evaluation – triggering transition f4;

• Completion of learning by skill – triggering transitions f2;

• completion of the testing process and transition to assessment - f6;

• Completion of the testing process and transition to assessment – f7.

The EU network allows you to evaluate the number of points scored in the process of studying a particular discipline. For this, additional variables are introduced, specified by color sets:

Color BALL = integer;

Color Failure = Bolean;

and corresponding variables: var β: BALL, var γ: Failure.

The variable β means the number of points scored by the student in the study of the discipline. Initially, there are 0 points in position g10, and then, if the answer is correct, the marking of this position increases. When training is completed, transition f8 is triggered. Transitions f8 and t4 are labeled transitions. The minimum number of points at which a positive assessment is possible is b0 points. If the current value of β turns out to be less than b0, then the learning process is considered unsuccessful, and the variable γ takes on the value true, which is transferred to position g11 when the transition t8 fires. All other transitions are then blocked. Since the described model will be the basis of the intellectual module of the educational process support information system, when writing the program code, each network transition will be described by a procedure, the input arcs of the transition will correspond to the arguments, and the output arcs will correspond to the return values of the procedure.

Obtained results. A review of the existing information systems for supporting the educational process in universities, which have an intelligent process control module, is made. The information flows and business processes that provide the process of teaching university students are analyzed. The choice of the mathematical model of the educational process is substantiated. A nested colored Petri net has been built, which reflects the logic and features of the educational process in the university.

Conclusion. The proposed mathematical model of the educational process in the form of a nested colored Petri net takes into account the human factor, which helps to effectively plan and implement the student learning process, and also makes it possible to assess students' competence. An algorithm for constructing a mathematical model is proposed. As well as a chart for determining the coefficient of student knowledge.

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New hardware-implemented stream encryption algorithm

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Annotation. This article describes a stream encryption algorithm called NHSA, which consists of 3 shift registers with a total length of 269 bits, 6 AND elements and 14 XOR elements. The results of evaluating the sequence generated by this algorithm for the degree of randomness and conclusions about the portability of certain cryptanalysis methods, as well as information about the number of elements required to implement the algorithm on hardware are presented.

Keywords. AND, XOR, NHSA, algebraic cryptanalysis, differential cryptanalysis, period of algorithm, NIST statistical tests

I. Introduction.

Stream cipher algorithms are encryption algorithms based on a stream of bits that transform each successive 1 bit of plaintext into encrypted text by performing an XOR operation with the corresponding 1-bit gamma key generated by a generator. [1].

$$c_i = p_i \oplus k_i \qquad (1.1)$$

The recipient performs an XOR operation on the encrypted text with the corresponding 1-bit gamma generated by the same encryption generator (using a secret symmetric key) in order to generate the plaintext from the received encrypted text.

$$c_i \oplus k_i = p_i \oplus k_i \oplus k_i = p_i \quad (1.2)$$

The resilience of cryptosystems based on stream ciphering against various attacks depends on the resilience of the generator used in the algorithm. The robustness of the generator is evaluated by the period of the generated sequence and the degree of randomness. If the generator produces the same sequence in each session or has a short repetition period, it becomes possible to XOR two encrypted texts using the XOR operation, resulting in the XOR sum of two plaintexts $p_1 \oplus p_2$. The complexity of decrypting this encrypted text is approximately equivalent to the complexity of decrypting a polyalphabetic cipher, which simplifies the cryptographic attack process. Numerous research studies have been conducted on stream algorithms and their assessment [5-21].

This article proposes an algorithm for stream ciphering named NHSA, which can be implemented in hardware.

II. Main Part

The initial state of NHSA (New Hardware Stream Algorithm) consists of 3 shift registers with a total length of 269 bits. Each state is modified through a combination of nonlinear bit propagation and feedback within cyclic right-shift registers. To initiate encryption, a 128-bit key value K and an initialization vector IV are loaded into the 3 shift registers according to a specified rule. The algorithm is executed 4*269 = 1076 times, which means that each bit of the initial state corresponds to each bit of the key, and the initialization vector ensures connection.

After the initialization phase, each cycle generates a new element of the output keystream, which is added to the next bit of the plaintext using an XOR operation (modulo-2 addition). Decryption is performed in reverse order — each bit of the encrypted text is combined using an XOR operation with each bit of the output keystream.

Initialization. The initialization process of the algorithm starts with loading a 128-bit key and a 128-bit initialization vector into 269-bit (89+83+97)-bit registers representing the initial state. The initialization process can be described using the following pseudocode.

For the case where the indices of register cells are expressed sequentially:

$(K_0, K_1, \dots, K_{79}, 0, \dots, 0) \rightarrow (a_0, a_1, a_2, \dots, a_{88})$
$(I_0, I_1, \dots, I_{79}, 0,0,0) \rightarrow (a_{89}, a_{90}, a_{91}, \dots, a_{171})$
$(K_{80}, \dots, K_{127}, I_{80}, \dots, I_{127}, 0) \rightarrow (a_{172}, a_{173}, \dots, a_{268})$
$for\ i = 0\ to\ 1075\ do$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + a_{161} \rightarrow t_0$
$a_{151} + a_{164} \cdot a_{165} + a_{166} + a_{155} \cdot a_{157} + a_{259} \rightarrow t_1$
$a_{232} + a_{263} \cdot a_{264} + a_{265} + a_{242} \cdot a_{244} + a_{68} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, a_{89}, \dots, a_{170}) \rightarrow (a_{89}, \dots, a_{171})$
$(t_0, a_{172}, \dots, a_{267}) \rightarrow (a_{172}, \dots, a_{268})$
$end\ for.$

For the case where the indices of register cells are expressed in a separate order for each register:

$(K_0, K_1, \dots, K_{79}, 0, \dots, 0) \rightarrow (a_0, a_1, a_2, \dots, a_{88})$
$(I_0, I_1, \dots, I_{79}, 0,0,0) \rightarrow (b_0, b_1, b_2, \dots, b_{82})$

$(K_{80}, \dots, K_{127}, I_{80}, \dots, I_{127}, 0) \rightarrow (c_0, c_1, \dots, a_{96})$
$for\ i = 0\ to\ 1075\ do$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + b_{72} \rightarrow t_0$
$b_{62} + b_{75} \cdot b_{76} + b_{77} + b_{66} \cdot b_{68} + c_{87} \rightarrow t_1$
$c_{60} + c_{91} \cdot c_{92} + c_{93} + c_{70} \cdot c_{72} + a_{59} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, b_0, \dots, a_{81}) \rightarrow (b_0, \dots, b_{82})$
$(t_0, c_0, \dots, c_{95}) \rightarrow (c_0, \dots, c_{96})$
$end\ for.$

Generation. The stream generator uses the values of 21 bits from the original 269-bit state registers to modify 3 bits of the state register values and compute 1 bit of the key stream. However, after the initialization process consisting of 1076 iterations, the values of these 21 bits can be entirely influenced by the key and initialization vector values. The process of generating an N-bit key N ($N \leq 2^{64}$) required for encryption can be expressed using the following pseudocode.

For the case where the indices of register cells are expressed sequentially:

$for\ i = 0\ to\ N\ do$
$a_{55} + a_{82} \rightarrow t_0$
$a_{151} + a_{166} \rightarrow t_1$
$a_{232} + a_{264} \rightarrow t_2$
$t_0 + t_1 + t_2 \rightarrow exit_i$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{161} \rightarrow t_0$
$a_{151} + a_{164} \cdot a_{165} + a_{166} + a_{259} \rightarrow t_1$
$a_{232} + a_{263} \cdot a_{264} + a_{265} + a_{68} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, a_{89}, \dots, a_{170}) \rightarrow (a_{89}, \dots, a_{171})$
$(t_0, a_{172}, \dots, a_{267}) \rightarrow (a_{172}, \dots, a_{268})$
$end\ for.$

For the case where the indices of register cells are expressed in a separate order for each register:

$for\ i = 0\ to\ N\ do$
$a_{55} + a_{82} \rightarrow t_0$
$b_{62} + b_{77} \rightarrow t_1$
$c_{60} + c_{93} \rightarrow t_2$
$t_0 + t_1 + t_2 \rightarrow exit_i$
$a_{55} + a_{80} \cdot a_{81} + a_{82} + a_{72} \cdot a_{74} + b_{72} \rightarrow t_0$
$b_{62} + b_{75} \cdot b_{76} + b_{77} + b_{66} \cdot b_{68} + c_{87} \rightarrow t_1$
$c_{60} + c_{91} \cdot c_{92} + c_{93} + c_{70} \cdot c_{72} + a_{59} \rightarrow t_2$
$(t_2, a_0, \dots, a_{87}) \rightarrow (a_0, \dots, a_{88})$
$(t_1, b_0, \dots, a_{81}) \rightarrow (b_0, \dots, b_{82})$
$(t_0, c_0, \dots, c_{95}) \rightarrow (c_0, \dots, c_{96})$
$end\ for.$

The addition and multiplication operations in the provided pseudocodes correspond to XOR and AND operations, respectively, which perform addition and multiplication modulo 2.

Using this algorithm, it is recommended to generate keys of length 2^{64} bits using a single key and initialization vector.

Below is an example of the correct organization of the generation process using the algorithm.

Input Parameters:

*Key:*0001110000000011000110110000110010000101100010010011000000001000110011101100110101000100100101111100011110000111010000111000101111

*IV:*11110000111000000110100001100000010110000101000001001000001000000000111000000110000000101010000000011000000010000000001000000000000000000

Values of the registers before the initialization process:

*a:*00011100000000110001101100001100100001011000100100110000000010001100111011001101000000000000

*b:*11110000111000000110100001100000010110000101000001001000001000000000111000000110000000000

*c:*000100100101111110001111000011101000011100010111101010100000000110000000100000000010000000000000000000

Values of the registers after the initialization process:

*a:*10110010010011010110101001101110110101100011110000010010111111110001110101101100101101000

*b:*01001110011100100110011000110100011010000011101000111010000110110101010011011110100

*c:*000000100000010101001101000100100111100100101111101001010001110101001001000100111110110100000000000

*output:*001001011101001111101111110111011010110110110000011000110010100000101101010000011 10…

III. Results.

NHSA is primarily a hardware-oriented adaptive algorithm. It aims to be compact in environments with gate limitations, energy-efficient on platforms with constrained power consumption, and fast in applications requiring high-speed encryption.

The requirement for compact implementation implies a bit-oriented approach. Additionally, it's necessary to ensure non-linearity in the output of the key stream generator's internal state registers. Moreover, the ability to provide efficient energy usage and rapid implementation is essential.

Based on the figures provided in [3] (i.e., 12 NAND gates for each flip-flop (shift register element), 2.5 NAND gates for XOR, and 1.5 NAND gates for AND), calculate the number of gates required for a possible hardware implementation. Comparative analysis results with the Trevium algorithm [2], which is one of the top stream cipher algorithms participating in the EStream competition, are presented in Table 1.

Table - 1. The number of gates required for the hardware implementation of the NHSA and Trevium algorithms is as follows:

Algorithm	**Trevium**	**NHSA**
Key length	80	128
IV length	80	128
Internal status register	288*12=3456	269*12=3228
AND gate	3*1.5=4.5	6*1.5=9
XOR gate	11*2.5=27.5	14*2.5=35
Total number of gates	**3488**	**3272**

Period of NHSA algorithms.

As the internal state of the algorithm evolves non-linearly, determining its exact period is challenging. However, the period of the algorithm's operation can be estimated through a series of observations. Firstly, it can be shown that any key/IV pair can produce a stream with a period of at least 2^{83-3}-1 if a complete linear circuit without NAND gates is obtained. This doesn't directly impact NHSA but can be considered an indication that the register lengths have been chosen correctly.

Secondly, the internal state of NHSA is updated in reverse order, and the initialization of the register $(c_0, .., c_{96})$ prevents state changes in fewer than 96 iterations. Assuming that NHSA behaves like a random permutation after a sufficient number of iterations (in this case, 269*4=1076 iterations), all cycle lengths up to 2^{269} are equally likely. Thus, for this key/IV pair, the probability that it generates a cycle shorter than 2^{128} is $2^{269-128}=2^{141}$.

However, it's recommended to generate a 2^{64} bit key using a single key/IV pair to ensure maximum reliability of the generated keys.

An algebraic attack on the NHSA algorithm.

At first glance, NHSA may appear to be a lightweight algorithm that could be efficiently targeted by algebraic attack methods. The complete scheme could be represented by very sparse low-order equations. However, due to the non-linear evolution of the algorithm's internal state, applying effective linearization methods used to solve equation systems created for schemes based on sufficiently long selected registers like LFSRs can be quite challenging.

Nevertheless, conducting research to draw conclusions about the algebraic properties of the algorithm would be prudent. It's known that the initialization process in the NHSA algorithm consists of 1076 steps. When applying algebraic cryptanalysis to this algorithm, the main goal is to construct and solve algebraic equations representing register cells after a certain iteration. From the following equations, it can be observed that in iterations 1 and 2, the bits of the key and initialization vector are involved in the equations representing the register cells.

Algebraic equation for iteration-1:

$$t_0 = k_{55} + 0 \cdot 0 + 0 + k_{72} \cdot k_{74} + IV_{72}$$
$$t_1 = IV_{62} + IV_{75} \cdot IV_{76} + IV_{77} + IV_{66} \cdot IV_{68} + IV_{119}$$
$$t_2 = IV_{92} + IV_{123} \cdot IV_{124} + IV_{125} + IV_{102} \cdot IV_{104} + k_{68}$$

Algebraic equation for iteration-2:

$$t_0 = k_{54} + 0 \cdot 0 + 0 + k_{71} \cdot k_{73} + IV_{71}$$
$$t_1 = IV_{61} + IV_{74} \cdot IV_{75} + IV_{76} + IV_{65} \cdot IV_{67} + IV_{118}$$
$$t_2 = IV_{91} + IV_{122} \cdot IV_{123} + IV_{124} + IV_{101} \cdot IV_{103} + k_{67}$$
$$(t_0, a_{172}, \ldots, a_{267}) \rightarrow (a_{172}, \ldots, a_{268})$$

Based on the formula provided, where the value of t_0 calculated from a quadratic nonlinear equation is written to the 172nd-order register cell before the 2nd iteration, the equations representing the cells of the third register begin to take on a quadratic form. Since the length of the third register is 97, 97 cycles are sufficient to transition this register to a quadratic form. In the second register, starting from the 63rd cycle, and in the first register, starting from the 73rd cycle, the algebraic level of equations representing the cells begins to increase. Thus, to achieve a complete quadratic representation, 73 + 89 = 162 iterations are required. The key bits are fully involved in the unknowns representing the equation system. The following table shows the change in the level of the equation system and the number of unknowns depending on the number of initialization process cycles:

Table – 2

Parameters of the equations formed using the algebraic cryptanalysis method for the NHSA algorithm

The minimum level of the equation system.	**Iteration step**	**The number of unknowns**	**Complexity O(n^3)**
Level-2	162	2^{14}	2^{42}
Level-3	162+97=259	2^{21}	2^{63}
Level-4	259+97=356	2^{28}	2^{84}
Level-5	356+97=453	2^{35}	2^{105}
Level-6	453+97=550	2^{42}	2^{126}
Level-7	550+97=647	2^{49}	2^{147}

It is evident that every 97 cycles after the 162nd iteration, the level of equations representing the register cells in algebraic form increases. From the Table 2 above, it is clear that the NHSA encryption algorithm is resistant to algebraic cryptanalysis due to the sharp increase in the number of unknowns (2^{49}) and the complexity of solving (2^{147}) after the 647th iteration of the initialization process.

Correlation attack on the NHSA algorithm.

In the security analysis of a synchronous stream cipher, cryptanalysts typically consider two different types of correlations. The first type is the correlation between the key stream bits and linear combinations of bits in the internal state, which potentially could lead to a complete state recovery. The second type of correlation attack involves the correlation between the key stream bits themselves.

It is evident that finding a linear correlation between the current key bits and the bits of the internal state is straightforward, as the i output bit is assumed to be equal to 〖output〗_i=a_55+a_82+b_62+b_77+c_60+c_93. However, unlike other ciphers based on LFSR , the internal state of NHSA changes non-linearly, making the process of combining these equations for efficient state recovery a rather complex problem.

The simplest way to find correlations of the second type is to traverse the linear paths of the cipher and set the output values of all encountered AND gates close to 0. However, the organization of operations in NHSA is designed in such a way that any path leads to the complete prediction of the values of at least 144 AND gate outputs in this specific type of observation. Below is an example of a linear combination to determine the correlation of key stream bits:

If we assume that the correlation of this linear combination is fully expressed in the considered specific manner, this equation will have a correlation coefficient of 2–144. To determine such a correlation, at least 2288 key stream bits are required, which significantly exceeds the security requirements and the full key selection method (2128).

Comparing the differential cryptanalysis method with the NHSA algorithm.

The idea of conditional differential cryptanalysis was expanded [107] and applied to constructions based on NLFSR (Non-Linear Feedback Shift Registers).

In the main concept of the differential cryptanalysis method, when applied to the NHSA algorithm, it involves observing two key values that differ only by a few bits and determining the probability of the difference value after each iteration. The difference between the key values is referred to as the increment.

Let the considered increment be Δf(k,x) and the 1-bit difference x in the i-th bit state be e_i. By neutrality of x_i in Δf, we understand the probability that Δf(k,x)=Δf(k,x⊕e_i) for a random key k. Using a single neutral variable as a differentiator requires estimating Δf at least twice. If the neutrality of x_i is p, then the overall probability is |1/2 - p|.

To determine the conditions for data collection, the following algorithm proposed in [4] was utilized:

Input: $a_1, a_2, \dots, a_d, r$

$J \leftarrow \emptyset$

foreach $a \in \{a1, \dots, ad\}$ **do**

for $i \leftarrow 0$ **to** $r - 1$ **do**

$f \leftarrow \triangle_a\, s_i(k,x) \bmod J$

if $f = 1$ **then**

add f to J

return J

In this case $a_1, a_2, \dots, a_d$ are binary vectors defined in space F_2^n.

During the analysis, we utilize a 24-bit adder. Conditions for 24 differences were determined using the algorithm mentioned above. We use the abbreviation $\triangle z_j = \triangle^{(24)}_{a_1,a_2,\dots,a_d} z_j$, here $z_j - j$ refers to the key stream generated in this iteration.

Using the algorithm provided above, conditions were analyzed for the case r = 200, where each increment is controlled for the first 200 iterations. After processing the first increment, the first increment (increment at point x_0) is generated as follows:

$$J = \langle x_0, x_{10}x_{11} + x_{13}, x_{13}x_{14} + x_{15}, x_{76} + k_{64}, x_{61} + x_{74}x_{75} + x_{74}k_{63} + x_{75}k_{62} + k_{49} + k_{62}k_{63} + k_{74}k_{75} + k_{76}, x_{63} + k_{51} + k_{76}k_{77} + k_{78}, k_{11}k_{12} + k_{13} + k_{55}, k_{13}k_{14} + k_{15} + k_{57}\rangle$$

At different algebraic parameters J, all pairs (k,x) have the same differential characteristic with respect to a_1 up to $r = 200$ periods. After processing all the increments, the value of J looks as follows:

$$J = \langle x_0, x_1, x_3, x_4, x_6, x_7, x_9, x_{10}, x_{12}, x_{13}, x_{15}, x_{16}, x_{18}, x_{19}, x_{21}, x_{22}, x_{24}, x_{25}, x_{27}, x_{28}, x_{30}, x_{31}, x_{33}, x_{34}, x_{36}, x_{37}, x_{39}, x_{40}, x_{42}, x_{43}, x_{45}, x_{46}, x_{48}, x_{49}, x_{51}, x_{52}, x_{54}, x_{55}, x_{57}, x_{58}, x_{60}, x_{61}, x_{63}, x_{64}, x_{66}, x_{67}, x_{69}, x_{70}, x_{72}, x_{73}, x_{75}, x_{76}, x_{78}, x_{79}, x_{81}, x_{82}, x_{84}, x_{85}, x_{87}, x_{88}, x_{90}, x_{91}, x_{93}, x_{94}, x_{96}, x_{97}, x_{99}, x_{100}, x_{102}, x_{103}, x_{105}, x_{106}, x_{108}, x_{109}, x_{111}, x_{112}, x_{114}, x_{115}, x_{117}, x_{118}, x_{120}, x_{121}, x_{123}, x_{124}, x_{126}, x_{127}, k_0, k_1, k_3, k_4, k_6, k_7, k_9, k_{10}, k_{12}, k_{13}, k_{15}, k_{16}, k_{18}, k_{19}, k_{21}, k_{22}, k_{24}, k_{25}, k_{27}, k_{28}, k_{30}, k_{31}, k_{33}, k_{34}, k_{36}, k_{37}, k_{39}, k_{40}, k_{42}, k_{43}, k_{45}, k_{46}, k_{48}, k_{49}, k_{51}, k_{52}, k_{54}, k_{55}, k_{57}, k_{58}, k_{60}, k_{61}, k_{63}, k_{64}, k_{66} + 1, k_{67}, k_{69}, k_{70}, k_{72}, k_{73}, k_{75}, k_{76}, k_{78}, k_{79}, k_{81}, k_{82}, k_{84}, k_{85}, k_{87}, k_{88}, k_{90}, k_{91}, k_{93}, k_{94}, k_{96}, k_{97}, k_{99}, k_{100}, k_{102}, k_{103}, k_{105}, k_{106}, k_{108}, k_{109}, k_{111}, k_{112}, k_{114}, k_{115}, k_{117}, k_{118}, k_{120}, k_{121}, k_{123}, k_{124}, k_{126}, k_{127}\rangle.$$

Only the bits $x_{61}, x_{64}, x_{67}, x_{70}$ in x are not specified and do not affect the increment. When all other variables x_i are set to zero, this makes them candidates for neutral bits for $\triangle z_j$. Empirical results confirm that they are likely to be neutral up to the 537th round. Table 3 shows the neutrality obtained in the experiment with 100 random keys. Note that neutrality equal to zero or one means that $\triangle z_j$ is linear in the corresponding variable (which can be used as an amplification coefficient with neutrality).

Table-3.

Neutrality indicators defined for the bits $x_{61}, x_{64}, x_{67}, x_{70}$

j	x_{61}	x_{64}	x_{67}	x_{70}
501	1.0	1.0	1.0	1.0
514	0.10	0.15	0.05	0.10
525	0.25	0.30	0.20	0.30
537	0.40	0.35	0.35	0.40
550	0.495	0.502	0.499	0.505

If experiments are conducted using weak keys, these neutrality values can be preserved until the iteration process (550+162=712), which is necessary before the complete update of the algorithm's register values. In subsequent cycles, the neutrality values approach 0.5. This parameter provides tolerance in statistical cryptanalysis methods. Therefore, it is sufficient to conclude the resilience of the NHSA stream cipher to differential cryptanalysis from the 712th cycle of the initialization loop.

Resynchronization Attack on the NHSA Algorithm.

Another type of attack is the resynchronization attack, where an attacker is allowed to manipulate the IV value and tries to gain information about the key by checking the corresponding key stream. The NHSA algorithm attempts to prevent this type of attack by performing a sufficient number of iterations in the initialization process before generating the key used for encryption. It can be shown that each bit of the state is nonlinearly dependent on each key and IV bit after two full cycles (i.e., 2 · 269 iterations). It can be noted that an additional two cycles are sufficient to protect the cipher from resynchronization attacks.

NHSA is a simple synchronous stream encryption algorithm that is well suited for applications requiring flexible hardware implementation. Despite the general rule to avoid sparse update functions at each algorithm iteration, only a few state bits are used. As a result, prediction and attack detection are undoubtedly complicated. A direct attack involves guessing the common 128-bit secret key (presumably the open key IV). Further research is needed to determine the extent to which more complex attacks can reduce this number. The conducted studies are crucial to draw conclusions about its security compliance.

Since the NHSA algorithm is analogous to the Trivium encryption algorithm in terms of its operation and structure, the evaluation results of cryptanalysis methods were compared with the Trivium algorithm (Table 4).

Table - 4

The evaluation results of the Trivium and NHSA algorithms for cryptanalysis methods are as follows:

Algorithm	**Trivium**	**NHSA (this case)**
Algebraic cryptanalysis	$2^{42.2}$ is unknown in the 625th iteration of the initialization cycle 110	2^{42} is unknown in the 550th iteration of the initialization cycle
Differential cryptanalysis	Resilient after the 961st iteration of the initialization cycle [108].	Resilient after the 712th iteration of the initialization cycle.
Resynchronization attack	2^{80} need to choose	2^{128} need to choose
Correlational cryptanalysis	A key stream of 2^{144} bits is required to determine the correlation coefficient of 2^{-72} [109]	A key stream of 2^{-144} bits is required to determine the correlation coefficient of 2^{288}

The results of evaluating sequences generated by the NHSA algorithm using NIST statistical tests for randomness.

Sequences generated using the above key and IV in the NewHSA algorithm were evaluated for randomness using NIST statistical tests. Below are the results of this test (Figure 1):

```
SUMMARY
-------
monobit_test                                0.3828976248514478 PASS
frequency_within_block_test                 0.6354841415737159 PASS
runs_test                                   0.48512504500511644 PASS
longest_run_ones_in_a_block_test            0.4084594094693384 PASS
binary_matrix_rank_test                     0.08050322562050827 PASS
dft_test                                    0.6543472577764083 PASS
non_overlapping_template_matching_test      1.00000828105159   PASS
overlapping_template_matching_test          0.03940335533694327 PASS
maurers_universal_test                      0.9991531960785148 PASS
linear_complexity_test                      0.6468061465110148 PASS
serial_test                                 0.16944057962301154 PASS
approximate_entropy_test                    0.16901368121036756 PASS
cumulative_sums_test                        0.16791543598886172 PASS
random_excursion_test                       0.04385947941605159 PASS
random_excursion_variant_test               0.12339191184909339 PASS
```

Figure 1. Results of evaluation of NHSA algorithm by Nist statistical test

From these results, it can be observed that the sequences generated using the NHSA algorithm meet the security requirements in terms of randomness.

IV. Conclusion

The description of the NHSA stream cipher algorithm, consisting of 3 shift registers with a total length of 269 bits, 6 AND gates, and 14 XOR gates, is provided. The evaluation results of sequences generated using the proposed algorithm in terms of randomness are presented, along with conclusions about the applicability of various cryptanalysis methods and information about the required hardware resources for implementing the algorithm.

It has been established that the NHSA encryption algorithm is resistant to algebraic cryptanalysis, differential cryptanalysis, correlation cryptanalysis, and resynchronization attacks. The sequences generated by the algorithm satisfy randomness criteria based on the evaluation of randomness levels using NIST statistical tests.

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NewHSA: New Hardware-Implemented Stream Encryption Algorithm

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Abstract. This paper presents a description of the NewHSA stream encryption algorithm, which consists of 4 shift registers, 3 AND elements and 23 XOR elements. The number of gates required for the hardware implementation of the NewHSA algorithm is 830. The results of evaluating sequences generated using this algorithm for randomness are provided. Additionally, information about the number of components required for implementing the algorithm on hardware devices is presented.

Keywords: Stream ciphers, hardware and software, LFSR, NLFSR, NIST, gate, AND, XOR.

I. Introduction

Stream cipher algorithms are gamma-based encryption algorithms that convert each successive 1 bit of plaintext to ciphertext by XORing the corresponding 1-bit gamma key generated by the generator [1]:

$$c_i = p_i \oplus k_i$$

The recipient performs an XOR operation between the encrypted text and the corresponding 1-bit gamma key. This gamma key is generated by the same encryption generator using a secret symmetric key. This process is done to generate the plaintext from the received encrypted text:

$$c_i \oplus k_i = p_i \oplus k_i \oplus k_i = p_i$$

Unlike block ciphers, there isn't a standardized model for developing stream ciphers. This has prompted cryptographers to create several models for stream ciphers. For practical implementation purposes, stream ciphers are categorized into different groups, and these categories include stream ciphers with distinct properties. These categories can be classified into three main directions[2]:

- hardware (Hardware) stream ciphers;
- software (Software)stream ciphers;
- hybrid (Hybrid) stream ciphers.

Hardware based. The classification of hardware stream ciphers includes stream ciphers based on FSSR/NLFSR, clock control, and LFSR. The utilization of hardware stream ciphers plays a significant role in the security of many cryptographic applications. Modern algorithms such as Trivium, Grain80, F-FCSR-H, Grain128, Mickey128, Mickey2(80), Pomaranch80, Pomaranch128, Moustique, Decim80, Decim128, Edon80pl, are examples of algorithms belonging to the category developed in the field of hardware design [3].

Software based. Software stream ciphers encompass T-functions, block ciphers, S-boxes, and simple logical and arithmetic operations. Compared to hardware stream ciphers, ciphers in this category differ in that they rely on bit manipulations (substitution, replacement) and appear more logically structured. Examples of software stream ciphers include modern algorithms such as RC4, DRAGON, HC-128, LEX, Salsa20, Salsa20 v2, Salsa20/12 v2, SOSEMANUK (M), SOSEMANUK (F).

Hybrid based. Hybrid stream ciphers consist of stream ciphers created by combining hardware and software components. Most stream ciphers in this category are based on LFSR (Linear Feedback Shift Register).

There have been many studies on streaming algorithms and their evaluation [4-20].

The proposed new stream encryption algorithm, NewHSA (New Hardware Stream Algorithm), is easy to implement in hardware. In terms of appearance and structure, it resembles the A5/1 encryption algorithm based on LFSR and the Trivium algorithm based on NLFSR. Therefore, a comparative analysis is conducted using these algorithms.

The initial state of NewHSA consists of 4 shift registers with a total length of 64 bits. Each state is changed through a combination of nonlinear bit transmission and feedback in cyclic shift registers to the right. For the encryption process, K key values of length 128 bits are written into the 4 shift registers according to a specified rule. The algorithm then runs 16*64 = 1024 times. Afterward, the remaining 64 bits of the key are added to the bits in the register using two modules, and the algorithm is executed another 1024 times. This ensures that each bit of the initial state depends on every bit of the key and the initialization vector.

After the initialization phase, each cycle generates a new element of the output key stream, which is added to the next bit of the plaintext using an XOR operation (modulus 2 addition). Decryption is performed in reverse order — each bit of the encrypted text is combined using an XOR operation with each bit of the output key stream.

II. Main part.

Initialization Process

The algorithm begins by loading a 64-bit key into the 64-bit initial state registers (17 + 19 + 13 + 15). The initialization process can be described using the following pseudocode:

$(K_0, \dots, K_{16}) \to (a_0, a_1, \dots, a_{16})$

$(K_{17}, \dots, K_{35}) \to (b_0, b_1, \dots, b_{18})$

$(K_{36}, \dots, K_{48}) \to (c_0, c_1, \dots, c_{12})$

$(K_{49}, \dots, K_{63}) \to (d_0, d_1, \dots, d_{14})$

$for\ i = 0\ to\ 1023\ do$

$a_5 + a_8 \cdot a_9 + a_{10} + a_{14} + a_{16} + b_{10} \to t_0$

$b_7 + b_{12} \cdot b_{13} + b_{14} + b_{16} + b_{18} + c_9 \to t_1$

$c_4 + c_6 \cdot c_7 + c_8 + c_{10} + c_{12} + d_{11} \to t_2$

$d_6 + d_8 \cdot d_9 + d_{10} + d_{12} + d_{14} + a_{13} \to t_3$

$(t_3, a_0, \dots, a_{15}) \to (a_0, \dots, a_{16})$

$(t_2, b_0, \dots, b_{17}) \to (b_0, \dots, b_{18})$

$(t_1, c_0, \dots, c_{11}) \to (c_0, \dots, c_{12})$

$(t_0, d_0, \dots, d_{13}) \to (d_0, \dots, d_{14})$

$end\ for.$

$(a_0 + K_{64}, a_1 + K_{65}, \dots, a_{16} + K_{80})$

$(b_0 + K_{81}, b_1 + K_{82}, \dots, b_{18} + K_{99})$

$(c_0 + K_{100}, c_1 + K_{101}, \dots, c_{12} + K_{112})$

$(d_0 + K_{113}, d_1 + K_{114}, \dots, d_{14} + K_{127})$

$for\ i = 0\ to\ 1023\ do$

$a_5 + a_8 \cdot a_9 + a_{10} + a_{14} + a_{16} + b_{10} \to t_0$

$b_7 + b_{12} \cdot b_{13} + b_{14} + b_{16} + b_{18} + c_9 \to t_1$

$c_4 + c_6 \cdot c_7 + c_8 + c_{10} + c_{12} + d_{11} \to t_2$

$d_6 + d_8 \cdot d_9 + d_{10} + d_{12} + d_{14} + a_{13} \to t_3$

$(t_3, a_0, \dots, a_{15}) \to (a_0, \dots, a_{16})$

$(t_2, b_0, \dots, b_{17}) \to (b_0, \dots, b_{18})$

$(t_1, c_0, \dots, c_{11}) \to (c_0, \dots, c_{12})$

$(t_0, d_0, \dots, d_{13}) \to (d_0, \dots, d_{14})$

$end\ for.$

Generation. The stream generator utilizes the values of the 8-bit segments from the 64-bit initial state registers to modify a 4-bit portion of the state register and the 28-bit values of the key stream, advancing by 1 bit. After an initialization process comprising 2048 iterations, the values of these 28 bits can be influenced entirely by the key and initialization vector values. The process of generating a bit key N ($N \leq 2^{64}$) required for encryption can be expressed using the following pseudocode.

$for\ i = 0\ to\ N\ do$

$a_5 + a_{10} \to t_0$

$b_7 + b_{14} \to t_1$

$c_4 + c_8 \to t_2$

$d_6 + d_{10} \to t_3$

$t_0 + t_1 + t_2 + t_3 \to output_i$

$a_5 + a_8 \cdot a_9 + a_{10} + a_{14} + a_{16} + b_{10} \to t_0$

$b_7 + b_{12} \cdot b_{13} + b_{14} + b_{16} + b_{18} + c_9 \to t_1$

$c_4 + c_6 \cdot c_7 + c_8 + c_{10} + c_{12} + d_{11} \to t_2$

$d_6 + d_8 \cdot d_9 + d_{10} + d_{12} + d_{14} + a_{13} \to t_3$

$(t_3, a_0, \dots, a_{15}) \to (a_0, \dots, a_{16})$

$(t_2, b_0, \dots, b_{17}) \to (b_0, \dots, b_{18})$

$(t_1, c_0, \dots, c_{11}) \to (c_0, \dots, c_{12})$

$(t_0, d_0, \dots, d_{13}) \to (d_0, \dots, d_{14})$

$end\ for.$

The provided pseudocode indicates that the addition ($+$) and multiplication ($\cdot$) operations are represented as XOR and AND operations, respectively, performing addition and multiplication modulo 2.

Here is an example of the proper organization of the generation process using the algorithm:

Input parameters:

*Kalit:*0001110000000011000110111000011001000010110001001001100000000100011001110110011010100010010010 1111100011111000011101000011100010 1111

Values of the registers before the initialization process:

a: 00011100000001100

b: 0110110000110010000

c: 1011000100100

d: 110000000100011

Values of the registers after the initialization process:

a: 10101001101000001

b: 1111111100101110010

c: 0000100110010

d: 110100111001100

*Output:*0001001011110010010010011111101000100001001000110001111100010001100101111110 1111…

Using this algorithm, it is recommended to generate keys with a length of 2^{64} bits, using a single key and initialization vector.

NewHSA is a hardware-oriented adaptive algorithm (Fig.1). It aims to be compact in environments with gate limitations, energy-efficient on platforms with limited power consumption, and fast in applications requiring high-speed encryption.

The requirement for compact implementation implies a bit-oriented approach. Additionally, it's necessary to ensure non-linearity in the output of the key stream generator's internal registers. Furthermore, efficient energy usage and quick implementation are also required.

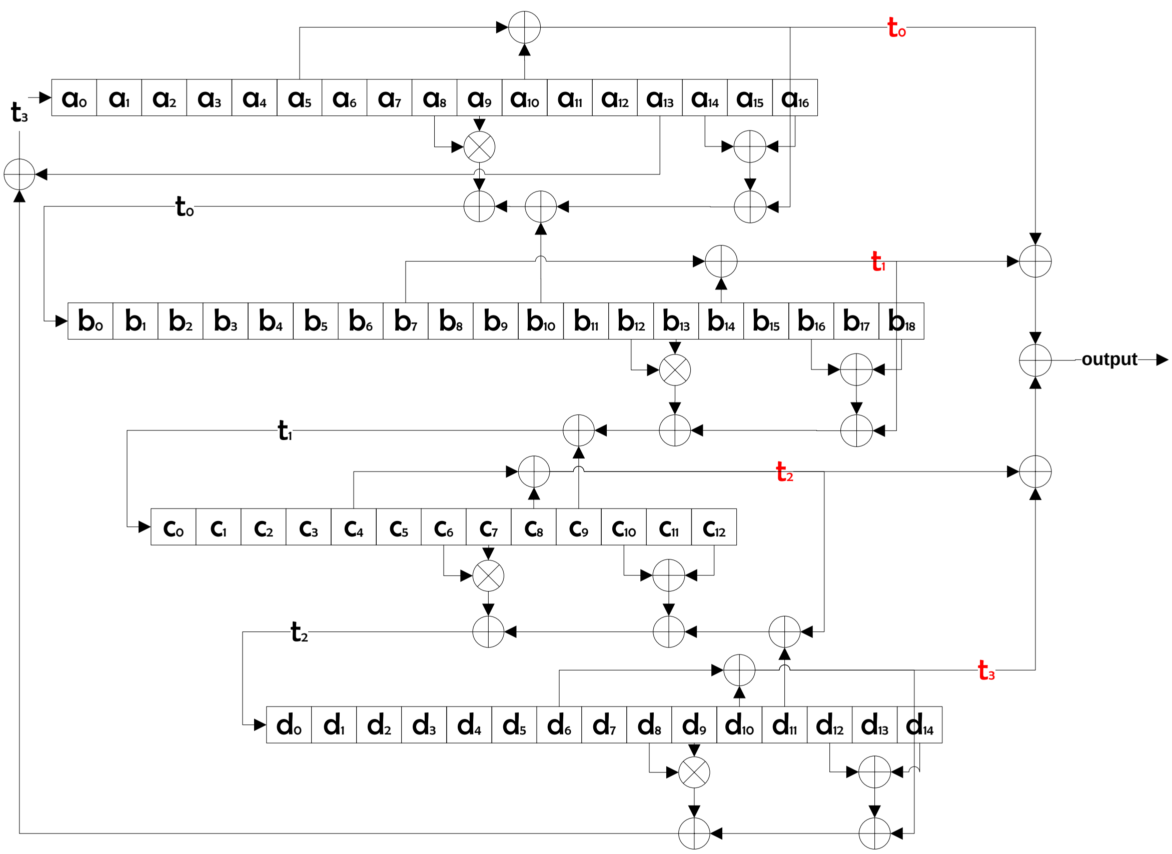

Figure 1. Scheme of the NewHSA algorithm

Based on the figures provided in [3] (i.e., 12 NAND gates per trigger (shift register element), 2.5 NAND gates for XOR, and 1.5 NAND gates for AND), you can calculate the number of gates required for a potential hardware implementation. The results of the comparative analysis with the Trevium algorithm [2], which is one of the top stream cipher algorithms participating in the EStream competition, are presented in Table 1.

Table 1. Number of gates required for hardware implementation of NewHSA, A5/1 and Trevium algorithms

Algorithm	**Trevium**	**A5/1**	**NewHSA**
Key length	80	64	128
IV length	80	-	-
Internal state register	288*12=3456	64*12=768	64*12=768
AND gate	3*1.5=4.5	3*1.5=4.5	3*1.5=4.5
XOR gate	11*2.5=27.5	17*2.5=42.5	23*2.5=57.5
Total number of gates	**3488**	**815**	**830**

III. Results

The period of the NHSA algorithm.

As the internal state of the algorithm evolves non-linearly, determining its exact period is challenging. However, the period of the algorithm's operation can be estimated through a series of observations. Firstly, it can be shown that any key/IV pair can produce a stream with a period of at least 2^{83-3}-1 if a complete linear circuit without NAND gates is obtained. This doesn't directly impact NHSA but can be considered an indication that the register lengths have been chosen correctly.

Secondly, the internal state of NHSA is updated in reverse order, and the initialization of the register $(c_0,..,c_{96})$ prevents state changes in fewer than 96 iterations. Assuming that NHSA behaves like a random permutation after a sufficient number of iterations (in this case, 269*4=1076 iterations), all cycle lengths up to 2^{269} are equally likely. Thus, for this key/IV pair, the probability that it generates a cycle shorter than 2^{128} is $2^{269-128}=2^{141}$.

However, it's recommended to generate a 2^{64} bit key using a single key/IV pair to ensure maximum reliability of the generated keys.

Sequences generated using the above key in the NewHSA algorithm were evaluated for randomness using NIST statistical tests. Below are the results of this test:

Table 2. Randomness test results using NIST tests

№	**Tests**	***p* palue**	**Result (PASS/FAIL)**
1.	The Frequency (Monobit) Test	0.79688	PASS
2.	Frequency Test within a Block	0.02757	PASS
3.	The Cumulative Sums (Cusums) Test	0.33667	PASS
4.	Tests for the Longest-Run-of-Ones in a Block	0.37428	PASS
5.	The Runs Test	0.18794	PASS
6.	The Binary Matrix Rank Test	0.88073	PASS
7.	The Discrete Fourier Transform (Spectral) Test	0.63110	PASS
8.	The Non-overlapping Template Matching Test	1.0	PASS
9.	The Overlapping Template Matching Test	0.47621	PASS
10.	Maurer's "Universal Statistical" Test	0.99971	PASS
11.	The Random Excursions Test	0.26745	PASS
12.	The Random Excursions Variant Test	0.05239	PASS
13.	The Approximate Entropy Test	0.24955	PASS
14.	The Serial Test	0.10822	PASS
15.	The Linear Complexity Test	0.94435	PASS

IV. Conclusion

This paper presents a description of the NewHSA stream cipher algorithm, which consists of 4 shift registers, 3 AND gates, and 23 XOR gates. The number of gates required for the hardware implementation of the NewHSA algorithm is 830. The results of evaluating sequences generated using the mentioned algorithm for randomness and conclusions regarding the transferability of certain cryptanalysis methods, as well as information about the number of elements needed for the implementation of the algorithm on hardware devices, have been presented.

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ANALYSIS AND ASSESSMENT OF THE SUSTAINABLE DEVELOPMENT OF FUEL AND ENERGY COMPLEX ENTERPRISES IN THE CONDITIONS OF THE FORMATION OF THE DIGITAL ECONOMY

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***Abstract* — The article discusses the main factors of sustainable development of the branches of the fuel and energy complex of the Republic of Uzbekistan. Methods and ways of improving the organizational and economic mechanism of sustainable development of energy enterprises are proposed. A methodology for sustainable development of enterprises of the fuel and energy complex is proposed, taking into account all groups of indicators in accordance with their role in the production process. Scientifically grounded proposals on the strategy of effective development and reforming of the fuel and energy complex of the republic have been developed.**

***Keywords* —** sustainable development, digital economy, nuclear energy, renewable energy sources, energy saving, energy efficiency, fuel and energy complex.

Introduction

The sustainable development of the fuel and energy complex remains a priority in the policy of any progressively developing state. The fuel and energy complex of the Republic of Uzbekistan is the largest association in Central Asia of enterprises for the extraction, processing, transportation of oil, natural gas, coal, production and distribution of electrical and thermal energy. Uzbekistan is rich in mineral resources - some data are given in table 1.

The Energy Strategy sets the task of ensuring long-term energy independence and security, increasing energy efficiency, and reducing the impact of energy on the environment. Solving these problems requires the development and implementation of new technologies based on scientific achievements that provide a safer, cleaner energy.

Over the past decade, the fuel and energy sector accounts for more than 23% in the formation of the GDP of the Republic of Uzbekistan (Fig. 1.).

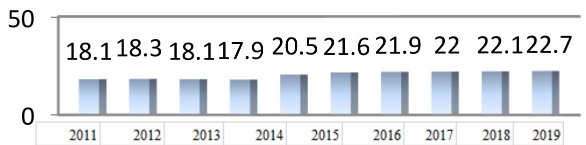

Figure 1. Dynamics of changes in the share of fuel and energy industries in the formation of the GDP of the Republic of Uzbekistan.[1]

However, Uzbekistan's economy is very energy-intensive by international standards. The GDP per unit energy consumption index (constant 2019 PPP US$ per 1 kg oil equivalent) for Uzbekistan in 2020 was US$1.5 per kg of oil equivalent. For comparison, the same indicator in the same year for Russia was 3, Turkmenistan - 1.7, the USA - 5.9, Switzerland - 10.6, Singapore - 12.5, Indonesia - 4.3. This is due to the use of technologically obsolete equipment, a high share of fuel and energy resources in the country's exports, relatively low prices for electricity and some types of fuel, an inadequate accounting system for the production and consumption of electricity and energy resources , etc. [2]

Reforms in the fuel and energy sector went in parallel with the reform of the country and were aimed at ensuring the fuel and energy independence of Uzbekistan, as well as providing fuel and energy resources for the needs of the country's economy.

Reforming fuel and energy enterprises is a complex and expensive process, therefore, at the initial stage of reform, priority goals and means to achieve them are determined.

The main goals of the transformations are [3]:

- improving the efficiency of fuel and energy facilities and fuel and energy sectors as a whole by creating new, market-based incentives for companies and eliminating cross-subsidization;
- attracting foreign investment in the development of fuel and energy companies;
- reducing the burden on the expenditure side of the state budget.

The ultimate goal of the reform is to create a competitive market for the fuel and energy complex , which will make it possible to most effectively use the existing innovative potential of the industry.

Let's analyze the economic state of the fuel and energy complex of the Republic of Uzbekistan. In 2011-2019, the fuel and energy sectors produced products worth 122881.5 billion soums, including 29579.6 billion soums in 2019. The share of these industries in the total industrial output of the country amounted to more than 20% (Fig. 2.).

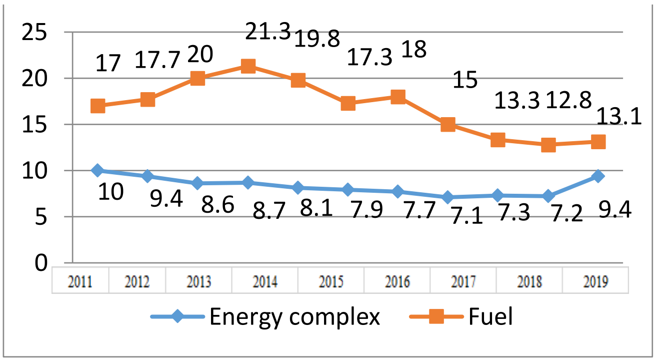

Figure 2. Dynamics of changes in the share of the electric power industry and the fuel industry in the total volume of industrial production[4]

As part of the industry, science-intensive industries grew rapidly, in which the main factor in the development of production is the availability and rational use of intellectual capital[5]. If in 1991 the share of these industries was 32.4% of the total industrial output, then in 2020 their share almost doubled and amounted to more than 61.8% (Fig. 4.).

It should be noted that a significant increase in the share of science-intensive industries was noted already in 1991–2020, that is, during the period of economic stabilization. This once again confirms our conclusion that the success of economic reforms in Uzbekistan, stabilization, and outstripping economic growth took place not only in the main areas of economic reform but also in key industrial technologies.

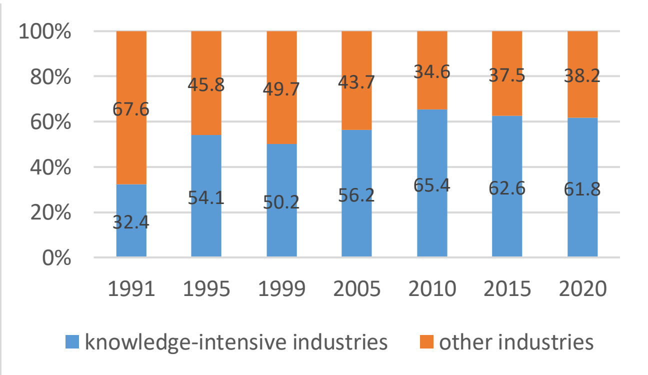

Figure 3. Dynamics of the share of science-intensive and other industries in the total volume of industrial production in 1991-2020.

Implementing the main priorities of the development of the economy, the fuel and energy industry attracts foreign investment to ensure the modernization, reconstruction, technical and technological re-equipment of enterprises through the introduction of both domestic and foreign innovative solutions. For the analyzed years, they amounted to more than 20 trillion sums. Their share in foreign investments attracted to the development of industry as a whole is more than 60% (Table 1.).

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Industry	56.6	30.4	33.7	42.5	45.9	46.2	67.7	68.0	87.7
Branches of fuel and energy complex	32.2	14.3	10.9	25.7	31.6	35.6	58.6	59.2	62.1
The share of the fuel and energy complex in the volume of foreign investments in the industry	56.9	47.0	32.3	60.5	68.8	77.1	86.6	87.1	90.2

Table 1. The share of foreign investments in the fuel and energy sector in their total volume in the Republic of Uzbekistan (%)[6].

The table shows that the share of foreign investments disbursed in the fuel and energy sector to their volume in industry increased over the analyzed period by more than 1.5 times and in 2019 was already 90% against 57% in 2011. Investments in the fuel and energy sector, created at the expense of all sources, were directed to a greater extent into fixed capital and capital repairs. These trends persisted throughout the analyzed period, but their proportion changed (Table 2).

	2011	2012	2013	2014	2015	2016	2017	2018	2019
TOTAL	100	100	100	100	100	100	100	100	100
Into fixed capital	91.1	94.6	86.0	92.5	95.0	93.4	95.4	93.6	96.1
for a major overhaul	8.9	5.4	13.9	7.4	4.7	6.6	4.6	6.4	3.9

Table 2. Dynamics of the investment structure in the fuel and energy sector for 2011-2019 (%)[7].

The main production assets of the fuel and energy complex industries have developed the following structure of fixed production assets that occupy a dominant position in their total volume in the industry as a whole (Table 1.). By 2019, it had significant differences from the structure of fixed assets for the industry as a whole (Fig. 6.).

The figure shows that if in the industry as a whole the largest share (about 44%) falls on machinery and equipment and more than 23% on structures, then in the electric power industry - about 36% falls on transmission devices and 34% - machinery and equipment, and in the fuel industry - more than 52% are buildings, about 22% - machinery and equipment, and about 18% - transmission devices. Such discrepancies are related to the specifics of the functioning of the fuel and energy industries.

Directions	2011	2012	2013	2014	2015	2016	2017	2018	2019
Industry	100	100	100	100	100	100	100	100	100
including:									
Electric power industry	13.1	13.8	13.6	12.4	12.8	14.8	14.7	14.7	15.1
fuel	29.6	30.1	28.9	31.3	30.7	31.2	31.4	31.8	32.4

Table 3. The structure of fixed production assets in the electric power industry and in the fuel industry[8].

Despite the significant funds invested in reconstruction and modernization, the depreciation rate of fixed assets remains high, and the renewal rate is relatively low. At the same time, it should be noted that these indicators are better than in the industry as a whole (Table 4.).

Directions	2011	2012	2013	2014	2015	2016	2017	2018
Depreciation coefficient of industrial and production fixed assets								
Industry	47.1	44.2	43.1	43.3	42.7	41.6	41.2	41.1
Incl.								
Electric Power industry	55.4	49.0	47.5	48.9	46.5	37.9	38.4	37.9
Fuel industry	31.8	30.0	32.5	32.7	34.2	34.9	34.7	35.9

Table 4. Dynamics of the level of depreciation of fixed assets by sectors of the fuel and energy complex[9].

As can be seen from the data presented, the wear factor in the fuel and energy sector is below the industry average, and in the electric power industry it tends to decrease. In the fuel industry, despite the fact that the level of wear is below average, however, in comparison with 2011, it has grown by almost 10%, and at the same time, an upward trend is visible.

During the analyzed period, the fuel and energy sector received profit from the sale of products in the amount of 28.6 trillion sums, and its annual size increased by 38.6%. In the electric power industry, during this period, profits were received from the sale of products by 7.8 trillion sums, and the annual amount increased in 2019 against 2012 by 3.2 times, in the fuel industry, respectively, 20.8 trillion sums, the annual increase was only 2.9%. However, the position of fuel and energy enterprises is complicated by the persistence of accounts receivable throughout the entire analyzed period, which in the electric power industry is about half, and in the fuel industry - more than 70% of all current (current) assets and, associated with this, accounts payable.

The structure of the production cost of manufactured products practically did not change during the analyzed period.

A comparison of the structure of the production cost of fuel and energy industries with the industry average for 2019 showed that the largest share is occupied by production material costs (about 70%), wages and social insurance contributions, as well as other costs are almost the same, respectively, 10% and 6%. Only the costs of depreciation of fixed assets differ, which in the fuel industry account for more than 16% (the most capital-intensive industry), while in the electric power industry it is only slightly more than 8%, and in the industry as a whole - 6.2%.

ACKNOWLEDGMENT

Thus, it can be said that, in general, the state of the fuel and energy complex sectors can be considered satisfactory, however, given the importance of their further sustainable development for the country's economy as a whole, it should be noted certain positions that, while maintaining the current trend in their dynamics, can lead to negative consequences. This, first of all, refers to the state of settlements, that is, to receivables and payables.

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[9] Constructed by the author on the basis of data from the State Statistics Committee of the Republic of Uzbekistan.

Structural features of epitaxial solid solution films$(Si_2)_{1-x}(GaN)_x$ grown on Si substrates from the liquid phase

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***Abstract* – On the basis of the crystal chemical representation, which takes into account the geometric factors and the shell structure of the atom, as well as the effective charge of the nucleus, the possibility of forming a substitutional solid solution based on Si and GaN is estimated. On Si (111) substrates with a diameter of 20 mm, continuous epitaxial layers of $(Si_2)_{1-x}(GaN)_x$ solid solutions were grown by liquid-phase epitaxy from a limited volume of a tin solution-melt. The grown films had n-type conductivity and a smooth surface with high adhesive properties to the substrate.**

An analysis of the X-ray diffraction pattern showed that the grown epitaxial film has a perfect single-crystal structure with the (111) orientation. The size of the film subcrystallites is ~40 nm. Due to the replacement of paired Si atoms by a molecule consisting of Ga and N atoms, a slight bending of the film towards the perpendicular to the reflecting surface was observed. Coherently arranged nanocrystals of cubic (c - GaN) and hexagonal (h - GaN) modification of gallium nitride with a crystallite size of $L_{GaN} \approx 47$ nm are formed in the crystal lattice of the epitaxial film.

Keywords: Substitutional solid solution, epitaxial film, generalized moment of molecules, photoluminescence, current-voltage characteristic, energy band.

I. Introduction

Gallium nitride (GaN) is a direct-gap semiconductor with a band gap of 3.4 eV, which allows the use of a wide spectrum of electromagnetic waves. By introducing Si, Mg [1] and Ge [2] into its composition, it is possible to grow GaN crystals with n- and p-type conductivities. The excellent optical and electrical properties of GaN make it an attractive material for optoelectronics and high-speed electronic devices, including LEDs, detectors, lasers [3–9], and high-power and high-frequency devices [10]. GaN-based devices are ideal for power amplifiers operating at frequencies that are unattainable with Si-based technology. GaN power electronics offer less power loss than Si devices and can operate at higher temperatures. The integration of GaN devices with Si integrated circuits provides a scalable CMOS (complementary metal oxide semiconductor) technology platform [11] for high-power and high-performance optoelectronics. Over the past 20 years, GaN has become the most researched semiconductor after silicon due to its excellent optical and electrical properties.

At present, due to the high cost of native substrates, GaN is grown on foreign substrates, such as sapphire (Al_2O_3), SiC, and Si [12–14]. However, there is a mismatch between the lattice constant and thermal expansion coefficient of the GaN film and the foreign substrate. As a result, dense point defects, threaded dislocations, and residual stresses appear in finished films, which reduce the service life and efficiency of optoelectronic devices fabricated on their basis [15–17]. When growing GaN on Si (GaN-on-Si), two main problems arise: (1) the nucleation of an AlN buffer layer grown to prevent the formation of a Ga-Si alloy and compensate for thermal stresses, as well as the quality of the resulting AlN/Si interface; and (2) cracking of the epitaxial layer due to the higher thermal expansion coefficient of nitrides compared to Si. GaN layers crack when the layer thickness exceeds ~1 μm [18]. At present, GaN-on-Si technology has greatly improved. However, the mass adoption of GaN-on-Si for illumination is still controversial, mainly because epitaxial layers on Si are more difficult to grow compared to GaN on Al_2O_3. For electronic applications, the situation is more favorable for GaN-on-Si due to the poor electrical and thermal conductivity of Al_2O_3 (sapphire) and the high cost of SiC, which are commonly used as substrates for GaN [19, 20]. High-quality GaN layers can be obtained on Si substrates through buffer layers from a continuous solid solution of molecular substitution $(Si_2)_{1-x}(GaN)_x$, with a smoothly changing composition from silicon to pure gallium nitride ($0 \le x \le 1$). This buffer layer, by leveling the mismatch between the lattice constant and the thermal expansion coefficient of the Si substrate and the GaN epitaxial film, prevents the occurrence of residual mechanical stresses in the transition region and, as a consequence, the reduction of point defects and threading dislocations in the epitaxial layer.

In this article, we report the possibility of growing epitaxial layers of solid solutions of molecular substitution $(Si_2)_{1-x}(GaN)_x$ on Si (111) substrates by liquid-phase epitaxy from a molten tin solution and present the results of an experimental study of the structural features of epitaxial films using the X-ray diffraction method.

II. Materials and Methods

A. Condition for the formation of a solid solution $(Si_2)_{1-x}(GaN)_x$

To assess the possibility of forming a solid solution, we rely on crystal chemical concepts based on the rules of generalized moments [21], according to which the smaller the absolute value of the difference between the generalized moments of ions, atoms, or molecules of solution-forming substances, the greater their mutual solubility:

$$c' = \frac{c''\cdot e^{-\frac{(m-m_0)\cdot(\varphi'-\varphi'')}{kT}}}{1+\left[e^{-\frac{(m-m_0)\cdot(\varphi'-\varphi'')}{kT}}-1\right]\cdot c''\cdot V} \qquad (1)$$

where c' and c'' are the mole fractions of the dissolved component in the solid (′) and liquid (″) phases, φ' and φ'' are the average values of the potentials of molecular fields in the phases (′) and (″), m and m_0 are the generalized moments of the solute and the solvent, respectively, k is the Boltzmann constant, T is the absolute temperature, and V is the effective volume of the dissolved component. In formula (1), the exponent is always negative, and therefore, the smaller the difference of generalized moments $|m - m_0|$, the greater c'.

To estimate the generalized moment of atoms, it was used an expression that takes into account the covalent radius, the shell structure of the atom, and the effective nuclear charge [4]:

$$m^* = \frac{(N-\gamma)\cdot e}{r_i} - \frac{1}{2}\cdot a_0 e\cdot\frac{n^*(n^*-1)}{r_i^2} \qquad (2)$$

where γ is the screening coefficient, N is the serial number of the chemical element in the periodic system, r_i is the crystallographic radius of the ion, a_o is the Bohr radius, and n^* is the effective principal quantum number.

The generalized moment (m^*) is similar to the potential of an ion or atom on its surface with a radius r_i, which is the sum of the potentials created by the nucleus with an effective charge $(N - \gamma)\cdot e$ and internal electron shells. m^* expresses the energy characteristic of an atom during its reaction with an external field and during intermolecular interaction.

For the generalized moments of molecules of binary compounds III-V in the solid phase, the arithmetic mean values of the generalized moments of atoms of groups III and V of chemical elements corresponding to the highest valency are taken:

$$m_{III-V}^{sol} = \frac{m_{III}^* + m_V^*}{2} \qquad (3)$$

The generalized moments of GaN and Si_2 molecules have close values: m^*_{GaN} = 109.4·10^2 and $m^*_{\mathrm{Si_2}}$ = 104.0·10^2 C/m (the difference is 5%). The mutual substitution of GaN and Si_2 molecules does not lead to a strong deformation of the crystal lattice, while the energy of elastic distortions of the crystal lattice will be minimal. These components form a solid solution of molecular substitution of the $(Si_2)_{1-x}(GaN)_x$ type.

B. Growing epitaxial layers of $(Si_2)_{1-x}(GaN)_x$ solid solution

Solid solutions $(Si_2)_{1-x}(GaN)_x$ were grown on Si (111) substrates by liquid-phase epitaxy from a limited volume of Sn solution-melt in an ambient H_2 atmosphere. The substrates were silicon washers of grade KDB-0.01, with *p*-type conductivity, doped with boron, with a resistivity of 0.01 Ω·cm, as well as grade KEF-5, with *n*-type conductivity, doped with phosphorus, with a resistivity of - 5 Ω·cm. The diameter and thickness of the substrates were 20 mm and 400 μm, respectively. The growth of epitaxial layers was carried out by varying the following parameters of the technological process: the composition of the solution-melt, the temperature of the beginning and end of solid solution crystallization, the rate of forced cooling and the thickness of the solution-melt. The composition of the Sn-Si-GaN solution-melt, in the weight ratio of components, was determined based on the results of preliminary experiments: Sn - 97.78 wt.%, GaN - 1.25 wt.%, Si - 0.97 wt.%. Epitaxial layers of solid solutions were grown at a temperature range of 950–850 °C, a cooling rate of 1 °C/min, and a solution-melt thickness of 1 mm. At the selected process parameters, the entire surface of the substrate was covered with a continuous epitaxial film. The adhesion of the epitaxial films to the substrate surface was of high quality. Over the entire surface, the thickness of the epitaxial layer was the same and amounted to ~10 μm. Specifically, undoped films had *n*-type conductivity with a concentration of ~ $3.4\cdot10^{16}$ cm^{-3}, a mobility of ~ 133 cm^2·V^{-1}·sec^{-1} of charge carriers and a resistivity of ~ 1.38 Ω·cm at 300 K.

III. RESULTS AND DISCUSSION

Structural studies of the resulting epitaxial film were carried out in the Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan on a DRON-3 M X-ray diffractometer (radiation CuK$_\alpha$, λ = 0,15418 nm) with an improved optical scheme, according to the Θ–2Θ scheme in step scan mode.

Fig. 1 shows an X-ray diffraction pattern of the Si substrate. The diffraction pattern contains several selective structural reflections with different intensities and one diffuse reflection at small scattering angles. The analysis showed that the substrate surface corresponds to the (111) crystallographic plane.

This is evidenced by the presence of a series of selective reflections of the (HHH) type (where H = 1, 2, 3), intense lines $(111)_{Si}$ with d/n = 0.3142 (2θ = 28.4°), $(222)_{Si}$ with d/n = 0.1568 (2θ = 58.8°) and $(333)_{Si}$ with d/n = 0.1045 nm (2θ = 94.95°). The beta (β) component of the structural line of the first order $(111)_{Si}$ is visible at 2θ = 25.8°, and the third order is visible at 2θ = 83.5°. High intensity ($2 \cdot 10^5$ pulses·sec^{-1}) of the main reflection $(111)_{Si}$, narrow width (FWHM = 4.36x10-3 rad) and good, close to the calculated splitting ($\Delta 2\theta \approx 1.75 \cdot 10^{-3}$ rad) in α_1 and α_2 radiation testify to the perfection of the substrate crystal lattice (Fig. 2, a). In addition, the presence of only the reference reflection (111) and its high orders (222) and (333) in the X-ray diffraction pattern of the substrate and the absence of diffraction reflections with other indices indicate that the substrate used is a single crystal.

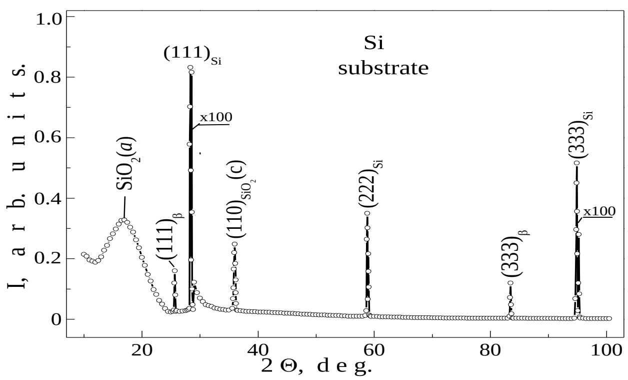

Fig. 1. X-ray pattern of a silicon substrate.

However, the equal intensities of the radiation components α_1 and α_2 indicate the presence of a local elastic growth microstress in the matrix lattice, which is associated with a nonuniform distribution of oxygen over the interstices of the silicon lattice [23, 24]. This conclusion is confirmed by the presence of the $(222)_{Si}$ forbidden reflection with d/n = 0.1568 nm for the Si lattice in the X-ray diffraction pattern, the intensity of which is related to the intensity of the main $(111)_{Si}$ peak as $I(222)/I(111) = 5.16 \cdot 10^{-3}$, which is much more than 10^{-4}, corresponding to the uniform distribution of oxygen in the matrix lattice [25]. According to the law of extinction of diffraction reflections, the $(222)_{Si}$ reflection should not be present in the X-ray diffraction pattern of an undistorted lattice of a diamond-like silicon structure. It appears only in the presence of distortions (elastic microstress) in the matrix lattice [26]. Good, close to the calculated splitting of the $(333)_{Si}$ reflection with characteristic intensity ratios for α_1 and α_2 radiation $[I_{333}(\alpha_1) \approx 2I_{333}(\alpha_2)]$ (Fig. 2b) and the same splitting of the main reflection $(111)_{Si}$ but inconsistent intensity ratios $[I_{111}(\alpha_1) \neq 2I_{111}(\alpha_2)]$ (Fig. 2a), indicates that the elastic stress is predominantly concentrated on the surface layer of the substrate and on the boundaries between the matrix blocks [3,4].

This conclusion is confirmed by the presence on the X-ray diffraction pattern, with a noticeable intensity, of the (110_{Si_2}) reflection with d/n = 0.2501 nm (2θ = 35.9°) caused by the impurity SiO_2 phase of the substrate. The narrow width (FWHM = $2.62 \cdot 10^{-3}$ rad) of this reflection indicates that the SiO_2 impurity phase in the bulk of the matrix is in the crystalline modification, SiO_2(c). The characteristic size of the structural fragments (subcrystallites) of this phase is ~ 58 nm. The ratio of the intensity of this reflection to the intensity of the main reflection (111)Si of the matrix lattice was – $I(110)_{SiO2}/I(111)_{Si} = 3.17 \cdot 10^{-3}$, which is more than 10^{-4}, corresponding to a uniform distribution of oxygen in the silicon lattice [24]. Due to the large ionic radius of oxygen compared to silicon, they are energetically preferred to be located in the interstices of boundary and near-boundary regions between grains and blocks (subcrystallites) of the substrate [24]. In these areas, the chemical bonds between the ions of the matrix are not saturated, and the nodes are somewhat displaced from their ideal positions. These factors contribute to the formation of structural fragments with low symmetry, consisting of silicon and interstitial ions, in comparison with the structure with high symmetry in the bulk of the blocks of the substrate, consisting only of silicon ions. The experimental value of the substrate lattice parameter was a_{Si} = 0.54293 nm, which is comparable with the tabulated value a_{Si} = 0.54307 nm. This shows that the volume fraction of the distorted lattice region is negligible compared to the entire volume of the substrate.

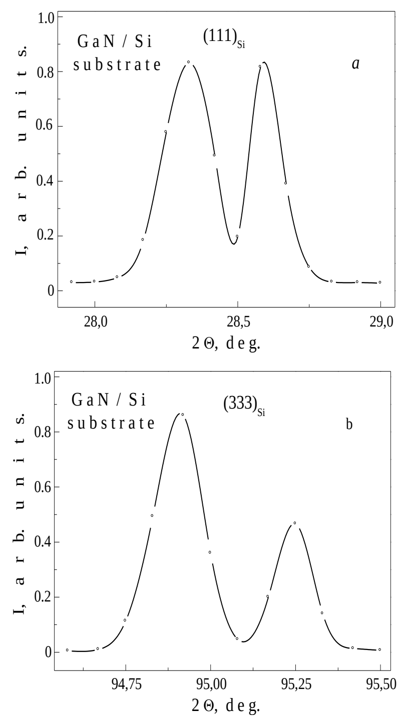

Fig. 2. The shape of the reflections (HHH) of the silicon substrate.

Figure 3 shows an X-ray pattern of an epitaxial layer of $(Si_2)_{1-x}(GaN)_x$ solid solution grown on Si substrates. This result significantly differed from the X-ray diffraction pattern of the substrate. In the X-ray diffraction pattern of the epitaxial layer, the intensity of diffuse reflection at small scattering angles decreased by more than 3 times, and the intensity of the main reflection $(111)_{Si}$ (2θ = 28.33°) of the film increased by ~ 6% compared to the intensity of the same reflection of the substrate. The intensity of the forbidden reflection (222) (2θ = 58.65°) decreased by a factor of 2, its intensity of the third order (333) (2θ = 94.70°) decreased by almost an order of magnitude, and the intensity of the reflection (110_{SiO_2}) (2θ = 35.8º) from the impurity phase of crystalline quartz decreased by 2 times. The average level of the inelastic background also decreased by 2 times.

The relatively narrow width (FWHM = $3.78 \cdot 10^{-3}$ rad) and high intensity ($2 \cdot 10^5$ pulses·sec-1) of the main reflection $(111)_{GaN/Si}$ indicate a high degree of perfection of the crystal lattice of the epitaxial layer of the solid solution $(Si_2)_{1-x}(GaN)_x$; that is, the grown film is a single crystal with a (111) orientation. The sizes of subcrystallites (blocks) of the film, estimated from the width of this peak by the Selyakov–Scherrer method [27], were approximately ~40 nm.

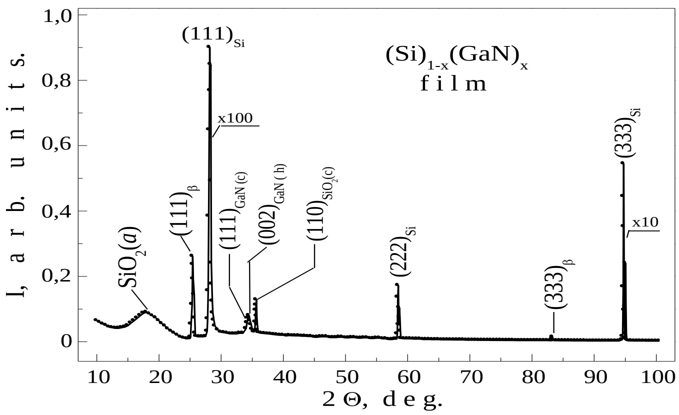

Fig. 3. X-ray pattern of the epitaxial layer of the $(Si_2)_{1-x}(GaN)_x$ solid solution.

However, the intensity of the main reflection of the $(111)_{GaN/Si}$ film is 6% higher than the intensity of the same line of the substrate, $(111)_{Si}$. This indicates the partial replacement of some paired silicon ions by molecules of gallium and nitrogen ions in the silicon lattice of the film. Since the X-ray scattering intensity is proportional to the atomic number (Z) of the elements ($Z_{Si} = 14$, $Z_N = 7$, and $Z_{Ga} = 31$), such a replacement of ions should lead to some increase in the intensity of this reflection, which is observed in the experiment.

At the same time, a multiple decrease in the intensity of the second (222) and third (333) orders of the main reflection (111) of the film is observed. The multiple decreases in the intensity of selective reflections of the (222) and (333) types cannot be explained by the substitution of atoms at the lattice sites of the film. A possible reason for such a decrease in intensity is the violation of the Bragg condition ($n \cdot \lambda = 2d \cdot \sin\theta$) during X-ray diffraction by a film; that is, the film partially leaves the reflecting position. This occurs when the film is bent in the direction perpendicular to the reflective surface of the film. In this case, the diffraction pattern of the film should show a shift in the angular positions of selective reflections toward small scattering angles compared to the angular positions of the same structural lines of the substrate. In this case, a reflection with a large angular position should correspond to a large displacement value ($\Delta 2\theta$), which is observed in the experiment: for the main reflection (111), the displacement value was $2\theta \approx 2$ arc minutes, which is within the experimental error, for the second order (222) $\Delta 2\theta \approx 9$, and for the third order $\Delta 2\theta \approx 15$ minutes of arc. The displacement of the angular position of the reflection (110_{SiO_2}) of the SiO_2 impurity phase was $\Delta 2\theta \approx 6$ arc minutes. All these effects are due to the replacement of paired silicon atoms with a molecule consisting of gallium and nitrogen atoms.

On the other hand, weak splitting of the main reflection (111) by α_1 and α_2 radiation with the intensity ratio $[I_{(111)}(\alpha_1) \neq 2I_{(111)}(\alpha_2)]$ (Fig. 4, a) and complete splitting $[I_{(111)}(\alpha_1) \approx 2I_{(111)}(\alpha_2)]$ (Fig. 4, b) of its third order (333) shows that the accumulation of elastic growth microstresses is mainly concentrated in the surface layers of the crystal lattice of the epitaxial layer solid solution $(Si_2)_{1-x}(GaN)_x$ [24-26]. Such a microstress in the film is apparently caused by the difference in the ionic radii of silicon ($r_{Si}^{4+} = 0.040$ nm), gallium ($r_{Ga}^{3+} = 0.062$ nm), and nitrogen ($r_N^{3-} = 0.146$ nm), which are located in the substitution nodes of the surface layer of the film.

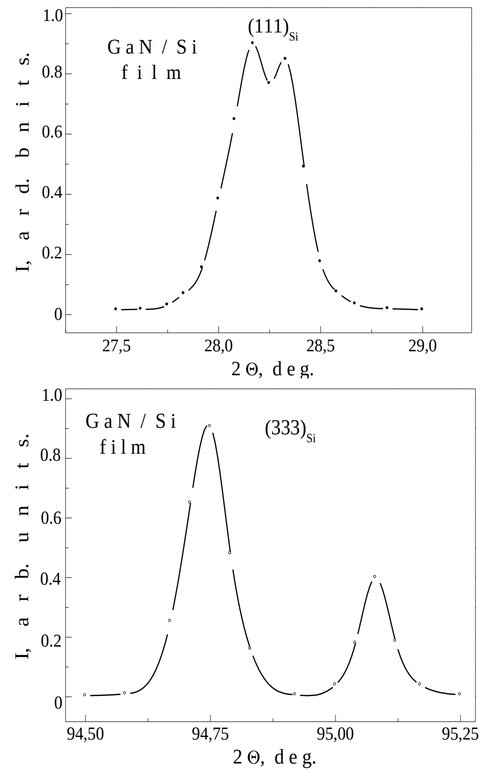

Fig. 4. The shape of reflections (HHH) of the epitaxial layer of the solid solution $(Si_2)_{1-x}(GaN)_x$.

Due to the difference in the lattice constants of Si (5.43 Å) and GaN (3.19 Å), as well as the thermal expansion coefficient (50% less for Si than for GaN) upon cooling from the epitaxy temperature (950–850 °C) to room temperature, deformation and curvature of the lattice of the epitaxial film occurs. Despite the difference in these physical parameters, which cause distortion of the crystal lattice of the epitaxial film, the high binding energy of $E_{Ga\text{-}N}$ ($E_{Ga\text{-}N} > E_{Si\text{-}Si}$ and $E_{Ga\text{-}N} > E_{Si\text{-}O}$ [28]) determines the perfection of the crystal lattice of the film. This conclusion is confirmed by a twofold decrease in the level of the inelastic background of the film compared to the level of the background of the substrate.

In addition, this conclusion is confirmed by the appearance of a new selective reflection with a noticeable intensity and a width of $3.2 \cdot 10^{-3}$ rad. near the main reflection (111) of the film. An analysis of the nature of this structural line showed that it consists of two selective lines very close in angular position and corresponding to two modifications of gallium nitride: cubic (c-GaN) - $(111)_{GaN}$ with d/n = 0.2599 nm ($2\theta = 34.4°$) and hexagonal (h-GaN) - $(002)_{GaN}$ with d/n = 0.2592 nm ($2\theta = 34.6°$). They are caused by gallium nitride nanocrystals $L_{GaN} \approx 47$ nm in size. These nanocrystallites are located in the near-surface layer of the film, as evidenced by the angular arrangement of the reflections corresponding to them. The close angular position of these reflections to the main $(111)_{GaN/Si}$ reflection made it possible to determine the GaN content of c-GaN and h-GaN nanocrystals in the film from the ratio of their intensities. It was 9.1 and 8.9 mol.%, respectively. Therefore, it can be argued that during liquid-phase epitaxy on a Si(111) substrate, it is possible to form a GaN-Si heterostructure with GaN nanocrystallites, both cubic (c-GaN) and hexagonal (h-GaN) modification.

CONCLUSIONS

Thus, based on the rules of generalized moments of atoms and molecules of elementary semiconductors and the binary compound GaN, the possibility of forming a substitutional solid solution based on Si and GaN is estimated. Continuous epitaxial layers of $(Si_2)_{1-x}(GaN)_x$ solid solutions were grown on Si(111) substrates 20 mm in diameter by liquid-phase epitaxy from a limited volume of a tin solution-melt. The epitaxial layers had a smooth surface with high adhesive properties to the substrate.

Analysis of the X-ray diffraction pattern showed that the resulting film is a single crystal with a (111) orientation. Coherently located nanocrystallites of cubic (c-GaN) and hexagonal (h-GaN) modification of gallium nitride with a crystallite size of $L_{GaN} \approx 47$ nm are formed in the crystal lattice of the epitaxial film.

ACNOWLEDGEMENT

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DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author by request.

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Analysis of methods for protecting bank payment systems from digital attacks

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***Abstract* — This article is devoted to the methods of protection against attacks on the bank payment system, in which the methods of protection against attacks on the bank payment system are explained in detail, and the concept of protection methods has been developed.**

***Keywords* — Multi-Factor Authentication (MFA), Encryption, Access Control, Data Loss Prevention (DLP), Backup and Recovery, Firewalls and Intrusion Detection/Prevention Systems (IDPS).**

I. INTRODUCTION

In the digital age, the financial sector has undergone a profound transformation with the advent of advanced technology and electronic payment systems. While these advancements have led to increased efficiency and convenience, they have also introduced new vulnerabilities and threats, particularly in the form of digital attacks on bank payment systems. As a result, safeguarding these systems has become a critical priority for financial institutions worldwide.

The objective of this analysis is to delve into the methods and strategies employed by banks to protect their payment systems from a wide range of digital attacks, including but not limited to phishing, malware, ransomware, and data breaches. This analysis will provide an overview of the evolving threat landscape and the pressing need for robust cybersecurity measures. It will then explore various protective measures that banks implement to counter these threats and ensure the security, integrity, and confidentiality of their payment systems and the sensitive financial data they handle [5,7].

II. METHODS FOR PROTECTING BANK PAYMENT SYSTEMS FROM DIGITAL ATTACKS

Protecting bank payment systems from digital attacks is of paramount importance in today's interconnected and technology-driven world. Cyberattacks are becoming increasingly sophisticated, and financial institutions need to implement robust security measures to safeguard their payment systems and customer data. Here are some methods to consider:

Multi-Factor Authentication (MFA): Implement MFA for all user accounts, including customers, employees, and administrators. Require multiple forms of authentication, such as passwords, biometrics, and one-time codes, to ensure that only authorized individuals can access the system.

Encryption: Use strong encryption protocols to protect data in transit and at rest. Employ end-to-end encryption for sensitive information to prevent unauthorized access even if data is intercepted.

Regular Security Audits: Conduct regular security audits and vulnerability assessments to identify weaknesses in the payment system's infrastructure and code. Address any vulnerabilities promptly.

Firewalls and Intrusion Detection/Prevention Systems (IDPS): Implement firewalls to filter incoming and outgoing network traffic. Use IDPS to detect and prevent unauthorized access or malicious activities within the system.

Access Control: Limit access rights to the payment system based on the principle of least privilege. Users should only have access to the resources necessary for their roles.

Data Loss Prevention (DLP): Implement DLP solutions to monitor and control the movement of sensitive data within and outside the organization. This can help prevent data leaks and unauthorized data transfers.

Backup and Recovery: Regularly back up critical data and establish a robust disaster recovery plan. Test backups and recovery procedures to ensure that you can quickly restore operations in case of a breach [3].

III. MULTI-FACTOR AUTHENTICATION AND ENCRYPTION METHODS

Multi-Factor Authentication (MFA), also known as Two-Factor Authentication (2FA) or Two-Step Verification, is a security mechanism designed to enhance the authentication process and make it more difficult for unauthorized individuals to access an account, system, or application. It adds an extra layer of protection beyond the traditional username and password combination [1].

In a typical MFA setup, the authentication process involves three factors:

Something You Know: This is typically your username and password combination, which is the first layer of security.

Something You Have: This refers to a physical item that only you possess, such as a smartphone, hardware token, or smart card. This item generates a time-sensitive one-time password (OTP) or a code that you need to provide during authentication.

Something You Are: This involves a biometric factor, such as a fingerprint, facial recognition, or iris scan. Biometric information is unique to each individual and provides an additional layer of security [1,2].

To authenticate using MFA, a user needs to provide at least two of these factors. For example, after entering their username and password, they might receive a text message with a temporary code on their smartphone (something they have), which they then enter to complete the login process.

TABLE I. BIOMETRIC SECURITY METHODS

Biometric method	Protection measures
Fingerprint recognition	- use liveness detection to prevent spoofing; - store biometric data in encrypted form.
Face recognition	- implement anti-spoofing techniques; - encrypt and secure facial templates.
Voice recognition	- use voiceprint analysis for liveness detection; - employ noise reduction and anti-replay measures.

TABLE II. PROTECTION LEVELS FOR AUTHENTICATION FACTORS

Authentication factor	High security level	Medium security level	Low security level
Something You know	strong password	security questions	memorable password
Something You have	hardware token	SMS OTP	Email OTP
Something You are	biometric (fingerprint, face)	voice recognition	behavioral biometrics
Something You possess	smart card	mobile device	static hardware token

Encryption method

Protecting encryption algorithms for bank payment systems from digital attacks is a critical aspect of ensuring the security and integrity of financial transactions. Here's a general overview of the types of encryption algorithms and security measures that banks often employ, along with some potential components for tables to provide a structured presentation of this information [3].

TABLE III. COMMON ENCRYPTION ALGORITHMS USED IN BANK PAYMENT SYSTEMS

Encryption algorithm	Description	Strengths	Weaknesses
RSA	Asymmetric encryption using public and private keys. Widely used for key exchange and digital signatures	High security due to mathematical complexity	Slower compared to symmetric encryption for large data
AES	Symmetric encryption with various key lengths. Efficient for encrypting large amounts of data	Fast and efficient encryption/ decryption	Key distribution and management challenges
SHA-256	Cryptographic hash function. Used for verifying data integrity and creating digital signatures	High collision resistance	Not suitable for encryption, only for one-way functions

Protecting encryption algorithms for bank payment systems from digital attacks requires a multi-layered approach that combines both hardware and software encryption solutions. Here's a general guideline on how to use encryption to safeguard bank payment systems:

Choose Strong Encryption Algorithms:

Select well-established and widely recognized encryption algorithms, such as AES (Advanced Encryption Standard), RSA (Rivest-Shamir-Adleman), and ECC (Elliptic Curve Cryptography). These algorithms provide a solid foundation for securing data.

Hardware Security Modules (HSMs):

HSMs are specialized hardware devices designed to securely manage and store encryption keys. They provide a high level of protection against attacks by keeping keys isolated from the rest of the system. HSMs also perform encryption and decryption operations, making it harder for attackers to intercept sensitive data.

End-to-End Encryption:

Implement end-to-end encryption, where data is encrypted at the source and decrypted only at the destination. This prevents attackers from intercepting sensitive information during transmission.

Public Key Infrastructure (PKI):

Utilize PKI to manage digital certificates and keys. This ensures secure communication and authentication between parties involved in transactions.

Secure Key Management:

Implement strict key management practices, including key rotation, separation of keys from data, and the use of strong authentication mechanisms to access keys [3].

Regular Software Updates:

Keep all encryption-related software up to date. This includes operating systems, encryption libraries, and any other software components that handle encryption tasks.

IV. REGULAR SECURITY AUDITS AND FIREWALLS AND INTRUSION DETECTION/PREVENTION SYSTEMS

Regular Security Audits

Regular security audits are systematic and periodic assessments of an organization's information systems, processes, and infrastructure to identify vulnerabilities, weaknesses, and potential security threats. These audits are conducted to ensure that an organization's security measures are effective in safeguarding its sensitive data, assets, and operations from unauthorized access, breaches, and cyberattacks [5,8].

Certainly, here's an example of what a table outlining the components of regular security audits in a bank's system might look like:

TABLE IV. REGULAR SECURITY AUDITS IN A BANK'S SYSTEM

Audit component	Description
Scope definition	Define the scope of the audit, including systems, applications, networks, and processes to be assessed
Methodology	Choose an audit methodology based on industry standards (ISO 27001, NIST, PCI DSS) to guide the audit process

External/Internal	Decide if the audit will be external (by third-party experts) or internal (by the bank's security team), or a combination of both for unbiased assessment
Vulnerability assessment	Identify vulnerabilities such as outdated software, misconfigurations, and unpatched systems that could be exploited
Penetration testing	Simulate real-world attacks to assess system defenses and identify potential breach points
Access controls	Review user access permissions and controls to ensure authorized access to sensitive data and actions
Data protection	Evaluate data encryption mechanisms for data at rest and in transit, ensuring proper implementation
Application security	Assess the security of banking applications, both web and mobile, to uncover vulnerabilities that could lead to data breaches
Network security	Review network infrastructure for vulnerabilities, open ports, and potential entry points for attackers
Physical security	Assess physical security measures protecting critical infrastructure like data centers and servers

Firewalls and Intrusion Detection/Prevention Systems (IDPS)

A firewall is a network security device or software that acts as a barrier between a trusted internal network and untrusted external networks, such as the internet. Its primary function is to monitor, filter, and control incoming and outgoing network traffic based on predetermined security rules and policies. Firewalls are a fundamental component of network security and play a crucial role in protecting systems, applications, and data from unauthorized access, cyberattacks, and other security threats [7].

There are different types of firewalls, each with its own capabilities and features:

Network Firewalls: These are the most common type of firewalls that operate at the network layer. They can filter traffic based on IP addresses, port numbers, and protocols.

Application Firewalls: These firewalls operate at the application layer and can inspect the content of the data to determine the specific application or service generating the traffic. They offer more granular control over application behavior.

Proxy Firewalls: Proxy firewalls act as intermediaries between clients and servers. They can provide additional security by intercepting and inspecting traffic before forwarding it to its destination.

Stateful Firewalls: These firewalls maintain a state table that tracks the state of active connections. They allow or block traffic based on the context of the connection, which helps prevent unauthorized access and attacks.

Next-Generation Firewalls (NGFW): NGFWs combine traditional firewalling capabilities with advanced features such as application identification, user-based policies, and intrusion prevention.

Web Application Firewalls (WAF): WAFs are designed to protect web applications from various attacks, such as SQL injection and cross-site scripting, by analyzing and filtering HTTP traffic.

Intrusion Detection/Prevention Systems (IDPS)

Intrusion Detection/Prevention Systems (IDPS) play a critical role in ensuring the security of bank systems and protecting sensitive financial information from cyber threats. IDPS are specialized security tools designed to detect and respond to unauthorized or malicious activities within a computer network or system. In the context of bank systems, they serve to safeguard customer data, transaction records, and financial operations from various cyber threats, including hacking attempts, malware, and insider attacks.

Here's how IDPS are typically used in bank systems:

Network Monitoring: IDPS constantly monitor network traffic for any abnormal or suspicious patterns. They analyze network packets, logs, and other data to identify potential security breaches. For banks, this includes tracking unusual communication between devices, potential signs of Distributed Denial of Service (DDoS) attacks, or attempts to exploit vulnerabilities in the network infrastructure [7,9].

Anomaly Detection: IDPS establish a baseline of normal behavior for the network and systems. Any deviations from this baseline are flagged as anomalies, indicating potential security incidents. In a bank's context, this might involve detecting unauthorized access to critical servers or abnormal spikes in data transfers.

Signature-Based Detection: IDPS maintain a database of known attack signatures. These signatures are patterns or characteristics associated with specific types of attacks or malware. When the system identifies a match between the observed network activity and a known signature, it triggers an alert. For instance, if a particular malware's signature is detected in the network traffic, the IDPS can take immediate action [1,7].

Intrusion Prevention: In addition to detection, some IDPS have intrusion prevention capabilities. They can actively block or mitigate threats by terminating suspicious network connections, blocking malicious IP addresses, or altering firewall rules to prevent attacks from succeeding.

Real-time Alerts: IDPS generate alerts to notify security personnel when potential security incidents are detected. These alerts help the security team respond promptly to threats and take appropriate actions to mitigate them [7].

Log Analysis and Forensics: IDPS store logs of detected incidents, which can be invaluable for post-incident analysis and forensic investigations. This information helps in understanding the nature of the attack, the extent of the damage, and the steps needed to recover.

V. ACCESS CONTROL, DATA LOSS PREVENTION, BACKUP AND RECOVERY AND ANALYSIS

Access control

Access control in a bank system refers to the methods and mechanisms put in place to regulate and manage who can access different resources, data, and functionalities within the banking system. This is a crucial aspect of ensuring the security, confidentiality, integrity, and availability of sensitive financial information and operations. Here are some key components and considerations for implementing access control in a bank system:

Authentication:

Username and Password: Users should authenticate themselves using a unique combination of a username and a strong password.

Multi-Factor Authentication (MFA): Implementing MFA adds an extra layer of security by requiring users to provide two or more verification factors, such as something they know (password), something they have (smartphone, token), or something they are (fingerprint, facial recognition) [2].

Authorization:

Role-Based Access Control (RBAC): Users are assigned specific roles (e.g., teller, manager, customer) with predefined sets of permissions. This ensures that users only have access to the resources and functions necessary for their job responsibilities.

Attribute-Based Access Control (ABAC): Access decisions are based on a set of attributes associated with the user, the resource, and the environment. This can provide more fine-grained access control [6,7].

Access Levels:

Define different access levels based on job roles and responsibilities. For instance, a bank teller might have access to customer account information, while a manager might have access to higher-level administrative functions.

Audit Trails:

Keep track of all access attempts and actions taken by users. This helps in investigating security breaches, unauthorized access, or suspicious activities.

Access Reviews:

Regularly review and audit user access rights to ensure that they are still appropriate and necessary. Remove any unnecessary or outdated access permissions.

Physical Security:

Control physical access to server rooms and data centers that house critical banking infrastructure.

Data Loss Prevention (DLP)

Sure, here's a table outlining various aspects of Data Loss Prevention (DLP) in a bank system, including types of hardware and software, a brief explanation of how they work, and some notable firms in the DLP industry.

TABLE V. DATA LOSS PREVENTION (DLP)

Aspect	Description
Types of Hardware	
Network Appliances	Hardware devices placed at network gateways to monitor and control data flows in real time.
Endpoint Devices	DLP agents installed on individual devices to monitor, manage, and prevent data leaks.
Storage Devices	Hardware-based encryption devices that secure data stored on various storage media.
Types of Software	
Content Discovery	Software that scans networks and storage for sensitive data patterns and classifies information.
Encryption Tools	Software solutions to encrypt sensitive data, both at rest and in transit, to prevent exposure.
Access Control	Software that enforces access permissions and user authentication to protect sensitive resources.
Notable Firms	
Symantec (Broadcom)	Offers comprehensive DLP solutions, including network, endpoint protection, and encryption.
McAfee (Intel)	Provides DLP software for network and endpoint protection, along with cloud data security.
Forcepoint	Specializes in human-centric cybersecurity, offering DLP solutions for user and data protection.
Microsoft	Offers DLP tools integrated into its security suite for data protection within the Microsoft ecosystem.
How They Work	
Network Appliances	Inspect network traffic, analyze content, and enforce policies to block or alert on data breaches.
Endpoint Devices	Monitor data activities, detect sensitive data patterns, and apply policies to prevent leaks.
Storage Devices	Encrypt stored data, control access using encryption keys, and manage data protection centrally.
Content Discovery	Scan data repositories, identify sensitive information, and apply policy-based actions.
Encryption Tools	Use cryptographic algorithms to convert data into unreadable format, ensuring secure transmission.
Access Control	Authenticate users, manage permissions, and control data access based on roles and policies.
How to Work	
1. Assessment	Identify sensitive data and potential vulnerabilities in the bank's data landscape.
2. Policy Creation	Develop comprehensive DLP policies based on data types, user roles, and regulatory requirements.
3. Implementation	Deploy DLP solutions across the network, endpoints, and storage infrastructure.
4. Monitoring	Continuously monitor data activities, enforce policies, and detect and respond to anomalies.
5. Incident Response	Have procedures to swiftly react to and mitigate any potential data breaches or policy violations.

Backup and Recovery:

Backup and recovery are crucial components of a bank's IT infrastructure to ensure data protection, compliance, and business continuity. Banks deal with sensitive financial data and customer information, making the need for robust backup and recovery strategies paramount. Here's an overview of backup and recovery in a bank system:

Backup Methods:

Full Backup: A complete copy of all data is taken. It provides a comprehensive restore point but requires more storage space and time for both backup and recovery.

Incremental Backup: Only the changes made since the last backup (whether full or incremental) are copied. It saves storage space and speeds up backup, but recovery involves restoring the last full backup and then applying subsequent incremental backups [8].

Differential Backup: Similar to incremental, but it copies changes since the last full backup. It simplifies the recovery process compared to incremental backups.

Backup Media:

On-site Storage: Backup data is stored within the bank's premises. Quick access is possible, but it's vulnerable to disasters affecting the bank's location.

Off-site Storage: Backups are stored at a different physical location from the bank. This protects against site-wide disasters, but retrieval time might be longer.

Cloud Storage: Backup data is stored on remote servers. It offers scalability, accessibility from anywhere, and can provide built-in redundancy [7,4].

Recovery Methods:

Bare-metal Recovery: Involves restoring the entire system, including the operating system, applications, and data. Useful for system failures, hardware replacements, or major upgrades.

File-level Recovery: Focuses on restoring individual files or folders. Useful for accidental deletion, data corruption, or restoring specific data items.

System Snapshot Recovery: Recovers the system to a known good state, often achieved through regular system snapshots. Helpful for rolling back system changes or recovering from software conflicts.

Key Considerations:

Data Encryption: Encrypt backup data to safeguard sensitive information, ensuring that even if backups are compromised, the data remains protected.

Retention Policies: Establish policies determining how long backups are retained. Consider regulatory requirements and business needs when setting retention periods [9,10].

Regular Updates: Periodically review and update backup and recovery strategies to align with changes in data volume, technology, and business requirements.

Off-site Copies: Maintain off-site copies of backups to safeguard against physical disasters that could affect the bank's primary location [8,10].

Monitoring and Maintenance: Regularly monitor backup processes, perform maintenance on backup systems, and test recovery procedures to ensure their effectiveness.

Sure, I can provide you with an analysis of the mentioned methods for protecting bank payment systems from digital attacks in a tabular format. Here's how the analysis could be structured:

TABLE VI. ANALYSIS OF METHODS FOR PROTECTING BANK PAYMENT SYSTEMS

Security method	Description	Advantages	Challenges
Multi-Factor Authentication (MFA)	Requires users to provide multiple forms of verification (password, biometrics, tokens) for access.	✔ Provides an extra layer of security. ✔ Mitigates risks of stolen or weak passwords.	✘ Can be inconvenient for users. ✘ Implementation complexity.
Encryption	Converts sensitive data into unreadable format, requiring a decryption key for access.	✔ Protects data confidentiality. ✔ Essential for securing data at rest and during transmission.	✘ Key management challenges. ✘ Performance impact on processing large volumes of data.
Regular Security Audits	Systematic assessment of security measures to identify vulnerabilities and weaknesses.	✔ Identifies and addresses security gaps. ✔ Maintains an up-to-date security posture.	✘ Resource-intensive and time-consuming. ✘ May require specialized expertise.
Firewalls and IDPS	Firewalls filter network traffic, IDPS detect and prevent unauthorized access and attacks.	✔ Blocks malicious network traffic. ✔ Monitors for abnormal activities.	✘ Need constant updates to detect new attack methods. ✘ Possibility of false positives/negatives.
Access Control	Restricts user access based on roles and permissions.	✔ Reduces the attack surface by limiting access. ✔ Enforces the principle of least privilege.	✘ Requires thorough user role definition. ✘ Overly restrictive access can hinder operations.
Data Loss Prevention (DLP)	Monitors and prevents sensitive data from leaving the organization's network.	✔ Prevents unauthorized data leakage. ✔ Protects against accidental data exposure.	✘ Configuring accurate DLP policies can be complex. ✘ False positives can disrupt legitimate workflows.
Backup and Recovery	Regularly backs up data and systems to facilitate recovery in case of data loss or system compromise.	✔ Enables restoration of systems after attacks. ✔ Mitigates damage from ransomware and data loss.	✘ Requires effective management of backup storage. ✘ Ensuring backup integrity is crucial.

CONCLUSION

This article is devoted to methods of protection against attacks on the bank payment system. The methods of protection against attacks on the bank payment system are explained in detail, and at the same time, each protection method is analyzed, and an analysis of other protection methods is developed.

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Enhancing DDoS Attack Detection with an Optimized Random Forest Machine Learning Model

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Abstract — **This article presents a comprehensive review of scientific articles authored by both local and international researchers, focusing on existing artificial intelligence-based methods and algorithms for detecting Distributed Denial of Service (DDoS) attacks. A comparative analysis of these approaches is carried out to assess their efficacy. Building upon the insights gained from this literature review, a novel method for DDoS attack detection is introduced. This method leverages optimized Random Forest algorithms within the framework of machine learning. A dedicated software model is developed and subjected to experimental studies, which substantiate the effectiveness of the proposed approach.**

***Keywords* — Artificial Intelligence (AI), Machine Learning (ML), K-nearest neighbors (k-NN), Random Forest (RF), K-Fold Cross Validation, Confusion Matrix.**

I. INTRODUCTION

In today's digital age, protecting against Distributed Denial of Service (DDoS) attacks is paramount. These attacks disrupt online services by flooding them with traffic. Traditional defenses often fall short. Machine learning offers a promising solution. [1]

This article explores our journey in developing an optimized machine learning model, specifically Random Forest (RF), for DDoS attack detection. RF excels in handling complex data patterns.

We begin with a review of existing methods and an introduction to our methodology, following the CRISP-DM framework. Our focus is on optimizing key RF parameters - max_samples, max_depth, and n_estimators - to achieve high accuracy and computational efficiency.

Our results show that our optimized RF model outperforms, offering accuracy, precision, recall, and speed - a practical solution for real-time DDoS attack detection.

Many machine learning methods can be broadly categorized into four types: supervised learning, semi-supervised learning, unsupervised learning, and reinforcement learning. Each of these models, in turn, encompasses several algorithms. No single machine learning algorithm can provide the best results for any dataset and data property. Typically, before selecting a machine learning model algorithm, factors such as dataset size, dataset characteristics, and the nature of the problem to be solved need to be considered.

If an inappropriate machine learning model algorithm is chosen, it not only fails to yield accurate results but can also lead to model overfitting or require longer training and prediction times for effective DDoS attack detection in realistic high-traffic networks. Thoughtful selection of machine learning model algorithms can improve accuracy, reduce prediction time, and enhance the model's generalization ability. Particularly in high-density data stream network systems, anomalous traffic can be swiftly and effectively detected through the judicious use of machine learning algorithm models.

In this section, we first examine the characteristics of the chosen machine learning algorithms - Random Forest and KNN, used in this research. The section will conclude with the development of an optimized RF algorithm.

The Random Forest (RF) algorithm is a versatile machine learning technique that relies on the use of an ensemble of decision trees. A single decision tree, on its own, often provides relatively low classification quality. However, when a large number of decision trees are combined into an ensemble, the results are significantly improved [1]. Moreover, this algorithm stands out as one of the few that can be applied to a vast range of tasks, making it a universal choice in machine learning [2].

Thanks to its flexibility, RF (Random Forest) is employed to address nearly any machine learning problem. This includes classifications (Random Forest Classifier) and regressions (Random Forest Regressor), as well as more intricate tasks such as feature selection, outlier/anomaly detection, and clustering.

II. PROPOSED OPTIMIZED ALGORITHM APPROACH

The key parameters of the Random Forest that need to be optimized are as follows:

(a) max_samples: The size of the training set is determined by max_samples.

(b) max_depth: The maximum depth of the decision tree, by default unlimited. If the model has a large number of samples and features, it's recommended to limit this value. A typical range is from 10 to 100. If the model has a substantial number of samples and features, consider adjusting this limit, typically within the range of 10 to 100.

(c) n_estimators: This parameter specifies the number of decision trees in the Random Forest, with a default value of 100. If n_estimators is too small, the trees may be too easily overfit, while if it's too large, it could demand significant computational resources. Thus, optimization is required to find a moderate value. The optimization algorithm is detailed below [3].

Algorithm: Random Forest Optimization Algorithm

Input: Dataset, max_samples, max_depth, n_estimators
Output: Optimized RF Model.
Procedure: Parameter Optimization.

```
Step 1: Define result variables as [Method, matrix, Accuracy,
             Precision, Recall, F1_Score, Average, predict_time].

Step 2: Initialize the RandomForestClassifier parameter
   (max_samples = 0.9, max_depth = 20, n_estimators = 100).

Step 3: Optimize max_samples.
for sam in [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]:
   model = RandomForestClassifier(max_samples=sam,
                  max_depth=20, n_estimators=100)
   model.fit
   test_output(y_test, y_pred)  # Performance testing function
      results.append(Method, matrix, Accuracy, Precision, Recall,
                  F1_Score, Average, predict_time)

Step 4: Select opt_max_samples with the highest results.

Step 5: Optimize max_depth.
for dep in range (10, 30, 2):
         model = RandomForestClassifier(max_samples=0.9,
                  max_depth=dep, n_estimators=100)
   model.fit
   test_output(y_test, y_pred)  # Performance testing function
   results.append(Method, matrix, Accuracy, Precision, Recall,
                           F1_Score, Average, predict_time)

Step 6: Select opt_max_depth with the highest results.

Step 7: Optimize n_estimators.
for est in range (10, 210, 20):
   model = RandomForestClassifier(max_samples=0.9,
                  max_depth=20, n_estimators=est)
   model.fit
   test_output(y_test, y_pred)  # Results of the testing function
   results.append(Method, matrix, Accuracy, Precision, Recall,
                  F1_Score, Average, predict_time)

Step 8: Select opt_n_estimators with the highest results.

Step 9: #Output the optimization result:
RandomForestClassifier(max_samples=opt_max_samples,
 max_depth=opt_max_depth, n_estimators=opt_n_estimators)
End of procedure.
```

TABLE I. THE RESULTS BEFORE OPTIMIZATION

	Accu racy	Preci sion	Recall	F1_ score	Ave rage	Prediction Time
Before Opt.	0.9959	0.9977	0.9953	0.9965	0.9964	0.2128

Dataset

The CICIDS2017 dataset contains both benign and the most prevalent contemporary attacks, including DDoS attacks that resemble real-world data. It also includes the results of network traffic analysis using CICFlowMeter with labeled flows based on timestamps, source and destination IP addresses, source and destination ports, protocols, and attacks (in CSV files) [4]. Another subset of DDoS attacks from the CICDDoS2019 dataset was used, consisting of 279,279 records, with 25,761 belonging to the "no attack" class, and the rest belonging to the "attack" class. The training dataset comprises 209,459 records, while the test dataset comprises 69,820 records. Initially, the feature space consists of 87 features. Below is the content of 5 rows from CICIDS2017.

RF Optimization

After initially selecting the appropriate model algorithm for Random Forest (RF) during the model selection phase, the initially chosen RF parameters - the sampling frequency of the Random Forest, the maximum tree depth, and the number of trees - were subsequently optimized using the RF optimization algorithm to further enhance the effectiveness of DDoS attack detection. Firstly, we set max_samples = 0.9, max_depth = 20, and n_estimators = 100 to initialize the RF parameters before optimization. The table below displays the results before optimization [5].

Study of Maximum Sampling (max_samples)

The RF optimization algorithm optimizes the max_samples parameter to control variables, always keeping the max_depth =20

AND N_ESTIMATORS = 100 PARAMETERS, WHILE MAX_SAMPLES IS CHOSEN WITHIN THE PARAMETER RANGE [0.1, 0.9], WITH EACH STEP INCREMENT OF 0.1

TABLE II. RESULTS WHEN MAX_DEPTH = 20 AND N_ESTIMATORS = 100

Max_ Sample	Accu racy	Preci Sion	Re call	F1_ score	Ave rage	Predic tion Time
0,1	0,9939	0,9959	0,9933	0,9946	0,9944	0,1586
0,2	0,9953	0,9970	0,9948	0,9959	0,9957	0,1676
0,3	0,9959	0,9976	0,9952	0,9964	0,9963	0,1797
0,4	0,9958	0,9973	0,9953	0,9963	0,9962	0,1972
0,5	0,9958	0,9974	0,9951	0,9963	0,9961	0,1856
0,6	0,9959	0,9974	0,9953	0,9964	0,9962	0,1811
0,7	0,9958	0,9974	0,9952	0,9963	0,9962	0,1939
0,8	0,9962	0,9975	0,9957	0,9966	0,9965	0,1832
0,9	0,9957	0,9975	0,9950	0,9962	0,9961	0,1858

Corresponding line graphs for Accuracy, F1_Score, and Average were plotted. It can be observed that as the maximum sampling size (max_samples) increases, the values of Accuracy, F1_Score, and Average show corresponding growth. However, when max_samples = 0.5, the rate of increase significantly slows down, and when max_samples = 0.8, Accuracy, F1_Score, and Average reach their maximum values.

To facilitate the analysis of the relationship between max_samples and model prediction time, the predict_time indicator was selected from Table 3.3.3 for the following Figure 3.3.10. It can be seen from the figure that predict_time exhibits a wave-like pattern with max_samples. However, increasing the size of predict_time does not show a significant increase, indicating that increasing the maximum sampling and its impact on prediction time are not significant.

Similarly, to facilitate the analysis of the relationship between max_depth and model prediction time, we will take the prediction_time data from Table 3.3.4, as shown in Figure 3.3.12. Predict_time does not increase as max_depth increases, and even after max_depth = 20, there are fluctuations up and down. It is evident that max_depth and predict_time have a significant impact on prediction time within a certain range, but this influence is not constant.

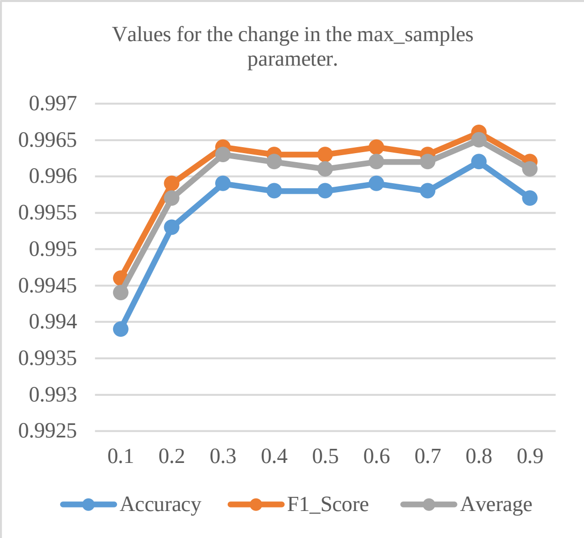

Fig. 1. Linear plot of Accuracy, F1_Score, and Average

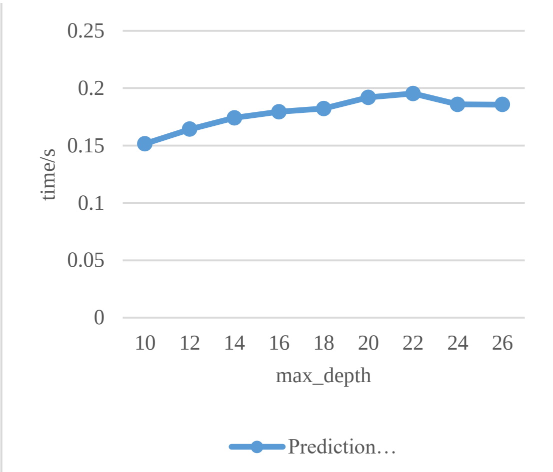

Fig. 2. Linear plot of prediction time

From a comprehensive perspective, it can be observed from the linear plots of Accuracy, F1_Score, and Average that within the maximum depth (max_depth) of 20, max_depth significantly influences prediction time. Meanwhile, the Accuracy, F1_Score, and Average indicators reached a more ideal state when max_depth = 26 on the linear plot, indicating that the optimized value for the max_depth parameter is 26.

III. Studying Decision Trees

The RF optimization algorithm was used to optimize the parameter n_estimators for decision trees, while keeping the parameters max_samples = 0.8 and max_depth = 26 to control variables. n_estimators were selected within the parameter range [10, 190], with each step increment equal to 20.

As evident from the graphs, the trend direction and overlap of the three curves for Accuracy, F1_Score, and Average are mostly consistent. It can be observed that within the n_estimators interval number of decision trees reaches 50, Accuracy, F1_Score, and Average peak. However, as the number of decision trees increases beyond this point, the indicators show fluctuations, eventually stabilizing. This also demonstrates that having an excessively large number of decision trees does not improve performance significantly but can incur additional model costs and increase model prediction time.

TABLE III. THE RESULTS WHEN MAX_SAMPLES = 0,8 AND MAX_DEPTH = 26

n_estimators	(Accuracy)	(Precision)	(Recall)	F1_score	Average	Prediction Time
10	0,9952	0,9971	0,9944	0,9958	0,9956	0,0207
30	0,9954	0,9970	0,9950	0,9960	0,9958	0,0572
50	0,9962	0,9978	0,9954	0,9966	0,9965	0,1085
70	0,9957	0,9973	0,9952	0,9962	0,9961	0,1377
90	0,9955	0,9967	0,9954	0,9960	0,9959	0,1655
110	0,9957	0,9970	0,9954	0,9962	0,9961	0,1966
130	0,9954	0,9966	0,9953	0,9959	0,9958	0,2309
150	0,9959	0,9972	0,9955	0,9964	0,9962	0,2745
170	0,9957	0,9969	0,9954	0,9962	0,9960	0,3060

Similarly, to facilitate the analysis of the relationship between decision trees and model prediction time, the predict_time indicator was selected from Table 3.3.5 and depicted as Figure 3.3.14 below. The relationship between predict_time and max_depth increases linearly.

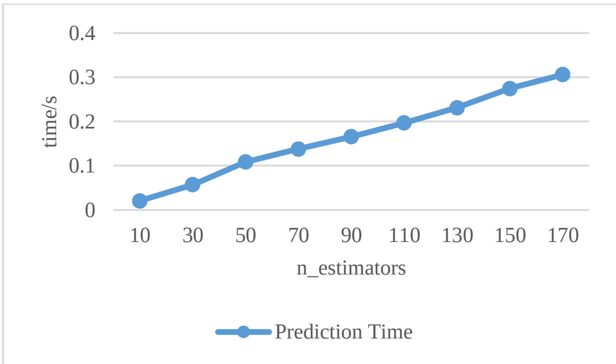

Fig. 3. Linear plot of time

Thus, the prediction time on the linear graph of n_estimators-predict_time shows a linear increase in prediction time with max_depth. On the linear plots of Accuracy, F1_Score, and Average, the performance of each tree reaches its maximum point when the number of decision trees is 50. Therefore, the optimized result for n_estimators is 50.

IV. Optimization Results

The parameters of the new model and the performance testing results after applying the RF optimization algorithm are presented in Table 3.3.6 and Figure 3.3.15, corresponding to the confusion matrix as shown in Fig. 3.

Model = RandomForestClassifier (max_samples = 0.8, max_depth = 26, n_estimators = 50).

Comparison before and after optimization is shown in Table 3.3.6 and Figure 3.3.15. Accuracy increased by 0.0003, Recall increased by 0.0001, and Average increased by 0.0001. However, the prediction time decreased from 0.2128 to 0.1085, which is 0.1043 less than the original, reducing prediction time by more than half. This is crucial in a real-time high-demand system and provides support for a model that will be deployed in production for real-time DDoS detection, demonstrating its practicality

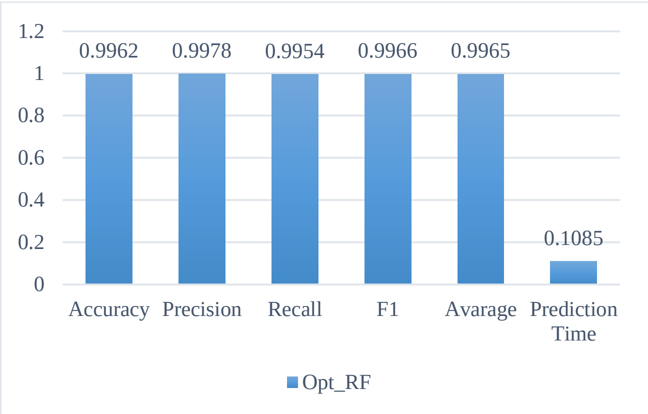

Fig. 4. Diagram of optimized RF results

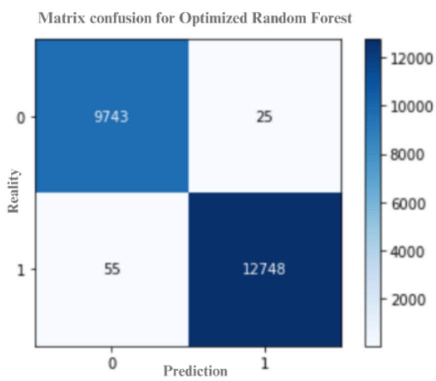

Fig. 5. Prediction results for test data

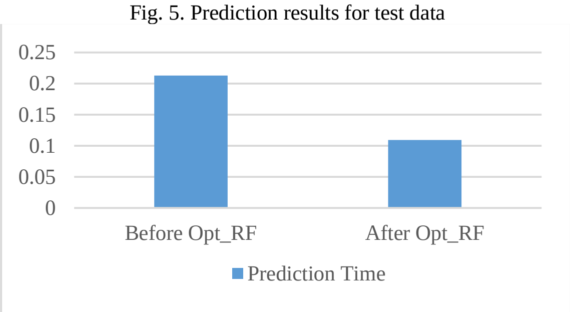

Fig. 6. Comparative prediction time graph

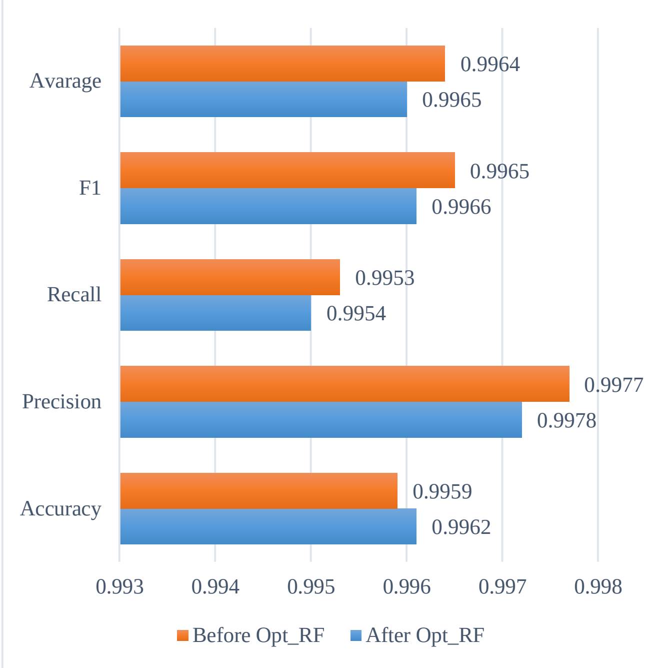

Fig. 7. Comparative graph before and after optimization

CONCLUSION

In conclusion, during the RF model optimization phase, the parameters max_samples, max_depth, and n_estimators were further optimized using the RF optimization algorithm. When tested on 225,711 sets of synthetic CIC-IDS2017 data, the results showed that the accuracy of detecting DDoS attacks with this infrastructure was 99.62%, precision was 99.78%, recall was 99.54%, and F1_Score was 99.66%, with a detection time (predict_time) of only 0.1 seconds. All results achieved excellent performance in the same category. Furthermore, the results demonstrate excellent generalization performance, having been tested on over 1 million synthetic data sets and over 330,000 CIC-DDoS2019 data sets. This structure achieves the goals of strong generalization capabilities, high prediction accuracy, and short prediction time for DDoS attack detection. For future work, this optimized RF model with high accuracy, short prediction time, and high generalization performance for DDoS attack detection is highly practical and can be deployed in production environments in real-time detection distributed systems in conjunction with big data technologies.

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USING THE METHOD SAMPLING IN DETERMINATION OF MOVING OBJECTS IN REAL TIME VIDEO

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Abstract—This article presents the results of scientific research on images, videos, as well as the separation of people from the camera in real time and their accounting. In this case, first of all, information is provided on the division of objects into categories. A model has been proposed for taking the background when separating objects from images. Methods for eliminating excessive noise (interference) in images are given. The software was developed using OpenCV in the Python programming language, using the capabilities of the tensorfow library for images, videos and real-time detection and accounting of human objects from the camera.

Keywords: *image, object, Robert, Sobel, Prewitt, method, frame, border, coordinate, Xaafa.*

Introduction

There are problems in the field of digital processing information in the form of images and identification logos which scientists and staff of the research institute are conducting research. Given that 80% of the information transmitted is images, it is possible to understand how urgent it is to scientifically solve problems related to images. Various errors can occur when creating an image in computer memory. This can be due to the movement of the camera or lens, objective data, defects in the photographic media, motion and changes in the autosphere, defects in the transfer of images to computer memory, and other reasons. The result is the spread of image boundaries, a decrease in the degree of differentiation areas, distortion of information in some parts, or obstructions in the form of scattered spots in the image. Of course, in this case this complicates the image analysis and sometimes leads to large errors. This means that when processing images, they must first be freed from these interference, or their impact on the outcome of subsequent steps must be minimized. This issue is called image quality improvement. Images of objects can be black and white (whiter) or color image. Black-and-white images can include text, book pages, documents, car license plates, X-ray images, and other types of images. Color images include a variety of scenes, crop fields, and similar images. Deciding on the state of an object based on the digital study of an object image is called the intellectualization image processing processes [2].

Today one of the most important issues in the world is the prevention of crime, security, drawing conclusions through the scientific analysis of digital images in various areas of research and production.

The images that need to be scientifically analyzed today can be distinguished on the basis of the following.

1) Images in motion. Examples of this type image are a person walking, a moving car, and so on.

2) Biometric images (human face, fingerprint, pupil and ear shape).

3) Biological or medical images (images of cells obtained using an electron microscope, etc.).

4) Space images (satellite imagery of the earth's surface or surface images of various other planets, etc.).

5) Maps and various geological images.

In the above issues, the task or problem of processing images, distinguishing their specific features will have to be solved.

Materials and Methods

The research was conducted to take images from surveillance cameras, to take into account people walking and to separate the objects in the image. When recognizing an object from an image, it is important to correctly distinguish the identification marks. The reason is that these symbols will be used in the future to identify objects in the image or to make other scientific conclusions. Each image has its own characteristics, in particular its own characteristics. There are many types of image characters. For example, characters related to pixel lighting, symbols based on the shapes of the object in the image, symbols based on the distances between certain points, and other similar symbols can be used. Different methods are used to identify the characters. In particular, it is possible to identify the characters in the image using direct image processing methods, statistical formulas, Xaafa substitutions, and other similar methods [10,3,6]. Depending on the nature of the image and the nature of the problem, image symbols are defined in different ways. The following is a structural interpretation of the process that reflects the character properties in the image (Figure 1).

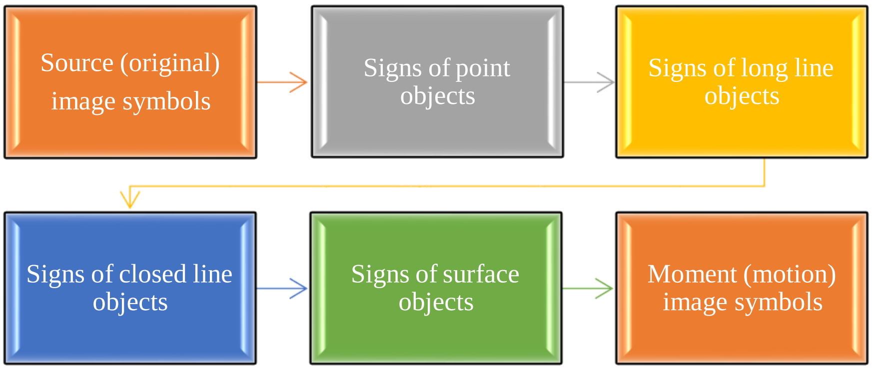


Figure 1. Properties of the characters in the image.

One of the most important issues in separating digital data from video images is the separation of objects in an image, i.e., segmentation. To do this, different methods are used to find and separate objects. Typically, image fragmentation methods are designed to be applied to existing class images. The most widely used algorithms for image segmentation are WaterShed, MeanShift, FloodFill, GrabCut [11,13]. The possibility of using the fragmentation method depends on whether the image satisfies a certain set of assumptions.

Before developing object detection systems in video images, it is important to know how to use object detection methods. The purpose of this is to consider the coordinate separation of moving objects. Below you can see the separation of the object in the video image.

Figure 2. Separating a moving object

In the images above, a model is constructed that detects a moving object in the selected video based on the observed situation and captures the moving object in a defined frame. To do this, when identifying objects in video images, it is necessary to pay attention to the separation of objects without the use of any database. Using the structure below, one can identify objects in video images.

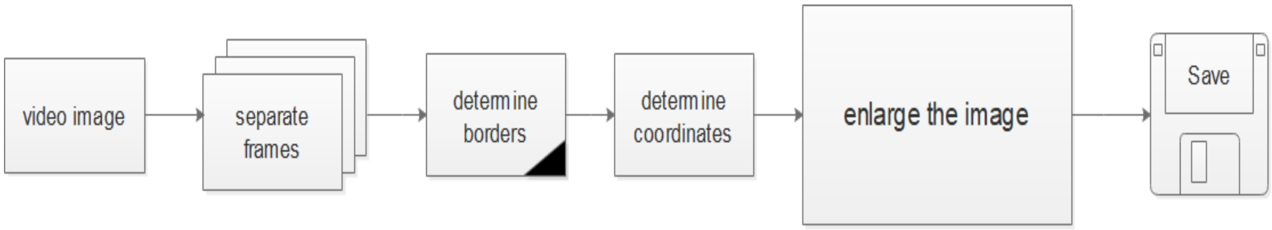


Figure 3. The initial structure of object detection in video

A video is a set of frames that are assembled in series, meaning that if there is a moving object in the video image, it is possible to observe the change in pixels and coordinates of each consecutive frame image. Suppose we divide the motion of objects in a video image into frames A and B, we can distinguish the presence of a moving object in the image by comparing it with the initial state of frame A and the position of frame B. [3] That is, the following formula is used to calculate the sequence of video taken from surveillance cameras.

$$S(a,b) = \begin{cases} 1, |\ f_k(a,b) - \ f_{k-1}(a,b)| \geq z \\ 0, |\ f_k(a,b) - \ f_{k-1}(a,b)| < z \end{cases}$$

where a, b are the frames defined by the invention, f is the total number of frames in the video Z is the boundary of the video image. In Figure 4 below, it can be seen that the video image is divided into a series frames.

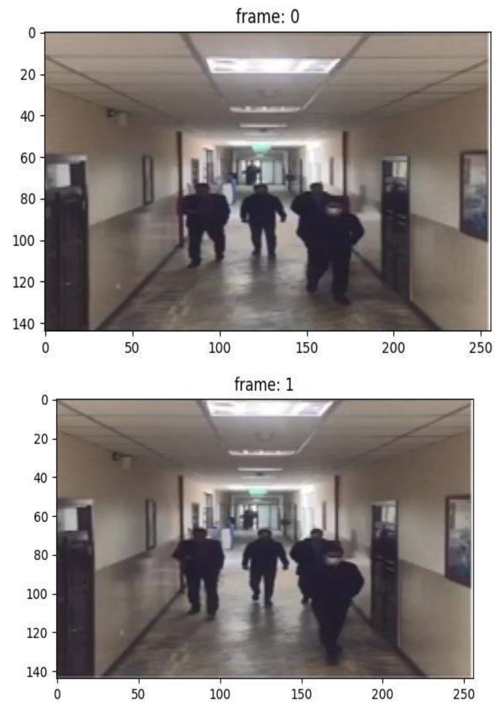


Figure 4. Frame the image and compare

Setting the image boundary

In this method, the gray pixel values in the image are assimilated to the values representing the white and black colors. Then, if the value of the pixel is greater than the limit value, one or the other values are assimilated [4,8].

It is shown from formula 1.1 that if a moving object moves in a straight line, the moving target object in the video image will be the same using the framing. The framing process can be done on two frames or by increasing the number of frames. In this case, the reliability of the result depends on the number of staff and the time spent on the process increases accordingly.

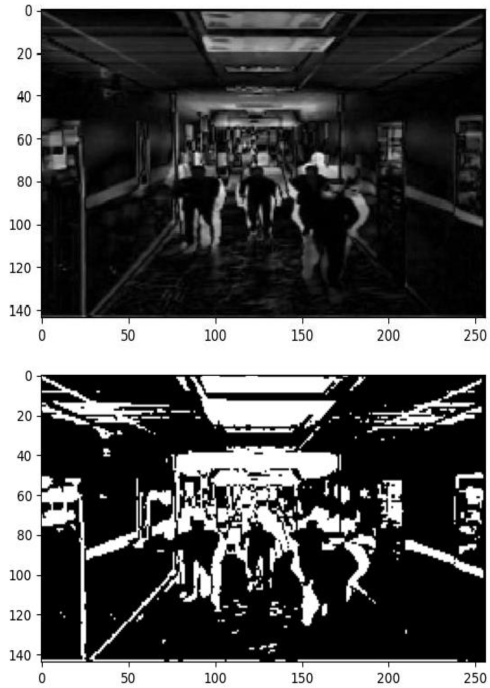


Figure 5. Define the boundaries of the image.

Defining contours

Typically, pixels are used to identify field contours that have the same color or intensity in an image. There are several methods for contouring, such as Robert, Sobel, and Previtt [11,13,14]. All of these methods are based on refracting light rays in an image. Given that a number of scientists have conducted scientific research on the above methods, the Sobel method has been found to be effective. Sobel operator is listed below:

$$S_x = (a_7 + 2a_8 + a_9) - (a_1 + 2a_2 + z_3)$$

or (1.2)

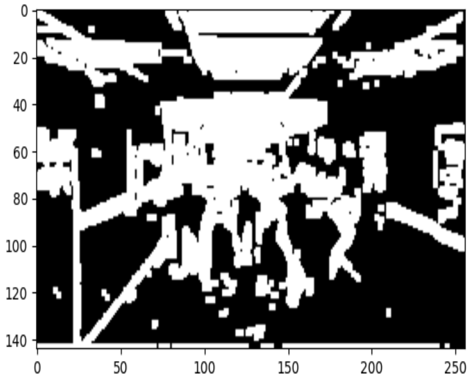
$$S_y = (a_3 + 2a_6 + a_9) - (a_1 + 2a_4 + z_7)$$

where is the pixel ratio of the two S_x *and* S_y images containing the approximate products at each x and y-points.

This extension is used to reduce the grinding effect by giving a high degree to the center points. The use of the Sobel operator is performed in the following 3 * 3 cases [7].

-1	-2	-1
0	0	0
1	2	1

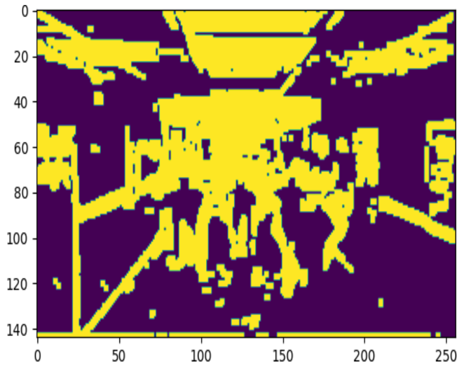
-1	0	1
-2	0	2
-1	0	1



Results and Discussion

In evaluating the proposed structure to identify the object in Figure 3, two different object classes were identified, moving or suspended. More than 100 image frames of 256x114 size were extracted from several video files for each class. By comparing the pixels and coordinates of any two images from the selected frames, it was determined whether a moving object was present in it or not.

After the step of defining the boundary of the above image, the following result can be obtained by defining the contours of the objects in it.



The process of detecting moving objects in video using the capabilities of the OpenCV library in the Python programming language was carried out on the basis of the structure of the moving object detection (Figure 3) by defining the boundaries of moving objects from the image in surveillance cameras. Figure 7 shows the results of this experiment.

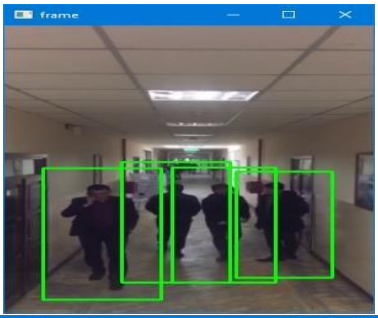
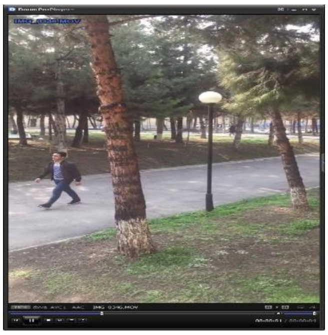
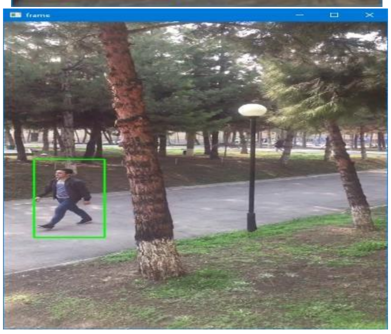
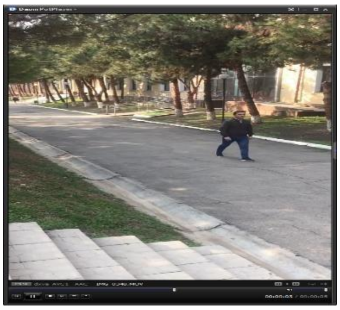
Types of images	**Incoming image**	**Outcoming image**
Video taken from straight		
Video taken from left		
Video taken from right		

Figure 7. Identifying the human object in the video images

Conclusion

The initial structure of the proposed object detection, based on the results of the experiment, can be concluded that the efficiency of the method of comparing frames to separate moving objects from video images was 91%.

But the disadvantage of this method is that it assumes the quality of a single object when the coordinates and pixels of the two objects in motion overlap. This shortcoming can be remedied by comparing the distances between objects.

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Conceptual Presentation of a Behavioral Interaction Model in Infocommunication Network Structures

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Abstract— The methodological approach to the study and analysis of info communication network structures and their functional capabilities, based on the use of the principles of system analysis and synthesis of intermediate software, and allowing to determine a set of objects, is presented (distributed elements) when implementing the functions and processes of a distributed environment, to study in detail the principles and mechanisms of the interaction of services and resources, as well as the effective interaction of network and system components both for the distributed architecture of the network itself, and for interacting protocols, services and interfaces.

Keywords— distributed information space, info communication network structure, associative environment, conceptual representation of a behavioral model, processes of interaction of system components.

I. INTRODUCTION

Let's turn to the methodology of analysis of processes of interaction of components of info communication network structures based on the principles of formation of network architecture and determine the features of network structures and processes operating in subsystems.

The functional architecture of the info communication network (ICN) defines a functionally related set of hardware-software tools for processing and exchange of information; the basic requirements when considering different scenarios in ICN are defined by properties or attributes, inherent functional and network element configurations in distributed computing structures (in terms of software architecture), i.e. info communication network structure is defined as any set of architectural and/or system components, involved in distributed network computing. At the same time: the architectural representation of distributed network computing defines different sides (behavioral, structural, logical, physical, implementation, etc.) of the system; the set of structures or representations has different levels of abstraction and shows different aspects of the architecture (class structure, deployment, component interaction scenarios, etc.); software component as a software unit, executed within a single process, and providing some set of services used through its external interface by other components, can be adopted to describe and implement complex relationships in the respective structures of distributed networks and systems.

To describe the architecture the method of sequential functional decomposition is applied, the levels of functional architecture, groups of functions, types and stacks of functionally oriented elements implementing these systems are defined. For such elements to interact, however, there must be an intermediate environment in which different internal and inter-system mechanisms are used, providing a standard cross-platform service for data exchange. The directions of information connections in the implementation of such mechanisms and their diversity predetermine the complexity of interacting processes, for the description of which it is proposed to use distributed associative processes in the interpretation of the theory of associative environments.

II. FEATURES OF THE ORGANIZATION OF DISTRIBUTED COMPUTING SYSTEMS

The field of distributed computing systems is currently characterized by a rapid pace of change in ideologies and approaches, when many different paradigms for the implementation of distributed computing appear, each of which brings something from the basic concepts or new approaches to development. There are two main approaches to the development of distributed computing systems [2]. On the one hand, the concept of the Web is a human-centered distributed information space; on the other hand, distributed object technologies such as CORBA and DCOM primarily focus on creating distributed environments that emulate the development and execution of local applications, providing the benefits of accessing network resources.

With the development of technologies, naturally, the provided capabilities of distributed computing systems grew, but they became more and more "heavy" in terms of development and use. At the beginning of the new millennium, the development of new methods of middleware for distributed computing systems gave impetus to the development of peer-to-peer (P2P) and Grid technologies, with all the advantages and disadvantages. At the same time, development of the next generation of specifications is ongoing to address the challenges of early distributed object technology standards through Web services and a service-oriented architecture.

The merger of different approaches to the provision of computing resources in the form of services has led to the emergence of a new concept called "Cloud computing" [3,4,5], where there is a space consisting not only of a set of servers that process user requests, but providing users with a whole set of platforms to which they can connect as needed and use only the part of this platform that is currently needed. (In this case, the platform refers to applications delivered as services via the Internet, hardware and software systems in data centers interconnected with each other).

Generalization of these approaches to implementation gives grounds to give a definition of a distributed computing system: it is a set of independent computers connected by communication channels, which, from the point of view of a user of any software, look like a single whole [6]. In this definition, it is important to note two essential points: the autonomy of the nodes and the presentation of the system to users as a single structure. At the same time, the main connecting link of distributed computing systems is software. The autonomy of the nodes allows us to consider units of software, and the uniformity of the structure - the presence of a single computing space or environment as the basis for the consolidation and unification of processes and resources involved in distributed computing.

Another important point is that the above options for the implementation of distributed computing systems are united by the basic idea of creating a single (virtual) layer over the existing infrastructure to ensure collaboration and use of shared resources.

Based on the context of the dissertation research, the task is to develop (determine the foundations for creating) a distributed computing environment, the purpose of which is to organize effective computing structures that allow the implementation of control functions for processes and / or mechanisms involved in distributed computing. As will be argued in subsequent sections of the dissertation, a distributed computing system can be described as a set of interacting components that exchange information representing certain categories:

- Details about the components and their functionality;
- Information about interactions between components;
- Generalized information about the workflow and more specific information on a particular task.

It is obvious that ensuring the functioning of such a system requires adequate methods of interaction between the components. The theory and practice of research in this area (software engineering and engineering of distributed systems) shows that for solving this problem, methods of interaction between agents and agent systems have proven themselves as a fairly complete tool that allows you to develop and standardize both architectures and languages of agent interaction [6, 7].

Agent technologies are used in two ways: on the one hand, it is a way of implementing control functions in distributed systems [8]; on the other hand, it is the basis of simulation for the study of dynamic and complexly organized systems. In both cases, the concept of a software agent is introduced as an autonomous process capable of reacting to the runtime environment and causing changes in the runtime environment, possibly in cooperation with users or other agents [9].

III. THE STRUCTURE OF INFOCOMMUNICATION NETWORKS INVOLVES ASSOCIATIVE PROCESSES

In accordance with the provisions of intelligent systems, the implementation of information processing and control technologies, and, consequently, the organization of the computational process, largely depends on the implemented principle of the system organization in each specific case, on the basis in which the models of dynamic objects and processes are represented, as well as from a number of other factors.

At the same time, it is important to study the intuitive or associative aspect of information processing by a person and its implementation in information technologies: a person is able to flexibly process information, because the brain connects a distributed presentation of information, highly parallel processing, the ability to learn and self-organization, as well as the ability to integrate information [10].

To take into account this possibility in technical implementation (including at the level of intelligent systems), the following features of information processes should be taken into account, namely:

- Functional, characterized by eligibility and integration of uncertain and questionable information and capacity to adapt and learn;
- Computing, which is characterized by highly parallel and distributed processing of multimodular and multidimensional data, with many informative links.

These features of information processing are developing and integrated in accordance with the development of technologies, the introduction of distributed computing resources and data storage, complex intelligent systems, the use of composite applications, etc.; in this case, naturally, various processes of information interaction arise in info communication network structures.

Changes that occur as a result of information interactions between sets of elements of one level of the hierarchy can be both quantitative and qualitative in nature. The former are characterized by changes within information systems, while the latter are characterized by changes in the hierarchical structure, as well as changes in relations and interconnections between sets of information systems at different levels of the hierarchy.

Taking into account the principles of multi-level organization of ICS interaction, one can consider the architecture of the global Internet, in particular, for the TCP / IP stack, represent the interaction of network node modules through an abstract associative environment, for which the basic concepts and principles of its concept are determined.

An information system in this regard is a system, the organization of which is based on formative rules that determine the properties of reflection, transmission, accumulation, analysis, transformation and exchange of information.

The architecture of the TCP / IP protocols is designed for an interconnected network consisting of heterogeneous packet subnets connected to each other, to which heterogeneous machines are connected [10]. Each of the subnets operates in accordance with its specific requirements and has its own nature of the communication means. For example, when an Ethernet frame hits an Ethernet network interface driver, it can be routed to either the ARP module or the IP module [11]. Where an Ethernet frame should be routed is indicated by the value of the type field in the frame header. If an IP packet enters the IP module, then the data contained in it can be transferred to either the TCP or UDP module, which is determined by the "protocol" field in the IP packet header. Data from the application process passes through the TCP and UDP modules, after which it enters the IP module and from there to the network interface layer.

In the case under consideration, a set of interacting components will be understood as a common node of the Internet (Fig. 1). The operation of the network node is based on the principles of a modular (protocol) architecture, and, accordingly, under the information system we mean a set of interacting modules (elements) of the network node in accordance with the level organization of the TCP / IP stack. The concept of an information system, a model of a certain level of the hierarchy SK(L) corresponds to the set PK(L) of the environment in a certain way ordered elements that have the properties of reflection, accumulation, storage, analysis, transformation and exchange of information [11]

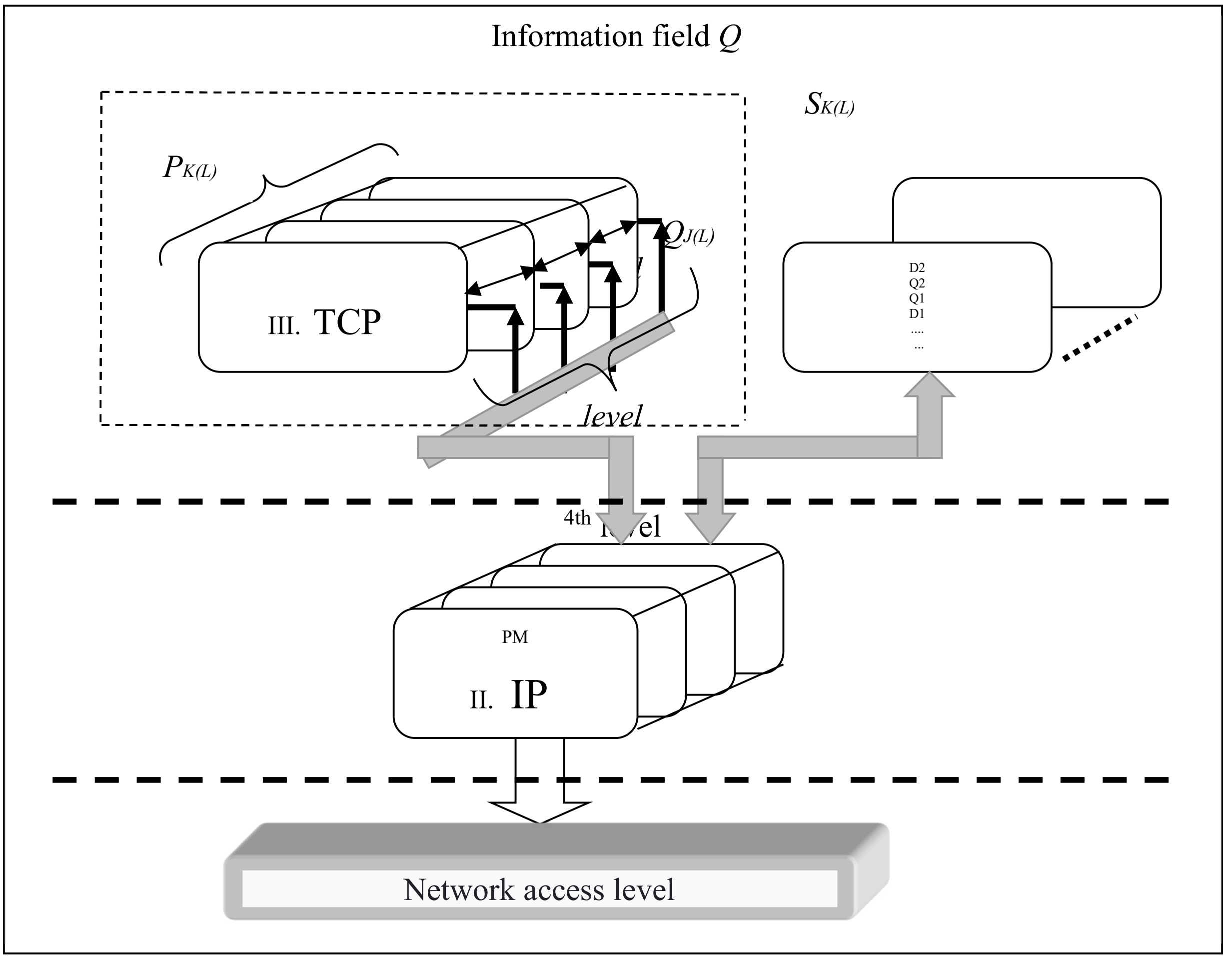

Fig. 1. Structure of TCP / IP stack modules.

The set $P_{K(L)}$ is characterized by the corresponding value of the selected attribute of the hierarchy level; here L is the hierarchy level for $S_{K(L)}$ and the value of the hierarchy attribute for $P_{K(L)}$; K is the index of the K-th subset of information systems of the L-th level of the hierarchy $E_{K(L)}$ and the index of the set from the totality of the set of elements of the L-th level of the hierarchy $\{P_{K(L)} / K = 1...Z\}$. E_L - a set of information systems of the L-th level of the hierarchy; $E_{K(L)}$ - K-th subset of the set of information systems of the L-th level of the hierarchy; $S_{K(L)}$ is an information system from $E_{K(L)}$.

In the general case, the information field Q is all information in a potential form about the state space of the information system, implying the information necessary for the interaction of various modules of the network node, and characterizing the interaction of elements in the network node, taking into account their level organization.

The level of the hierarchy of the information field *QL* (where *L* is the level of the hierarchy) is information from the information field *Q*, which can be reflected by information systems of a certain level of organization of the level model in all sets of cells of the corresponding *L*-th (not higher) level of the hierarchy.

Hierarchy level layer of the information field QJ (L) (where L is the hierarchy level, J is the layer index) is information available for a separate subset of information systems of a certain hierarchy level (reflected in a separate set (in the limiting case, in a separate set PK (L)) sets of elements of the L-the hierarchical level)); Characterized by a combination of interactions of sublevels and levels of a multidimensional model. The information characterizes the fundamental aspects of the functional purpose of the corresponding sublevels and their components in conjunction with the interaction of protocols of certain levels of the hierarchy.

CONCLUSION

Thus, the information exchange processes in the model show that within the model there are hierarchies of interacting levels, each of which determines its own requirements for the exchange process; Depending on the chosen implementation of the network architecture, different functionally oriented elements (objects) are possible.

On the basis of systematization and categorization of interaction aspects regarding the processes and components on which distributed computing or application is based, we substantiate the need for special resource management mechanisms in distributed environments: to coordinate and integrate them. Bases of functional organization of system components of info communication network structures used and created to meet the needs of users of distributed environment in various services are created, Ensure transparent and flexible resource allocation, taking into account multiple processes of varying complexity, nature and intensity.

A methodological approach to the study and analysis of infocommunication network structures and their functional capabilities, based on the application of the principles of intermediate software and allowing to determine a set of objects (distributed elements), has been proposed and substantiated when implementing the functions and processes of a distributed environment, in order to study in detail the principles and mechanisms of interaction of services and resources, as well as the effective interaction of network and system components as for the distributed architecture of the network itself, and for interoperable protocols, services and interfaces.

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Creation of A Three-Dimensional Model of The Underground Layer Using Digital Processing of Signals Obtained From Field Geophysical Research

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***Abstract*—This article is devoted to the creation of a three-dimensional model of the underground layer using digital processing of geophysical signals measured by the electroprofiling method. First, the general concepts of measuring signals from the underground layer using the electroprofiling method, which is one of the main search methods of geophysics, are presented. As a research object, the 4th zone of the copper processing factory of the Almalyk Mining and Metallurgical Combine was selected for conducting geophysical research. The layout of 27 electroprofiles for measuring signals in the study area is presented. The measured signals from all profiles are summed to form a two-dimensional signal. In solving the research problem, mathematical methods were used to determine the coefficients, fast Haar transform algorithm and the B-spline interpolation methods were used to restore the values. Based on the obtained results, three-dimensional graphs are presented to represent the anomalous zones of the underground layer. Contour plots mapping the subsurface structure at 10m and 25m depths corresponding to the measured signals are depicted. By means of interpolation, the layers between the two layers are identified and represented graphically. Based on the obtained results, a three-dimensional graphic model of distribution zones of electrical resistance in geological environment was created.**

Keywords*—*geophysical signal, electroprofiling, digital signal processing, fast Haar transform, interpolation, B-spline.

I. Introduction

Often in geophysical research, samples are taken from the research area using geoelectric sensors or induced electromagnetic sensors to search for some anomalies. Also, in geological exploration, gravity exploration, electric exploration and magnetic exploration methods are used. These methods make it possible to analyze the changing gravitational, electric and magnetic fields on earth [1],[19].

One of the main research methods of geophysics is the method of electroresearch. It is based on the study of natural and artificial electromagnetic fields created under the influence of constant and alternating electric current sources. This method is used in the study of the underground structure, in the search and exploration of minerals, in solving and studying various problems of engineering geology and hydrogeology. Portable devices are used in the exploration of small depths (up to 500m) in electroresearch. Various electroreconnaissance stations are used to study great depth (up to 5 km) [2],[15]-[16],[20].

The use of mathematical methods in solving geophysical problems is very important. Spectral analysis and spline methods are widely used in solving geophysical problems [1],[3].

Spectral analysis is a comparative and independent analysis method used in studying the properties of geophysical objects. This method is used to obtain information about the spectrum, spectral part, spectral direction and other properties of geophysical objects. Spectral analysis is important in determining the structure of geophysical objects and considering their changes [3]-[5],[7]-[8].

In recent years, the mathematical apparatus of splines, developed by the efforts of many researchers, has taken a worthy place among the methods and algorithms of digital signal processing [1],[9]-[10].

In the digital processing of geophysical signals, a spline is one of the mathematical models used for statistical data interpolation and analysis. Splines can help to analyze key features and changes in to data. Connecting specific points together to analyze changes in the signal helps to identify and explain the changes between points. Splines are used to visually analyze data and identify important features in data [1],[21].

II. Measurement of Geophysical Signals

A. Electroprofiling

One of the most widely used methods in electroresearch is the electroprofiling method. Electroprofiling is an exploration method based on measuring electrical resistance, in which changes in relative resistance of subsurface rocks are studied with devices of constant dimensions along given profile directions. In this method, the distance between the supply electrodes does not change during operation, which means to study the approximately constant thickness of the rocks under all points of the profile [15],[18]-[20].

In practice, a simple four-electrode symmetrical device is widely used. When using such a device, the name of the electric cut is called symmetrical electric cut. Let the positive pole be connected to the electrode A and the negative pole be connected to the electrode. Let the distances be AM = BN, AN = BM, that is, the center point of the device is symmetrically located at O (Fig. 1) [19].

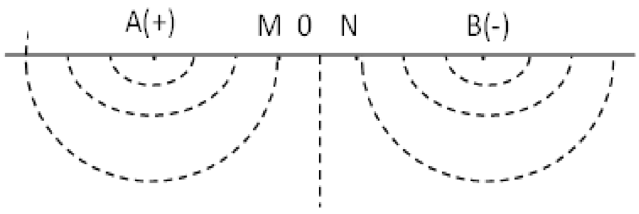

Fig. 1. Electroprofiling method

In symmetric electroprofiling with four electrodes, a device is used, and during observations, it is moved from picket to picket in a row without changing the distances between these electrodes, and the value is measured. The values of ρ_k calculated from the measured $\Delta u, J$ values are determined along the profile

$$\rho_k = k\frac{\Delta u}{J}$$

The specific electrical resistance of different rocks varies in a very wide range: from 0.001 Ohm to 1015 Ohm in pure metals [19]-[20] .

The depth of study is determined by the depth of the passage of electric current into the medium. The greater the distance between the supply electrodes (A and B), the greater the penetration depth of the electric current. In a homogeneous medium, most of the electric current delivered to the two supply electrodes A and B does not exceed the penetration depth equal to the distance $\frac{1}{2}$AB. If the rocks with low resistance lie under the upper layer, the depth of the current will be greater. If there are rocks with high resistance under the upper layer, the penetration depth of the current will be small. Thus, in order to increase the depth studied in resistance methods, the distance between the supplying and receiving electrodes is increased [20].

B. *Measurement of geophysical signals from the research object*

As a research object, the territory of conducting geophysical research on the construction of the planned dump of the copper processing plant of the Almalyk Mining and Metallurgical Combine was selected. The tasks of geophysical research are as follows:

- determining the level of underground water;

- determination of geoelectrical conditions and detection of disturbances in Quaternary deposits;

- determination of elastic modules;

To solve the problems that are shown above, the two-horizon symmetric electroprofiling geophysical method was used. The electrical search by the method of electroprofiling was carried out using a two-span symmetrical AA'MNB'B installation [2],[20]. The distance A'B' is 50m, and the distance AB is 130m. The length of the MN receiving line is 10m. The distance between the measurement points of electroprofiling is 100m. Values were measured by electroprofiling method from 27 profiles installed in parallel in the study area (Figure 2). McOHM-EL (Japan) electric search system was used as the measuring equipment.

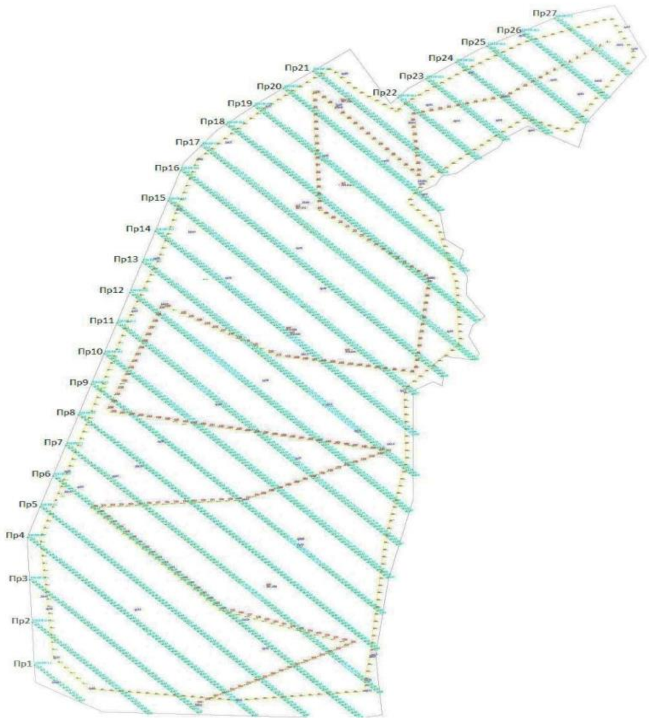

Fig. 2. Location drawing of electrical profiles in the 4th area of the copper processing plant of the Almaliq Mining and Metallurgical Combine

The signal values measured by electroprofiling with A'B'=50m and AB=130m were recorded in a file as shown in Table 1 for each profile.

X(north latitude) and Y(east longitude) presented in the table represent the coordinates of the profile points set in the research area. AB=130m and A'B'=50m columns show the signal values obtained from the profile point at the depth corresponding to these intervals.

TABLE I. MEASURED VALUES FROM PROFILE 1

Profile point	X(north latitude)	Y(east longitude)	AB=130м	A'B'=50м
1	-23476,749	-31226,411	11,6	9,5
2	-23547,283	-31155,615	12	9
3	-23617,899	-31084,834	11,8	8,3
4	-23688,668	-31014,045	12,5	9
5	-23759,298	-30943,228	13,2	8,7
6	-23829,978	-30872,543	13,5	9
7	-23900,58	-30801,772	14	9,5
8	-23971,316	-30731,004	15	10,3
9	-24041,915	-30660,247	14,5	9
10	-24112,522	-30589,42	15	11
11	-24183,814	-30518,557	17	13
12	-24253,78	-30447,85	19	17,5
13	-24324,545	-30377,178	17	17
14	-24395,242	-30306,353	16,5	16,5
15	-24466,15	-30235,205	17	15

Graphical representation of geophysical signals measured by electroprofiling on profiles at intermediate points of the profile allows for visual analysis of signal values. Figure 3 below shows a graph of the change in electrical resistance in profile 8. Then the resistances in both intervals A'B'=50m and AB =130m are almost identical. In the range of 1-78 points, the resistance values vary from 10 Ohm to 30 Ohm, which is suitable for sandblasters. Between points 79-84, resistances vary from 80 Ohm to 185 Ohm, which means that this rock layer consists of gravels.

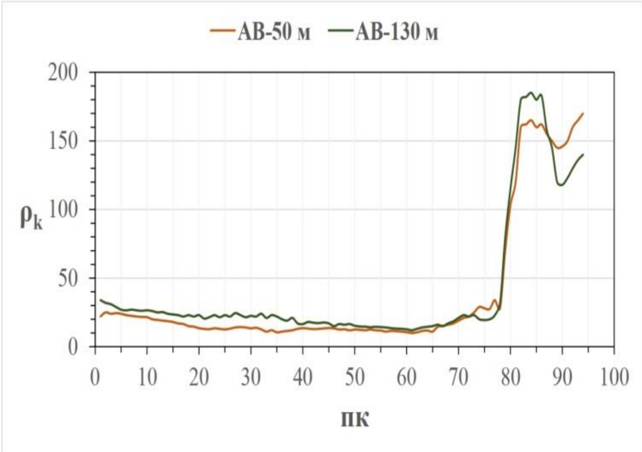

Fig. 3. Graph of change of electrical resistance in 8 profiles

In order to have general information about the signal values obtained for all 27 profiles, for the purpose of better visual representation, digital processing and analysis, we formed a two-dimensional array based on them. For the analysis of two-dimensional geophysical signals, we use mathematical methods of digital processing of signals to determine coefficients and restore signal values.

III. Two-dimensional fast Haar transform

A two-dimensional signal can be viewed as an ordered collection of one-dimensional signals. With this in mind, many of the principles and practices of one-dimensional signal processing in signal analysis and processing apply to two-dimensional signal processing [4]-[8],[12]-[14].

Two-dimensional basis functions are formed by multiplying two one-dimensional basis functions [7]-[8]. Also, the two-dimensional Haar basis is defined as:

$$har_{n,m}(x,y) = har_n(x) * har_m(y)$$

Correct discrete permutations of two-dimensional signals using bins are determined by the following formula:

$$C_{n,m} = \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} X(i,j) har_n(x_i) har_m(y_j) \qquad (1)$$

In the above equation, with the system of basis functions depending on the argument of the inner sum, we form the following:

$$S_m(i) = \sum_{j=0}^{M-1} X(i,j) har_m(y_j) \qquad (2)$$

Then it can be written as follows:

$$C_{n,m} = \sum_{i=0}^{N-1} S_m(i) har_n(x_i) \qquad (3)$$

Inverse two-dimensional discrete permutations with respect to basis functions are performed as follows:

$$X(i,j) = 2^{-p} 2^{-q} \sum_{k=0}^{N-1} \sum_{l=0}^{M-1} C_{k,l} har_k(x_i) har_l(y_j) \quad (4)$$

$$A(i) = 2^{-p} \sum_{k=0}^{N-1} C_{k,l} har_k(x_i)$$

$$X(i,j) = 2^{-q} \sum_{l=0}^{M-1} A(i) har_l(y_j)$$

Here $p = 1,2,\dots,log_2 N$; $q = 1,2,\dots,log_2 M$.

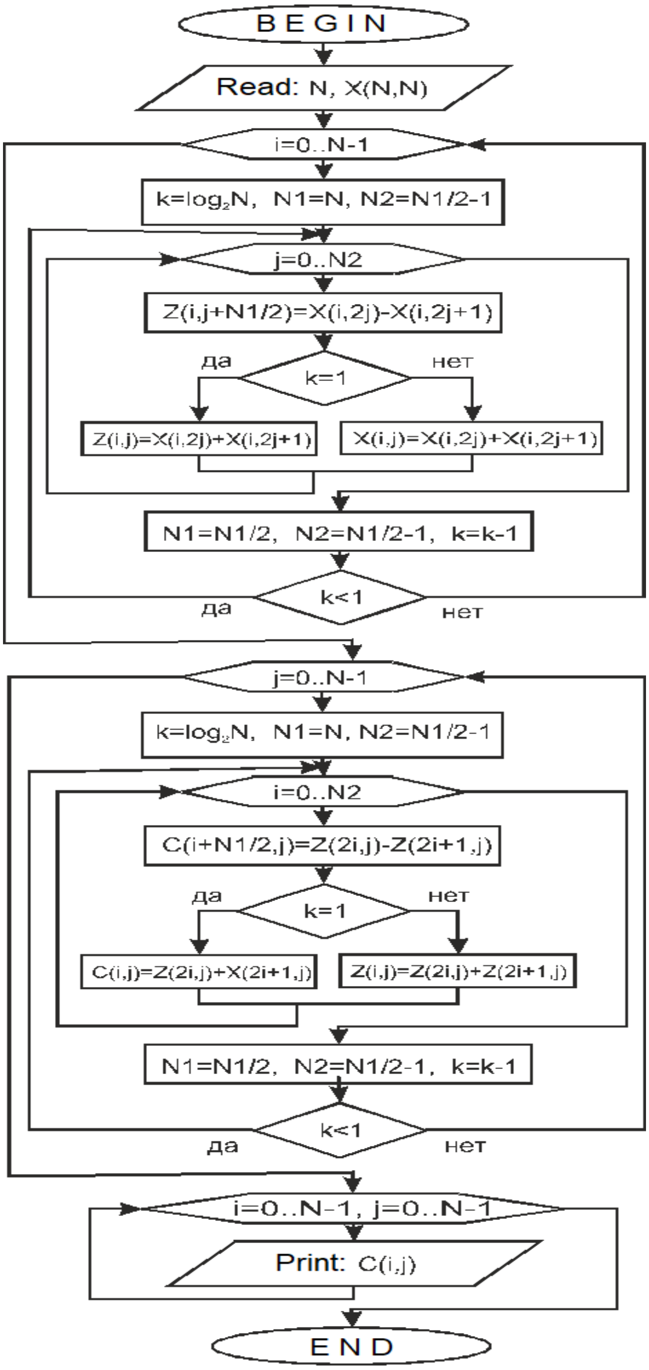

Fig. 4. Algorithm block diagram of fast Haar transform by Andrews of two-dimensional signals

Based on the formulas (2)-(3) given above, we use the algorithm of digital processing of one-dimensional signals by rows and columns in the digital processing of two-dimensional signals. First, sequential array elements per row are numerically processed, and the resulting result is numerically processed into sequential array elements per column [7].

Figure 4 shows the block diagram of the fast Haar transform by Andrews of two-dimensional signals.

IV. CUBIC B-SPLINE

Interpolating cubic splines approximate the object being interpolated well, and the construction appears simple. The level of the spline being constructed does not depend on the node points. The spline function being built is not built in [a,b] interval, but in $[x_i, x_{i+1}]$ (i=0, n-1) intervals, and this spline function consists of polynomials with the same structure in each interval [5],[10]-[11].

Cubic B-splines are expressed as:

$$B_3(x) = \begin{cases} 0, & x \geq 2, \\ \dfrac{(2-x)^3}{6}, & 1 \leq x < 2, \\ \dfrac{1}{6}(1 + 3(1-x) + 3(1-x)^2 - 3(1-x)^3), & 0 \leq x < 1, \\ B_3(-x), & x < 0. \end{cases}$$

Figure 5 shows a set of splines with a cubic basis shifted to a constant step h=1.

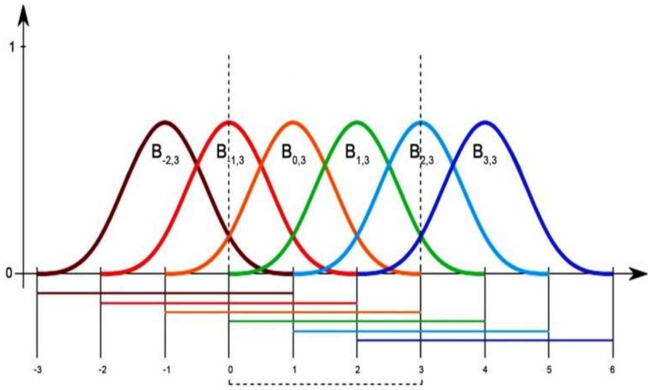

Fig. 5. Complex of cubic basis splines.

A spline Sm(x) of degree m with 1 defect interpolating the function f(x) can be summed only using B-splines:

$$f(x) \cong S_m(x) = \sum_{i=-1}^{m+1} b_i \cdot B_i(x), \quad a \leq x \leq b \qquad (6)$$

Constructing splines based on experimental data (analytical and tabulated) consists in finding b_i coefficients [9]-[10].

The 3-point local formula for splines of degree 3 looks like this:

$$b_i = \frac{1}{6}(-f_{i-1} + 8f_i - f_{i+1}) \qquad (7)$$

These formulas preserve the smoothness properties of the approximation, while the coefficient values do not depend on the reading of the node points, sufficiently far from the current point. The formulas are symmetric, but they can only be applied to the internal nodes of the interval. The coefficient values at the boundary points, as mentioned above, can be determined by separate extrapolation at the beginning and end of the interval, as well as by introducing additional nodes [10],[21].

V. RESULT

Coefficients were determined by digital processing of two-dimensional signals according to the fast Haar transformation algorithm. A three-dimensional graph was drawn based on the obtained results. Figure 6 shows the graphs of signal results obtained for A'B'=50m and Figure 7 for AB=130m. Signals received at the interval A'B'=50m represent the underground layer at a depth of about 10m, while signals received at the interval AB=130m represent the underground layer at a depth of about 25m.

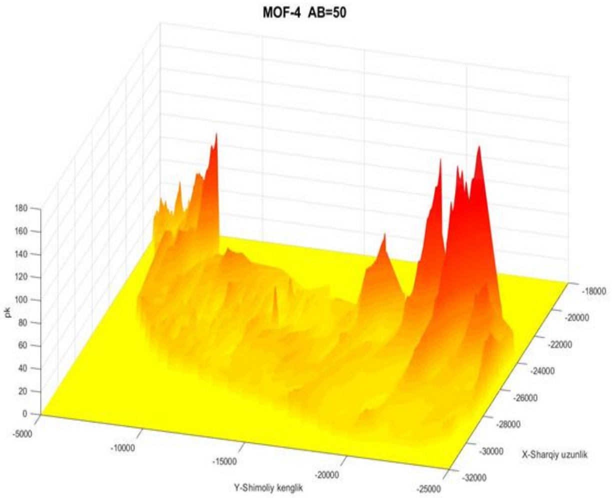

Fig. 6. A graph of the received signal results for A'B'=50m

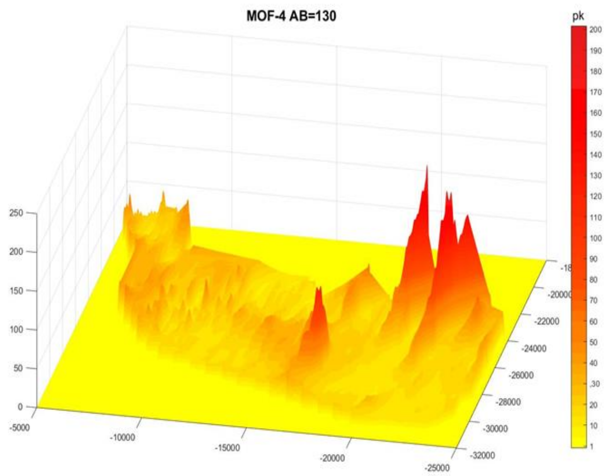

Fig. 7. A graph of the received signal results for AB =130m

A contour plot was drawn to more accurately represent the subsurface layer. The contour graphic made it possible to map the subsurface layers at depth. Figure 8 shows the contour graph representing the signal results obtained at the interval A'B'=50m at a depth of approximately 10m, and Figure 9 shows the contour graph representing the signal results obtained at AB=130m at a depth of 25m. The high peaks and areas marked in red in the above graphs represent zones of high electrical resistivity associated with the different metal content of the rocks in the geological environment.

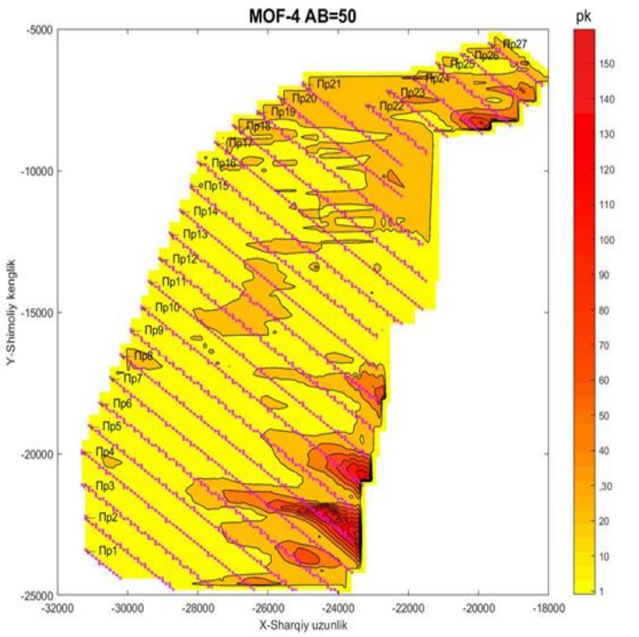

Fig. 8. A contour plot of the received signal results for A'B'=50m

For intervals A'B'=50m with a survey depth of about 10m, the resistances are distributed as follows:

- in the central and western parts of the region, the rock resistance varies from 9 to 20 Ohm;
- in the northwestern and southwestern parts of the region, the resistance of the rocks increases to 40-60 Ohm.

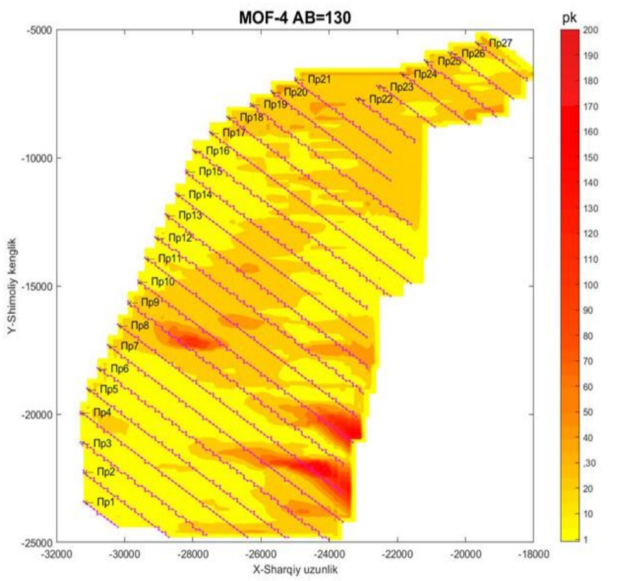

Fig. 9. A contour plot of signal results obtained at AB=130m

In the interval AB=130m with a survey depth of about 25m, the specific resistances are distributed as follows:

- in the southwestern, western and eastern parts of the region, the rocks are characterized by a relatively low resistance of up to 20 Ohm.m;
- in the northern and central parts of the region, the resistance increases to 30-50 Ohm. The highest resistivities of about 40-70 Ohm are recorded in the southeastern part of the region.

According to the received signal results, we can only have information about the structure of the underground layer at a depth of 10m and 25m. In order to determine the anomalous zones of the layers between them, the values between them were determined by interpolating the signal values obtained on the intervals A'B'=50m and AB=130m using B-spline. Figure 10 presents a three-dimensional contour plot representing the subsurface layer at every 5 meter interval between subsurface layers at 10m and 25m depth.

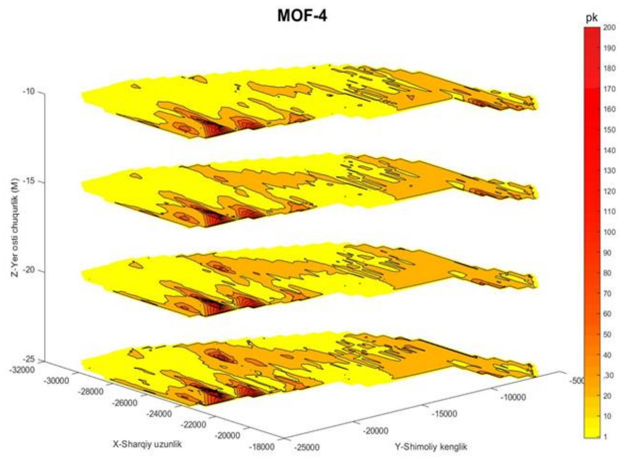

Fig. 10. A contour plot representing the subsoil layer at depth every 5 meters

Based on the obtained results, three-dimensional modeling of the distribution zones of electrical resistance in the geological environment of the research facility was carried out. Figure 11 presents a three-dimensional model representing electrical resistance of the underground layer at a depth of 10m and 25m.

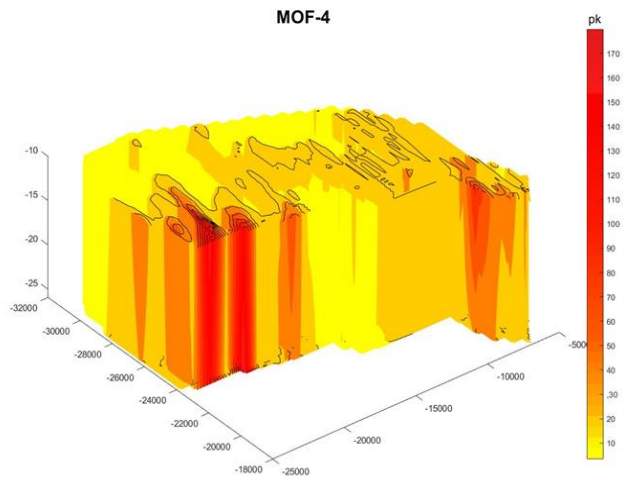

Fig. 11. A graph of a three-dimensional model representing the subsurface layer at depth

CONCLUSION

Expressing the signals measured from the parallel installed profiles in two-dimensional signal form and determining their coefficients through digital processing made it possible to depict the anomalous zones in three-dimensional graphs. In addition, we were able to represent the distribution of electrical resistance and anomalous zones in the underground layers at the depth of 10m and 25m by depicting them in a contour graph. As a result, it is possible to see which parts of the study area have high or low resistance distribution. This helps to determine the structure and composition of underground layers in depth. The intermediate values were determined by interpolation to obtain information about the subsurface layer between the two layers at 10m and 25m depth. As a result of interpolation, we can obtain information about an arbitrary layer between two layers.

The use of the developed program made it possible to determine in more detail the anomalous zones of specific electrical resistance associated with the composition of various metals in rocks and to observe their distribution in depth.

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Structure And Algorithms That Provide Communication Between Software Tools And Bluetooth Devices For Fast Transmission And Reception Of Signals

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***Abstract*— In recent decades, there has been an increasing demand for wireless communication devices and technologies that can transmit and receive signals over long distances. This is due to the fact that in today's modern industry, as well as in the field of geophysics, processes such as transmitting and receiving geophysical signals are carried out using wireless methods. However, various challenges and technical issues can arise in this context. One of the widely used wireless communication technologies is Bluetooth, which enables the integration of different devices using standardized protocols and allows for communication through data exchange. In our scientific research, algorithms and structures are proposed to facilitate the reception, aggregation, and transmission of geophysical signals.**

Keywords—Neutron, γ - rays, Bluetooth, SPI, MISO, NRF24l01, GNU.

I. INTRODUCTION

The detection and rapid transmission methods of geophysical signals play an important role in locating the place where chemical missiles are deployed. This is because geophysical signals have the characteristic of repeatedly occurring multiple times within a certain period. The detection and rapid transmission of such signals are quite complex. They are determined as follows: In underground and in materials, the quantification of elemental quantities is based on the gamma-neutron method, which is related to the nuclear photoelectric effect. This phenomenon or reaction is described by the absorption of γ-rays from the nuclei of certain elements, resulting in the emission of neutron particles from themselves. The starting energy point of gamma-neutron reaction varies for different elements. This value is 1.660±0.002 MeV (mega electron volts) for the elements beryllium (Be) and uranium ($^{219}_{92}U$), while for other elements, it exceeds 4.0 MeV[1]. The amount of radiation emitted from missiles can be determined using the following devices: radiometers and spectrometers, which consist of measurement sensors and control panels. The operation of measurement devices is similar to radiometers, except that a neutron counter is installed in the measurement sensor. The neutron counter measures the radiation emitted from missiles and extends it to the device in the form of a signal. The signal obtained from the device is extended through wireless extensions and displayed on an electron periodic table format. During this process, errors may occur in wireless extensions, and incorrect information may be sent regarding the location of the missiles. Developing communication devices without wires and designing their structures and algorithms are crucial in overcoming these problems[3,4,].

II. METHODS

The rapid development of wireless communication devices has resulted in fast information exchange and reduced energy consumption. One of these devices is the NRF24l01, which is designed for creating systems with sensors and controllers located within a range of 100-250 meters from each other. The NRF24l01 operates in the 2.4 gigahertz frequency range and allows for wireless data transmission between multiple devices. It is cost-effective and can be used in various applications. The Bluetooth radio technology is used in consumer electronics and wireless networks within the frequency range of 2.4-2.4835 GHz. Bluetooth utilizes frequency hopping for spectrum transmission, which is easy to implement and affordable[1,2] Currently, Bluetooth devices are used in various fields. They transmit signals at a frequency of 1600 times per second with a total bandwidth of 1 MHz Each transmission is synchronized with the receiver by sending it at the same time interval of 625 microseconds (one-time slot) from one frequency to another. Multiple transmitters or receivers can operate simultaneously without interfering with each other. The Bluetooth architecture consists of a single master device and up to seven slave devices within a radius of 10 meters. Let's examine the signal transmission structure through the NRF24L01 Bluetooth model of wireless communication devices.[2,3]

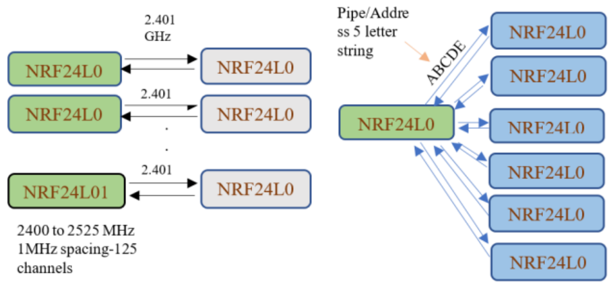


Figure 1. Time diagram of the SPI writing process.

The Bluetooth architecture manages time multiplexing and divides the time intervals between the main buttons. This process is implemented by the following protocols. The link management protocol installs logical channels between devices, manages power modes, encryption, and service quality. This protocol is located above the baseband controller, and its protocols are usually located on the Bluetooth chip. The advantages of the NRF24L01Bluetooth device are as follows.

The ability to establish wireless connections without the need for cables allows for convenient and flexible placement of devices, reducing the cost of establishing and expanding these connections. The high speed of modern networks (up to 600 Mbit/s) provides the ability to handle a wide range of tasks.[5,7] Mobile devices that connect to local wireless networks can move within the coverage area without interruption. The NRF24L01 device has technical features that contribute to its performance and functionality in wireless communication systems.

Low energy costs; Data transfer speed 250 Kbit/s, 1 Mbit/s and 2 Mbit/s; Fully compatible with all standard NRF24l01 series as well as NRF24YE and NRF240 series; Power supply 3.3V; Operating temperature -40 C to 85 C, storage temperature -40 C to 125 C; The communication range is 100-250 m. Data exchange interface: SPI; Reception and transmission frequency: 2.4 GHz; Number of channels: 128, each in 1 MHz step; Networking on one channel: 7 modules (1 receiver and 6 transmitters).

Based on the above analysis, we will consider the suitability of the technical properties of fast transmission of geophysical signals using the NRF24l01 module based on the table.

Table 1.

Correspondence of properties of geophysical signals and properties of wireless communication module

Elements	Energy (MEV)	Frequency (GHz)	NRF24l01 module frequency(GHz)	Data transfer speed (Mbs)
Uranium (U)	24.6, 16.7, 14.8	2.2 GHz	2,4 GHz	1-2 Mbs
Hydrogen (H)	2.23	1.4 GHz	2,4 GHz	1-2 Mbs
Carbon (C)	4.95, 3.68, 1.26	1.8 GHz	2,4 GHz	1-2 Mbs

Based on the information in the table, the NRF24L01 module has suitable parameters for transmitting geophysical signals. This module is adapted for use in a large number of systems integration, manufacturing and other industries. NRF24l01 wireless module communicates with Arduino for data transfer. Signal transmission and reception structures are implemented as follows.[8,10]

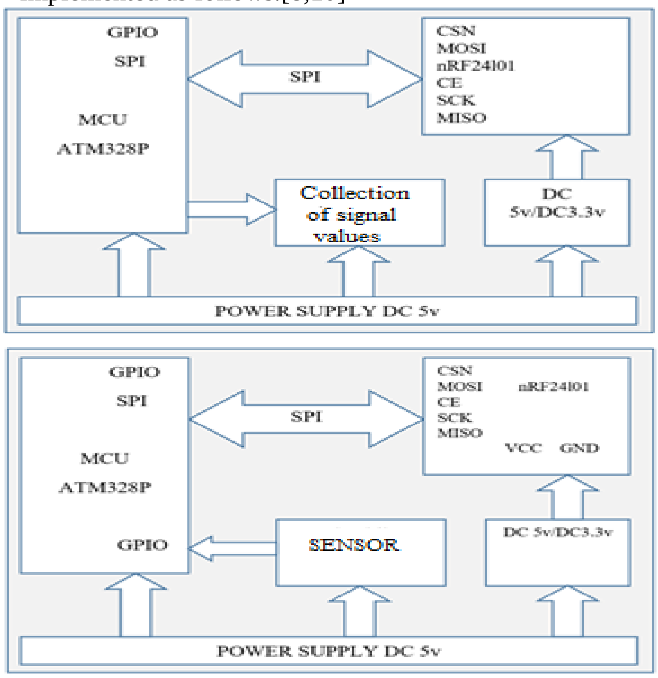


Figure 2. Block diagram of the device that transmits and receives signals.

The above figure shows the scheme of sending a signal using ATM328P microcontroller and nRF24L01 module. The communication between the microcontroller and the sending device nRF24L01 is carried out through the SPI interface. Using the CSN, MOSI, CE, SCK and MISO pins of the NRF24L01 module, the signal reading process is carried out and the remote signal is sent to the receiver.

Abbreviations in the diagrams in the second figure have the following meanings. GPIO - (general-purpose input/output) - General input/output communication interface between computer system components, microprocessor and various peripheral devices. GPIO pins can act as both input and output - this is usually configurable. SPI (Serial Peripheral Interface) is a synchronous serial communication interface specification used for short-range communication in embedded systems. Typical applications include Secure Digital cards and liquid crystal displays. Multiple devices can implement chip select (CS), sometimes called chip select (SS) paths. MOSI-main output (Master Out Slave in). Used to transfer data from sender to receiver. MISO - accepts master input signals (Master in Slave Out).[6,9,11] SCLK or SCK is a serial clock signal. It serves to transmit a signal in time for receiving devices. CS or SS chip selection (Chip Select, Slave Select). UART-Universal asynchronous receiver and transmitter interface. In order for the structure proposed above to be fully functional, it requires the development of a software algorithm. We will develop a software algorithm for the first signal sender and then for the signal receiver module and as follows (Figures 3 and 4).

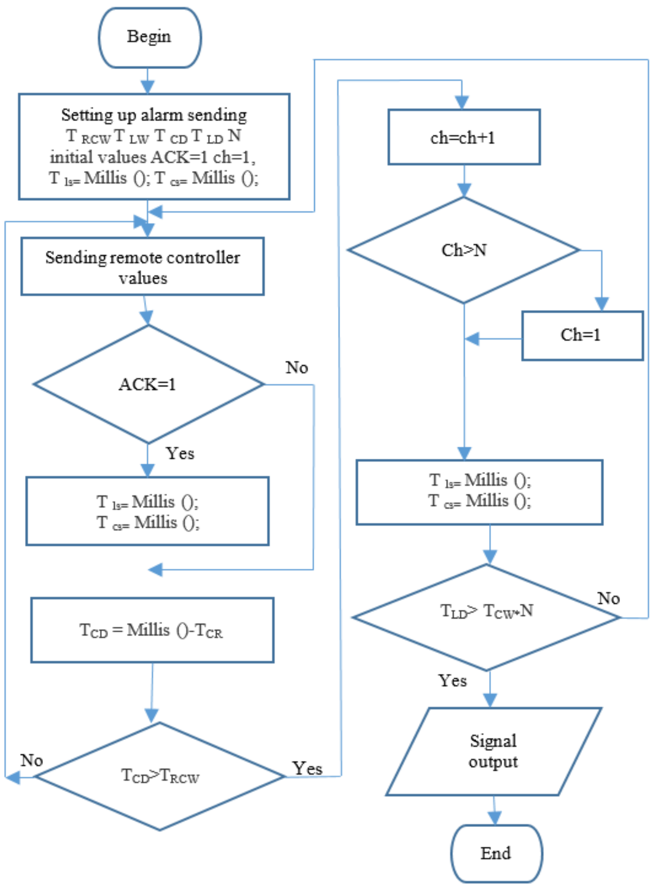


Figure 3. Block diagram of the signal sending algorithm.

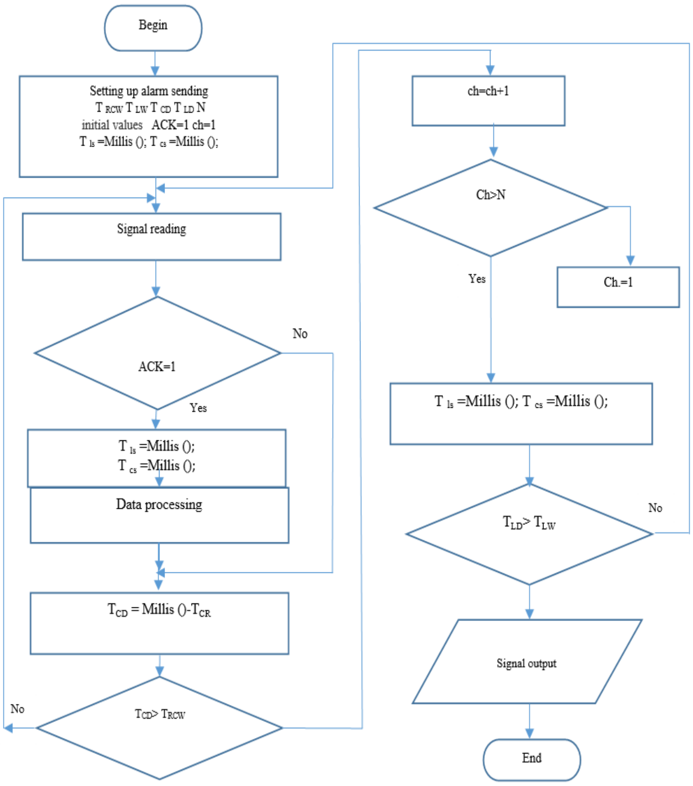


Figure 4. Block diagram of the signal receiving algorithm

Abbreviations in algorithms have the following meanings. T_{RCW} is the waiting time for receiving a signal from the channel. T_{LW} is the waiting time for receiving a signal on the link. T_{CD} is the channel cut-off time. T_{LD} is the link down time. ch is the sequence number of the channel. N is the number of channels used. C(N)- Number of used channels. ACK - confirmation of receiving incoming signals. T_{LR} is the last signal reception time of the link. T_{CR} is the time when the channel received the last signal. Millis () - Time reading function.[1,2]

With the help of the above software algorithm, we can make the two-dimensional geophysical signal received from the sensor look like the array we need based on the receiving and transmitting module (Table 2).

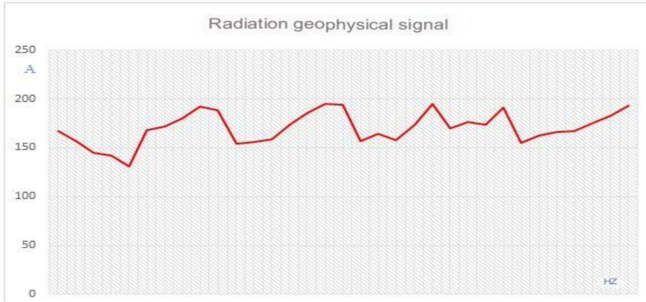
Using the above software algorithm, we convert the received two-dimensional geophysical signal from the sensor into the required array format using the receiving and transmitting modules.

Table 2

Two-dimensional Geophysical signal collection

№	Mev	№	Mev	№	Mev	№	Mev
1.	167	**7.**	172	**13.**	159	**19.**	164
2.	157	**8.**	180	**14.**	174	**20.**	158
3.	145	**9.**	192	**15.**	186	**21.**	174
4.	142	**10.**	188	**16.**	195	**22.**	195
5.	131	**11.**	154	**17.**	194	**23.**	170
6.	168	**12.**	156	**18.**	157	**24.**	176

The representation of two-dimensional Geophysical signals in the image.



As can be seen from the results in the table and the figure, the collection of two-dimensional geophysical signals has resulted in a one-dimensional matrix. This causes an error in determining the ores in the underground layer from the surface layer. An additional algorithm is required to convert geophysical signals into a two-dimensional matrix.[8,12]

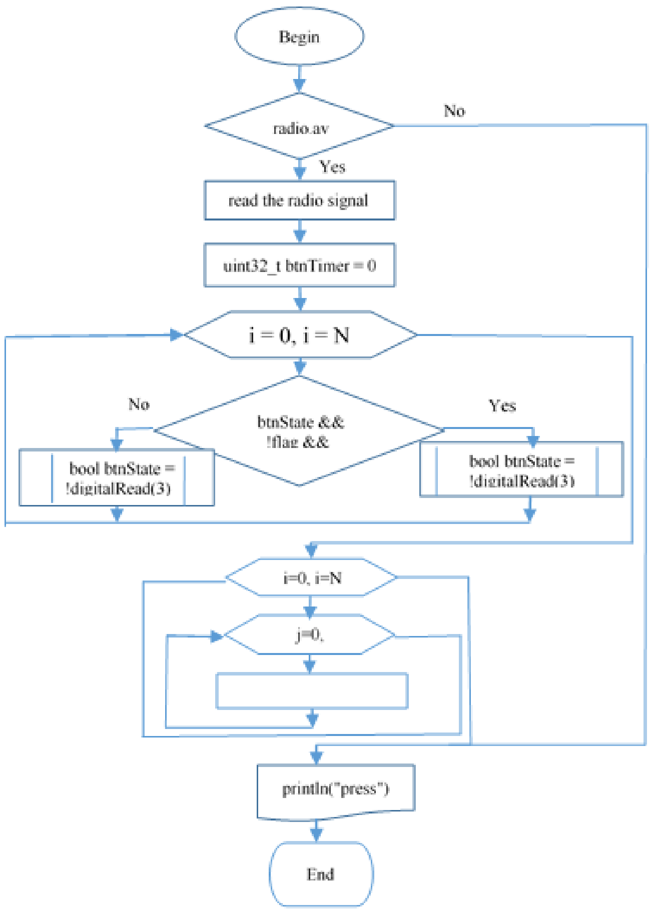
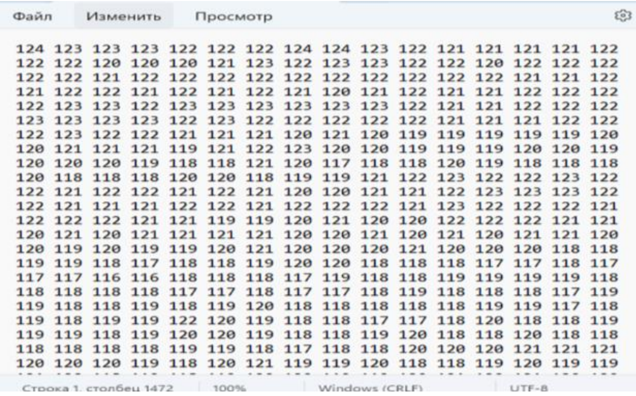


Figure 5. Algorithm block diagram for receiving and displaying data.

Using the above algorithm, the two-dimensional signal received from the receiving module can be presented in a tabular form. It is carried out as follows, in the first case, the amount of radiation received from the upper layer of the earth is measured every 100 meters, and in the next case, it is re-measured at a horizontal distance of 10 meters, and these values are stored in the second column of the table.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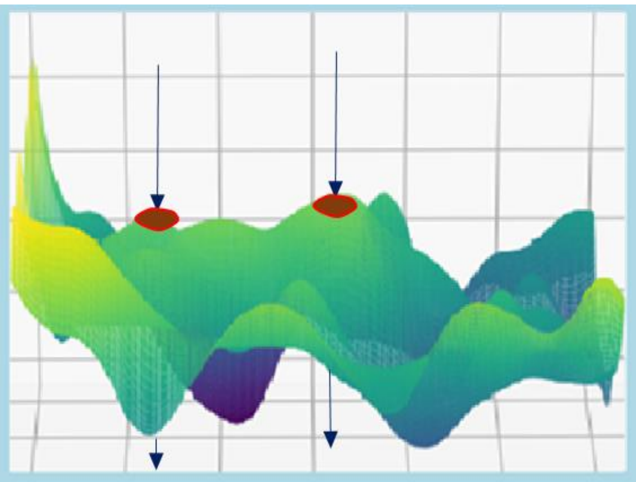

Figure 6. Sensing method received radiation geophysicist signal matrix in appearance from collection harvest has been graph.

Figure 6 shows the process of gathering radiation signals in the form of a two-dimensional matrix using our proposed algorithm. It is possible to predict the location of ores by digitally processing signals in the form of a two-dimensional matrix with the help of the developed algorithm in figure 3. In this case, the highest points indicate the place where the amount of radiation is the highest[3,5].

CONCLUSION

NRF24l01 the possibility of rapid data transfer using the device was investigated, but it was necessary to use an additional Arduino device to analyze and process these data on a computer. Structures providing interaction between the computer and the device have been developed. This is from the technical capabilities of the device come radiation in the range of 2.4GHz geophysicist able to transmit signals the fact that known it happened. In the research work of this part, a structure and an algorithm were proposed for applying Bluetooth technology to the process of transmitting radiation signals. According to our experimental results in the research process, the proposed algorithm is proven to be appropriate of the device invasive didn't happen feature him research for both, the field to himself in the circumstances special to the tool turns.

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Impact of SDN Technology on Big Data Transfer in Cloud Infrastructure

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***Abstract* - This article discusses the methods of transfer and analysis of Big Data, as well as the main problems of transfer and analysis of big data in the cloud infrastructure. A simulation model of a Cloud infrastructure for transferring Big Data using SDN and TCP/IP technologies has been developed. An analysis of the effectiveness of the used data transmission technologies was carried out.**

Keywords* – *Cloud Computing, Big Data, SDN, TCP/IP, Simulation.

I. INTRODUCTION.

Nowadays, more and more organizations and enterprises are turning to cloud computing to store and process their data. Cloud infrastructure offers flexibility, scalability and ease of use, allowing you to efficiently manage and access information from anywhere in the world [1].

As characteristics for big data, the concept of Big Data is defined as a technology in the field of hardware and software that integrates, organizes, manages and analyzes data characterized by the "3 V's": Volume, Variety and Velocity. Below are the characteristics of big data in more detail [2, 3]:

Volume: Big data is usually huge in size and requires special infrastructure solutions for storage and processing.

Variety: Big data can be structured, such as data from databases, as well as semi-structured and unstructured data, such as text documents, videos, images, logs and social media.

Velocity: Big data can arrive at significant speed and requires fast processing in real time.

The cloud infrastructure provides an efficient and flexible solution for processing and storing big data. It allows organizations to distribute and process bulk data on remote servers rather than on local computers or servers [1,3].

But a large volume of data requires large computing power, which is concentrated in data processing centers that ensure guaranteed trouble-free operation of the information system with specified levels of availability, reliability, security and controllability. The use of technology for creating data processing centers makes it possible to create backup headquarters of enterprises while maintaining the maximum possible functionality of the information system in emergency circumstances [4].

But data centers, which play a key role in modern information infrastructure, sometimes encounter problems in transmitting data. Traditional network architectures based on physical switches and routers can limit flexibility and scalability, making it difficult to manage and maintain efficient network operations.

To overcome these problems, the implementation of software-defined network concepts has become relevant, allowing to ensure security [5], increase network throughput [6], increase fault tolerance [7], reduce latency, etc [8].

SDN (Software-Defined Networking) is an approach to network management that separates the management of network equipment (switches, routers) from data transmission [9].

NFV (Network Functions Virtualization) is an approach to virtualizing the functions of network devices and services that typically run on specialized hardware such as routers, firewalls, load balancers, etc [10].

SDN and NFV are often used together to create flexible, software-driven, and virtualized networks. SDN provides centralized management and control of network infrastructure, while NFV allows network functions to run and scale virtually on shared hardware. This makes it easier to deploy new network services, manage load, provide flexibility, and quickly adapt to changing network requirements [11].

SDN solves the problem of optimizing the transfer of large amounts of data, due to the fact that all control logic is placed in controllers based on the OpenFlow protocol, capable of monitoring the operation of the entire network. OpenFlow is the first standardized open interface responsible for the interaction between the control plane and the communication plane. OpenFlow provides access, information exchange and delivery of control commands to network infrastructure elements.

The SDN controller [12] acts as a single centralized control point that interacts with the application layer through an open API interface, and also monitors and manages physical network devices through an open interface - the OpenFlow protocol.

II. MAIN (EXPERIMENTAL RESULT)

In article [8], a comparative analysis of channel throughput was carried out, based on SDN technology and traditional TCP/IP technology.

In this work, an experiment was conducted to test the latency indicators for data transmission using the TCP/IP protocol and SDN technology. Table 1 lists the topology parameters that will be used in the simulation [13,14].

TABLE I. CONFIGURATION OPTIONS

Parameter	Configuration #1	Configuration #2
Data transfer technology	TCP	SDN
Number of hosts	10	10
Number of switches	6	6
Number of Routers	4	SDN Controller

Configuration #1 is a network that transmits data using the TCP/IP protocol. This standard approach involves transmitting data over a network using a set of protocols. The device that distributes packets in the network is the router, which operates on the basis of the routing table.

On the other hand, configuration #2 is a network that uses Software Defined Networking (SDN) principles for data transmission. SDN differs from TCP/IP technology by the principle of network management, in which control is concentrated on a single device - a controller using the OpenFlow protocol.

For the purity of the experiment, identical topologies were built for both configurations, but when transmitting data using traditional technology, 4 routers were used in the network, and when transmitting data using SDN technology, 1 controller was used.

The results of the work carried out are shown in Figures 1 and 2. To analyze the effectiveness of data transmission technologies, we used data on delay (ms) obtained during the transmission of the first packet, based on when the first packet is transmitted from one host to another.

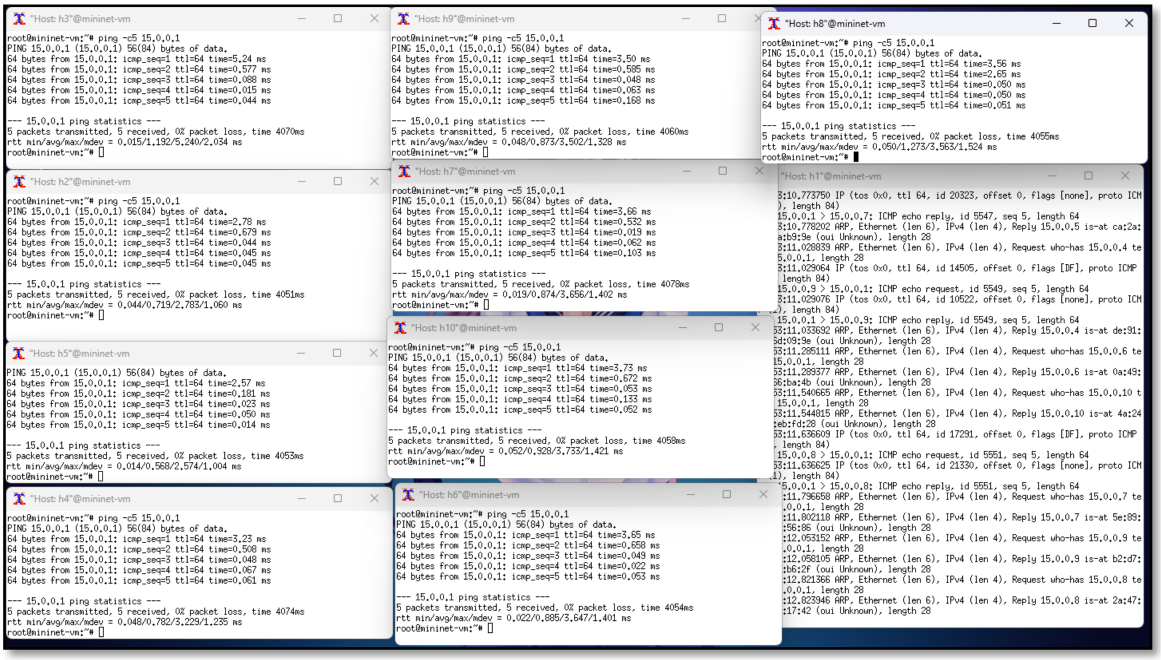

Fig. 1. Data transfer using TCP / IP technology (Configuration № 1).

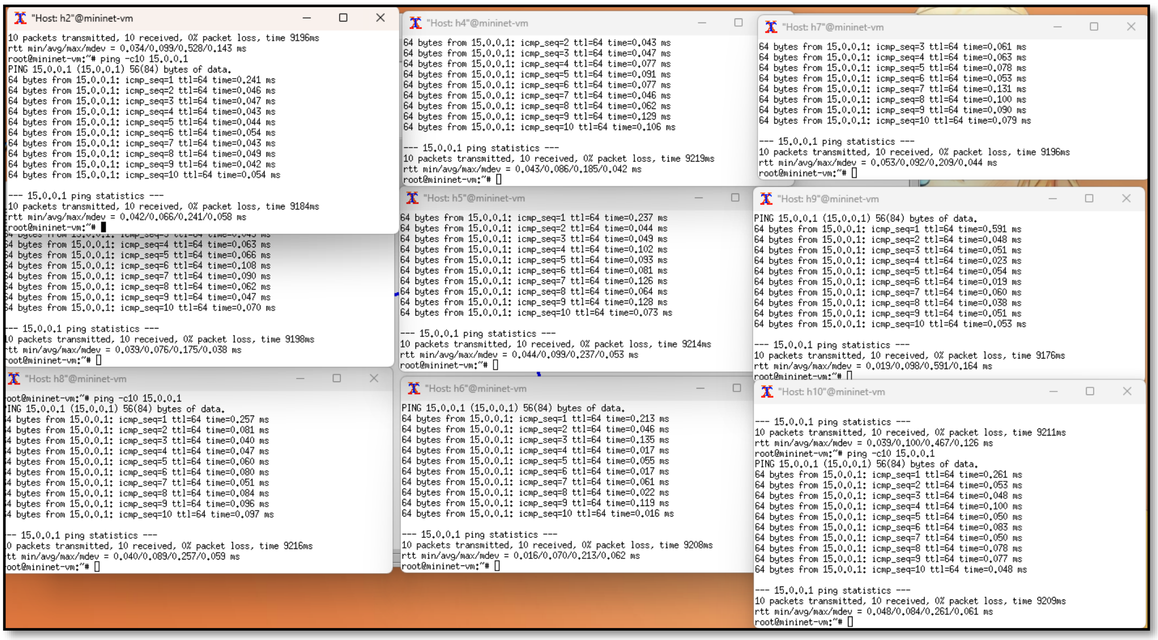

Fig. 2. Data transfer using SDN technology (Configuration № 2).

The data obtained are summarized in Table 2.

TABLE II. DATA FROM EXPERIMENTS 1 AND 2

Parameter	Configuration #1 TCP	Configuration #2 SDN
Host 2	2.78	0.241
Host 3	5.24	0.175
Host 4	3.23	0.185
Host 5	2.57	0.237
Host 6	3.65	0.213
Host 7	3.66	0.209
Host 8	3.56	0.591
Host 9	3.5	0.261
Host 10	3.73	0.257
Total transfer time	31.92	2.369

Based on the table, it can be seen that the total packet transfer time with TCP/IP is 13.18 times slower than with SDN. Table 2 data is shown in Figure 3.

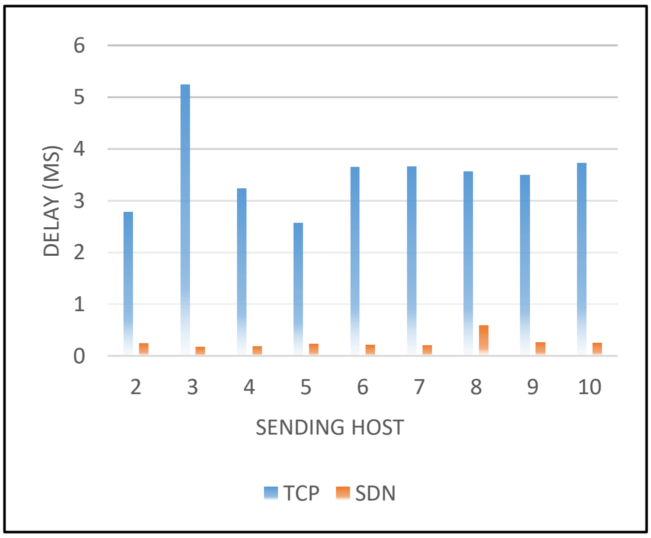

Fig. 3. Delays in the transmission of the first packet.

Since the routing process is carried out at the expense of the routing table, each router on the path of the first IP packet processes information about the routing tables to lay the best route, while generating a delay in the transmission of the IP packet.

At the same time, thanks to SDN technology, packets can be immediately directed to the end device, since the route is laid by a centralized controller [12]. As a result of this process, the initial delay is reduced, resulting in faster data delivery and improved transmission efficiency.

For a detailed analysis of the transmission parameters of all packets in a given system, you can use the Wireshark program. With Wireshark, you can examine the contents and properties of each packet, analyze protocols, and identify possible network communication problems.

Figure 4 and 5 show a graph of transmitted packets for 1 (ms).

From figures 4 and 5, it can be seen that the network using SDN is more stable and does not exceed a delay of 70ms, while TCP / IP transmits data with a delay of more than 80ms.

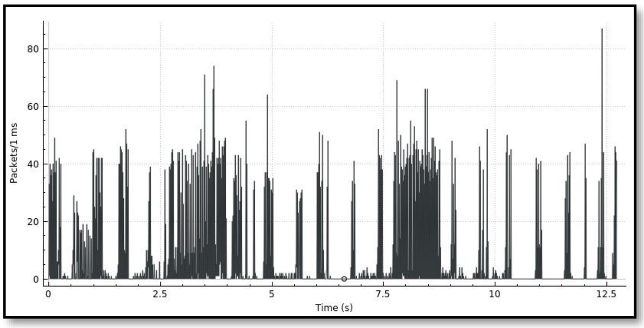

Fig. 4. Graph of transmitted packets using TCP/IP technology.

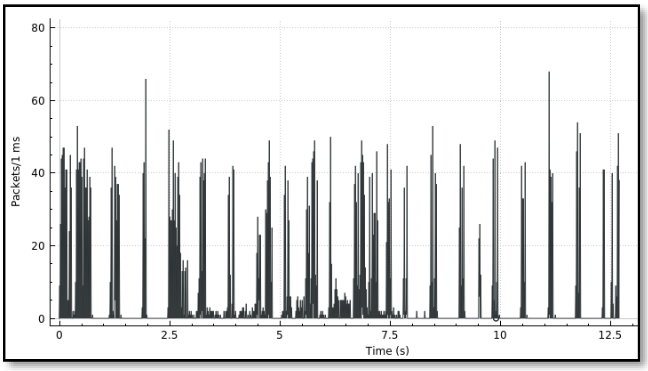

Fig. 5. Graph of transmitted packets when using SND technology.

Analyzing the data provided, we can conclude that the use of SDN technology for transferring big data allows you to transfer data with minimal delay, due to the lack of routers that process information from the IP header. Compared to TCP / IP technology, the use of SDN reduces the delay time by 10-15 times on average. This is achieved through an innovative approach where network resources are controlled and managed in software rather than through traditional hard-coded network devices.

III. CONCLUSION

SDN offers a flexible and dynamic architecture that allows you to manage network traffic, resources, and policies through a centralized controller. As a result, data can be transmitted over the network with lower latency, as traffic is routed and handled in software, optimizing transmission paths to avoid unnecessary delays.

This is essential in today's networks where low latency is critical to achieving high performance and reliability.

The use of SDN makes it easy to configure network rules and policies, administrators can change them on the controller and apply changes to all devices. It also provides easy scalability of the network infrastructure and the possibility of network virtualization. SDN represents an evolution in network management, providing a more controlled and efficient network infrastructure, improving performance and security. With the increase in data volume, SDN is becoming an increasingly important factor in the development of network technologies and the improvement of user experience. At the moment, SDN is being actively implemented in the work of data centers that ensure the operation of the cloud infrastructure.

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MODELING OF OPTIMAL PARAMETERS OF THE ENERGY EFFICIENCY OF A SOLAR CELL WITH MANY NANO-HETEROJUNCTIONS

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***Annotation* — The growth parameters, optimal electrophysical and optical properties that ensure sufficiently high rates of conversion of solar radiation into electricity and a predictable and controllable nature of the efficiency value are determined by computer modeling of a semi-phenomenological model of a heterocontact structure and its voltage characteristics.**

***Keywords* — solar cell, non-crystalline silicon, lead chalcogenides, nano heterojunction, zone diagram, multi-exciton generation, carrier multiplication.**

INTRODUCTION

The efficiency of a solar panel is determined mainly by the efficiency of its main component – the solar cell (SC), or rather by the property of its p–n junction, where the energy of solar radiation is converted into electricity. The process of mass introduction of solar energy takes place on a large scale and in large volumes [1-5], taking into account many existing global accompanying trends and hindering problems. The scientific substantiation of the prospects for its use and improvement is carried out by photovoltaics. It defines the problems and contradictions of solar energy, taking into account socio-economic and scientific and technological aspects.

The main function in the process of converting radiation energy into electricity is performed by a solar cell. Therefore, the prospects for the development of solar energy and its effectiveness in scientific terms depend on the quality of the solar cell and the characteristics of its semiconductor heterostructural contact field (or p-n junction). Direct conversion of solar radiation into electricity is carried out precisely in the contact field, in which the generated electron-hole pairs are divided into an electron and a hole, as well as their transfer to the corresponding electrodes.

A solar cell with a highly efficient separating hetero p-n junction on a semiconductor substrate means:

- the cheapness of its production technology,
- the cheapness of the materials used in their creation,
- its long-term and stable functioning in harsh climatic conditions,
- extended light absorption spectrum,
- low cost of materials and technologies,
- increased Q-factor and service life of the solar cell.

Therefore, the creation of efficient solar cells requires active research, new technologies and materials for their production. In addition, it is necessary to look for new unconventional approaches and methods, both for choosing a semiconductor substrate and for creating a heterocontact junction.

The paper proposes a SC, the p-n junction of which is a contact between two innovative components that are absolutely not traditional for solar energy: a macro–dimensional structureless non-crystalline semiconductor in contact with another nano-dimensional crystalline semiconductor. The paper specifically considers the nano-macro-contact (or nano-heterojunction - NHJ) formed between silicon (Si) and nano-sized lead chalcogenide – PbX (X can be S; Se; Te), that is, NHJ <Si:PbX> is a specific silicon SC with many NHJs.

The unconventionality of the proposed contact structure caused the need to determine the appropriate technology for their production, as well as a more detailed justification of the choice of its components and the mutual compatibility of the contacting materials of the NHJ.

The use of cheap structureless non-crystalline Si as one of the components of the SC required a particularly thorough justification. The fact is that traditionally, the high efficiency of the SC was achieved only with the use of monocrystalline, expensive Si (or, in extreme cases, polycrystalline Si). Therefore, contrary to all negative expectations, such an unconventional combination of structureless Si and nano PbX crystals turned out to be possible due to a number of experimentally supported and patented properties presented below:

- improvement of the transformative properties and efficiency of a single p-n junction with a decrease in its size [6,7];

- a significant increase in the efficiency of photo conversion due to the effects of multi-exciton generation and multiplication of carriers in PbX nano crystals on the surface of α-Si [8,9];

- the most probable and predominant growth of the "islands" of the PbX nano crystal is precisely on individual crystalline sections of structureless Si [10].

Let us consider separately the peculiar optical and electrophysical properties of structureless silicon and nano crystals of lead chalcogenides, which provide an improvement in the converting properties of NHJ <Si:PbX>.

NON-CRYSTALLINE SILICON IN A SOLAR CELL

Any solid body, including non-crystalline silicon, contains a certain number of various foreign bodies: structural defects, interstitial vacancy atoms, lattice imperfections, etc. (hereinafter we will call them defects). In the energy band theory of silicon, all these foreign additions are determined by their discrete levels.

Localized defective energy states are determined by:

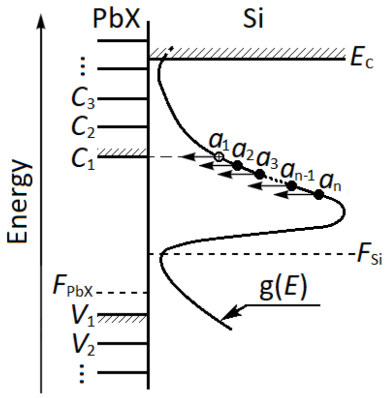
- energy density - g(E);

- the value of the binding energy of the defect E(r) to the conduction band;

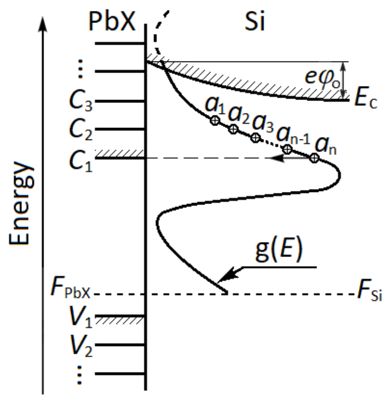
- concentration - software that is large and can reach $10^{24}\div10^{26}$m^{-3};

- Localized defective energy states have donor and (or) acceptor properties;

- may partially or completely cover the entire prohibited area.



a)



b)

Fig.1. Formation of NHJ by transferring electrons from a_1, a_2, ..., a_n deep localized defective energy states of silicon to c_1 – multi-exciton state PbX: a) beginning; b) end.

Using the contact field in NHJ <Si:PbX> is possible if a PbX is installed on a local network at the user level. Simultaneously with the growth of nano PbX crystals from deep defective localized energy states in the "forbidden zone" of Si, the formation of NHJ occurs. At the same time, the Si electrons, under the influence of Coulomb interaction between themselves, will transition from a_i (i = 1, 2, ..., n) to deep localized defective states of energy c_1 – the multi-exciton state of the PbX (c_1 is an analog of the conduction band of the nano-PbX crystal, Fig. 1). It is assumed that deep localized defective energy states (concentrations of the order of $10^{24}\div10^{26}$m^{-3}) have donor properties. Transitions are carried out until the Fermi levels of the contacting materials are equalized ($\Delta\mu = e\varphi_o = F_{PbX} - F_{Si}$).

Nano-sized PbX crystals in the formed NHJ <Si:PbX> have peculiar optical features. In ultra-small quantum-limited PbX crystals, due to the effect of carrier multiplication (CM), several electron-hole pairs are generated extremely quickly (relaxation time of the order of 10-20 fs) when one high-energy photon is absorbed ($\hbar\omega >> E_g^{PbX}$). In the process of relaxation of a high-energy electron in a crystal, they are created by multi-exciton generation (MEG) of several secondary low-frequency photons, each of which in Si causes the birth of many additional PbX due to the effect of CM extremely quickly (relaxation time of the order of 10-20 fs) generate several electron-hole pairs when absorbing one high-energy photon ($\hbar\omega >> E_g^{PbX}$). In the process of relaxation of a high-energy electron in a crystal, they are created by MEG of several secondary low-frequency photons, each of which in Si causes the birth of many additional electron-hole pairs and increases the efficiency of the process of converting light radiation into electricity.

Fig. 2 shows the process of interaction of high-energy radiation with NHJ Si:PbX. The high-frequency photon ħω of solar radiation falls on the NHJ, and the second-born low-frequency photons ħω' are directed and absorbed in silicon with the birth of many new electron-hole pairs.

The absorption of a high-frequency photon (ħω) is accompanied by the birth of an electron–hole pair, the electron of which reaches the upper level of the multi-exciton discrete states of the analog of the conduction band, and the hole occupies the lower level of the multi-exciton discrete states of the analog of the valence band.

In nano-sized lead chalcogenide, the transition of an excited electron from the nth to the (n - 1) level of a linear series of multi-exciton energy states is accompanied by the emission of a ħω' - secondary photon, which, passing into silicon, causes a new generation of an electron-hole pair due to its impurity or interband absorption, that is, the Auger effect is realized - generation.

In turn, an electron trapped at the (n - 1) th level can move to the (n - 2) th lower multi-exciton level with the birth of a second low-frequency photon of the infrared region of solar radiation ħω'. And so, the process in NHJ Si:PbS can continue until the initially generated electron loses almost all of its acquired energy, that is, after the generation of 4 electron-hole pairs. These 4 electron-hole pairs, concentrated in silicon, will contribute to the process of converting light radiation into electricity. This contribution became possible precisely due to the absorption of high-frequency photons, which previously only heated the solar cell.

Thus, in SC NHJ <Si:PbX> high-frequency photons are effectively involved in the production of electricity due to the manifestations of two peculiar phenomena in PbX nanocrystals: CM and MEG.

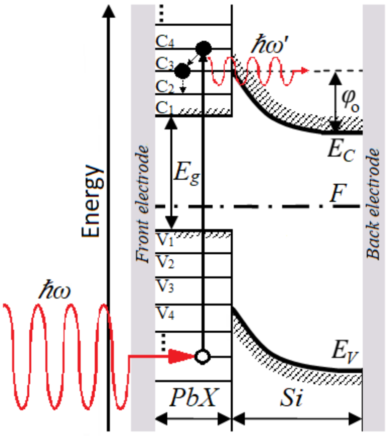


Fig.2. The process of interaction of high-energy radiation with nano heterojunction Si:PbX

The generation of four electron-hole pairs was observed in PbS nano crystals due to CM and MEG, and even seven pairs were observed in PbSe [11]. In other words, CM and MEG allow us to observe higher values of the quantum yield in the SC NHJ <Si:PbX>.

METHOD OF COMPUTER MODELING

The method of mathematical modeling is comparable in its breadth and universality with the possibilities arising from fundamental laws. Its essence is multifaceted and depends on the choice of the task under study. In physics, many complex phenomena can be explained and solved by the so-called variational principle, according to which a certain coefficient characterizing the studied regularity of a sufficiently complex object (or system, or phenomenon) is considered as a variational parameter. By varying its value, the maximum approximation to the known experimental dependence is achieved. The coincidence of the type of dependence is achieved by the fact that the studied pattern of a rather complex object is selected as close as possible to the known pattern characteristic of a simpler version of this object.

For example, the current-voltage characteristic (CVC) of a photocell with many nano-dimensional p-n junctions should be quite similar to the CVC of an ideal p-n junction, which has been studied very carefully for a long time, but with a different characteristic coefficient.

In this example, the similarity of the patterns of individual manifestations in both the simplest and rather complex object demonstrates the correctness of the choice of a variational method (computer modeling) for solving this problem. The principle of "from simple to complex" is implemented, when the next step in the study of complex processes is done after a sufficiently detailed study of a simple model.

The method of modeling is comparable in its breadth and universality with the possibilities arising from fundamental laws. Its essence lies in the application of very general statements about the object under consideration (system, phenomenon) and from all possible variants of its manifestations chooses only those that satisfy a certain condition.

According to this condition, a certain parameter associated with an ideal object and sufficiently correctly described experimental manifestations is chosen as a variable parameter of a complex system, by varying which they achieve the maximum approximation of the calculated values with experimental data [12].

CONCLUSION

Some problematic aspects of renewable energy sources are considered and the expediency of their active implementation is determined.

The factors ensuring the competitiveness of solar energy in comparison with hydrocarbon energy are determined.

It is shown that with the use of modern nanotechnological methods in combination with the principle of self-organization of matter, it is possible to achieve a significant increase in the efficiency of solar cells and thus reduce the cost of solar energy products.

It is shown that mathematical modeling of the semi-phenomenological volt-ampere characteristics of a solar cell makes it possible to determine its optimal effective parameters.

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Automated electronic document management and employee workflow system

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Abstract This text discusses the need to implement an automated electronic document management system (ACS EDO) in a large Equator company. The text describes the problems that the company faces when manually processing a large number of documents, as well as the advantages and requirements for such a system.

Keywords *automation, electronic document management, company, access, data security*

I. Introduction

The large mining company Equator has branches in several cities across the country. Branches are both deposits where gold is mined, and office centers that work with documents, layouts, drawings and other logistical tasks.

Within the company, many hundreds of documents are processed manually by employees every day. Logistics centers contain employees who are responsible for processing various documents.

Processing takes place in a live form with the signing of documents by writing means, seals and transportation of documents from one employee to another.

Often, the employees needed to process any set of documents may be located in cities that are remote from each other, then the set of documents is sent by mail to the necessary employees, who may be several at certain stages of the document lifecycle. A copy of the documents may not always be legally binding, which is confirmed by the company's lawyers.

Also, some employees of the company work remotely from home, and they also have access to the company's existing services, but cannot work directly with documents. When it becomes possible to work remotely with documents, these employees should be able to use such a function.

This situation has acute problems that worsen the company's work:

- due to the huge time spent on transporting documents from one employee to another, the company incurs inconspicuous but significant losses, which are caused by possible stagnation in some emergency places that do not work, do not bring profit to the company, because they are waiting for the processing of the necessary documents;
- employees spend considerable time to transport documents, for example, to take a set of documents to the right employee / place or to send documents by mail to another locality;
- during transportation, documents may be damaged (torn, crumpled, they may be filled with liquids), after which they may lose them legal force:
- in paper form, in case of an error, there is no way to fix the data imperceptibly, it is necessary to start the entire document processing process from the beginning;
- paper documents are not protected from prying eyes, thus anyone passing by documents that are unobserved, an employee, can find out confidential information that can damage the company.

The Equator company needs an automated electronic document management system (ACS EDO).

II. Relevance of System Development

The EDO automated control system is a system that helps to process and store information, in particular documents, allows you to differentiate access among employees, have quick access to the necessary set and keep the data intact.

The most important advantage of such a system from the traditional model of document processing is its speed. Due to the ability to access the desired document regardless of location, the speed of document processing increases significantly, especially if people from different localities have to work with the document. A simple example: in the traditional. The document processing model requires the signatures of 3 signatories from different cities. Copies of documents are sent by mail to the necessary cities. Two of the three signatories sign the documents, and the third employee returns the documents with an error. After correcting the error, it is necessary to perform the same operation again. The EDO Automated Control System simplifies this process down to a few minutes, when people can receive documents, process them in an electronic environment and send them on, without having to forward documents by mail.

Also, now all the documents are in one application and employees
there is no need to go to a special place to receive/hand over documents, they can quickly and easily access documents by logging into the web interface of the system.

Electronic documents are exempt from physical problems, they cannot be damaged, torn or lost.

Incorrectly entered data can be corrected by processing the document again, which eliminates the need to restart the process from the beginning.

Users divided into roles can view and modify only the documents available to them with the required degree of confidentiality.
It is recommended to always lock the computer when leaving the workplace.

Such systems are already quite common in our world, and even in Russia, especially in large companies that value every minute of production, which have a large volume of document flow and which have funds for the development of automated control systems, this is confirmed by article.

In another article, the author speaks about the flexibility of these systems in the field
of information processing and storage, thereby increasing the productivity of workers [1-2].

III. System Structure

The automated control system should be developed in the form of a web service, an interface for the computers of the company's workers.

Also, this system automatically processes the necessary information, and protects confidential information from inaccessible users.

If necessary, the documents can be printed.

An example of such a hardware system is shown in Figure 1.

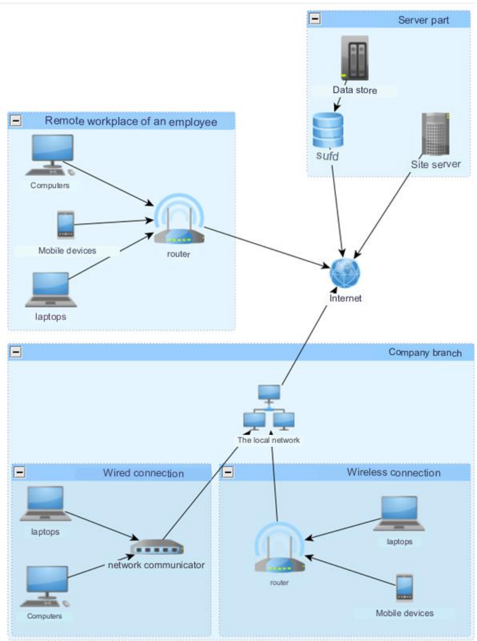

Fig. 1 – Hardware structure of the system

The EDO automated control system consists, in particular, of the following basic elements: documents, sets of documents, a group of companies, the roles of document processors and a list of processors. Figure 2 shows the content structure of the system.

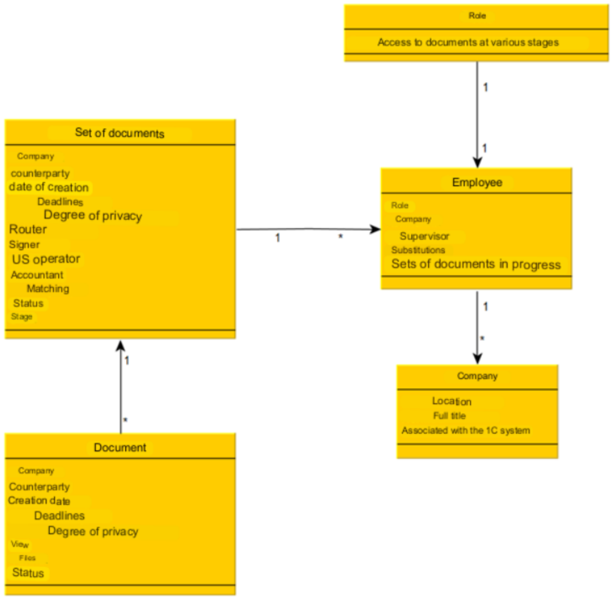

Fig. 2 – The content structure of the system

IV. System Requirements

The web interface of the system is built in such a way that different employees will have the same functionality and appearance of the interface, the difference will be in their capabilities and permissions to work with the document.

Figure 3 shows the interface of the main page (card file) of the interface, where employees can select /sort/filter sets of documents that they will work with.

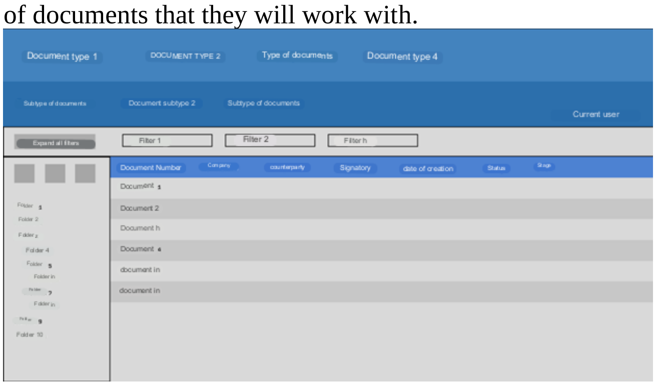

Fig. 3 – Layout of the card file interface

The interface of the set of documents, where you can change various settings of the set, is shown in Figure 4.

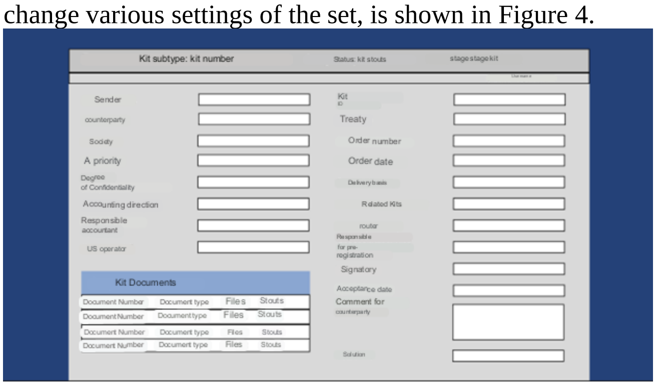

Fig. 4 – Layout of the document set interface

V. CONCLUSION

In the course of the work, an automated electronic document management system for the Equator company was studied, evaluated, updated and projected.

This system will allow the company to speed up the processing of documents, due to the fact that all necessary users will have access to the documents immediately through a web interface, which they can connect to in a couple of seconds. Also, the data will be restricted from unnecessary users, and it will be very difficult to circumvent this restriction. Also, thanks to the absence of physical form, documents will not be damaged or lost, which will also increase the productivity of workers, eliminating unnecessary repetitions of chains of actions for new copies of documents from their work.

The system will be available from various connection types: Employees of the company's branch will be able to connect to the system via the company's router, as well as through a network communicator with a wired connection. An employee who is working remotely via a router will also be able to have access.

A plan was also developed for the implementation of this environment in the document flow companies in such a way as not to disrupt the already existing process of working with documents and simultaneously deploy a new one, and later smoothly switch to it.

Decompositions of system use cases were developed together with flowcharts. These diagrams depict the stages of the work of the target roles in various situations and moments. Sample layouts of the web interface were created for more convenient display and presentation of their ideas for developers who will develop this system in the future.

A lot of schemes with sources will be useful to developers, designers and technical writers at all stages of the work on creating a system.

Ultimately, the introduction of such a document processing environment will allow the company to increase employee productivity and reduce the cost of unnecessary production downtime. This system will not depend on specific employees, it will be extensible and it will be easy to increase the functionality for new types and subtypes of documents.

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SOLAR CELLS BASED ON GaAs/AlGaAs TRANSPARENT TO LONG-WAVE PHOTONS BEHIND THE EDGE OF THE ABSORPTION BAND

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***Annotation* - In this work, the photoelectric, optical, and thermal properties of transparent solar cells (SCs) based on GaAs/AlGaAs heterostructures with a GaP substrate crystal obtained by liquid-phase epitaxy are studied. It is shown that the large band gap, high thermal conductivity, indirect band structure of GaP, transparency of the SC design to photons beyond the long-wavelength edge of the main absorption band extend the functionality of concentrator SCs in the mode without special cooling to a degree of solar flux concentration of 100 times.**

***Keywords* - solar cell, heterostructure, solar radiation concentrator, open-circuit voltage, dark and light current-voltage characteristics, short-circuit current, optical window, degree of light flux concentration, solar cell transparency to long-wavelength photons beyond the edge of the main absorption band, thermal regime , photon recycling**

INTRODUCTION

At present, despite the high development of the technology for obtaining and the study of solar cells (SCs) in the GaAs/AlGaAs system, their potential capabilities are far from being exhausted [1,2]. Among the factors limiting the potential capabilities of existing device structures is the fact that the depth of absorption of quanta and the length of the diffusion displacement of electrons and holes in heterostructures mainly limit the physical thickness of the narrow-gap layer within 5 μm or less [3–5].

These factors are the main reason for the decrease in the transmittance of non-photoactive long-wavelength photons and the occurrence of premature heating of p-n junctions when illuminated with both direct and concentrated light fluxes.

These circumstances necessitate limiting the total thickness of the strongly absorbing narrow-gap SC layer, bringing the “geometric” thickness of this layer into line with their “physical” thickness. Undoubtedly, the practical implementation of such SC based on GaAs/AlGaAs is associated with certain difficulties related to the presence of a GaAs substrate and insufficiently optimal optomechanical properties, and the studies carried out on the implementation of thin-film SCs do not yet give the expected results [6, 7].

In this regard, it is of interest to obtain and study SCs with strongly absorbing layers on transparent semiconductor substrates, in particular, single-crystal GaP. GaP single crystals are of interest because, in addition to a large band gap (Eg = 2.25 eV), they have an indirect band structure and relatively high thermal conductivity [8], GaP is technologically compatible with GaAs, and some III–V compounds [8, 9].

As is known, Bolkhovityanov Yu.B. and other scientists made a great contribution to the study of non-isoperiodic heterostructures. [10-12]. Despite this, the production of structurally perfect heterostructures on nonisoperiodic GaP substrates requires further research in terms of developing a technology for obtaining structurally perfect layers for the development of specific types of SCs.

Obtaining photoactive layers with an extremely limited thickness on wide-gap substrates would open up broad prospects in the development of fundamentally new types of device structures, in particular, SCs with bilaterally sensitive p-n junctions based on GaAs and other III–V compounds, as well as heterostructures with increased transparency to long-wavelength photons. , promising for multijunction solar cells with a cascade structure. Efficient GaAs/AlGaAs SCs based on GaP supporting crystals, as is known, can be implemented due to the possibility of reducing the mismatch between the lattice parameters of contacting materials by introducing an intermediate buffer layer of variable composition [13].

In solar cells of a similar design, an improvement in their thermal mode of operation is also achieved [14], and prospects for their use in cascade systems open up.

It follows from the above that the preparation and study of solar cell heterostructures with an extremely limited thickness of the absorbing layer are of scientific and practical interest, their development is associated with the development of physical and technological foundations for obtaining thin, crystalline photon excitation of the photoactive layer. Another advantage of multi-junction SCs of transparent design based on wide-gap semiconductors is the possibility of effective control over the characteristics of cascade-type SCs by varying the band gap of the wide-gap structure due to its optical transparency.

METHODOLOGY FOR OBTAINING THE DESIGN OF A SOLAR CELL

Taking into account the above considerations, this article presents the results of studies of the photoelectric and thermal properties of SCs created on the basis of GaAs/AlGaAs/GaP heterostructures under direct and concentrated natural sunlight (in a mode without special cooling) up to a degree of light flux concentration K_s = 1…100 multiple Fig.1 shows one of the studied SC structures. It includes a semiconductor substrate of n-type GaP, buffer layer n-AlxGa1-xAs, layers n and p GaAs, p-AlxGa1-xAs, and ohmic contacts. To fabricate the SC structure by liquid-phase epitaxy, a chemical-mechanically prepared n-GaP substrate with an electron density of 10^{17}...10^{18} cm^{-3} is taken. A buffer layer nAlxGa1-xAs with a near-boundary AlxGa1-xAs1-yPy layer with y=0.8...0.9, 3...5 µm thick is built up on it. After that, gradually replacing the solution - the melt, the layers of n and p GaAs, p AlGaAs were successively grown. The thickness of the nGaAs layer is 0.5…2 µm, pGaAs-2.5…3.0 µm, frontal AlxGa1-xAs - 2…3 µm. The concentrations of electrons and holes in layers of n and p types of conductivity, respectively, are close to the values usually used in GaAs/AxGa1-x As SCs of traditional design.

The indicated buffer layer is formed by contacting the substrate with the Ga+GaAs(Te) + Al melt at T= 1125 K, holding at this temperature for 15...20 min. followed by forced cooling at a rate of 1K/min. Then, by replacing solutions - melts, layers of n and p GaAs, as well as p AlxGa1-xAs, with a thickness of 0.5 ... 1.0 µm, are formed. To achieve high transparency of the SC structure to long-wavelength photons beyond the edge of the main absorption band of the base layer, E-shaped ohmic contacts are deposited not only on the front side of the SC structure but also on its back side (Fig. 1).

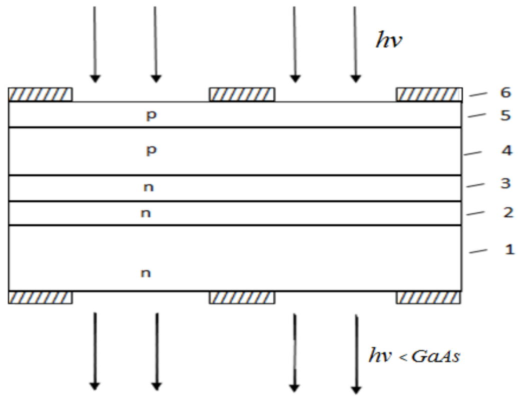

Fig.1. Heterostructural solar cell with GaAs p-n junction and increased transparency in the infrared region of the spectrum. 1 - substrate GaP, 2 - AlxGa1-xAs(P) layer, 3, 4 - GaAs, 5 - AlxGa1-xAs, 6 - ohmic contacts.

Ohmic contacts to the regions of n and p-type conductivity were deposited by electrochemical deposition of layers of silver (Ag) and nickel (Ni) with subsequent thermal annealing at temperatures of 675–775 K. After the deposition of Ag and Ni films, they were tinned in POS-61 solder. It should be noted that the W-shaped ohmic contacts had stripes, where the distance between the strips was 1 mm, each strip had a width of 100 µm. Each investigated structure had a total area of ~ 1 cm^2. Specific contact resistance after heat treatment in the above temperature range for 2…3 min. in an atmosphere of purified hydrogen was 5.10^{-4} Ohm.cm^2. Antireflection coatings are made by anodic oxidation on both surfaces of the cell, which made it possible to reduce reflection losses to 10% from the front and rear surfaces of the cell. Fresnel lenses were used as a concentrator of sunlight.

Since, under conditions of illumination with concentrated sunlight, thermal energies can be released in a solar cell for a solar cell of a transparent design, it is very necessary to consider their thermal properties.

Volt-ampere characteristics of SC illumination are described by the expression [14]

$$I_n = I_{ph} - I_0 \left\{ exp\left[\frac{q(U_n - R_п I_n)}{AkT} - 1\right]\right\} \quad (1)$$

where I_n, U_n - load current and voltage; I_{ph}, I_o - photocurrent and saturation current p-n transition.

As is known, for SC structures with a base layer thickness d Ln + Lp, the saturation current density is described by the expression [15]

$$I_0 = q\frac{n_i^2}{N_A} d\left[\frac{1}{\tau_{nr}} + \frac{1}{\varphi\tau_r} + \frac{S}{d}\right] \quad (2)$$

where N is the concentration of charge carriers in the base layer, ni is the intrinsic concentration of charge carriers, τ_{nr} ,τ_r, are the nonradiative and radiative lifetimes of carriers, respectively, s is the recombination rate of charge carriers at the rear nGaAs-AlGaAs heterojunction, φ is the photon recycling coefficient in double heterostructures and is equal to ~10 [15].

As the analysis showed, due to the very small thickness of the base layer and the presence of a rear heterojunction, the dark current is additionally reduced by 1.5 ... 2 orders of magnitude, which contributes to the improvement of their photoelectric characteristics. From the dark and light current-voltage characteristics of the solar cell, the following main parameters were identified: saturation current I_o = 10 - 11 A / cm^2, long-wave absorption edge - $\lambda \approx 0.88$ μm, short-circuit current I_{sc} = 22 mA / cm^2, open circuit voltage U_{oc} = 0.98 V.

In this work, we also studied the optical properties of experimental SCs in order to determine their transmittance (T) beyond the long-wavelength edge of the absorption band in GaAs. The value of T in this region of the spectrum was determined by the known method [16], where a silicon-based SC was used as a recording sensor.

The spectral dependence of T for the studied structures was determined from the relationship [17]

$$T(\lambda) = (1 - R_1)(1 - R_2)e^{\alpha_1 d_1}e^{\alpha_2 d_2}e^{\alpha_3 d_3}e^{\alpha_4 d_4} \quad (3)$$

α_1, α_2, α_3, α_4 are the absorption coefficients of surface AlGaAs, n and p GaAs layers, transition AlGaAs and substrate GaP, R_1, R_2 are reflection coefficients from the front rear surface of the heterostructure

As is known, in the region beyond the edge of the main absorption band, the optical transmission of a SC structure with a single-crystal substrate can be affected by absorption by free charge carriers. The studies of the spectral distribution of T in samples with different thicknesses and doping levels, including the substrate, revealed that the optical loss in the near-infrared region of the spectrum due to absorption by free charge carriers does not exceed 10%.

In this case, the value of T corresponds to the condition when the air medium served as an optical channel between the solar cell and the photo sensor. It is known that when optical radiation propagates from a medium with a refractive index n_1 to a medium with a refractive index n_2, part of the radiation is reflected and so-called Fresnel losses occur [18].

In order to increase the efficiency of radiation output from the SC structure, studies were carried out on the effect of antireflection and the method of processing the back surface on the change in T (Fig. 2). It was experimentally revealed that, depending on the processing of the back surface of the SC structure, the current of the photosensor can change up to 50%. The decrease in the photosensor current when using mechanically processed crystals (Fig.3) can be explained by the enhancement of dispersed light scattering [19] when the radiation is extracted from the rear side of the structure. The reduction of losses of this kind to a minimum can be achieved by chemical polishing in the etching process, where an increase in the current of the photosensor is detected to values where the highest transmission efficiency of non-photoactive light fluxes is found. When using antireflection layers of silicate adhesives [20], the photosensor current increased by up to 20%.

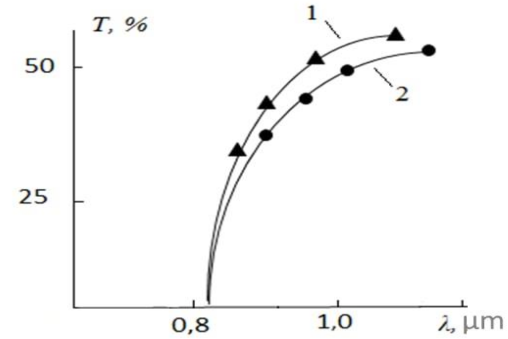

Fig.2. Transmission spectra of non-photoactive photons through heterophotoconverters at GaP thicknesses of 100 μm (1) and 200 μm (2).

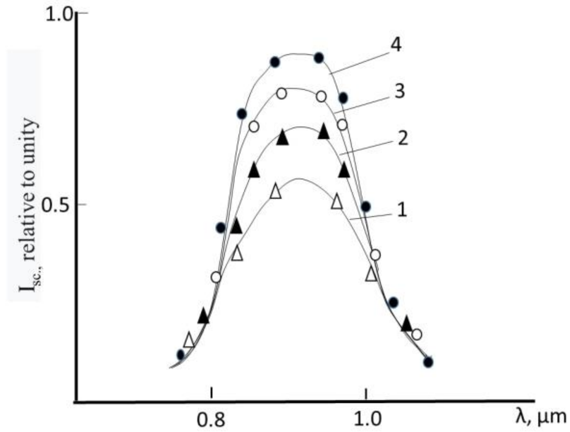

Fig.3. Relative change in the current of the photosensor due to mechanical treatment of the rear surface of the GaP substrate (1, 3) methods of antireflection (2, 4), interelement gap (1, 3), grinding in M5 powder (2, 4), diamond polishing (1, 2) air gap, (3, 4) - silicate glue

The SCs under consideration have the maximum degree of useful use of the band gap Eg of the base region.

This parameter, defined as the ratio of U_{oc} and Eg, is 0.75. This is due to the specifics of the electrical properties of the SC structure, in particular, to low dark currents. Dependences of U_{oc}, I_{sc} and coefficient of performance (COP) on temperature were studied in the illumination range of 80 - 8000 mW/cm2. It was revealed that the temperature coefficient U_{oc} in the given interval is negative and varies within (1.75…1.98).10-3 V/K.

The temperature coefficient I_{sc} has a positive value, varies within $(1.9…2.4)10^{-5}$ A/K and depends on the spectral characteristic of the SC structure. For example, in solar cells, the characteristics of which have a constant photosensitivity region, the change in the temperature coefficient are rather weak. For solar cells, where the spectrum has a narrow region of constant photosensitivity, an increase in current is observed with increasing temperature. The study of the temperature change in the efficiency of the investigated solar cell structures showed that in the temperature range of 300...320 K this value is close - 0.05%/K, and at 321...350K it approaches - 0.03%/K.

In the range of K_s = 80…200, the U_{oc} value increases. This indicates the absence of significant heating in the SC. Studies have shown that due to the small thickness of GaAs and the presence of a wide-gap GaP single crystal, the absorption of thermal photons is significantly weakened. This leads to a weakening of the temperature increase and an improvement in the thermal regime of the solar cell, and the decrease in efficiency shifts towards a high value of K_c (Fig. 4). To improve the thermal regime of the SC, the high thermal conductivity of GaP (0.77 W/cm.K) [8] relative to the thermal conductivity of GaAs (0.46 W/cm.K) also plays an important role. Since the heat flux in structures with a GaP support crystal increases by more than 1.5 times compared to SC on a GaAs substrate, heat removal is noticeably improved. Studies show that in the range K_s = 1…100, the relative temperature increase is 90 K. This is almost 2 times lower than in known SCs based on GaAs/AlGaAs heterostructures. Consequently, at the same level of illumination, the electrical losses in the SC with a carrier GaP crystal are 2 times lower. As is known, losses of this kind can also be reduced by choosing the optimal SC width. It was found that based on heterostructures with a GaP substrate, it is possible to fabricate concentrator SCs operating in the mode without special cooling (Fig. 4) up to K_s = 100 [21].

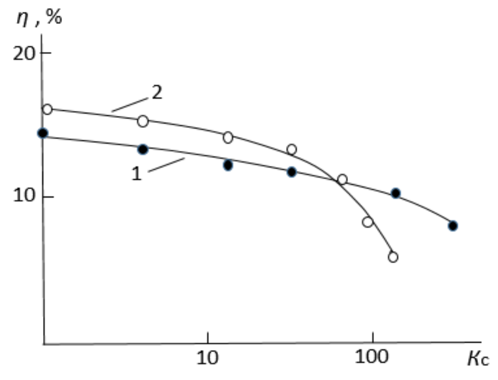

Fig.4. Dependence of efficiency on Kc for GaAs-AlGaAs in the mode without special cooling. 1 – SC designs with GaP substrate; 2 – SC with GaAs substrate.

Thus, the creation and study of solar cells capable of operating with luminous flux concentrators are a promising direction on the way to reducing the cost of electricity produced in proportion to the degree of luminous flux concentration. At the same time, under conditions of natural-convective heat transfer of SC, the thermal load on the p-n junctions of the SC increases significantly, which makes it promising to solve this problem by using the design of SC that are transparent beyond the long-wavelength edge of the absorption band of the base region of the SC.

CONCLUSION

The structural perfection of the epitaxial layers was evaluated by X-ray and metallographic methods. The compositions of the grown layers were determined by measuring the band gap of the semiconductor, in which the photoluminescence method was applied.

Thus, limiting the total thickness of a highly absorbing GaAs layer with a GaP carrier crystal makes it possible to improve their thermal operation when converting concentrated light fluxes.

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Mathematical model of diagnosing diseases among cattle with multiple parameters

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***Abstract*—According to COST (European Cooperation in Science and Technology), the campaign for "Standardization of control based on products for the control of unregulated diseases in cattle in the European Union" (SOUND control) aims to harmonize the results of surveillance and control of selected diseases in cattle and management programs (PU). The article deals with the development of models of the processes of formation of parametric data in the fight against diseases, the con-struction of a mathematical model on this basis and a solution-oriented studies.**

The authors aim to provide an integrated approach to the multi-parameter analysis of diseases and the diagnosis of diseases in cattle, which is an important agricultural problem. The results of the study demonstrate the effectiveness of the model in detecting diseases among cattle with high ac-curacy, which may be important for the prevention and control of livestock diseases

Keywords— cattle diseases, diagnostics, modeling

I. INTRODUCTION

To date, many diseases of cattle have been identified, which are dealt with by vet-erinary specialists and specialized scientific and practical centers. According to the World Organization for Animal Health (WOAH), scientific and practical research and sources related to this field have been analyzed and about 120 animal diseaseshave been identified. Of these, about 10 important diseases that are of great concern to the world's animal husbandry (for example, mastitis, lameness, shortness of breath) have been under in-depth study [1,13]. In particular, it has been established that mastitis alone is causing great economic damage to animal husbandry [2,3,4,5]. Moreover, a very important task is considered to be determination of the time of molting of cattle, which is characteristic of the animal's life cycle. In the studied scientific papers, more emphasis is placed on the study of certain diseases of cattle. This is because the damage caused by these diseases is linked to the economy and human well-being. Diseases can, in one way or another, be divided into different classes, for example, infectious or non-infectious; clinical symptoms are overt or hidden; the disease can be treated or not (eg, tuberculosis).

Mathematical models of disease detection in cattle have received a lot of attention in recent years as they offer a fast and cost-effective means of identifying and moni-toring disease problems. These models are usually built using several parameters, in-cluding clinical signs, laboratory results, and demographics, to provide a comprehen-sive assessment of the health status of cattle.

Research in this sphere has explored the use of mathematical models to detect livestock diseases. In particular, a logistic regression model has been used to predict the likelihood of respiratory disease in cattle based on clinical signs and demographics [6]. Another study used artificial neural networks to detect various diseases in cattle based on the results of blood tests [7].

The use of hybrid models that combine multiple machine learning algorithms to improve accuracy can also provide efficient results [8,9]. In addition, traditional statis-tical models , in the field of application of deep learning algorithms for disease detec-tion in cattle, a convolutional neural network can be used to diagnose mastitis based on breast ultrasound images [10].

In general, mathematical models show that they can be very effective in detecting diseases in cattle, and machine learning and deep learning algorithms are particularly promising. However, it should be noted that these models may not be equally applica-ble in all situations, and further research is needed to refine and test these approaches.

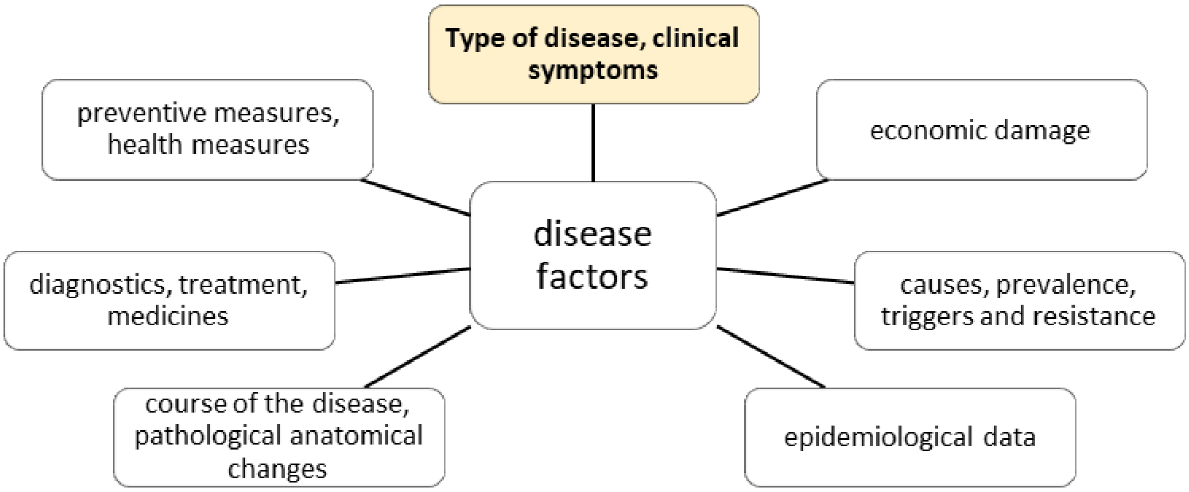
II. MATERIALS AND METHODS

2.1. disease factors

In general, the various aspects related to disease within animal disease are pre-sented by the authors as follows

There are many factors that influence the occurrence of diseases in an animal, in-cluding age of cattle, current life cycle and metabolism, feed supply and timing, vac-cination, environment, weather, presence of other diseases in the animal, number of animals in the herd, disease incidence. seasons, as well as biological, mechanical, nat-ural, alimentary and thermal factors . Among these factors, within the framework of the research topic under consideration, only the type of disease and its clinical symp-toms are considered.

ICT, advanced technologies and artificial intelligence tools are becoming popular, which are developing in harmony with the fields of science and production. In partic-ular, advanced technological tools are being developed and made widely available, such as sensors that detect clinical signs and behaviors indicative of disease in cattle. In particular, on the 4D4F website (4d4f.eu), more than 300 types of intelligent tech-nologies for dairy farming are classified by manufacturer and specific aspects. A sen-sor/meter is a technical device that automatically/mechanically perceives/reads one or another sign/symptom/parameter, in particular, clinical signs and behavior, and con-verts (and transmits) it into digital information [11,12,13,14,15] . The data obtained from these advanced technologies are automatically analyzed using various mod-els/laws or algorithms through a certain criteria base, and when an extreme situation is observed, the computer software sends a message to the appropriate employee. In general, the sensor-software complex can be called sensory tracking. The symptoms of the disease, which were previously detected only by visual observation of a person, are now realized with the help of technology. Therefore, the symptoms can be divided into several classes in terms of observation: human intervention and visual observation, sensory technique, laboratory means and their combination.



2.2. Mathematical description.

This research work is devoted to the problem of mathematical classification of cattle diseases and signs representing the disease. Diseases in this research are represented $K = \{k_i\}$ $(i = 1..m)$, by disease symptoms $P = \{p_c^j\}$ $(i = 1..n)$. Here k_i - i type of disease; p_c^j - type of clinical sign c- $j$type - $j$scale representing the indicator of the clinical sign (exact number, interval, nominal sign), - m −number of the type of disease, n- total number of signs. For example, j- body temperature; c– can be an interval range. For clarity, it should be noted that in animals the temperature is taken in relation to the organs of the body, and in the stages of different diseases the temperature is different. For example many diseases have several stages, many forms and degrees, all types of diseases are considered to have at least one stage and / or form and / or degree. They are important for the classification of diseases. It is also necessary to take into account such aspects as the proximity of diseases to each other and causing each other. K Clinical signs and behaviors may be repetitive and symptom indicators may be the same and/or different depending on the type of disease.P

2.3. Symptoms of the disease

Now the main symptoms representing diseases are considered. Key symptoms in-clude body temperature (rectal, udder, breast, ear/tympanic, vaginal), age, heart rate, weight, milk yield (volume, milk quota, milking interval), loss of appetite/feeding re-fusal, salivation from the mouth, runny nose . nose, tears, weight loss, tremors, depres-sion, weakness, cough, shortness of breath, respiratory rate, skin hair growth and loss, redness, swelling, ulcers and injury, throat symptoms (vomiting, placental abruption, drooling) , constipation/passing, lameness, abnormal movements, neck movements, jumping, walking (speed and amount), irritability, screaming/whining, drooling, lick-ing, depression, stress, routines (eating, resting, lying down, sleeping, getting up), etc. These symptoms are literally divided into 2 related classes: biological and behavioral indicators of cattle. These symptoms recur depending on the type of disease, and most depend on factors such as the life cycle of the animal. Symptom detection can be de-tected through human intervention and/or advanced technology. At the same time, the possibilities of popularized cheap advanced technology are limited, and expensive technologies with broad capabilities do not justify themselves in most farms. Therefore, it is important to detect more symptoms with less cost and to diagnose the disease with high probability and high accuracy as a result of scientific experiments with symptom indicators. In short, more information needs to be generated from fewer parameters. An analysis of the literature and experience points to the existence of golden rules. The golden rule: to diagnose a disease, it is enough to correctly use the indicators of certain parameters, that is, if there are sufficiently consistent indicators of the final sympto-matology of a disease of a living organism, then the result of deep scientific mecha-nisms of combined data processing (intelligent analysis, artificial intelligence, fuzzy set theory, knowledge base, etc.) will fix the exact diagnosis of the disease. Currently, scientific research is being carried out with a large audience in order to identify the disease according to certain parameters that can be easily and technologically con-trolled in real time. For example, by real-time analysis of the composition of Indian cow's milk in a milking parlour, one can determine whether it has been drunk [18,19]. Even more interesting fact is that visual or sensory observations can be made at any time or at certain intervals or continuously (with short intervals) depending on the requirements and conditions, and this time of observation will necessarily correspond to the life cycle of the animal.

2.5. Modeling the process of obtaining information from sensors

The main purpose of this scientific and practical work is to identify the symptoms of the disease using sensors. Sensors are diverse and their information is limited. It should also be noted that although some sensors directly receive biological symptoms (eg, temperature, weight), most sensors do not or cannot read indicators of disease symptoms that are obvious by visual observation and inspection. In such cases, scientific experiments to detect diseases show that they measure the parameters of changes in various parts of the body, for example, the behavior of cattle, and jointly process, the obtained data with the available accounting and regulatory data, that is, by processing information from sensors such as a pedometer, accelerometer, color (light), humidity, temperature, information similar to the symptoms of a disease is created together in time.

One or more of them are involved in the detection of symptoms of a disease, defined as information obtained from types of sensors (invasive and/or non-invasive) $D = (d_1, d_2, \ldots, d_p)$aimed at certain areas of the animal's body. The author proposes a conditional mathematical model for detecting symptoms of the disease using sensors:

$$p_j = \rho_j \Phi^j(\eta_1^j d_1, \eta_2^j d_2, \ldots, \eta_p^j d_p) \qquad (1)$$

here, $d_i -$ - i sensor information indicator; $\eta_i^j = \langle 0,1 \rangle$ - during data processing, $i$the value of the sensor indicator is 0 if this indicator is not needed to detect a symptom; $\Phi^j - j$a special function that processes information about the symptom; $\rho_j \in [1, 100]$ is a percentage, and j is the significance or accuracy of the symptom value Φ^j.

When building a generalized model, the participation of the necessary information in all sensors to determine the symptom of an optional disease η is determined by a binary value. Moreover, the task is to build a function with different weights of information received from sensors and algorithms for its processing for different symptoms.Φ

Unusual behavior in cattle B is considered a sign of the disease, and bringing it to a unique appearance is a difficult task. This includes deviations from time-dependent daily routines such as voice, walking, eating, sleeping, chewing, and abnormal appearance of the eyes, mouth, nose, and skin. For example, cattle sleep/rest 12-14 hours, eat 3-5 hours and drink 0.5 hours as well as included in the offer of movements in the body: free movement, unwillingness to move, lying down and inability to move, prolonged standing, lameness, lifting the leg with neck movement, S-shaped body position, turning to the side, stumbling, crossing the legs, immobility. According to movement and appearance, they can be divided into the following groups: eye (tears, redness), ear, mouth (salivation, voice), incisor (runny nose, breathing), movements of the legs, neck and head, trunk, udder, skin changes, hair and agendas. The notation associated with an action is expressed as follows:

$$B = \langle K, \beta \rangle \ = \{b^{i,j}\},$$

where i- type of action j- compatibility of the disease with the parameter, $b^{i,j}$- normative indicator of action, the time interval during which this normative indicator is determined is expressed in seconds. For example, lameness in cattle can be detected with a triaxial accelerometer using triaxial accelerometers for body position (sleep, rest, immobility in lying, standing, walking, neck movements, rotations, S-shaped posture) and variability in average gait (walking speed (m/s) = 1.350 ± 0.150; stride length (m) = 1.591 ± 0.005; stride time (s) = 1.523 ± 0.009; support time (s) = 1.011 ± 0.007; stride overlap (m) = 0.011 ±0.003 and their asymmetry scores) are analyzed over time and compared with norms to determine one of the following levels of lameness [20]:

Degree	Grade criteria
1- healthy	Cow' both standing and walking' keeps the back straight for a long time step throws _
2- a little lame	Instead of standing' keeps the back straight_ shoulder bends, walks , with small steps, Any definite to the leg weight does not quit
3- medium lameness	Cow bends waist, walks with_ small step, moves ; damaged leg (weight does not fall). Weight damaged to the leg when it comes to head to the ground owns _
4- strong lameness	Cow bends waist, instead of standing. And walks , with damaged leg does not fall . Slows down, moves slowly(walks), often stops , pain secondary symptoms observed : weight loses a tooth returns , a lot of saliva emits _
5- Very strong lameness	The waist is bent . Damaged leg lames, All in all , doesn't drop small movement

The data received from the sensors (1) are processed according to the expression , the result $b^{i,j}$is compared with the norms and the symptom of the disease is determined.

In general $\{k_i\}$, clinical signs corresponding to the type of disease $\{p_c^j\}$are defined as follows:

$$S = \langle K, P \rangle \ = \{s^{i,j}\},$$

where i-type $j$is a scaled standard indicator of a clinical symptom corresponding to the type of disease. For example, i - mastitis disease, j - normal body temperature is 38.6°C±1.1°C. Two-dimensional matrix in notation S.

In most cases, the occurrence of certain types of diseases or the incidence of cattle depends on the life cycle and age of the cattle. Other factors of cattle are determined, such as clinical parameters of the disease: age of cattle A(Age) and life cycle L(Life Cycle), etc. In this case, factors related to the type of disease can be expressed as follows:

$$A = \langle K, \alpha \rangle \ = \{a^{i,j}\} \ L = \langle K, \gamma \rangle \ = \{l^{i,j}\}$$

here α the age of cattle (1-10 days, 10-20 days, 20-30 days, 2 months, 3 months, 6 months, 9 months, 1 year, etc.) and life cycle (calves, heifer, farrowing , periods γsuch as overload, rest, service, lactation) the correlation values of indicators with the type of disease are expressed within 0-100%.

Can be diagnosed, identified, or predicted using the symptoms of the disease and additional factors that influence the disease. The author proposes a conditional generalized mathematical model of multi-parameter detection of a disease in the following form:

$$\begin{cases} F = \lambda_1 F^1(S) \oplus \lambda_2 F^2(A) \oplus \lambda_3 F^3(B) \oplus \lambda_4 F^4(L) \oplus \ldots \to max \\ \forall F^i = 0 \ \to F \in \emptyset. \end{cases} \qquad (2)$$

Here F- is considered as a general function of detecting a disease and approaches a certain type of disease, F^i- a multi-level and branched mathematical-algorithmic complex in the form of a special function that processes input data, λ_i- a given weight coefficient to the factors, $\oplus$- an arbitrary mathematical operation between the limits. If the optional F^ivalue is zero, the function is usually F undefined. This means that the disease cannot be diagnosed.

Processing the biological and physiological parameters of cattle, determined by different technologies and visual observation, $F^i$are structurally different from each other with respect to the corresponding factor.

III. Results

Now let's look at the practical example of the above-mentioned. Let -index be mastitis among all types of diseases l: k_l = mastitis. For simplicity, among all clinical signs, p_{lj} $\left(\forall p_{lj} \in P\right)$ those related to mastitis are conditionally defined, since they consist of the following parameters:

p_{l1} - milk temperature (temp. >25°C, and the norm is 38°C) ;

p_{l2}- the number of days in the milk of cattle (Days in milk - DM);

p_{l3}- milk productivity (Milk yield - MO, per day / cow);

p_{l4}- milk yield per hour (MYH - milk yield per hour, kg/hour);

p_{l5} - electrical conductivity of milk (Electrical conductivity - EU, ms/cm);

p_{l6}- average milk flow rate (moving average - MA);

p_{l7}- the highest milk flow rate (Moving maximum - MM);

p_{l8}- the number of somatic cells in milk (Somatic cell count - SCC, cells / ml);

p_{l9} - lactate dehydrogenase (Lactated dehydrogenase - LDH);

p_{l10}- color of milk or amount of blood in milk (Milk Color - MC));

p_{l11}- duration of milking;

p_{l12}- full milking.

Having studied the accepted parameters of clinical signs of mastitis, they can be expressed in the form of table 1.

k_i \ p_j	…	p_{l1}	p_{l2}	p_{l3}	p_{l4}	p_{l5}	p_{l6}	p_{l7}	p_{l8}	p_{l9}	p_{l10}	…
…	…	…	…	…	…	…	…	…	…	…	…	…
k_l		>25°C	<305	≥7	>1 0	≥7.5	5	12	200000	2.8-3.5	1	
…	…	…	…	…	…	…	…	…	…	…	…	…

Many parameters such as temperature, CB, MF, EC, MA, SCC, LDH, MC are required to detect mastitis in cattle using intelligent sensors in automatic milking systems. However, it is difficult to determine all these parameters due to the presence of sensors and the level of capabilities. It is known that the reliability of the disease detection algorithm is determined by the number of parameters included in it and accurate test results. Currently, there are algorithms that process samples according to several parameters to reliably detect mastitis. In particular, the use of methods for calculating sensitivity and specificity has become popular. Despite the fact that they are the result of processing information received from sensors, they can be included among the parameters that determine the disease. Sensitivity is the proportion of positive (eg, true disease) samples that are correctly identified by the device or test. Specificity is the proportion of healthy samples that are negative for the disease. TP is true positive, FD is false positive, TN is true negative, FN is false negative.

$$Se = \frac{TP}{TP + FN} \times 100\%\,, \qquad Sp = \frac{TN}{TN + FP} \times 100\%$$

ensitivity and specificity for mastitis can be determined from experimental results: Se > 70% and Sp ≥ 99%. According to the analyzes of the work carried out, this method is widely used in the diagnosis of mastitis. In this case, the function in (1) has any of the following forms:

$$p_{mastit} = \left\{ \begin{matrix} \rho_1 \Phi^1(EC) \mid \rho_2 \Phi^2(MY, EC) \mid \rho_3 \Phi^3(MY, EC, MA) \mid \\ \rho_4 \Phi^4(MY, EC, LDH) \mid \rho_5 \Phi^5(MY, LDH) \mid \rho_6 \Phi^6(EC, SCC) \mid \\ \rho_7 \Phi^7(EC, MilkColor) \mid \rho_8 \Phi^8(MY, LDH, SCC), \ldots, \rho_l \Phi^l(\ldots) \end{matrix} \right\},$$

where Φ^i- the functions consist of algorithms of various structures, the arguments of which are coarse information received from one or more sensors and / or semi-finished product parameters pre-processed to this coarse information, - the degree of accuracy of the result obtained ρ_i.

From the point of view of determining the norms of clinical signs, it should be noted that in most cases, instead of the norms, the ratio of the change in one or another parameter in an individual cattle to the previous period has been used. The idea of this technique means registering the average change in the health status of cattle over a period of time and a small number of previous deviations, and then the deviations of the current change from this indicator are carried out through the maximum number of deviations. For example, if there is a previous deviation $\varepsilon_{old}$and a later deviation ε_{new}, then the limiting case $|\varepsilon_{old} - \varepsilon_{new}| \geq \varepsilon_{old}$is the condition.

Mastitis occurs only in dairy cows (17.5% in the service period, 20-23.7% in the lactation period). It is also known from experience that mastitis depends on the age of the animal (0% up to 1.5 years old, 12.1% up to 5 years old, 63.6% up to 5-10 years old, 24.3% over 10 years old). The age of animals and the percentage of the life cycle depending on the type of disease are also given in the table [21-27].

The correctness of the condition of expression (2) can be shown on the same case of mastitis. Mastitis does not occur in animals under 1.5 years of age or in non-nursing animals, that is, if there are visual or sensory clinical signs directed towards mastitis, but if the age $F^1(S)$ or life history $F^3(B)$ of the animal $F^2(A)$is null for mastitis, the result is that the animal does not have mastitis.

Therefore, the following rule works: when determining the type of disease, analytical algorithms are appropriate Sonly in cases where A - the age of the animal and - B the life expectancy are not equal to zero - clinical signs and - symptoms of action.L

IV. Conclusions

This article is a continuation of the scientific and practical research carried out within the framework of the innovative project IL-392103072 - "Creation of a mobile application for electronic management of livestock complexes". The article proposes a mathematical model of detecting multiparametric diseases in cattle using sensor tech-nologies. Currently, various systems for early detection of a disease by disease param-eters have been introduced in practice, and all of them have limitations in one aspect or another, such as the detection of only one disease, the integration of various func-tional sensors, the mathematical basis for processing with changing parameters. This means that there are many more problems in this area.

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Generating Cryptographic Certificates Using a Mobile Phone

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***Abstract* — In today's digital age, security and privacy are paramount concerns when it comes to online interactions and transactions. Cryptographic certificates play a crucial role in ensuring the authenticity and confidentiality of digital communications. Traditionally, generating cryptographic certificates required complex setups and technical expertise. However, with the advancement of technology, it is now possible to generate cryptographic certificates using something as ubiquitous as a mobile phone. This article delves into the process of generating cryptographic certificates using a mobile phone and explores its implications for security and convenience.**

Keywords — security, generation, cryptographic key, cryptographic certificates, mobile phone, generating cryptographic certificates

I. Introduction

Cryptographic certificates, often referred to as digital certificates or SSL/TLS certificates, are digital documents used to verify the authenticity of a website, service, or individual in online communications. They rely on encryption technology to establish secure connections and verify the identity of parties involved. This is crucial to prevent malicious actors from intercepting or altering sensitive information exchanged between users and servers.

Mobile phones have evolved from simple communication devices to powerful computing tools. Modern smartphones come equipped with robust processors, secure storage, and various cryptographic capabilities, making them suitable for tasks that require security and computation [1]. Generating cryptographic certificates is no exception.

In an increasingly digital world, where data privacy and security are paramount, the role of cryptographic certificates in safeguarding sensitive information cannot be overstated. These certificates serve as digital credentials that validate the authenticity of entities, such as websites, individuals, or devices, and ensure encrypted communication [2]. However, the process of obtaining and managing cryptographic certificates has traditionally been a complex and technical endeavor, often requiring specialized knowledge and equipment.

Enter the era of convenience and accessibility: the capability to generate cryptographic certificates using something as ubiquitous as a mobile phone. This technological leap brings forth a revolution in digital security, making it possible for individuals and organizations to harness the power of encryption without the need for sophisticated setups or extensive expertise. This paradigm shift not only democratizes access to advanced security measures but also paves the way for a more secure online landscape [3].

This paper explores the innovative method of generating cryptographic certificates using mobile phones, providing an accessible and user-friendly approach to enhancing digital security. By leveraging the computing power and connectivity of modern smartphones, individuals can now take control of their cybersecurity without relying solely on external certificate authorities. From understanding the fundamentals of cryptographic key pairs [4] to the step-by-step process of generating certificates, this paper offers a comprehensive guide that caters to both novice users and seasoned professionals.

Key benefits of generating cryptographic certificates using mobile phones include:

- Accessibility: Mobile phones have become ubiquitous tools that are carried by billions of people worldwide. Leveraging their availability, this approach makes robust security measures accessible to a broader demographic.
- User Empowerment: By offering an intuitive interface and simplified procedures, this method empowers individuals who may not have extensive technical knowledge to take charge of their digital security.
- Reduced Dependence: Traditionally, the issuance of cryptographic certificates involved relying on third-party certificate authorities. Now, users can generate their own certificates, reducing dependence on external entities.
- Enhanced Security: Generating certificates directly on a mobile device minimizes the exposure of sensitive cryptographic keys, reducing the risk of interception and unauthorized access.
- Real-time Implementation: The mobile-based approach allows for on-the-spot certificate generation, ideal for scenarios where immediate security measures are required.
- Cost-Efficiency: Eliminating the need for specialized hardware or professional services reduces the overall cost associated with implementing robust encryption.

As we delve into the intricacies of generating cryptographic certificates using mobile phones, this paper will also address potential challenges, security considerations, and future implications of this approach. By embracing this innovative method, individuals and organizations can fortify their digital presence while contributing to a safer and more secure online environment for all. In a world where data breaches and cyber threats loom large, this paradigm shift stands as a beacon of empowerment, enabling individuals to harness the full potential of encryption through the device that is never far from their reach – the mobile phone [5-7].

II. Generating Certificates Using a Mobile Phone.

Software for mobile phones has been created to generate cryptographic certificates. The uniqueness of this software lies in the fact that it used the algorithms O`zDSt 1092: 2009 [8] and O`zDSt 1106: 2009 [9]. In Fig. 1, the user generates a cryptographic certificate for himself in the case of entering his data.

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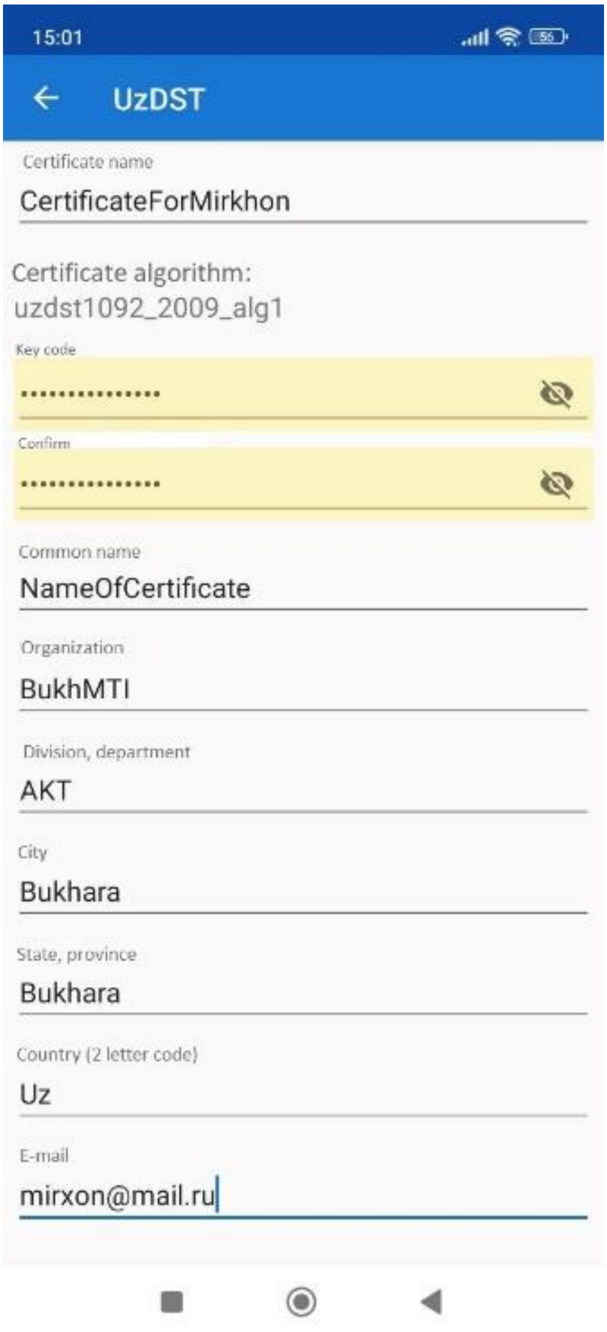

Fig. 1. Generating Cryptographic Certificates.

And in Fig. 2, we can see the contents of the generated certificate.

Fig. 2. Generated cryptographic certificate

And in Fig. 3, we can see the closed key content of the generated certificate.

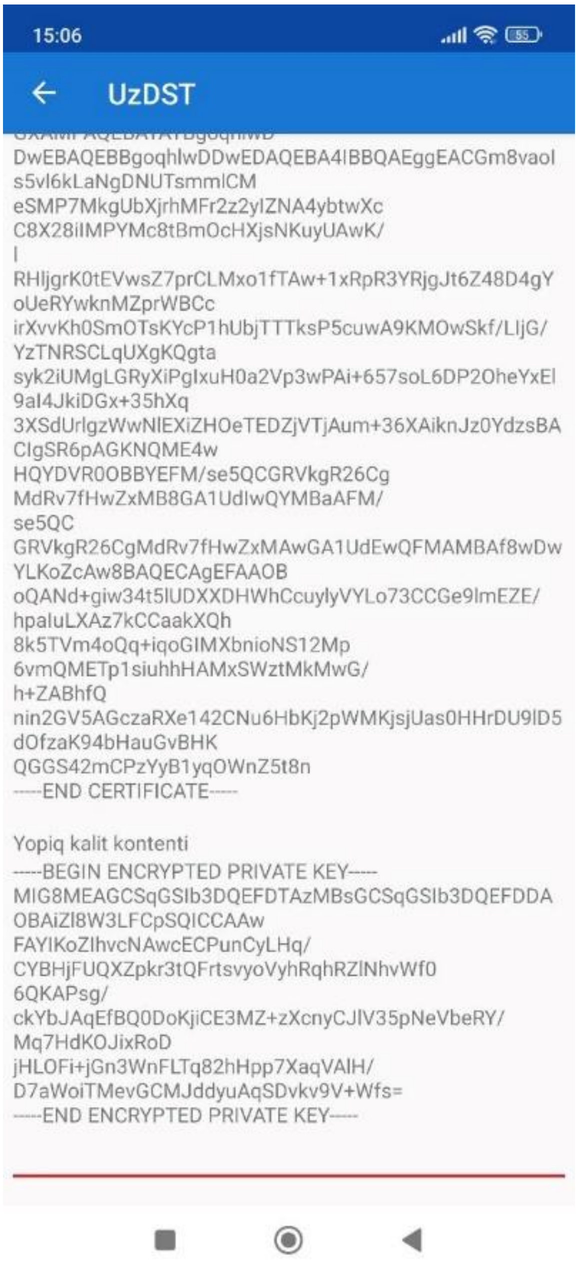

Fig. 3. Generated content of the cryptographic certificate

We can also get detailed information on the x509 standard [10] by clicking on the X509 INFO button in Fig. 4. And in the content section, we can see the generated certificate and its closed key content (Fig. 5).

Fig. 4. X509 cryptographic certificate information

Fig. 5. Generated content of the cryptographic certificate

There is also the option to export the generated certificate to a file.

A. *Implications and Benefits:*

- Accessibility: With the widespread use of smartphones, generating certificates becomes more accessible to individuals and small businesses who may not have access to traditional computing resources.
- Enhanced Security: The private key generation and storage within the secure enclave of modern smartphones add an extra layer of security. It reduces the risk of private key exposure to potential threats.
- Convenience: The ability to generate certificates directly from a mobile phone eliminates the need for complex setups and specialized knowledge. This makes it easier for non-technical users to implement secure communication practices.
- Rapid Deployment: Mobile-generated certificates can be quickly deployed for various purposes, such as securing email communication or setting up secure connections for websites or applications.

B. *Challenges and Considerations:*

- Key Storage: While smartphones offer secure enclaves for key storage, the overall security of the device remains crucial. Compromised devices can still lead to private key exposure.
- User Education: While the process is simplified, users must still understand the importance of safeguarding their private keys and using certificates appropriately.
- Certificate Trust: Mobile-generated certificates might not be initially trusted by all devices or platforms. Widening their acceptance might require collaboration with established Certificate Authorities.

III. Future Trends

Generating cryptographic certificates using mobile phones is likely to become more prominent in the future due to several technological and societal trends. Some potential future trends in this area:

- Increased Mobile Processing Power: Mobile phones are continuously becoming more powerful in terms of processing capabilities. This means that they can handle more complex cryptographic operations required for generating certificates without significantly impacting device performance.
- Enhanced Security Measures: As mobile devices become more integrated into our lives, the need for secure authentication and authorization mechanisms will grow. Generating cryptographic certificates on mobile phones can provide a convenient and secure way to verify identities and authorize transactions.
- Decentralized Identity and Blockchain: Decentralized identity solutions, often built on blockchain technology, are gaining traction. Mobile phones could play a crucial role in these systems by generating and storing cryptographic certificates that prove a user's identity without relying on centralized authorities.
- Biometric Integration: Mobile phones are equipped with various biometric sensors, such as fingerprint scanners and facial recognition cameras. These can be used to enhance the security of certificate generation by tying them to unique physical attributes of the user.
- Secure Element Integration: Some modern mobile devices have a dedicated secure element—a hardware component that provides a high level of security for sensitive operations. Generating cryptographic certificates in such secure elements adds an extra layer of protection against attacks.
- Mobile-First Workforce: With the rise of remote work and the "mobile-first" approach in various industries, having the capability to generate cryptographic certificates on mobile devices can facilitate secure access to corporate resources and sensitive data from anywhere.
- IoT Device Management: As the Internet of Things (IoT) continues to grow, there will be a need for secure device management and communication. Mobile phones can act as hubs for managing and authenticating IoT devices through the generation of certificates.

- User-Centric Control: Empowering users to have control over their own cryptographic certificates can enhance privacy and security. Mobile phones provide a user-friendly interface for managing these certificates, allowing individuals to grant or revoke access as needed.
- Standardization and Interoperability: Future trends might see the development of standardized protocols and formats for cryptographic certificates generated on mobile devices. This would promote interoperability across various platforms and services.
- Environmental Considerations: As awareness of energy consumption grows, there could be efforts to optimize cryptographic operations for mobile devices, ensuring that certificate generation doesn't overly strain battery life.

It's important to note that while these trends suggest a promising future for generating cryptographic certificates on mobile phones, there will also be challenges to address, such as ensuring the security of the mobile environment, protecting against new forms of attacks, and maintaining user privacy. As technology evolves, the balance between convenience and security will be a key factor in shaping the adoption of these trends.

Conclusion

The ability to generate cryptographic certificates using a mobile phone marks a significant advancement in the field of cybersecurity. This innovation democratizes access to secure communication by simplifying the complex process of certificate generation. As smartphones continue to evolve and security measures strengthen, we can anticipate even more secure and convenient cryptographic practices in the future. However, it's crucial to remember that while mobile phones offer new possibilities, the fundamental principles of cybersecurity and responsible key management remain unchanged. Facilitating the generation of cryptographic certificates via a mobile phone represents a notable advancement in promoting broader access to digital security for a more diverse audience. It empowers individuals and organizations to take control of their online privacy and secure their communications without the need for extensive technical expertise. However, as with any technological advancement, it's crucial to balance the convenience with security measures and a thorough understanding of the underlying processes. With responsible usage, mobile-generated cryptographic certificates can contribute to a safer and more secure digital ecosystem for all.

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The comparison of Grover's algorithm and classical algorithms in search

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***Abstract*— One of the urgent tasks of computer science is to search for the desired information from the data set. This process is an important tool for finding the necessary information from databases, and gathering information on the Internet in an effective and optimal way. Classical algorithms dominated the field for a long time, but Grover's algorithm, which appeared after the invention of quantum computing, introduced new approaches to the field of search. This article examines the advantages and disadvantages between Grover's algorithm and classical search algorithms.**

Keywords*— Quantum computing, Grover's algorithm, classical algorithms, quantum search, binary search, linear search

I. Introduction

Information retrieval is a fundamental computational task spanning a variety of fields from databases and cryptography to optimization and artificial intelligence. Classical algorithms have been one of the main elements of the processes in the field of search for many years, and even now these algorithms are used in a constant state. However, the advent of quantum computing has raised interesting questions about the limits of these algorithms and the potential of quantum algorithms. This study presents a comparative analysis between Grover's algorithm and classical search algorithms related to quantum computing. Grover's algorithm was created by Lov Grover in 1996 and outperforms classical algorithms in quadratic speed when searching with irregular data sets. Based on the principles of quantum parallelism and interference, it uses the unique properties of quantum bits (qubits) to increase the probability of finding the desired item in an unsorted database. In contrast, there are classical search algorithms such as linear and binary search. Has long provided effective solutions for various search scenarios. Linear search works on sorted or unsorted lists, binary search is preferred when the data set is sorted [1]. These classical methods are based on iterative or recursive procedures and often rely on comparisons to reduce the search space. Through a comparative analysis of Grover's algorithm and classical search algorithms, this study aims to understand in detail the strengths and limitations of each approach. By highlighting the theoretical foundations and algorithmic subtleties, we illuminate the quantum mechanical concepts underlying Grover's algorithm and the classical paradigms underlying traditional search methods. We examine implementation complexities, interactions between quantum and classical resources, and specific situations where Grover's algorithm can demonstrate its quantum superiority.

II. Classical Search Algorithms

In the world, with the help of classical computers, various search algorithms have been used for a long time to find the necessary elements in data structures such as arrays, lists or databases. Some of the most popular among these algorithms are Linear Search, Binary Search Algorithms.

1. The term linear search, also called sequential search, is one of the simplest search algorithms used to find a specific element in a data set. It is often used when data is unsorted. A linear search algorithm works by successively examining each element in a set until the desired element is found or the entire set is searched.

The sequence of operation of the linear search algorithm is as follows:

a. Initialization: Start with the first element of data collection.
b. Compare: Compare the current item with the target item you are looking for.
c. Matching: If the current element matches the target element during the search, the search is considered successful and the algorithm completes its work.
d. Progression: If the current item does not match the target item, move to the next item in the set.
e. Iteration: Steps 2-4 are repeated until the target element is found and all elements are checked again.
f. Termination: If the entire set is searched without finding the target element, the algorithm terminates with the conclusion that the element does not exist in the set.

The time complexity of the linear search algorithm is O(N), where N is the number of elements in the set. The worst case for this algorithm is that the algorithm must examine every element in the set before finding the target element or concluding that it does not exist. As a result, linear search is less efficient than algorithms such as binary search for larger data sets. ladi

Linear search is typically used in situations where the data is small or the data is unordered, and for algorithms such as binary search, the overhead of sorting the data is greater than performing a linear search.

It is important to keep in mind that although linear search is a simple and easy algorithm to implement, its efficiency can be significantly reduced for larger data sets. In such cases, advanced search algorithms such as binary search or hash-based methods may be preferred.

2.The Binary search technique is a widely used searching method that is employed with ordered datasets to efficiently locate a specific element. It proves notably swifter than linear search strategies when applied to extensive datasets due to its practice of halving the search space for each comparison. Particularly in scenarios involving ordered datasets, the Binary search algorithm demonstrates exceptional efficiency, boasting a time complexity of O(log N). This stands in stark contrast to the time complexity of O(N) associated with linear searches.[2]

The operational steps of the Binary search algorithm are outlined as follows:

a. Initialization: The procedure commences with a fully arranged dataset.
b. Comparison: A comparison is drawn between the middle element within the current search range and the target element under scrutiny.
c. Matching: In case the middle element aligns with the target element, the search operation is deemed successful, and the algorithm presents the outcome.
d. Refinement of the search range: If the middle element surpasses the magnitude of the target element, the right half of the present search range is removed (as the target must reside within the left half). Conversely, if the middle element is smaller than the target element, the left half of the current search range is discarded.
e. Repetition: Steps 2 to 4 are reiterated, now with a fresh, reduced search range.
f. Conclusion: When the search range becomes devoid of elements (indicating the absence of the target element within the set), the algorithm concludes its operation without locating the sought-after element.

Each iteration of the Binary search effectively slashes the search range in half, systematically eliminating half of the remaining possibilities. This approach significantly expedites the search process, particularly when dealing with voluminous datasets.

While the Binary search strategy excels with ordered datasets, it mandates a prerequisite sorting of the data. In cases where data is unsorted or the sorting overhead is considerable, other search algorithms like linear search or hash-based methodologies might prove more fitting.

III. GROVER'S ALGORITHM: THE QUANTUM ADVANTAGE

One of the search problem-based algorithms of quantum computing is Grover's algorithm. This algorithm was proposed by Love Grover in 1996 and is considered one of the important algorithms for quantum computing. Searching for the necessary information from unstructured data sets is one of the main problems in the field of informatics. Grover's algorithm is an important tool in solving this problem. Classical search algorithms can achieve the goal in O(N) or O(log(N)) attempts when the number of elements in the database is N when finding the desired element. However, Grover's algorithm requires $\sqrt{N}$ attempts to achieve this goal. The emergence of Grover's algorithm marked significant advances in the field of quantum computing, highlighting the potential of quantum computers to provide significant speedup over classical algorithms in solving unstructured search problems. This algorithm finds practical applications in fields such as intelligent data analysis and cryptography and has further advanced the innovation of additional quantum algorithms for optimization and machine learning tasks. Before the introduction of Grover's algorithm, the widely accepted quantum search algorithm was Deutsche's algorithm, which was limited by its rules that exhibit specific structural properties.

Grover's algorithm is a quantum algorithm that searches an unstructured database of N elements to find a specified element. This procedure involves creating a quantum superposition containing all possible states of the database, and then applying an operator designed to increase the amplitude of the element being searched for. This operator, called the Grover operator, is precisely defined as:

$$G = 2|s\rangle\langle s| - I \qquad (1)$$

Where (1) |s> denotes the uniformly distributed superposition containing all possible states, and I denote the identity matrix. The Grover operator serves to reflect the amplitude of the specified element relative to the average amplitude of all objects, thereby increasing the amplitude of the specified element while reducing the amplitude of the remaining elements[7].

Thus, this algorithm includes 3 stages. These are:

a. Initialization Phase: Commencing within a superposition spanning all potential states, the algorithm initiates by executing a sequence of quantum procedures. These operations are performed to establish an equitably balanced probability distribution across the complete range of conceivable states.
b. Amplitude Enhancement:
The stage of amplitude enhancement is designed to magnify the amplitude about the sought-after item, simultaneously dampening the amplitudes linked to other items.
Utilize the oracle operation (2) (Uo) for designating the target item:

$$|s'\rangle = Uo\,|s\rangle \qquad (2)$$

Employ the Grover Diffusion Operator (3) (Us) to intensify the amplitude corresponding to the average state:

$$Us = 2\,|s\rangle\langle s| - I\,|s''\rangle = Us\,|s'\rangle \quad (3)$$

This progression of amplitude enhancement (consisting of both the oracle and diffusion steps) is iterated approximately $\sqrt{N}$ times to optimize the likelihood of accurately identifying the measured state.
c. Measurement: In the final phase, execute the measurement process on the evolved superposition state |s"⟩ to acquire the desired item with a notably elevated likelihood.

Mathematical Expressions
Hadamard Gate (4) (H):

$$H = \sqrt{\tfrac{1}{2}}|0\rangle\langle 0| + \sqrt{\tfrac{1}{2}}||0\rangle\langle 1| + \sqrt{\tfrac{1}{2}}||1\rangle\langle 0| - \sqrt{\tfrac{1}{2}}||1\rangle\langle 1| \quad (4)$$

Oracle (Uo)
Uo |x⟩ = (-1) f(x) |x⟩, where f(x) equals 1 for the target item and f(x) equals 0 for all other instances.
Grover Diffusion Operator (5) (Us):

$$Us = 2\,|s\rangle\langle s| - I \qquad (5)$$

In synopsis, Grover's algorithm effectively leverages quantum superposition and interference principles to navigate through unordered datasets. The algorithm iteratively employs the oracle and diffusion operations to enhance the probability of successfully measuring the sought-after item, while simultaneously diminishing the probabilities of other items. The efficiency of the algorithm shines particularly in larger datasets, showcasing the quadratic acceleration over classical search algorithms. Nonetheless, it's imperative to acknowledge that the triumph of Grover's algorithm is probabilistic, necessitating multiple repetitions to achieve a robust likelihood of success[8].

IV. SOFTWARE PART

Let's look at programs to find the desired element from a given database in Python using linear search, binary search, and Grover's algorithms. As an assignment, we were given the names of several individuals. The task of finding the name of a voluntary person from this set of data is set. First, we download a small library for Python. We get an API token for the quantum emulator by registering at quantum computing.ibm.com. We need this to get the results into our program created for the Quantum Algorithm.

Linear Search Implementation:

```
def linear_search(database, target):
for index, element in enumerate(database):
if element == target:
return index
return -1
database = [ "Abdinabiyev Akrom", "Abdurakhimov Akhrorjon", "Abubakirov Sardar", "Akramov Azizjon", "Bakhtiyorova Mohirui", "Bobajanov Khumoyun", "Hasanov Akbar", "Ismailov Jahangir", "Jumayev Asadbek", "Muhammadjonov Nuriddinjon", "Nuriddinov Behruz", "Urinboyev Daniyorbek", "Saidov Okhunjon", "Sulaymonov Davron", "Suyunkulov Jaloliddin", "Turayev Nurmukhammad", "Toyirov Sherzodjon", "Khamrayev Mansur", "Khojimirzayev Abdumalik", "Khushbakov Sherzod"]
target = "Bobajanov Khumoyun"
linear_result = linear_search(database, target)
if linear_result != -1:
print(f"{target} found at index {linear_result} using linear search.") else:
print(f"{target} not found using linear search.")
```

Binary Search Implementation:

```
def binary_search(database, target):
low = 0
high = len(database) - 1
while low <= high:
mid = (low + high) // 2
if database[mid] == target:
return mid
elif database[mid] < target:
low = mid + 1
else:
high = mid - 1
return -1
database.sort()  # Binary search requires a sorted list
binary_result = binary_search(database, target)
if binary_result != -1:
print(f"{target} found at index {binary_result} using binary search.")  else:
print(f"{target} not found using binary search.")
```

Grover Implementation:

A program for Grover's algorithm using qiskit, a popular Python library for quantum computing:

```
from qiskit import QuantumCircuit, Aer, transpile, assemble
from qiskit.visualization import plot_histogram
# Given database
database = ["Abdinabiyev Akrom","Abdurakhimov
Akhrorjon", "Abubakirov Sardar","Akramov Azizjon",
"Bakhtiyorova Mohirui", "Bobajanov Khumoyun", "Hasanov
Akbar", "Ismailov Jahangir", "Jumayev Asadbek",
"Muhammadjonov Nuriddinjon","Nuriddinov Behruz",
"Urinboyev Daniyorbek","Saidov Okhunjon", "Sulaymonov
Davron", "Suyunkulov Jaloliddin","Turayev Nurmukhammad",
"Toyirov Sherzodjon", "Khamrayev Mansur",
"Khojimirzayev Abdumalik", "Khushbakov Sherzod"]
target = "Bobajanov Khumoyun"
# Grover's Algorithm
def grover_search(database, target):
n = len(database)
oracle = QuantumCircuit(n)
for idx, name in enumerate(database):
if name == target:
oracle.x(idx)
diffusion = QuantumCircuit(n)
for idx in range(n):
diffusion.h(idx)
for idx in range(n):
diffusion.x(idx)
diffusion.h(n-1)
diffusion.mct(list(range(n-1)), n-1)
diffusion.h(n-1)
for idx in range(n):
diffusion.x(idx)
for idx in range(n):
diffusion.h(idx)
grover_circuit = oracle + diffusion
grover_circuit.measure_all()
return grover_circuit
backend = Aer.get_backend('qasm_simulator')
grover_circuit = grover_search(database, target)
grover_circuit_transpiled = transpile(grover_circuit, backend)
qobj = assemble(grover_circuit_transpiled, shots=1000)
result = backend.run(qobj).result()
counts = result.get_counts()
print("Grover's Algorithm Results:")
print(counts)
```

V. CALCULATION RESULTS

In the given dataset, there is an unsorted collection of 20 elements. When searching for a specific element, the number of steps taken in algorithms depends on the number of elements in the dataset. The number of steps in algorithms occurs in the following order:

Linear Search: In the worst-case scenario, linear search may require searching through all 20 elements one by one. Therefore, the number of steps can be up to 20.

Binary Search (if the data is sorted): Binary search, in the worst case, will require $\log_2(20)$ steps, which is approximately 4.32 steps. Since binary search is a divide-and-conquer algorithm, it divides the dataset in half with each step, making it very efficient. Unsorted Data (sorting required) + Binary Search: If the data needs to be sorted first and then a binary search is performed, the steps involve sorting the 20 elements first and then performing a binary search. Sorting the data will take O(20 log 20) steps, which is approximately 86.4 steps. After sorting, the binary search would take an additional $\log_2(20)$ steps, which is approximately 4.32 steps. So, in this case:

Linear Search: Up to 20 steps.

Binary Search (if the data is sorted): Approximately 4.32 steps. Unsorted Data + Binary Search: Approximately 86.4 (sorting) + 4.32 (binary search) = 90.72 steps. These steps give you an idea of the number of operations each algorithm would require in this specific scenario.

When using the Grover algorithm to search for a specific element in a dataset of 20 items, it would take approximately 3.54 steps. This algorithm leverages quantum parallelism to enhance the probability of finding the desired element and is significantly faster compared to classical algorithms.

The following table shows the variation of the number of steps in these 3 algorithms according to the number of data elements.

TABLE I. THE NUMBER OF WORST STEPS FOR SEARCH ALGORITHMS ON UNSORTED DATASETS

Number of elements	**Algorithm types and formulas**		
	Liner search	***Binary search***	***Grover's algorithm***
N	O(N)	O(N*Log(N)) + O(Log(N))	$\pi/4*\sqrt{N}$
20	20	90,72	3,54
30	30	152,12	5,09
40	40	218,21	5,75

Based on the values in this table, we can create the following graph.

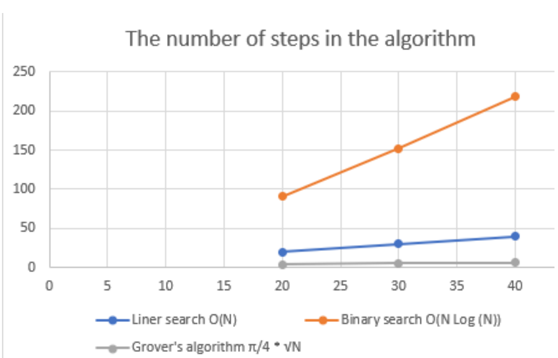

Fig. 1. A graph of the increase in the number of steps depending on the number of elements

VI. Comparative Analysis

Linear Search: Linear time complexity (O(N)). Suitable for small databases but inefficient for larger ones.

Binary Search: Logarithmic time complexity (O(log N)) after sorting. Efficient for larger databases.

Grover's Algorithm: Provides quadratic speedup on quantum computers. In a quantum emulator, the results might not be as efficient as on actual quantum hardware, but it's still significantly faster than classical algorithms for large databases.

In this specific case, since the database size is relatively small, the classical search algorithms are likely to perform better. However, Grover's algorithm demonstrates its true power on large databases where the quadratic speedup becomes more apparent. Keep in mind that Grover's algorithm implementation here is a simplified version for emulation and might not fully capture the quantum advantage.

VII. Conclusion

In the ongoing evolution of computing, the comparison between Grover's algorithm and classical search algorithms exemplifies the innovative shifts that quantum computing can bring to information retrieval. While classical algorithms have served as the backbone of search operations, Grover's algorithm offers a glimpse into the quantum advantage, demonstrating a quadratic speedup for unsorted search tasks. As quantum computing technology advances and matures, it holds the potential to reshape how we approach complex search problems and optimization tasks. The path forward involves not only refining quantum algorithms but also addressing the challenges of quantum hardware and ensuring the ethical and responsible integration of quantum technologies into our computational landscape.

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Analysis of Mobile Application Development Methods and Technologies for Literary Purpose

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***Abstract*— ICT heavily relies on software development, which is a crucial aspect of this field. With numerous software being developed daily, several companies have emerged to cater to this demand. Standardized methodologies are used for software development, including those for mobile applications. Choosing the appropriate methodology is vital since it can impact the quality and duration of the development process. The literary industry is also not far behind in adopting mobile applications for various purposes. In this paper, we will analyze the various mobile application development methods and technologies that are suitable for literary purposes. Also, in this paper discussed the database, its management system, and the mobile application that presents a card file based on folklorisms in the poetry of the famous Karakalpak poet Ibrahim Yusupov. The work initially analyzed the technologies used in the development of the database management system and mobile application. Also, discussed the possibilities and peculiarities of the developed database admin panel and mobile application.**

Keywords—mobile application, database, admin panel, software, application, cross-platform, data format

I. Introduction

In today's era of rapid development of information technologies, it is difficult for a 21st-century student to receive information in traditional forms. For these reasons, the use of modern information and communication technologies is required even in literary studies [1].

The literary industry has been undergoing a digital transformation in recent years, and mobile applications have played a significant role in this transformation. Mobile applications have made it easier for readers to access books, articles, and other literary works on their mobile devices. Mobile applications have also made it easier for authors to publish their works and reach a wider audience [2-4].

In this regard, we are trying to use modern information technologies in our research work, creating a database, a control panel and mobile application for the collection of folklorisms edited by I. Yusupov. In this article, it is appropriate to disclose the database, its control panel and mobile application, as well as the technologies used in its creation, which organize the collection of folklorisms edited by I. Yusupov.

II. Analysis of Mobile App Development Tools

Mobile applications have become an integral part of our daily lives. The use of mobile devices has increased rapidly in recent years, and so has the demand for mobile applications. Mobile app development tools play a vital role in the development of mobile applications. There are several mobile app development tools available in the market, each with its unique features and functionalities. In this article, we will analyze some of the popular mobile app development tools and compare them based on their features, performance, and usability. We have analyzed following mobile app development tools [5-8].

Android Studio is one of the most popular mobile app development tools used by developers worldwide. It is an integrated development environment (IDE) that provides developers with a comprehensive set of tools for developing Android applications. Android Studio offers features such as code editing, debugging, and testing. It also provides support for various programming languages such as Java, Kotlin, and C++. Android Studio is free to use and is compatible with Windows, Mac, and Linux operating systems.

Xcode is another popular mobile app development tool used by iOS developers. It is an IDE developed by Apple that provides developers with a set of tools for developing iOS applications. Xcode offers features such as code editing, debugging, and testing. It also provides support for various programming languages such as Swift and Objective-C. Xcode is free to use and is compatible with Mac operating systems.

React Native is an open-source mobile app development tool developed by Facebook. It allows developers to develop cross-platform applications for both Android and iOS platforms using a single codebase. React Native offers features such as live reloading, hot reloading, and modular architecture. It also provides support for various programming languages such as JavaScript and TypeScript. React Native is free to use and is compatible with Windows, Mac, and Linux operating systems.

Flutter is another open-source mobile app development tool developed by Google. It allows developers to develop cross-platform applications for both Android and iOS platforms using a single codebase. Flutter offers features such as hot reloading, widget library, and modular architecture. It also provides support for various programming languages such as Dart. Flutter is free to use and is compatible with Windows, Mac, and Linux operating systems.

To compare the mobile app development tools, we will analyze them based on their features, performance, and usability.

Features. Android Studio offers a comprehensive set of tools for developing Android applications. Xcode provides developers with a set of tools for developing iOS applications. React Native and Flutter allow developers to develop cross-platform applications for both Android and iOS platforms using a single codebase.

Performance. Android Studio and Xcode provide excellent performance when it comes to developing native applications. React Native and Flutter also provide good performance when it comes to developing cross-platform applications.

Usability. Android Studio and Xcode have a steep learning curve and require developers to have prior knowledge of programming languages such as Java, Kotlin, Swift, and Objective-C. React Native and Flutter are easier to learn and require developers to have knowledge of programming languages such as JavaScript and Dart.

In general, mobile app development tools play a vital role in the development of mobile applications. Android Studio, Xcode, React Native, and Flutter are some of the popular mobile app development tools used by developers worldwide. Each tool has its unique features and functionalities. Developers can choose the tool that best suits their needs based on their features, performance, and usability.

III. Cross-Platform Mobile Applications

Cross-platform mobile applications are an essential part of modern-day app development. They allow developers to create apps that can run on multiple platforms, reducing the time and cost required to develop native apps for each platform. Cross-platform mobile applications are classified based on several factors, including development approach, code sharing, user interface, and performance [9-13].

There are three main approaches to developing cross-platform mobile applications: hybrid apps, native apps with cross-platform frameworks, and Progressive Web Apps (PWA). Hybrid apps use web technologies such as HTML, CSS, and JavaScript to create a single codebase that can be deployed across multiple platforms. These apps are essentially web applications wrapped in a native container that provides access to device-specific features. Native apps with cross-platform frameworks use programming languages such as C# or JavaScript to create a single codebase that can be deployed across multiple platforms. These apps are designed to provide a native look and feel on each platform while still allowing for code reuse. Progressive Web Apps (PWA) are web applications that are designed to look and feel like native apps. They can be accessed through a web browser and do not require installation from an app store. PWAs offer the advantage of being easily discoverable through search engines and can be updated without requiring users to download new versions.

Cross-platform mobile applications can also be classified based on the percentage of code shared between platforms. There are two main types of code sharing: partial code sharing and full code sharing. Partial code sharing involves sharing only a portion of the codebase between platforms. This approach allows developers to take advantage of platform-specific features while still reducing development time and cost. Full code sharing involves sharing the entire codebase between platforms. This approach offers the most significant reduction in development time and cost but may limit access to platform-specific features.

Cross-platform mobile applications can also be classified based on the user interface. There are three main types of user interface: native look and feel, custom look and feel, and hybrid look and feel. Native look and feel apps are designed to look and feel like native apps on each platform. They offer the best user experience but may require more development time and cost. Custom look and feel apps are designed to have a unique look and feel that is consistent across all platforms. They offer a balance between user experience and development time and cost. Hybrid look and feel apps are designed to have a mix of native and custom elements. They offer a compromise between user experience and development time and cost.

Cross-platform mobile applications can also be classified based on performance. There are several factors that affect app performance, including performance benchmarks, user experience, and platform-specific features. Performance benchmarks measure the speed and efficiency of an app on each platform. They can help developers identify areas where improvements can be made to increase app performance. User experience is a critical factor in app performance. Apps that provide a seamless user experience across all platforms are more likely to be successful than apps that do not. Platform-specific features can also affect app performance. Apps that take advantage of platform-specific features are more likely to provide a better user experience than apps that do not.

Cross-platform mobile applications are an essential part of modern-day app development. They offer a cost-effective solution for businesses looking to reach a wider audience without the need to develop separate apps for each platform.

IV. Advantages of Cross-Platform Mobile Applications

Cross-platform mobile applications have become increasingly popular in recent years. These applications are developed using a single codebase and can be deployed on multiple platforms such as Android and iOS. In this article, we will analyze the advantages of cross-platform mobile applications and how they can benefit businesses and developers. Cross-platform mobile applications have the following advantages [14-15]:

- Cost-Effective. Developing cross-platform mobile applications is cost-effective compared to developing separate native applications for each platform. This is because developers can use a single codebase to develop applications for multiple platforms, reducing the development time and cost.
- Faster Development. Developing cross-platform mobile applications is faster compared to developing separate native applications for each platform. This is because developers can use a single codebase to develop applications for multiple platforms, reducing the development time.
- Consistency. Cross-platform mobile applications provide consistency across different platforms. This is because the same codebase is used to develop applications for different platforms, ensuring that the application looks and feels the same on all platforms.
- Wider Audience. Cross-platform mobile applications can reach a wider audience as they can be deployed on multiple platforms such as Android and iOS. This increases the potential user base for the application, resulting in increased revenue for businesses.
- Easier Maintenance. Maintaining cross-platform mobile applications is easier compared to maintaining separate native applications for each platform. This is because developers can use a single codebase to make changes to the application, reducing the maintenance time and cost.

- Improved User Experience. Cross-platform mobile applications provide an improved user experience as they are consistent across different platforms. This ensures that users have a seamless experience when using the application on different platforms.

Cross-platform mobile applications offer several advantages over separate native applications for each platform. They are cost-effective, faster to develop, provide consistency across different platforms, reach a wider audience, easier to maintain, and provide an improved user experience. Businesses and developers can benefit greatly from developing cross-platform mobile applications, resulting in increased revenue and a wider user base.

V. Mobile Application of Folklorisms in the Poetry of Ibragim Yusupov

Below, we will provide analytical information about the mobile application, which provides a card index of the poetry of Ibragim Yusupov.

Figure 1 shows the main window of the mobile application. As can be seen from the figure, the application is called “I.Yusupov poeziyasında folklorizmler” (“Folklorisms in the poetry of I. Yusupov”). The main window has four menus:

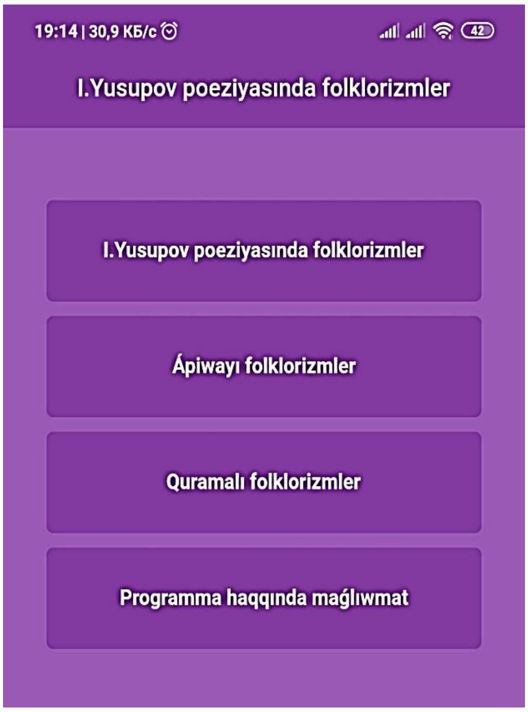

Fig. 1. The main window of the mobile application

- “I.Yusupov poeziyasında folklorizmler” (“Folklorisms in the poetry of I. Yusupov”) menu. This menu presents the classification of the typology of folklorisms in the work of I.Yusupov;
- “Ápiwayı folklorizmler” (“Simple folklorisms”) menu;
- “Quramalı folklorizmler” (“Complex folklorisms”) menu;
- “Programma haqqında maǵliwmat” (“App Info”) menu. This menu contains detailed information about the application.

Figure 2 shows the “Simple Folklorisms” window of the application, which includes the following four types of folklore:

Fig. 2. Section of the mobile application “Apiwayı folklorizmler” (“Simple folklorisms”).

- Proverbs (“Naqıl-maqallar”);
- Folklore turns (“Folklorlıq aylanıslar”);
- Folk phraseology (“Folklorlıq frazeologizmler”);
- Other types of simple folklorisms (“Ápiwayı folklorizmlerdiń basqa túrleri”).

Figure 3 shows the “Complex Folklorisms” window of the application, which includes the following three types of folklorisms:

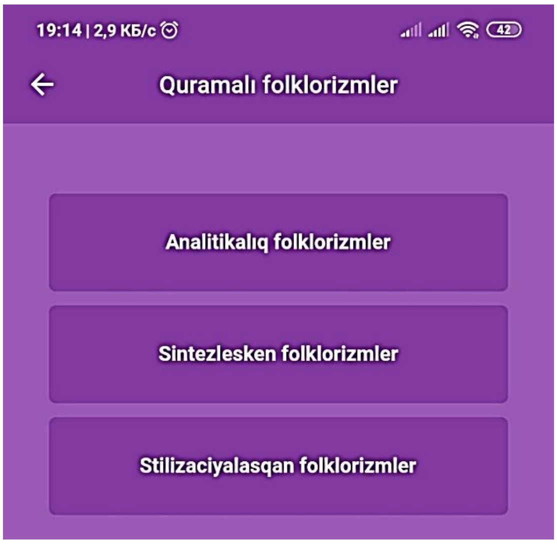

Fig. 3. Section of the mobile application “Quramalı folklorizmler” (“Complex folklorisms”)

- Analytical folklorisms (“Analitikalıq folklorizmler”);
- Synthesized folklorisms (“Sintezlesken folklorizmler”);

- Stylized folklorisms ("Stilizaciyalasqan folklorizmler").

Figure 4 shows an example of a poetic line containing folklorism in the application.

Fig. 4. Providing a line of poetry with folklorism in the mobile application

Options for future improvement of the application were also considered, including changing the format of data presentation.

VI. Database of Folklorisms in the Poetry of Ibragim Yusupov

Below we provide analytical information about the technologies used in the development of the database of florisms in I. Yusupov's work and its control panel [16-17].

Element UI. UI Kit - a set of ready-made user interface solutions. It can be buttons, input fields, sections, menus, keys, forms – all elements that help users interact with a site or application.

Usually a ready-made set is a graphic in layers for work in Photoshop or Sketch. The document stores interface design elements that can be used or edited to match the style of the project.

MongoDB. MongoDB is a document-oriented database management system that does not require the specification of a table schema. Considered one of the classic examples of NoSQL systems, it uses a JSON-like document and database schema. Written in C++. It is used in web development, specifically the JavaScript-oriented MEAN stack.

The system supports temporary queries: they can return custom document fields and custom JavaScript functions. Regular expression searches are supported. You can also configure the query to return a random set of results.

Mongoose. Mongoose is a JavaScript object-oriented programming library that creates a connection between MongoDB and Node.js environments.

Access to the database admin panel is protected by login and password protection. This includes granting access to the admin panel to users with various access rights (write (add), edit, delete, and their combination).

In our case, the record in the base is mainly poetic lines that reflect some type of folklorism in its composition. For adding a new record to the database, it is necessary to fill in three elements for add new record: 1) enter the title of the new record (in most cases, it can be entered according to the poems name, but it is optional); 2) choosing a category, that is, a type of folklorism. In this case, one of the types of folklorism listed in the classification in Figure 1 is selected; 3) entering a poetic text. Once the above three elements are filled in, it will be possible to save a new entry to the database.

Figure 5 shows the window for viewing, editing and deleting records entered in the database. Information corresponding to each entry in the database is displayed in five columns: 1) order number of the entry; 2) title; 3) the text of the poem; 4) category (type); 5) date of addition. There are also appropriate icons for viewing, editing, and deleting each record in its entirety. Also in this window there is an "Qo'shish" ("Add") button, which allows you to go to the window for adding a new record to the database.

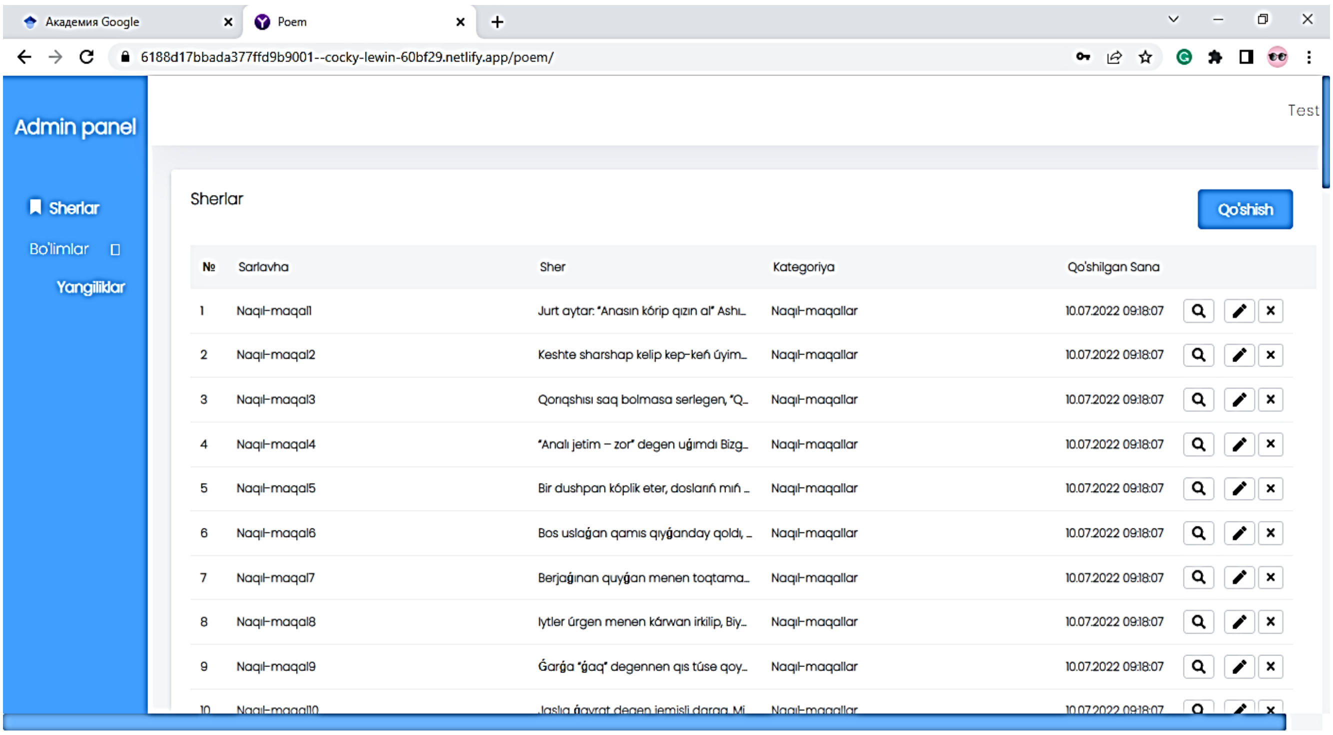

Fig. 5. Window for viewing, editing and deleting records in the database

In the development of this database admin panel, the possibility of expanding the functionality in the future was also taken into account.

VII. Conclusion

In conclusion, it can be said that the use of modern information and communication technologies in various fields, including the field of literary studies, can give good results. There are various mobile application development methods and technologies available for literary purposes. The choice of method and technology depends on the requirements of the application, such as performance, user experience, and development cost. This can be proven in the example of the mobile application discussed in this work. Because, poets and writers can save samples of creativity in an easy and convenient format, make further changes easily and ensure mobility in presentation to users.

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DEVELOPMENT OF AN ALGORITHM FOR CALCULATING THE COVERAGE AREA OF A DIGITAL TELEVISION TRANSMITTER TAKING INTO ACCOUNT THE TERRAIN AND CLIMATIC CONDITIONS

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***Abstract*— The main characteristic of network radio broadcasting is the service area of a single transmitter, which determines the required number of transmitters and antenna-mast structures necessary to cover a given territory. The service area of the transmitter is a part of the earth's surface bounded by a closed curve, at each point of which, with a probability not lower than a given field strength from the transmitter provides satisfactory reception in the presence of interference.**

The coverage area of digital broadcasting signals is characterized by a very rapid transition from the reception quality close to ideal to the absence of reception in everything, so it is very critical to determine exactly which territory should be covered by a digital radio broadcasting signal and which should not. The coverage area of the sensor and the quality of signal reception depends on the terrain, the power of the transmitter, the frequency of the signal, the orientation of the transmitting antennas in space and their elevation, the design and efficiency of the feeder system, the characteristics of the signal and the sensitivity of the receiver, as well as weather conditions.

***Keywords*— Digital broadcasting, radio, economic aspect, ICT, DAB+, DBR+, digital project, FM.**

INTRODUCTION

Frequency planning is a multidimensional process that includes minimum signal levels and protective relationships, as well as parameters such as distances between transmitters, heights of transmitting antennas and their type. When building any terrestrial broadcasting network, the main issues are the definition of the service area and coverage of the population by broadcasting. Appropriate assessments are made by determining the level of useful signals and the level of interfering signals.

Recall [1] that the service area of the transmitter is called the territory around the radio transmitting station, where the level of the useful signal exceeds the total level of the receiver's own noise, atmospheric and industrial noise, interference from neighboring stations by a certain value for a given time and the minimum required value of the field strength of the useful signal, determined by the relevant standard and recommendation ITU-R [2].

Planning criteria. To develop a T-DAB Plan in ranges III, IV and V, the following planning criteria were used (they should also be used to change the Plan):

- minimum median field strength;
- the intensity of the interference field.

They are based on the following parameters:

- values of the signal-to-noise ratio (C/N);
- protective relationships;
- losses due to the structure for internal reception;
- location correction factors and percentage of time;
- possible limitations of the spectral mask applied to digital transmission.

For T-DAB experiencing interference from DVB-T or it is necessary to use the protective relations contained in Annex 3.3 to the GE-06 Agreement. These protective relationships are based on ITU-R BS.1660-7 Recommendation [2]. It is necessary to use the protective relations contained in the Recommendation ITU-R BT.655-7 [3].

MATERIALS AND METHODS

A DAB block is a frequency channel 1.536 MHz wide. A 176 kHz guard band separates adjacent DAB blocks. DAB in VHF has been introduced in the pre-existing 7 MHz raster of analogue TV; therefore 4 DAB blocks fit into one TV channel with a guard band of 320 kHz or 336 kHz between TV channel limits. The blocks are designated according to their TV channel position in Band III (channels 5 to 12) and labelled A through D for each TV channel, e.g., 5A for the lowest DAB block in VHF Band III. Channel 13 (230 MHz - 240 MHz), which is not covered by GE06 and retains to WI95revCO07, contains 6 DAB blocks with a guard band of 176 kHz. There also remains a plan entry in Band I, labelled 4A.

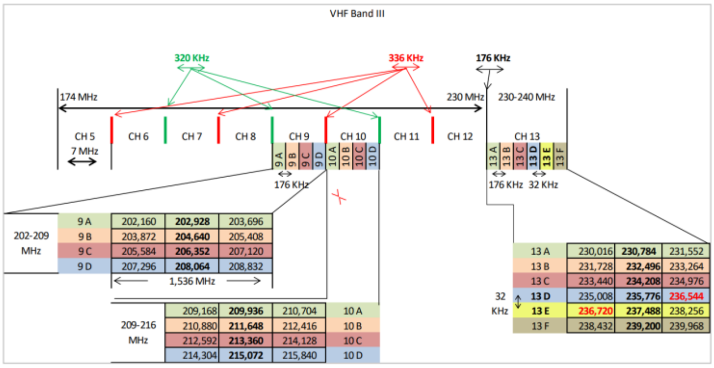

Figure 1: DAB blocks in Band III

In the allotment concept, geographical areas are identified where a frequency is used with certain restrictions regarding the outgoing interference produced by the network implemented in this area and for which a certain protection is to be respected. No detailed specification of the characteristics of the individual transmitters within the network is necessary. It is left to the particular network implementation to respect the overall restrictions regarding the outgoing interference. The allotment concept is a suitable frequency planning approach for transmission systems based on single frequency networks. It gives more freedom to the network planner and allows for a better adaptation of the technical aspect of frequency planning to the design of broadcast service areas which are determined by social, cultural and political aspects. In frequency planning the impact of the outgoing interference originating from a network is relevant. Since with the allotment concept the real network implementation is not yet known at the stage of the establishment of the frequency plan - and it is not even desirable to fix it once and forever - a representative network is defined to describe the expected and, under a regulatory aspect, allowed outgoing interference. The outgoing interference of a network is called its interference potential and the representative, artificial network is called reference network. Based on these assumptions and definitions a frequency plan can be synthesized where certain frequency re-use conditions need to be obeyed.

DAB transmitter requirements To avoid distortion the OFDM signal needs to be transmitted using a linear amplifier. The linear amplifier must also have a sufficiently high Modulation Error Ratio (MER). A poor MER will create degradation in C/N performance before the transmitter output, and may consequently also reduce coverage.

Given the MER of the power amplifier used, the loss in C/N performance can be calculated. The result is shown in Figure 2.

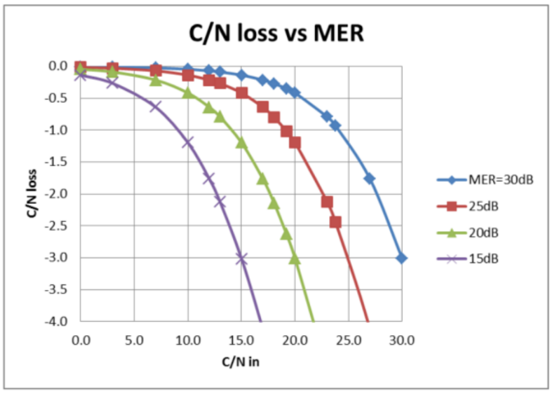

Figure 2: C/N loss as a function of different MER values

The T-DAB digital audio broadcasting system is designed to organize multiservice audio broadcasting for reception on mobile, portable and stationary receivers in rough terrain. It is designed to work in terrestrial, satellite and cable broadcasting networks (Table 1).

Table 1 - DAB+ operating modes

Mode	Mode I	Mode II	Mode III	Mode IV
Typical usage	Terrestrial broadcasting, VHF band	Terrestrial broadcasting, L Range	Satellite broadcasting, L Range	Terrestrial broadcasting in the city, L Range
Number of carriers, n	1536	384	192	768
Carrier separation, Df, kHz	1	4	8	2
Character duration, T_U, μs	1000	250	125	500
Duration of the protection interval, T_G, μs	246	62	31	123
Total duration of the symbol, T_S, μs	1246	312	156	623

The parameters of the DAB system for different levels of protection of audio signals are given in Table 2. The table shows the values of the signal-to-noise ratio at the radio frequency receiver input, provided that the error coefficient is provided at the output of the convolutional code decoder (Viterbi decoder). It should be noted that the total transmission rate of the DAB signal, taking into account the correction code for all levels of protection, is 2.4 Mbit/s. When planning a DAB network, the third level of protection is usually used.

Table 2- Protection levels in DAB

Protection level	Code speed	C/N (dB) at $\kappa_{ош}=10^{-4}$ for the channel			Transmission speed, Mbit/s
		Gaussian	Rise	Rayleigh	
1	0,34	5,9	7,1	12,1	0,78
2	0,43	6,7	8,0	12,6	0,99
3	0,5	7,4	8,8	13,3	1,15
4	0,6	8,4	10,0	14,9	1,38
5	0,75	10,2	12,0	18,6	1,73

When planning a digital broadcasting network, it is necessary to know the minimum signal power at the receiver input, at which the output of the Viterbi decoder provides an error rate of P = 10-4. The minimum signal power at the receiver input is determined by the receiver bandwidth and its noise figure:

$$P_n = F + 10logkT_0B \quad (1)$$

$$P_{Smin} = P_n + \frac{C}{N} \quad (2)$$

where: B - receiver noise bandwidth, Hz;
C/N - signal-to-noise ratio at the radio frequency, dB;
f - radio frequency, MHz;
F - receiver noise figure, dB;
P_n - noise power at the receiver input, dBW;
P_{Smin} - minimum signal strength at the receiver input, dBW;
$K = 1{,}38 \cdot 10^{-23}$ W/Hz · grad - Boltzmann constant;
$T_0 = 290°$ K - absolute temperature.

The development of software that allows you to determine the coverage areas of digital TV transmitters is an urgent direction in planning and optimizing TV broadcasting networks and assessing the mutual influence of electronic means. Taking into account the analysis of the above methods for calculating the field strength of a digital TV signal, metrological factors and terrain of the Republic of Uzbekistan, software has been developed to calculate the coverage area of a digital TV transmitter [4]. One of the modern programming languages, Python, was used to create the program. The program uses SRTM electronic maps and models to calculate the network service area.

At the first stage, the program reads the elevation files of the terrain and places them in memory. Then it calculates the losses for the entire area and writes the output to a file. Finally, the program plots the results by displaying a color map.

In the future, both the terms site and point, which is a pair of Cartesian coordinates (longitude and latitude), will be used to indicate the location. After receiving the altitude values in memory, the program receives the location of the transmitter, which can be located anywhere within the specified limits of the area.

Figure 3 shows an algorithm for calculating the coverage area of a television transmitter, taking into account the terrain and climatic conditions. Figure 4 shows a scheme for calculations taking into account the terrain. Figure 4 shows that as the distance between the antennas increases, the field strength decreases. Figure 5 clearly shows a window for entering climatic conditions.

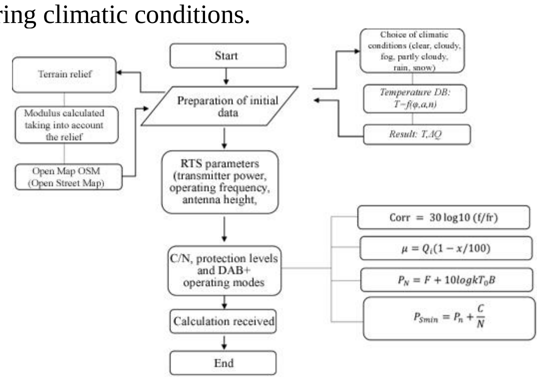

Figure 3. Algorithm for calculating the coverage area of digital audio broadcasting, taking into account the terrain and climatic conditions

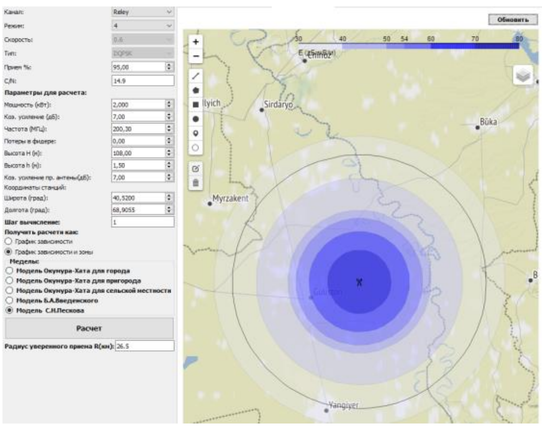

Figure 4. Terrain accounting scheme for calculating

Figure 5 shows the dependence of the parameters of the transmitter and antenna on the distance.

Taking into account the terrain, demographics and the needs of the population, the number of channels can be revised depending on the needs of the region. It is also possible to select additional channels if necessary.

As a result of work on this stage of the dissertation, virtual calculations were carried out on the basis of software in the Republic of Uzbekistan, mutual interference was calculated, important points on the interference situation were considered. A plan was also developed for the placement of digital audio transmitters of the DAB+ standard

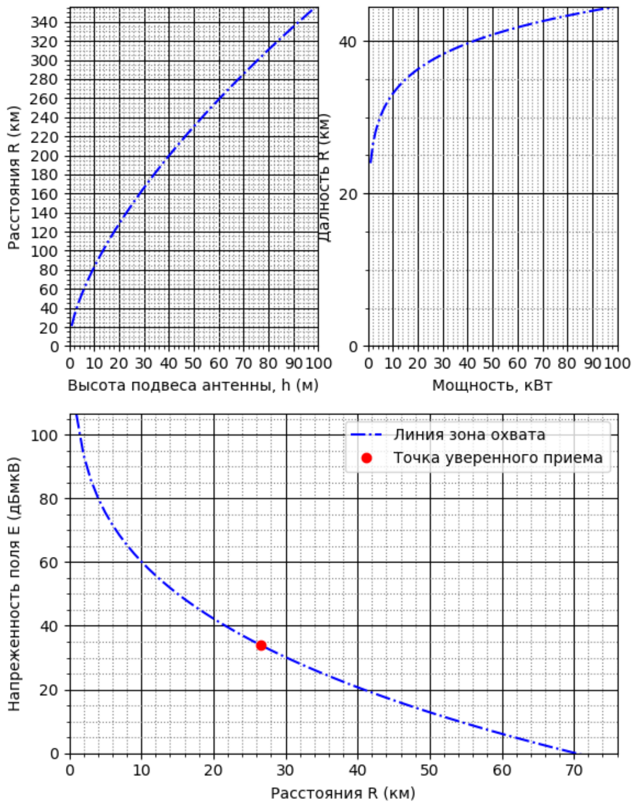

Figure 5. The window of the results obtained in the form of a dependence of the parameters of the radiobroadcasting transmitter

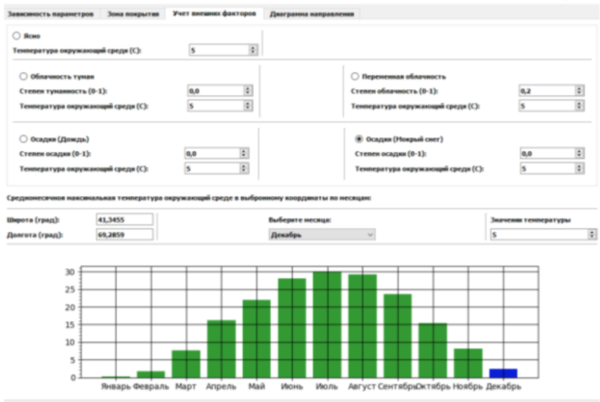

Figure 6. Window for entering climatic conditions

RESULTS AND DISCUSSION

Research on digital radio broadcasting in the republic, the development of a system for monitoring the parameters of the provision of the population with high-quality digital television and radio broadcasting of urban and rural residents is an extremely urgent problem. The developed algorithm for calculating the strength of the electromagnetic field taking into account the terrain, transmitter parameters, antenna height, climatic conditions (winter, spring, summer, autumn), temperature, wind conditions, precipitation (snow, rain, etc.) allows you to calculate and plot diagrams of coverage areas and areas of confident reception of digital audio broadcasting throughout the territory Of the Republic of Uzbekistan.

With the launch of the DAB+ digital broadcasting standard system in Uzbekistan, dozens of new types of DAB+ digital receivers will be delivered to the country, the cost of which, due to the economies of scale, will be quite affordable for the population. At the same time, it is also possible to consider the issue of launching local production of digital DAB + receivers for cars and in stationary versions.

The disadvantages of digital broadcasting include the high complexity of signal processing in the radio receiver, which is reflected in its cost. But in the modern era of widespread development of high-tech microelectronics, this circumstance turns out to be not very important: all conversions are implemented using specialized microcircuits, and as a result, the receiver becomes consisting of only a few inexpensive nodes.

Today, DAB+ digital broadcasting is carried out in China, Indonesia, the Republic of Korea, Germany, Australia, Switzerland, Denmark, Norway and a number of other European countries.

For Uzbekistan, the introduction of the DAB+ digital broadcasting standard is a very topical issue, since it not only makes it possible to significantly increase the number and quality of programs and additional services to the population, but also contributes to a more efficient use of the radio frequency spectrum, reducing the energy consumption of radio stations, as well as creating new jobs in as part of the localization program.

For the Republic of Uzbekistan, the introduction of the DAB+ digital broadcasting standard is very relevant, as it not only makes it possible to significantly increase the number and quality of programs and additional services to the population, but also contributes to a more efficient use of the radio frequency spectrum, reducing the energy consumption of radio stations, and creating new jobs within the framework of localization programs, i.e. mass production of digital receiving equipment. The future is digital broadcasting.

CONCLUSION

For the Republic of Uzbekistan, the introduction of the digital radio broadcasting standard DAB+ is very relevant, since it not only makes it possible to significantly increase the quantity and quality of programs and additional services to the population, but also contributes to more efficient use of the radio frequency spectrum, reducing the energy consumption of radio stations, and the possible creation of new jobs within the localization program, i.e. mass production digital receiving equipment.

As part of the general tasks for the speedy introduction of digital radio broadcasting in the Republic of Uzbekistan, it is necessary to take measures to address a number of major technical and organizational issues. Namely:

- to conduct research in order to create an optimal network of state and commercial radio broadcasting, both in the existing analog and in the digital formats being implemented. To identify the principle of interaction, simultaneous coexistence and complementarity of these formats in order to ensure the most effective implementation of radio broadcasting on the territory of the republic and broadcasting to foreign countries;
- to develop regulatory legal acts aimed at improving the legislation on licensing activities in the field of communications and legal regulation of new types of services provided by digital broadcasting systems, including the Concept of digital Broadcasting;
- develop regulatory and technical documents regulating the requirements for digital audio broadcasting systems;
- solve legal and legal issues;
- to amend legislative acts regulating the activities of electronic and online mass media;
- to solve the issues of frequency regulation in analog and digital formats, which provides for participation in the work of ITU on the development of international agreements regulating the allocation of radio frequency resources for the construction (creation) of audio broadcasting networks;
- performance of work on international coordination of radio frequency assignments of digital broadcasting;
- to conduct scientific research in the field of creation and optimal construction of radio transmitting, coding, modulating, matching, radio receiving, optical, satellite, communication, etc. equipment necessary to create an effective technological chain of digital broadcasting;
- to orient the radio industry towards the development of domestic receiving facilities for digital audio broadcasting systems for three types of reception (fixed, portable and mobile) in accordance with the decision taken;
- to find and provide sufficient and regular funding for the implementation of digital broadcasting in the Republic of Uzbekistan.

The implementation and solution of the issues and tasks set can take place in conditions of state interest and regulation in the form of a Targeted program with the involvement of interested commercial structures, which will subsequently be provided with certain services of broadcasting digital technologies.

Taking into account the results of this article, measures are proposed for the prospective use of the 174-230 MHz frequency band and the planning of digital audio broadcasting networks in the republic.

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Algorithms and methods of insect detection through the ways of deep learning

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***Abstract.* In Uzbekistan, locusts cause serious damage to crops every year. In this research, a new application is used to create an intellectual detection system for monitoring these pests. We used the drone, which can take photos to detect the pest and used a YOLOv5 neural network model built into a built-in system to recognize the locust in the field to determine the location of the pest in real time. Later the location of the pest is used to plan the optimal direction for the agricultural drone in order to spray pesticides. This research allows grasshopper control organizations to determine the direction of pest spread and take appropriate measures in real time. Agricultural drone sprays pesticides only when it is necessary, as a result this reduces pesticide use as well as environmental damage, and reduces extra expenses in pesticide purchases.**

Keywords— intellectual detection system, insect, YOLOv5, deep learning, real time.

I.INTRODUCTION

Due to the population growth, the demand for food and crops is also increasing. However, due to water shortages and climate change, the area of fertile land is shrinking. At the same time pests and diseases remain the main enemy of the crop and its quality[1,2]. Whether we talk about its commercial importance or about the need of mankind for it, agriculture remains as one of the main fields of Uzbekistan. Today, a large part of the economy of each country depends on its crops. However, agricultural crops are a favorite feed of the insects, so wherever it is planted, there is a high risk of insect damage. Diseases affect its quality, as well as its growth and production. Therefore, the development of plans for the effective fight against pests and diseases of agricultural crops is much more relevant for the present day[3,4].

Since spraying chemical drugs to combat grasshoppers is the main method, these traditional methods of detecting them are not so effective as it is demanded. Chemical drug spraying methods, due to the inability of identifying target locusts correctly, cause many problems such as the loss of large amounts of chemicals, adverse environmental effects, and the destruction or killing of other insects. The reason to the above mentioned circumstances is that the field study report on Locust detection is not as accurate and fast as necessary.

In recent years, the development of drones in intelligent agriculture has become more and more common and is ideal for the application of intellectual systems to agriculture. Drones capable of aeroimaging have been used to document the damage to farming lands. Industrial drones are equipped with a high-precision sensor that performs a variety of applications, and they are robust enough to work outdoors day and night. In this study, we used small-unmanned drones. It is used to capture the image of a grasshopper, which is then transmitted to the server to determine the stage and location of the pest's habitat. An extensive computing server is used to plan the optimal direction of pesticide application.

II. THE MAIN PART

A. APPLICATION OF DEPTH TRAINING IN AGRICULTURE

The increasing popularity of artificial intelligence applications in various fields has helped to apply in-depth learning in many areas. Among these applications, object recognition technologies through the image are widely used in agriculture. For example: agricultural land mapping, crop image segmentation, and target identification of grazing animals. Image recognition is mainly used in training neural network models when using convolutional neural networks (CNN) to identify categories and isolate target regions through images, segment objects, as well as determine the number and species of pests in leaves.

MODERN METHODS OF OBJECT DETECTION

We divide modern methods of object detection into two main groups: two-stage detectors and one-stage detectors.

Two-stage detectors

Two-stage detectors consist of a classification stage which follows a regional proposal stage. Some well-known two-stage detectors include:

R-CNN, Fast R-CNN, Faster R-CNN.

Single stage detectors

One-stage detectors predict object delimitation boxes and class probability directly from the image. Some popular single-stage detectors include:

YOLO, SSD, Retina Net.

COMPARATIVE ANALYSIS

In this section, we compare different ways of identifying an object in the COCO data set[5]. The results are summarized in Table 1.

Table 1. Comparison of object recognition methods in the COCO data set

Method	Average precision (AP)	Frames per second (fps)
R-CNN	53.3	0.5
Fast R-CNN	70.0	5
Faster R-CNN	73.2	7
YOLOv5	57.9	140
SSD	72.1	19
RetinaNet	74.8	12

The results of Table 1 show that two-stage detectors such as Faster R-CNN typically achieve higher average precision (AP) compared to single-stage detectors such as YOLOv5 and SSD. However, single-stage detectors are faster in number of frames per second (fps), making them more suitable for real-time applications.

III. METHODOLOGY

Grasshopper is the common name for the together-living species of the large family of locusts. The grasshopper is a pest of crops (wheat crops, alfalfa, Acorns, etc.). It is found in the countries such as Southern Europe, the Southern and the Eastern Asia, Africa, Southern and Northern America as well as Australia. Information about the plague that locusts bring to crops is found in ancient Egyptian written sources (4 thousand years ago).Among the species distributed in Uzbekistan, the most dangerous are Asian Locust, Oasis Locust, Moroccan Locust and desert locust. Grasshoppers are especially dangerous due to the fact that they fly over long distances and suddenly attack in order to destroy crops. The swarm of Grasshopper moves in a certain direction in search of food and ends up eating the Greens found in their path[6].

This study uses an agricultural drone to detect areas where locusts are spreading in real time before spraying pesticides. The pest images obtained by the detecting drone are sent to the system installed through the network. The system determines the Locust and location in real time.

To calculate the flight path of an agricultural drone, the height of each tree on the slope and the location of the pest are taken into account. The flight sequence and the total distance of the optimal path are then transmitted to an agricultural drone for spraying pesticides.

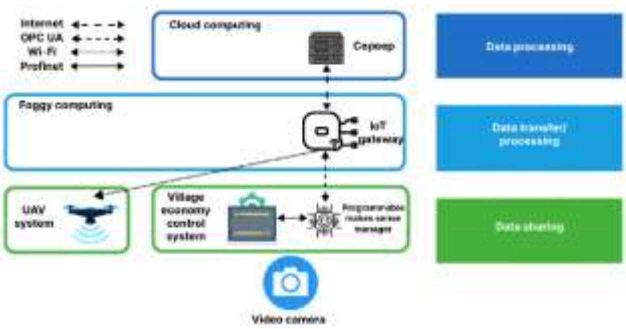


Image 1. The suggested platform unmanned aerial vehicle (UAV)- (Internet of Things)IoT

This research focuses on the agricultural drone which helps to applying pesticides only when it is necessary, and the application of new applications for remote intelligence in agricultural control. Timely use of pesticides allows you to effectively prevent the spread of pests, reduce the use of pesticides and reduce environmental damage. Figure 1 shows a scheme of the system architecture.

YOLOV5 MODEL AND MODIFIED-YOLOV5 MODEL

The purpose of this study is to provide immediate feedback as the drone performs pest detection. However, since grasshoppers are physically very small, drones must have the ability to detect small targets with high accuracy. To fulfill these requirements, a light and fast AI model is necessary. For this reason, we offer the YOLOv5 model and the modified YOLOv5 model as identification models for this study[7,8].

1) COLLECTING TEACHING SAMPLES

Deep learning models should have sufficient training patterns to avoid over-matching training data and negatively affecting the frequency of Locust recognition. We have collected about 2,500 images of locusts in different periods of time and in different angles of the grasshopper (for example, Side View, front view, etc.).k.) from the Internet in order to train samples for the YOLOv5 model and modified - YOLOv5. An additional 473 untrained images were used as test samples. Samples are manually labeled for the training of YOLOv5 and modified - YOLOv5 models, so as not to adversely affect the recognition of the grasshopper by these models. Before training the YOLOv5 and modified - YOLOv5 models, it is necessary to put a tick mark inside each image. To establish the different life stages and periods of the Grasshopper, we used the LabelImg tool to mark the exemplary images collected.

Image 2. Labelling application of the marked object through the image

LabelImg interface target pixel data (as shown in the image 3). The data is touched to the images it contains, and this is stored in XML format.

2) TEACHING THE MODEL YOLOV5

YOLO(you only look once) Series are neural network algorithms for detecting an object. They are implemented in the Darknet architecture. The basic idea of YOLO's algorithm is as follows. First, to extract properties from an input image to obtain a map of properties of known size, using a feature extraction network. For example, the YOLOv5 architecture according to figure 3 and 4 is listed[9].

As we compared above, YOLO has a high speed of object recognition in real time, which distinguishes it from other algorithms. In Yolo, all images are entered at the same time. However, they only pass through the network once. The YOLOv5 network architecture consists of three parts: Backbone, Neck, Head (Output). The Backbone stage releases informational features (see Image 3). The focus module decomposes the inserted image into parts. After that, four layers of feature maps of different sizes are created and combined for the original image to reduce data loss.

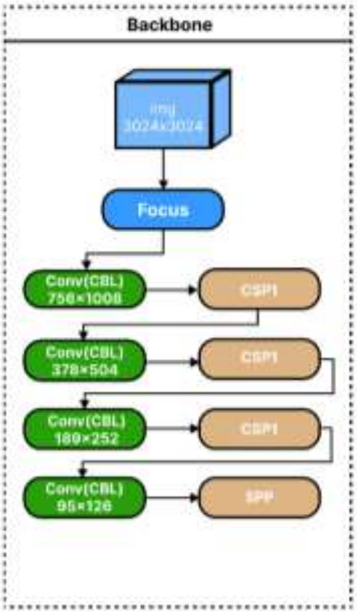


Image 3. Backbone stage

Results from the Focus module are consistently applied to the CBL module: Convolution + Batch Normalization + Leaky - ReLU. This module consists of a mixture of convolution operation, data normalization, and Leaky - ReLU activation function. Normalization is a method of pre-processing widely used for the purpose of standardization of data. This method opportunity of having different sources of data in the same range. Failure to normalize data before training can cause network problems that make training much more difficult and slow down the speed of learning. To normalize data, basically use a formula with data points worth from 0 to 1:

$$x\_normalizatsiya = \frac{x-m}{s}, \qquad (1)$$

Here, x is the normalizable data point, m is the average value of the data set, and s is the standard deviation of the data set. Thus each reference point receives a standard normal distribution. Whith the helpof this approach, we will get rid of the inaccuracy of features and it will be better to learn.

While using CSP, the output speed increases and the complexity of the calculations decreases. The principle of Cross Stage Partial Network (cspnet) is to separate and combine images without losing optimal speed and accuracy. The Cross Stage Partial Network (cspnet) was used to identify objects using the DarkNet framework (prints out detected objects, reliability, and the time it took to locate them). This network divides the main layer feature map into two parts: the first part passes through the dense layer and the transition layer; the second part is then combined with a feature map transmitted to the next step.

The architecture shows that the last layer was replaced by a layer of Spatial Pyramid Pooling (SPP). The use of SPP is due to the fact that in order to access the fully connected layer, the size of the input must be of a specified length. To get an output of the allowed size, you need to make the merge window and step proportional to the entered image. The SPP layer can apply multiple merge operas at outputs of different sizes and combine them. In this layer, for each N operationality is considered to be a number N with pxp lattice size.

Thus such operation is applied to each characteristic map with an M-value that is obtained as a result of the previous convolution operation. They are leveled and sent to the next layer. The SPP layer allows the CNN model to produce consistent results from the size of the input image. The Neck step (See Image 4) takes the results of the last three layers of the feature map. The SSP results of the Backbone stage are transferred to the Concat function, which is responsible for tensor Fusion opera. And the SSP block, which replaced the last SSP layer, is transferred to the inter-phase partial network of the second stage. The Neck stage also uses the Upsample module used for Image high sampling opera (NN from the PyTorch frame.Upsample method). In digital processing, the main function of sampling is to obtain the same size of input and output image data. This module has several functions that allow users to specify the output size. The mode parameter selects one of 5 types of high sampling algorithms: <<nearest", "linear", "bilinear", <<bicubic", and "three linear" (the standard algorithm would be "nearest"). When using linear, bilinear, or Trilinear algorithms, output tensors can be used to align the input angle to preserve the values of these pixels.

After Concat operation, the SSP network is re-applied to maintain accuracy and
reduce model size

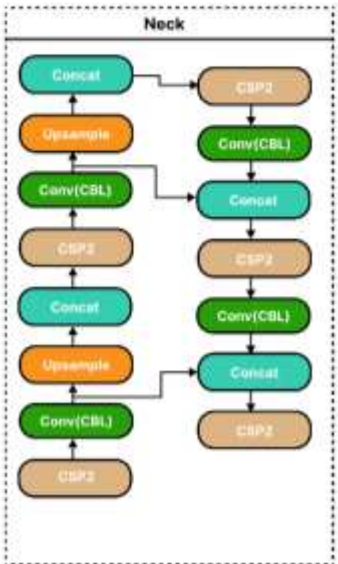


Image 4. Neck stage

Our study presents an improved YOLOv5 architecture shown in Image 5. Its difference lies in changing the architecture by adding an ECA-Net-based Etibar module to achieve better neural network performance. ECA-Net is a focus mechanism designed to balance complexity and performance parameters and was previously used in neural network architectures such as ResNet and ImageNet. In ECA-net, the data input is given as a four-dimensional tensor. Each tensor will consist of four parameters: party size, number of channels, and spatial resolution (height and width) of the image of each feature map. We define them as b,c,h,W. While leaving the network there is is a four-dimensional tensor (b,c,h,w). ECA-Net consists of 3 operations:

1. Global function descriptor;
2. Ability to adapt with neighbors;
3. Scaling the transfering.

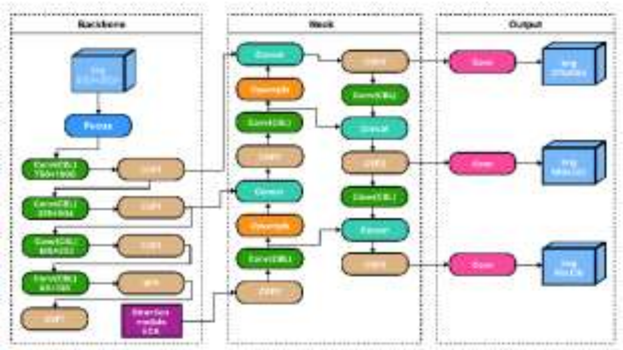


Image 5. Architecture of YOLOv5 with focus module

The focus module is applied to the Csp1 results of the Backbone stage before the Neck stage. An important factor in the study of the teaching module is the reduction of dimensionality. In the main stage, the csp1 results of the first stage are sequentially transferred to an additional focus module, so the performance and detection capabilities of the model are improved.

IV. THE RESULTS OF THE EXPERIMENT

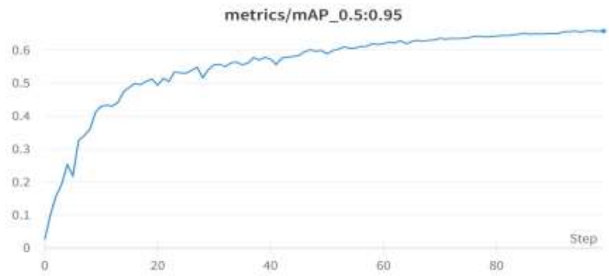
This section describes the experimental process and results. First, we made a comparison of their speed and accuracy when identifying a grasshopper on a computer on which various models of YOLOv5 and modified-YOLOv5 are installed.

Table 2. Comparison of YOLOv5 and modified – YOLOv5

Method	Average precision (AP)	Frames per second (fps)
YOLOv5	57.9	140
Modified – YOLOv5	58.4	140

According to the results of the system that detects pests in the image taken in the drone, the results of YOLOv5 and modified– YOLOv5 were positive.

Mean precision is often used to evaluate models of object-detection such as YOLO. Since our model has objects distributed over 3 classes, it is primarily the average precision (AP) for each class. Then the mean of AR for all classes is determined, which is called MAP. Image 6 shows the MAP score for both architectures in increments of 0.5.



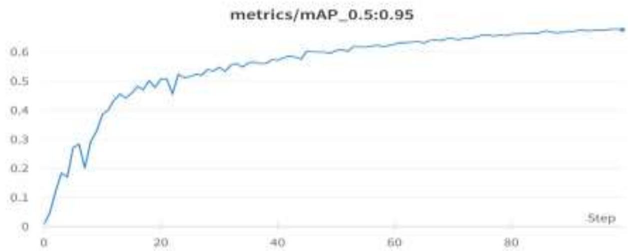


Image 6 - Results of detecting average precision are given in the Image 7

Image 7. YOLOv5 results of detecting locusts

V. CONCLUSION

The images were selected with different lighting, from different angles and different levels of background noise. The color display model has significant disadvantages, and often the lack of data delivery is a serious problem in the field of computer vision. For example: the effect of low light and shadows can reduce the effectiveness of Locust color recognition. It is very difficult to set the desired color tone, since the tone determines the degree of color difference. Due to these two disadvantages, it was decided to use the YOLOv5 neural network. The use of Yolov5 to identify tomatoes in our data exceeds the quality assessment indicators reported in previous studies. Performance analysis for small objects and images of different sizes, again, affirms that with the help of improved YOLOv5 network, Locust detection conditions have a high reliability of detecting objects of different sizes and images of different sizes that can meet needs. The B-complex evaluation results confirm that the developed YOLOv5 algorithm has high accuracy in object recognition.

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COMPARATIVE ANALYSIS OF LOCAL AND BASIC SPLINES IN DIGITAL SIGNAL PROCESSING

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***Abstract*— The article deals with the application of systems of basic splines for approximation functions and local splines for function interpolation. Algorithms for determining the parameters of splines are proposed. For real-time systems should use "point" formulas. Peculiarity of these formulas lies in the independence of the value of the approximating spline in a given section from the values. Estimates of the approximation errors by cubic basic splines and local interpolation splines are also given.**

***Keywords*— spline, basic spline, local interpolation spline, approximation, interpolation, b-coefficients, families of basic splines, "point" formulas, approximation error, algorithm.**

I. INTRODUCTION

Currently, the increasing requirements for accuracy and performance in solving modern problems of signal processing and recovery predetermine the transition to computational super technologies [1, 5].

Signals coming from sensors of various devices in the form of data on the state and measurement of temperature, radiation, electromagnetic, gravitational, thermal and other physical fields are often multidimensional and complex [2,3,4].

In recent years, much attention of specialists has been attracted by those methods of digital signal processing that make it possible to obtain simple algorithms that require a small amount of calculations at acceptable accuracy values.

Spline functions are an emerging area of function approximation theory and numerical analysis. Having gained popularity in the 60s, mainly as a means of interpolating complex curves, splines later became an important method for solving various problems in computational mathematics and applied geometry.

In technical applications, the most common are splines of low degree, in particular parabolic and cubic. The process of constructing such splines is much simpler than the process of constructing splines of a higher degree. The matrix of the system of equations that determines the parameters of the spline is tridiagonal with a dominant main diagonal, and efficient methods can be used to solve the system [6,7].

Any spline of sufficient smoothness can be represented in terms of basic splines. In particular, for d=1, the so-called "normalized" basic splines of degree m (B - splines) are used for decomposition. They are local (finite), piecewise polynomial functions [8, 9, 10]

II. Methods for modeling functional dependencies based on cubic basic splines

To ensure approximation over the entire interval [a, b], B-splines must be defined on a wider area by introducing 2m additional nodes i=-m, m+1, ... , n+m, moreover, all nodes can be located uneven.

Cubic B-splines are given expressions

$$B_3(x)=\begin{cases} 0, & x\ge 2, \\ (2-x)^3/6, & 1\le x\le 2, \\ (1/6)\cdot\left(1+3(1-x)+3(1-x)^2-3(1-x)^3\right), & 0\le x\le 1, \\ B_3(-x), & x<0. \end{cases} \quad \textbf{(1)}$$

On Fig. 1 shows one basic spline, and Fig. 2 families of cubic basic Splines shifted by a constant step h = 1

For splines of 3rd degree, local 3-the dot formula has the following form:

$$b_i = (1/6)(-f_{i-1} + 8f_i - f_{i+1}); \quad \textbf{(2)}$$

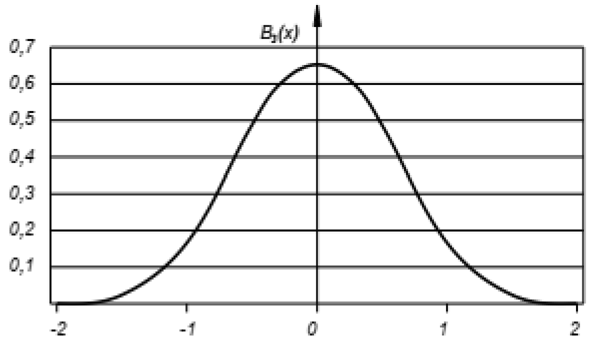


Fig 1. Cubic basic B-spline

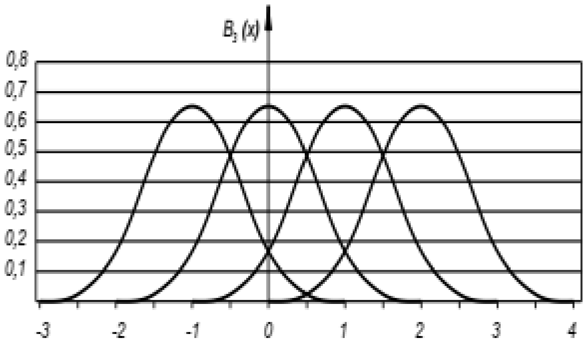


Fig. 2. Families of cubic basic splines

Any spline $S_m(x)$ of degree m of defect 1 interpolating a given function f(x) can be uniquely represented by B-splines as a sum [11,12]:

$$f(x) \cong S_m(x) = \sum_{i=-1}^{m} b_i B_i(x), \quad a \le x \le b \qquad \textbf{(3)}$$

where b_i is the coefficient, its definition is given in the formula. According to formula, the value of the interpolated function at an arbitrary point of a given interval is determined by the values of only m + 1 terms - pair products of basis functions by constant coefficients. For example, cubic B-splines require four base terms.

The value of the function is calculated by the formula:

$$f(x) \cong S_3(x) = b_{-1}B_{-1}(x) + b_0B_0(x) + b_1B_1(x) +$$
$$+b_2B_2(x) \quad at\ [0,1] \qquad \textbf{(4)}$$

The remaining basic splines on this subinterval are equal to zero and, therefore, do not participate in the formation of the sum.

It should be noted that there are different methods for calculating b coefficients: interpolation and "point" formulas smoothing splines, the least squares method. However, for real-time systems, "point" formulas should be used. The peculiarity of these methods lies in the independence of the value of the approximating spline in this section from the values

The methodological error of interpolation of the function f(x) by cubic basic splines is determined by the inequality:

$$\varepsilon \le \frac{5}{384} h^4 \max\left| f^{IV}(x) \right| \qquad \textbf{(5)}$$

For the function, *f(x)=ln(1+x)* we get:

$$\varepsilon \le \frac{5}{384 \cdot 1{,}0 \cdot 32^4} = 0{,}12 \cdot 10^{-7} \qquad \textbf{(6)}$$

III. METHODS FOR MODELING FUNCTIONAL DEPENDENCIES BASED ON LOCAL CUBIC SPLINES

Definition. The function is called a local interpolation spline function of the third degree if the following conditions are met [9,10]:

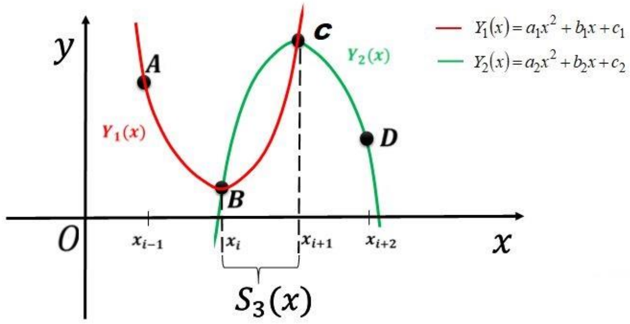
$$S_3(x) \in H_3(x),\ x \in [x_i, x_{i+1}], i = \overline{0, n-1}$$

$$S_3(f; x) \in C^2[a,b]$$

$$S(x_i) = f(x_i), i = \overline{0,n}$$

Construction of a local interpolation model of a cubic spline

$$A(x_{i-1}, y_{i-1});\ B(x_i, y_i); C(x_{i+1}, y_{i+1}); D(x_{i+2}, y_{i+2});$$



Using the interpolation condition to determine the coefficients of the above parabolas, the following two systems of equations are formed:

$$\begin{cases} ax_i^2 + bx_i + c = y_i \\ ax_{i+1}^2 + bx_{i+1} + c = y_{i+1} \\ ax_{i+2}^2 + bx_{i+2} + c = y_{i+2} \end{cases} \qquad \begin{cases} ax_{i-1}^2 + bx_{i-1} + c = y_{i-1} \\ ax_i^2 + bx_i + c = y_i \\ ax_{i+1}^2 + bx_{i+1} + c = y_{i+1} \end{cases}$$

we find a, b, c in the system and form the following parabolic functions.

$$Y_1(x) = a_1x^2 + b_1x + c_1 \qquad Y_2(x) = a_2x^2 + b_2x + c_2$$

$t = (x - x_i)/h$: as a result of the replacement, the parabola looks like this:

Based on a linear combination of the above parabolas Y and Y1 in each $x \in [x_i, x_{i+1}], i = \overline{0, n-2},\ t \in [0,1]$ interval

$$S3_i(t) = (1/4 + t)Y_i(t) + (3/4 - t)Y_{i+1}(t)$$

$$S_3(f; x) = \sum_{j=0}^{3} \varphi_{j+1}(t) f(x_{i+j-1}),$$

Where

$$\varphi_1(t) = -\frac{1}{8}t + \frac{5}{8}t^2 - \frac{1}{2}t^3, \quad \varphi_2(t) = 1 - \frac{9}{8}t - \frac{11}{8}t^2 + \frac{3}{2}t^3,$$

$$\varphi_3(t) = \frac{13}{8}t + \frac{7}{8}t^2 - \frac{3}{2}t^3, \quad \varphi_4(t) = -\frac{3}{8}t - \frac{1}{8}t^2 + \frac{1}{2}t^3.$$

$$t = (x - x_i)/h \qquad h = \frac{b-a}{n},\ n = 1,2,\ldots$$

As a result of solving the systems of equations, we obtain the coefficients of the local cubic spline.

Results of simulation of a one-dimensional biomedical signal by cubic splines.

TABLE I. RESULTS OF SIMULATION OF A ONE-DIMENSIONAL BIOMEDICAL SIGNAL BY CUBIC SPLINES.

№	Time, seconds	Amplitude	№	Time, seconds	Amplitude
1	1	0.0334	**11**	11	0.0471
2	2	0.0381	**12**	12	0.0440
3	3	0.0428	**13**	13	0.0444
4	4	0.0341	**14**	14	0.0462
5	5	0.0432	**15**	15	0.0464
6	6	0.0468	**16**	16	0.0416
7	7	0.0456	**17**	17	0.0471
8	8	0.0443	**18**	18	0.0471
9	9	0.0525	**19**	19	0.0422
10	10	0.0484	**20**	20	0.0452

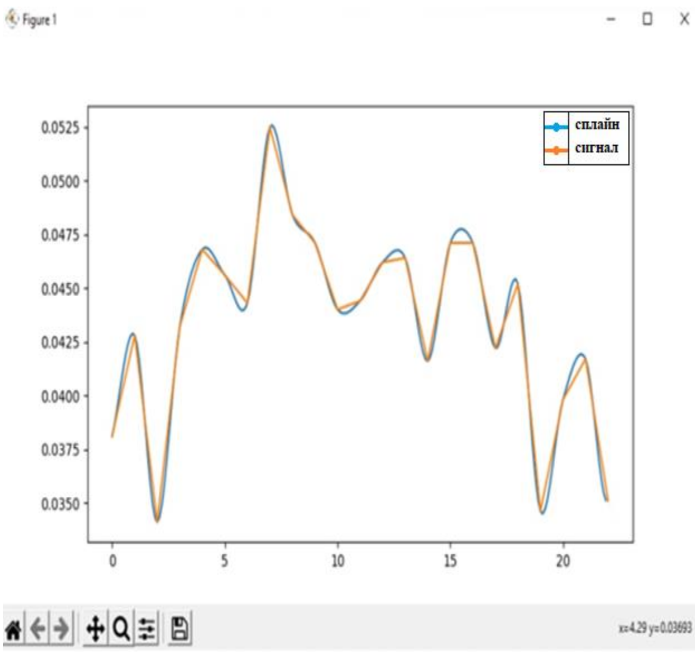


Fig 1. graph of modeling a one-dimensional biomedical signal by cubic splines.

IV. METHODS FOR CALCULATING THE COEFFICIENTS FOR MODELING FUNCTIONAL DEPENDENCIES BY BASIC SPLINES

The task of constructing a spline based on experimental data (both tabular and analytical data) is to find the coefficients bi and, in the general case, to determine the spline mesh Δ.

There are various ways to determine the coefficients: interpolation and local formulas, smoothing splines, local compression, the least squares interpolation method [13,14].

When constructing an interpolation spline, the grid is obtained from the grid Δ with the addition of several additional $x_{-1}, x_{-2}, x_{i+1}, x_{i+2}$. nodes. To determine the coefficients bi, we obtain a system of linear equation.

$$
\begin{aligned}
&b_{-1}\, B'_{-1}(x_0)+b_0 B'_{-0}(x_0)+b_1 B'_1(x_0)=f'(x_0)\cdot h\\
&b_{i-1}\, B_{i-1}(x_i)+b_i B_i(x_i)+b_{i+1}B_{i+1}(x_i)=f(x_i)\\
&b_{N-1}\, B'_{N-1}(x_i)+b_N B'_N(x_i)+b_{N+1}B'_{N+1}(x_i)=f'(x_i)\cdot h
\end{aligned}
\qquad (7)
$$

where $h=x_{i+1}-x_i$ - interpolation step;

$f'(x_0)$ and $f'(x_N)$ the derivative of the function at the ends of the grid.

The matrix of this system is tridiagonal, and the first and last equations are reduced to it. To solve it, there is an efficient sweep method [15,16]. The considered scheme gives the accuracy [17]:

$$\varepsilon=\frac{\sqrt{3}}{216}\max\left|f'''\right| h^3 \qquad (8)$$

Computational problems are greatly simplified when referring to a local spline approximation, in which the values of the approximating spline function on each segment depend only on the values of the approximated function from some neighborhood of this segment. Another feature of such methods is that they do not require the solution of systems of algebraic equations when finding the spline parameters. The required amount of computational work does not depend on the number of grid nodes Δ, but is determined only by the degree of the spline. Therefore, it is much smaller than when constructing interpolation splines, and the resulting approximating formulas are slightly inferior in accuracy.

In works [18] it is shown that the coefficients can be obtained by calculation using formulas of the form $b_i=b(f(x))$. It is advisable to bring these formulas in finished form in order to estimate the amount of computational operations and the possibilities for organizing the processes of parallelization and pipelining. The following formulas will be called K point formulas. For splines of the second degree:

1) three-point

$$b_i=\frac{1}{8}\left(-f_{i-1}+10f_i-f_{i+1}\right) \qquad (9)$$

2) five-point formula:

$$b_i=\frac{1}{64}\left(f_{i-2}-12f_{i-1}+86f_i-12f_{i+1}+f_{i+2}\right) \qquad (10)$$

Table II also shows the results of approximation of real experimental data of geophysical observations by the method of local approximation using “point” formulas.

Local formulas preserve the smoothness properties of the approximation, and the values of the parameters do not depend on the reports at points sufficiently remote from the current point with index i. They are symmetric, but only work for interior points of the area [a, b].

With this approach, there are difficulties with determining the coefficients in the extreme sections. To determine them, the following methods are proposed in [19]:

1. Calculation of the coefficients in the extreme sections using explicit formulas, but this leads to a decrease in the approximation accuracy in the extreme sections.
2. 2. Using a number of experimental data points outside the signal definition (if possible).

If the experimental data are known with errors, then it makes no sense to build an interpolation spline. In such cases, it becomes necessary to use smoothing splines in order to reduce errors.

A smoothing spline is a spline passing near the experimental values, but more "smooth" than the interpolation one [20].

We will minimize the functional [75]:

$$J(f)=\int_a^b \left|S''(x)\right|^2 dx+\sum_{i=0}^{N} 1/R_i\left(f-S_i\right)^2 \quad \textbf{(11)}$$

where $R_i>0$ are given values. The smaller the coefficients R_i, the closer the spline function passes to the given values f_i.

Based on the constructed spline, the weight factors are recalculated and a new spline is built using the new Ri. The iterative process should continue until the spline values are in the given "corridor".

The disadvantage of this method is the lack of compression of experimental data.

For the simultaneous solution of the problems of compression and restoration of signals, the method of least squares gives good results.

In the case of using the least squares method for approximation, the nodes of the function are located much more often than the nodes of the spline.

In this case, it is necessary to minimize the functional

$$I(f)=\sum_{i=1}^{N}\left(f_i-S_i\right)^2 \quad \textbf{(12)}$$

where S_i is a spline function
f_i is a given functional dependence.

To minimize the functional, it is necessary to solve the system of linear equations [30]:

$$\sum_{i=1}^{N} < B_i, B_j > b_i = < B_i, f > j=1,2,...,N \quad \textbf{(13)}$$

The system of equations has a band matrix due to the finiteness of B-splines. In the case of B-splines of the third degree, the matrix of the system is five-diagonal.

Table 1.3 shows the results of smoothing real experimental data of geophysical observations using the least squares method for N-16

TABLE II. RESULTS OF APPROXIMATION OF REAL EXPERIMENTAL DATA OF GEOPHYSICAL OBSERVATIONS BY THE METHOD OF LOCAL APPROXIMATION USING "POINT" FORMULAS.

F(x)	*S(x)*		Δ 1%	Δ 2%
	3-point.	5-point.		
0,88	0,995	0,824	7,091	3,601
0,99	1,000	0,940	0,709	3,540
1,02	1,021	0,980	0,071	2,831
0,92	0,968	0,960	3,468	2,830
0,61	0,690	0,692	5,670	5,801
0,05	0,111	0,114	4,251	4,530
-0,65	-0,605	0,651	0,049	0,002
-1,21	-1,230	-1,241	1,410	2,121
-1,31	-1,240	-1,243	4,252	4,531
-0,81	-0,681	-0,789	8,510	0,780
0,04	0,037	0,038	0,210	0,150
0,83	0,858	0,861	1,981	2,121
1,3	1,152	1,156	8,101	8,301
1,41	1,407	1,411	0,212	0,071
1,28	1,325	1,391	2,832	7,810
0,81	0,816	0,850	0,425	2,821

TABLE III. THE RESULTS OF SMOOTHING REAL EXPERIMENTAL DATA OF GEOPHYSICAL OBSERVATIONS BY THE LEAST SQUARES METHOD.

x	*f(x)*	*S(x)*	Δ
1	0,88	0,879	0,071
2	0,99	0,991	0,000
3	1,02	1,018	0,141
4	0,92	0,915	0,351
5	0,61	0,629	1,340
6	0,05	0,048	0,141
7	-0,65	-0,702	3,682
8	-1,21	-1,165	3,191
9	-1,31	-1,282	1,411
10	-0,81	-0,853	3,540
11	0,04	0,062	1,421
12	0,83	0,834	0,282
13	1,3	1,281	1,401
14	1,41	1,425	1,061

CONCLUSION

Thus, splines as a class of piecewise functions, due to the universality of sampling algorithms, good differential and extremal properties, high convergence of approximation estimates, ease of calculating shapes and parameters, and weak influence of rounding errors, are increasingly used in the creation of hardware and software tools for analyzing and restoring one-dimensional and multidimensional signals, expanding the scope of traditional approaches. The main results obtained in the framework of our article are as follows:

An analysis of methods for calculating the coefficients of approximation by cubic splines showed that the problem of constructing spline functions from experimental data is reduced to the problem of calculating b-coefficients. A method for calculating the coefficients by "point" formulas is proposed. The use of basic cubic splines makes it possible to avoid solving systems of equations, the algorithms derived from them are simple and allow the use of point formulas, but they are not much inferior in accuracy to local interpolation cubic splines

From the results obtained, known main functions provide effective results in the field of geophysics. you can see this in the example in tables 2 and 3

To simulate signals, you can use local interpolation cubic splines obtained by constructing two parabolas. They provide high accuracy, but require the solution of systems of equations, the algorithms derived from them are complex and require large amounts of calculations.

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Enhancing the Methodical System for Working with Gifted Students

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Abstract— The use of virtual educational environments in education has become increasingly prevalent in recent years. This paper presents a review of the literature on the implementation and effectiveness of virtual educational environments in education, with a focus on the Uzbekistan context. The review synthesizes the findings of a range of studies on virtual educational environments, including their benefits, challenges, and impacts on student learning outcomes. The paper concludes with a discussion of the implications of these findings for educators, policymakers, and researchers interested in the use of virtual educational environments in education.

This article describes a new online virtual classroom-like environment for higher education. Students can enter this virtual world as their avatars and watch lectures and labs together. An initial evaluation with 20 users showed that overall the online virtual learning environment was enjoyable and usable.

Keywords: special education, higher education, post-OT education, distance learning, collaboration, communication, motivation, academic performance, technological development, education and learning, 3D environment, serious games, virtual training, vAcademia, Virtual Worlds, v-Learning, virtual environments.

I. Introduction

Virtual educational environments have emerged as a powerful tool for enhancing student learning outcomes in Uzbekistan. These environments offer students access to a range of educational resources and learning opportunities, as well as the ability to engage with peers and instructors in new and innovative ways. However, the implementation of virtual educational environments in education presents a range of challenges, including issues related to infrastructure, teacher training, and student engagement. This paper presents a review of the literature on the implementation and effectiveness of virtual educational environments in education, with a focus on the Uzbekistan context.

The increasing popularity and use of virtual worlds in recent years have opened up new opportunities for teaching and learning in higher education. The use of games, such as game-based learning and serious games, has become an area of interest for educators who seek to engage students in innovative ways that promote active learning and critical thinking. The serious gaming industry has grown rapidly, with online gaming being one of the most successful markets globally [1]. As a result, serious gaming has become an attractive option for educators seeking to incorporate game-based learning into their teaching.

The control element of virtual worlds and games makes them attractive to users, as they can create and manipulate their own experiences within the virtual world [2]. This level of control also has significant potential for student engagement in learning activities, as students can actively participate and take ownership of their learning experiences. Additionally, virtual worlds and games offer a unique opportunity to create immersive learning environments that can promote learning through exploration and discovery.

However, the use of virtual worlds and serious games in higher education also presents challenges. One significant challenge is the need for educators to understand the pedagogical principles that underpin effective game-based learning. They must also be able to design and develop games that align with learning outcomes and assessments while being engaging and enjoyable for students. In addition, educators must consider the cost and resource implications of incorporating games into their teaching, such as the need for technical infrastructure and support.

There are various research approaches, publications, and best practices that focus on the components of education, their interactions, and their impact on the development of the entire process. For thousands of years, learning and teaching have always been closely related, and this has become a classic model of education. A virtual environment platform or distance learning has emerged as a source of information and a process that provides access to learning when students are separated by time and distance. Starting with the need to provide education in remote places, development and various scientific research works were carried out in this field. There are various chronologies that list specific activities and events that influenced the development of this discipline. Isaac Pitman, recognized as the first modern distance teacher (Leedham & Downton, 1987; Nagabhushan & Murali, 2003), adapted the basic principles of his shorthand system to postcards [24]-[25]. He sent the postcards to students, who were instructed to transcribe passages of scriptures into shorthand and send them back to them to correct the transcription. It was simply an attempt to guide, instruct and educate students across a large geographical distance.

The virtual environment platform is often associated with technology and its development, practical implementation and new solutions. New communication tools, video conferencing, teleconferencing solutions, web-enhanced instruction and web-based resources have brought a new dimension to education by providing an enhanced virtual environment platform.

However, the process of a virtual environment does not always have to be defined by the latest and greatest technological solutions. The general idea that this type of education is adding technology to traditional education is wrong and completely beyond understanding. In essence, the virtual environment platform includes open opportunities and a different organization of resources that changes the balance between institutions and individuals to create a global approach to learning and teaching and a more efficient process.

With such an approach, this form of education means that funds directed to education and training by institutions will be more effective and economically useful.

Therefore, this study focuses on one aspect of distance education in evaluating various factors to enhance the learning experience of students. The ability of these systems to store, index, and deliver information through computer-assisted instruction, exercises, simulations, and collaboration has transformed the way students interact with content and learning materials. Identifying the relevant variables of such a learning process can provide tools to increase the likelihood of a positive student experience. By evaluating these systems, we explored the relationship between several variables that may influence the level and perceived quality of students' educational experiences. This paper presents a systematic model that captures several aspects of how students interact with content and how different variables relate to each other when using these learning systems.

Currently, the virtual environment platform must develop algorithms to render 3D objects without loss of quality and to simplify the number of polygons. This article considers a scenario in which the educational process is considered as a complex (psychological, physiological and pedagogical) object aimed at creating virtual computer models. We all know that the whole world has been fighting the coronavirus for almost a year and a half. The coronavirus or COVID-19 pandemic has been described as the most obvious global health crisis of our time. Naturally, the current pandemic situation in the world also affected the quality of education. The establishment of virtual universities abroad is recognized as a modern innovative pedagogical technology. The number of supporters of virtual education is increasing. The number of virtual participants in higher education in countries such as the USA, Great Britain, Germany, Korea, and Japan, where the system has been implemented, is several million people per year.

Distance learning is convenient and affordable compared to traditional education in educational institutions, and most importantly, it allows users to learn at their own convenience through virtual simulation and virtual simulator training. Developed countries have created their own 3D constructive national virtual university platforms. For example, the Russian National Virtual University platform, the American National Virtual University platform, the British National Virtual University platform, the German National Virtual University platform and the Finnish National Virtual University platform. Currently, projects on geometric modeling of the generalized national system of the virtual university on information technologies based on 3D technologies have not been implemented in the republic.

Currently, virtual reality technology has become a new educational tool for the development of education. Traditional education only provides students with knowledge, now virtual reality technology can be used to help students create a vivid and lively learning environment so that students can experience it in real life. Compared with passive infusion, compared with passive infusion, the sense of memory enhancement, using virtual reality technology, the implementation of autonomous learning can allow the student to accept, it is easier to stimulate students' interest in learning. a virtual world about topics that help students learn better using virtual reality technologies.

In particular, significant work is being done on the use of virtual education in the higher education system of Uzbekistan. As an example, we can take the innovative project work No. IL-4721071198 entitled "Creating a national virtual university of information technologies based on 3D technologies". This project is intended for 2022-2023, and it is planned to carry out large-scale works within the framework of the project [5].

II. METHOD

Virtual Academy offers a qualitatively new approach to learning in virtual worlds. The use of Web 2.0 technologies and the possibilities of the virtual world allows creating interactive educational content available to all Internet users.

Virtual worlds provide excellent opportunities for effective distance and online learning by supporting groups or communities that bring together subject matter experts, teachers, and students from different countries or locations. Thus, the development of new collaborative e-learning approaches is facilitated.

Virtual Academy is a three-dimensional multi-user educational platform that allows you to conduct training courses, meetings, presentations, trainings for groups of one to several dozen users at the same time and provides services in which you can participate.

The use of the vAcademia program is effective in organizing virtual education. After enrolling in this program, it will be possible to participate in the classes of scientists from all over the world by organizing an optional course on any subject.

One of the main partners of the work carried out within the framework of the project, quality work is being organized together with the head of the Multimedia System Laboratory, Associate Professor Mikhail N. Morozov. The many tutorials they have created using vAcademia are a good resource for students and freelancers alike. We also organize virtual classes in Uzbek using the vAcademia program as part of the project.

First of all, we register in the vAcademia program and organize the course. This process continues with entering information about the course.

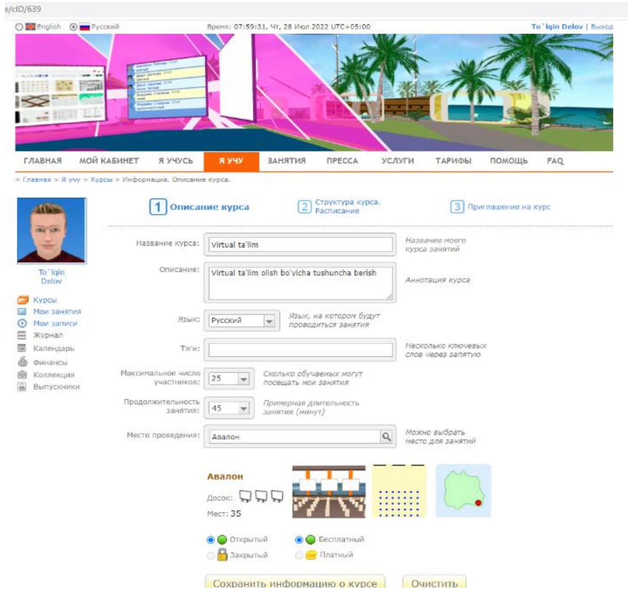

Figure 1. Enter information about our course.

We will make a lesson schedule:

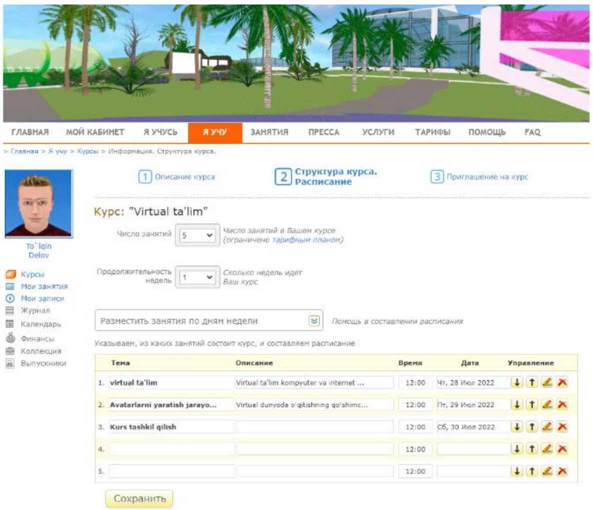

Figure 2. Creating a lesson schedule.

We invite students to attend our classes via email:

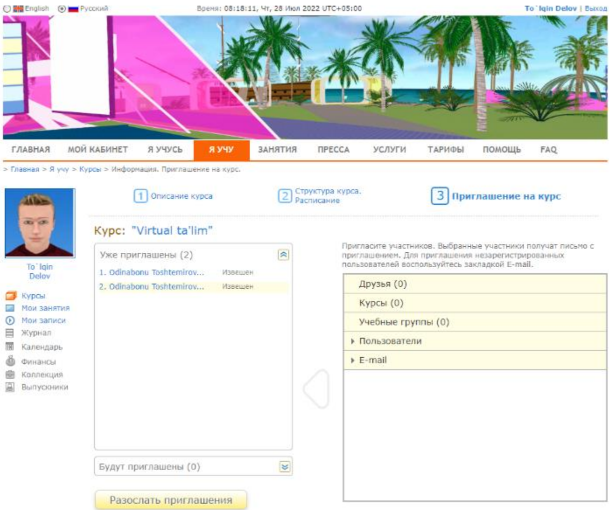

Figure 3. Invite participants to the lesson

virtual ACADEMIA

Уважаемый(ая) To`lqin Delov!

Приглашаю Вас посетить мой курс "Virtual ta'lim", который состоится в виртуальном мире vAcademia.

Описание курса:
Virtual ta'lim olish bo'yicha tushuncha berish

Длительность курса: 1 неделя - с 28.07.2022 по 04.08.2022

Количество занятий: 7

Ближайшие занятия:

1. virtual ta'lim
   28 июля 2022, 10:00 МСК
   Зайти на занятие можно по ссылке (http://vacademia.com/site/gotoLesson/id/40037)
2. Avatarlarni yaratish jarayoni
   29 июля 2022, 10:00 МСК
   Зайти на занятие можно по ссылке (http://vacademia.com/site/gotoLesson/id/40038)
3. Kurs tashkil qilish
   30 июля 2022, 10:00 МСК
   Зайти на занятие можно по ссылке (http://vacademia.com/site/gotoLesson/id/40039)

Место проведения: Локация «Авалон»

Если вы согласны принять приглашение и записаться на курс, проследуйте по ссылке:
http://vacademia.com/join/course/639
или скопируйте её в адресную строку браузера.

Доступ в занятие открывается за 30 минут до его начала.

Полезные советы:

- Если на вашем компьютере уже установлена программа vAcademia, то она запустится автоматически.
- Если программа vAcademia уже запущена, то Вы окажетесь на занятии, которое уже началось или скоро начнется, уже через несколько секунд.
- Если vAcademia не установлена на вашем компьютере, Вам следует предварительно проследовать по ссылке: http://vacademia.com/site/downloadclient, загрузить и установить на свой компьютер клиент vAcademia.

С уважением,
To`lqin Delov
http://vacademia.com/userprofile/show/id/16361

Figure 4. electronic invitation.

The main goal of this project was to improve the quality of teaching by creating an innovative AVATAR learning environment. The development of educational environment, methodology and resources within the framework of the AVATAR project made it possible to expand education in the traditional classroom. As a result, tools and functionality were provided that allow for the use of various educational strategies and methods for conducting virtual training in various disciplines, encouraging the active participation of students and their involvement in the educational process. The AVATAR learning environment is a hybrid environment that includes an e-learning platform and a virtual learning environment [2].

Figure 5. Choosing an avatar in vAcademia.

The user representation in vAcademia is a three-dimensional character - an avatar, which has a unique customizable appearance.

Avatar selection is done during registration on the site. In the future, we can change the appearance using the avatar editor.

Figure 6. Workflow with 3D objects in vAcademia.

Tools for working with 3D objects are grouped into the following tabs:

Objects - for placing objects

Landscape - saving and restoring the placement of objects in a location.

Bots - for hosting computer characters-bots.

Scripts - for programming the behavior of three-dimensional objects in the vJS language.

When organizing a lesson, it is necessary to equip the auditorium.

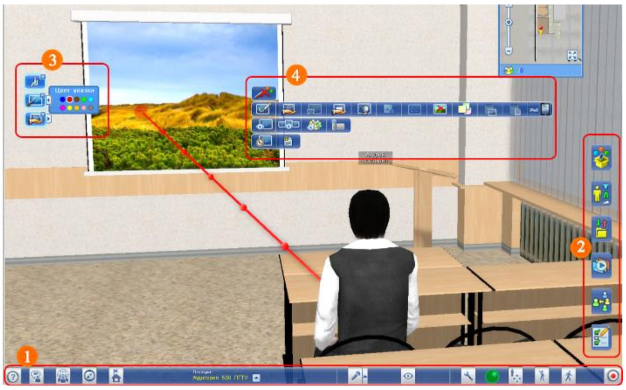

Figure 7. Let's take a look at working with our interactive whiteboard.

In this case, the process of working with an interactive board consists of the following:

1. The main menu contains buttons for changing application settings, controlling the movement and communication of avatars.
2. Toolbar - consists of buttons for placing objects, setting the appearance of the avatar, working with a set of resources, conducting lessons and viewing records, inviting other users and creating tests.
3. The notification panel is formed when working with the application through the context menu, and the context menu can contain different sets of buttons depending on the object to be called. Used to exit modes and applications.
4. Context menu - is called by right-clicking on an object and contains a set of buttons for performing possible actions on this object.

We will include the necessary information for our lesson in the lessons of our course.

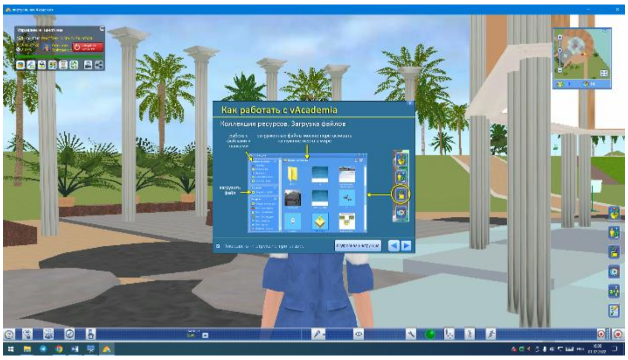

Figure 8. Entering the necessary information for our lesson.

Figure 9. Carrying out the lesson process.

Our lesson is about distance education, in which the formation and development of competences among the participants of the interaction in the educational process, based on the laws specific to the information, distance and communication technologies of education, mainly depends on the students' different it was found that it occurs as a result of independent work with training. and methodical manuals (electronic textbooks, interactive educational programs, electronic knowledge base), in addition, in the use of communication networks (Internet), this is a constant enrichment of the experience of creative activity to a greater extent, a mechanism of self-management helps to form.

III. RESULTS

The sample consisted of 20 students studying in the 3rd-4th year of the Bachelor's degree at the Tashkent University of Information Technologies named after Muhammad al-Khorazmi. Participants enrolled in Distance Learning Technologies reported that they had some understanding. Students were first asked to complete the activities designed for this experiment in a traditional classroom and then had to use virtual classes to complete the same activities [5]. This virtual education is selected because it offers many opportunities to learn authentic subject-specific information and online learning tools. The participants were 7 women and 13 men aged 20 to 27 years.

A mixed methods design with qualitative and quantitative data was used. To measure the outcomes, a questionnaire was administered to the participants before the start of the trial and after completing each of the proposed tasks of this study. Quantitative data were supplemented by interviews to elicit participants' opinions. To obtain feedback on the virtual classroom processes, a two-stage evaluation was conducted with 20 participants and qualitative and quantitative feedback was recorded.

All end users had some computer literacy or some experience with online virtual environments. The assessment took approximately 1 hour per participant and the feedback recorded is presented in the subsections below. On the positive side, most of the participants noted that the virtual class through the platform is very enjoyable and has great potential for distance learning. One user commented, "I feel this is one of the most convenient learning solutions available today and it's going to be a big bang in the tech market," while another commented, "Sounds like a new learning curve." "he noted. At the same time, it was noted that there are additional opportunities for further learning. As an example, he noted that "he has the ability to learn new things around the system and do things that he cannot do in the audience." In addition, users positively evaluated the idea of distance education.

Another commented, “Well developed because I work full time and come home in the evening. This way, I can easily re-learn the lessons that I didn't learn in class at home using the system" and another "Great, I don't have to sit in the classroom all day or waiting for the lessons to finish."

In addition, users liked the idea of creating additional thematic "interesting zones" during virtual lessons. Finally, one of the users preferred to combine traditional methods with the proposed platform and said, “I can learn more useful information at my own pace than sitting together in traditional classes. interesting concept" he said.

On the downside, some participants didn't like spending a certain amount of time familiarizing themselves with the platform. One of them commented, "I don't have extra time to use it because it takes a while," while another said, "I don't have time to go into the virtual world as I'm busy with university". Only two users were not satisfied with the educational platform and it was very satisfactory. One is "I can learn things in a classroom instead of virtually, bad idea doesn't work for me" and the other is "It's no different than online learning classes, they have all the features. So what's the point of using virtual platforms?" they expressed their opinion.

The first question was related to the general evaluation of the virtual learning experience. All of the participants responded very well and liked the idea of organizing learning and learning processes in the Virtual World (Figure 10).

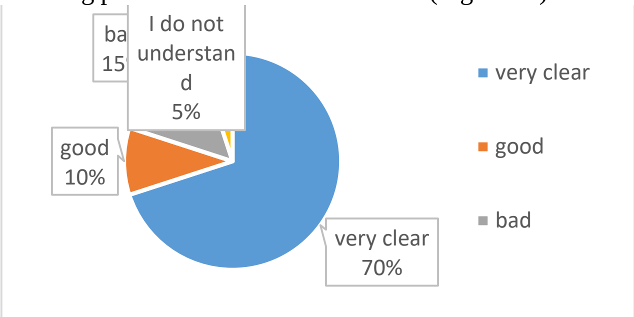

Figure 10. Virtual learning experience.

In practice, it seems that the idea of virtual learning has aroused great interest among students of all ages, as can be seen from the answers to the question. 70% of students agree with the idea of learning things virtually and they think that this is the idea of learning things. 10% of people said that the idea was just "good" but that an interactive teacher was also needed. The next type of person who thinks the whole idea is "bad" and confusing, and they make up 15% of the total opinion. 5% of users said they don't fully understand yet because they don't know how much it will help users and will it be useful in the real world? The question remains open to them. These questions are addressed by answering the following test questions to the users.

The next question concerned the distance learning experience of users for interactive learning in higher education institutions (Figure 11). Here, participants were asked this question to test and see how a virtual learning environment can help them learn while staying at their homes. Their advantage is that they can log in at any time and start following the module. They can also interact with students and staff.

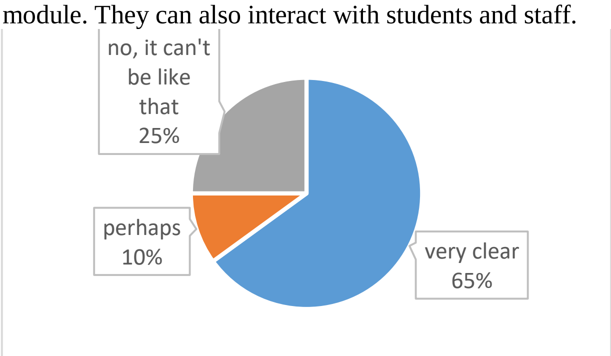

Figure 11. Distance learning experience.

In the next question, participants were asked to comment on the effectiveness of combining audio-visual aids. During the training session, they will be able to navigate to web pages/blogs, stream videos online and activate executable demo applications. Participants were asked about this question and their responses to the level of interactivity in the virtual world were recorded in the form shown in Figure 12.

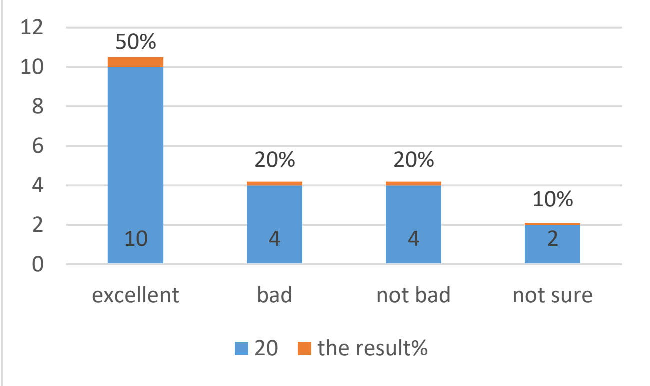

Figure 12. Effectiveness of audio-visual aids.

IV. *DISCUSSION*

Virtual worlds also have different technological requirements. They can be accessed via a standard web browser by installing a plug-in (if they don't have full 3D graphics), or if they have a full 3D world, the user will need to install the appropriate computer hardware and a standalone software client (app). Most advanced virtual worlds also require a broadband internet connection on the user side.

The analysis of the reviewed data shows that the participants of the experimental group were first used in traditional education, and then conducted training in the virtual world. By the end of the lesson, students' abstract questions about the organization of training in the virtual world decreased significantly. Organizing courses and planning lessons in a virtual system is a really clear, suggested activity.

V. *CONCLUSION*

Preliminary results with 20 users showed that, overall, online virtual learning environments are useful and can be used to develop distance learning courses and degrees. In general, most of the participants liked the system and would like to see it used in practice in teaching more subjects. Only two users were very negative and clearly stated that they prefer traditional teaching methods. Integrating online virtual learning environments with higher education can increase student engagement and possibly lead to more effective learning. Those who are not interested in traditional learning practices can adjust things for themselves and increase their confidence level.

Virtual world platforms are software frameworks that allow users to create their own virtual worlds, and some of these platforms (mostly open source) allow users to host their own worlds on their own servers.

The use of the vAcademia virtual platform is convenient even for science teachers who are not informatics teachers.

CONFLICT OF INTEREST

"The authors declare no conflict of interest"

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Technical capabilities of the Internet of things in the management of water heating in the tank

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***Abstract*— The integration of the Internet of Things (IoT) with water heating systems develops the management of water heating in an iron tank. This article discusses the technical aspects, advantages and challenges of using IoT technology to control the heating of water in an iron tank. This article provides a complete overview of water temperature sensors, their configuration, advantages and disadvantages in use. It also shows a device based on a temperature control sensor for managing a smart home project.**

Keywords— Internet of Things (IoT), Smart Home, Water Heating, Tank Management, IoT Sensors, IoT Integration

I. Introduction

For those who revel in the world of programming and hold a passion for teaching, delving into the technological intricacies of the IoT-driven management of water heating brings forth a fascinating opportunity. This article aims to explore the technical capabilities that the Internet of Things brings to the forefront when applied to the realm of water heating tanks. By merging the realms of programming prowess and smart home innovation, we embark on a journey to uncover the multifaceted advantages, challenges, and potential future developments in this dynamic field. In tank water heating management, sensors are the most important part of an IoT system. Various types of sensors are placed inside the tank to collect the necessary information.

II. Temperature Sensors

These sensors measure the temperature of the water inside the tank and provide real-time readings, allowing the system to determine if the water needs further heating or maintaining the desired temperature.

Now the following types of sensors are used in the management of water heating in a tank:

The RTS is essentially just a wire wound resistor that by its nature only has two leads. Therefore, its resistance increases with increasing temperature. PT100 and PT1000 are two common RTS types. PT100 indicates that the resistance at 0°C is 100 ohms and PT1000 has a resistance of 1000 ohms at 0°C. A high quality RTS typically uses a platinum wire whose resistance changes linearly and predictably with temperature. Platinum is commonly used as a sensing element due to its stability and wide temperature range. But if a platinum wire is attached to two copper wire leads, the resistance of the leads will increase. Because of this, the system may stop working, since the platinum wire makes up a smaller proportion of the total resistance.

A. The advantages of this sensor are:

- RTS achieves high repeatability accuracy, which is very important when establishing accurate temperature measurements.
- Simplifying calibration provides a linear relationship between temperature and resistance.
- Platinum RTSs are considered the industry standard for accurate temperature measurements due to their consistent and well-defined characteristics.
- Platinum has high strength and corrosion resistance, which allows Platinum RTS to maintain their accuracy over time and show minimal deflection.

B. Of course, there are also disadvantages:

- Higher Cost: Platinum is more expensive than copper, resulting in a higher cost for platinum RTS sensors.
- Slower response time: Platinum's lower thermal conductivity can result in slower response time compared to copper.

C. Recommendations for use:

- Precision and Accuracy: When high accuracy and stability are critical, platinum RTS are preferred. They are commonly used in industries such as pharmaceuticals, laboratories and industrial processes where accurate temperature measurements are required.
- Cost-effective: Copper RHTs may be selected for applications where accuracy requirements are less stringent and cost-effectiveness is a priority.
- Temperature range: The temperature range of the application also plays a role. Copper RTDs are suitable for wider temperature ranges, while platinum RTDs are excellent for applications with a narrower, well-defined temperature range.

Thus, the choice between copper and platinum RTDs depends on factors such as accuracy requirements, budget constraints, and the specific temperature range of the application. Platinum resistance sensors are preferred when high accuracy and stability are critical, while copper resistance sensors can be a cost-effective solution for less demanding temperature measurement applications.

III. Thermocouples

Thermocouples are good temperature sensors for monitoring the temperature of a water tank due to their durability, accuracy, and ability to withstand a variety of environmental conditions. They can be used to provide the desired tank water temperature for specific applications such as hot water or temperature sensitive processes. Currently, thermocouples are widely used and are used almost everywhere. In practice, thermocouples of the K type, as well as J and T, are most often used. They measure the temperatures of water, air, gases, lubricants, and so on.

Thermocouples can play a critical role in monitoring and controlling the temperature in a water tank in a smart home environment.

To use this sensor, you must first select a thermocouple type that matches the temperature range of your water tank. For most applications, the Type K thermocouple with Chromel and Alumel wires is a good choice due to its wide temperature range and versatility. After that, we need to place the thermocouple sensor in the water tank where we want to measure the temperature.

To avoid inaccuracies caused by external factors, it is worth making sure that the sensor is securely installed and properly insulated. To accurately measure temperature, we need to ensure the correct wiring configuration: typically, in a water tank, a simple and common thermocouple wiring configuration involves placing the thermocouple's sensing junction (hot junction) in direct contact with the water inside the tank. And the reference junction (cold junction) can be located in a controlled environment. The reference junction application in the water tank can be maintained at a constant temperature using a temperature comparison module or a thermally stable medium.

The voltage generated by a thermocouple is very small, usually in the millivolt range. In order to accurately measure this voltage, the signal must be amplified and conditioned. After signal conversion, the amplified voltage signal must be converted into a digital format for processing. To do this, we use an analog-to-digital converter (ADC). The digital data can then be transferred to the microcontroller. After that, you will need to select a microcontroller that is compatible with IoT platforms. By connecting the ADC output to the microcontroller, we will write a code for reading digital temperature data.

To communicate with the IoT platform, we will use communication protocols such as Wi-Fi, Ethernet or cellular data to connect the microcontroller to the IoT platform or cloud service. And then we will transfer the temperature data to the cloud platform for storage and analysis. On the cloud platform, we can analyze historical temperature data, set temperature threshold alerts, and create visualizations to monitor water tank temperature trends. And based on the thermocouple temperature readings, we can implement automatic control logic. For example, we can turn on a water heater when the temperature drops below a certain threshold, and turn it off when the temperature reaches the desired level.

Using thermocouples to control the heating of a water tank has its advantages and disadvantages:

A. The advantages are:

- Thermocouples can operate over a very wide temperature range, from extremely low to extremely high temperatures. This makes them suitable for applications involving various temperature levels.
- Thermocouples are known for their high accuracy and stability, especially when properly calibrated.
- Thermocouples respond quickly to temperature changes, which is useful for applications where fast temperature control is required.
- Thermocouples are durable and can withstand harsh environments, mechanical stress and vibration.
- Thermocouples generate a voltage directly proportional to the temperature difference between their two junctions. This voltage can be measured and converted into a temperature reading without the need for additional circuitry.
- The thermocouple output is a voltage that can be easily interfaced with analog-to-digital converters (ADCs) on microcontrollers for temperature monitoring and control.

B. The disadvantages of this type of sensor are:

- Thermocouples require temperature compensation at the point where the thermocouple wires are connected to the measuring circuit (cold junction). This compensation is necessary to accurately calculate the temperature at the hot end of the thermocouple.
- The voltage generated by a thermocouple is not linearly proportional to temperature. This non-linear response requires conversion equations or lookup tables for accurate temperature readings.
- Some types of thermocouples may be sensitive to electromagnetic interference and electrical noise, which may affect the accuracy of temperature measurements.
- Various types of thermocouples are available (e.g., Type K, Type J, Type T), and the choice of thermocouple material affects factors such as temperature range, accuracy, and environmental compatibility.
- Although thermocouples are reliable and accurate, they can be more expensive than other temperature measurement solutions such as thermistors or RTS.
- When multiple thermocouples are used in a system, managing cold junction compensation and ensuring accurate measurements can become more complex.
- Thermocouples require direct contact with the medium they measure. In some cases, this direct contact may not be ideal, especially in situations where contamination or chemical reactions may occur.

Thus, thermocouples provide an accurate and reliable temperature measurement for controlling the heating of water in a tank, making them suitable for a variety of industrial and commercial applications. Thermocouple type selection and proper calibration are critical to achieving reliable results in water tank heat control scenarios.

IV. THERMISTORS:

Thermistors are temperature-sensitive resistors that change their resistance with temperature fluctuations. They are commonly used for temperature measurement and control in a variety of applications, including IoT systems for temperature control of water tanks.

There are two main types of thermistors: NTC (Negative Temperature Coefficient) and PTC (Positive Temperature Coefficient). NTC thermistors have a resistance that decreases with increasing temperature, while PTC thermistors have a resistance that increases with temperature.

Using thermistors to control tank water heating has a number of advantages and disadvantages:

A. Advantages:

- Thermistors are relatively inexpensive compared to other temperature measurement solutions.
- Thermistors are small and compact, allowing them to be easily integrated into various systems, including IoT installations.
- Thermistors can provide fast response times to temperature changes. This allows you to quickly adjust the heat.
- The circuitry required to interface thermistors to microcontrollers or other control systems is often simple and includes basic components such as resistors and analog-to-digital converters (ADCs).
- NTC and PTC thermistors are available in a wide range of temperature ratings to suit a variety of heat control scenarios.
- Thermistors can be selected with specific resistance and temperature specifications to suit the requirements of the water tank heating system, resulting in improved accuracy and control.

B. Flaws:

- Thermistors have non-linear resistance-temperature characteristics, which means that accurate temperature readings require calibration and compensation to achieve reliable control.
- Achieving accurate and consistent temperature measurements with thermistors can be challenging due to their non-linear behavior.
- While thermistors provide decent accuracy for many applications, they may not provide the same level of accuracy as more advanced temperature sensors such as resistance temperature sensors (RTS) or thermocouples.
- External factors such as thermistor self-heating, ambient temperature fluctuations, and electrical noise can affect the accuracy of the thermistor-based temperature measurements.
- Thermistors are electronic components and can fail over time due to factors such as electrical stress, physical damage, or prolonged exposure to high temperatures. While thermistors are suitable for many temperature measurement applications.
- The resistance of thermistors can change over time, affecting the accuracy of temperature measurements. Regular recalibration may be required to maintain accuracy.

Thus, thermistors offer an economical and compact solution for tank water heating control, especially when integrated into IoT systems. To control the temperature of a water tank, when integrating thermistors into IoT systems, there are several important aspects to consider:

Be sure to select the appropriate type of thermistor (NTC or PTC) depending on the temperature range and desired system control characteristics.

Thermistors can be connected in a variety of wiring configurations to achieve the desired accuracy and functionality. There are two common configurations: the voltage divider configuration, which involves connecting a thermistor in series with a fixed resistor and energizing the two elements. The voltage across the thermistor changes depending on the temperature, which can be measured and used to measure temperature; In the current source configuration, the thermistor is connected in series with a fixed resistor and a constant current source. The voltage across a thermistor is proportional to its resistance and can be measured to measure temperature.

The analog voltage from the thermistor needs to be converted into a digital signal that can be processed by the microcontroller or processor of the IoT system. This is usually done using an analog-to-digital converter (ADC).

Thermistors may exhibit non-linear behavior and their resistance/temperature relationship may not be entirely consistent. Calibration is necessary to compare resistance values with accurate temperature readings.

We need to connect the output of the thermistor circuit to the microcontroller or processor of our IoT system. This can be achieved using GPIO pins or dedicated analog input channels, depending on the capabilities of the microcontroller.

After this, we will need to implement the necessary software to process the temperature readings, apply control algorithms and adjust the temperature of the water in the tank accordingly. This may involve turning heating elements or other cooling mechanisms on or off to maintain the desired set temperature.

If the IoT system is part of a larger network or cloud system, we can enable remote monitoring and control of the water tank temperature. This allows you to receive data in real time and make adjustments remotely.

It is imperative to consider power consumption and energy efficiency, especially if the IoT system is battery powered or has limited power resources.

It is important to remember that accurate temperature control requires not only accurate sensor integration, but also careful algorithm design and system tuning. Regular calibration and maintenance can help ensure the continued accuracy of the water tank temperature control system in an IoT installation.

V. PROGRAMMING WATER TEMPERATURE

Programming water temperature sensors for tank smart home applications is a common use case in the IoT space. We can achieve this by using various temperature sensors such as DS18B20, DHT11, DHT22 or BMP180 depending on our requirements and required accuracy. In my use of the DS18B20 temperature sensor, I used the Blynk environment and the C++ programming language to control the temperature of the water in the tank.

A. Description of my device

The device allows you to maintain the heating of water at a given temperature. Heating is carried out by an electric heating element with a power of 3 kW, switched by a powerful triac BTA41-600, controlled by an ESP8266 NodeMcu microcontroller with Wi-Fi on board. The control interface is implemented on the BLYNK application (for android devices). It is possible to select the water heating temperature (0 - 50 °C), save the temperature value in the controller's memory (using the UPD button), remotely turn the device on and off. In real time, the controller transmits the temperature of the water and the temperature of the radiator of the switching key - triac BTA41-600.

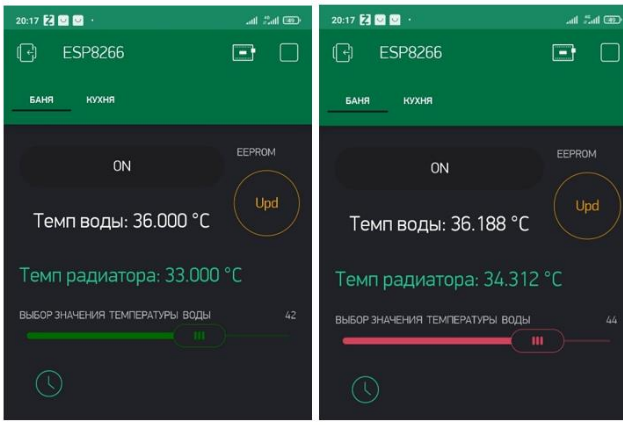

Fig. 1. View of temperature control on a mobile application for Android

The application is synchronized with the device, that is, when the device is turned on / off with a physical button, the state of the touch button in the application changes. In the process of temperature selection, when the value has changed, the color of the slider changes to red, and after a successful update of the value in the controller's memory, it changes to green.

To control the water heating process, an LED display is provided, which displays the water temperature and the current time (updated from the BLYNK application). In the absence of an Internet connection, the device operates autonomously, maintaining the set temperature.

Fig. 2. Connecting the sensor to the container and controlling the temperature via buttons on the container itself.

B. DEVICE FEATURES

- Remote turn on / off the device
- Choice of water heating temperature from the application.
- Update date/time from service.
- To prevent frequent switching on / off of the power switch, a hysteresis of 1 °C is provided
- When the heatsink, temperature reaches 50 °C, the controller starts the cooler fan
- The LED display shows the water temperature and the current time
- Two DS18B20 digital temperature sensors are used, temperature values are transferred to the application.
- When turned on, or in case of power failures (turning off / on the light), the device starts in passive mode - heating of the heating element is turned off
- The program code is implemented in the application ARDUINO IDE v1.8.13, programming language C/C++

C. Conclusion.

In this article, I explored the integration of the DS18B20 temperature sensor into the Blynk remote water temperature monitoring platform. By combining hardware and software components, it created the basis for a comprehensive smart home system. This system allows real-time data collection and remote interaction through the Blynk app.

The DS18B20 temperature sensor provides accurate temperature readings, making it ideal for tank water monitoring and a variety of other applications. Using the platform, Blynk established a seamless connection between the sensor and my mobile device, allowing me to monitor the water temperature from anywhere.

By customizing the provided code with your specific credentials and settings, you can easily integrate this technology into your smart home setup. This project serves as a starting point for further exploration of the world of IoT programming and smart home control, allowing us to innovate and expand on the foundation outlined here.

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Architecture for optimizing traffic filtering rules

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***Abstract*— This article explores the critical role of architectural considerations in effectively optimizing traffic filtering rules within network security systems. By strategically designing the architecture of these rules, organizations can enhance security, streamline network performance, and maintain operational efficiency. The article delves into key architectural principles and strategies, highlighting their impact on traffic filtering efficacy.**

Keywords—domain, rules of filtration, firewall, IP format.

I. INTRODUCTION

A packet filtering rule R can be modeled as an ordered set, $R=(F_1, F_2,...,F_d)$ where each field F_k, $k \in 1...d$ represents a set that can be fully defined and is specified as a range in a standard prefix format. Firewall rules are typically represented as five fields consisting of: Source IP address, Destination IP address, Source port number, Destination port number, and Protocol. Let us define the domain of a rule Domain (R) as the set of all packets over the fields $F_1, ... ,F_d$. Each filtering rule R is associated with an Action(R), which is Accept or Deny.

II. DEPENDENCY OF RULES

Let R_i and R_j- two firewall filtering rules. This means that R_i and R_j are dependent if Domain $(R_i)\bigcap(R_j) \neq 0$ and Action $(R_i) \neq$ Action (R_j).

Using the rule definition, the firewall configuration can be modeled as an ordered list of n filtering rules $R_1,R_2, ... , R_n$. Starting with the first rule, packet p is sequentially compared with each rule R_i until a match is found, after which the appropriate action is performed. This means that R_i has a higher priority than R_j, and R_i precedes R_j if $i < j$.

The proposed architecture is a function-parallel design that allows policy propagation without duplicating packets. Two variations of function-parallel with preprocessing are presented. First, policy distribution and meta-rule generation are explained. Then, initial processing and options for performance improvement are defined.

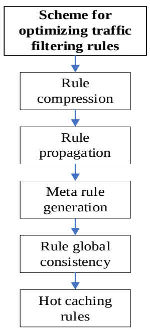

Fig.1. Scheme with traffic filtering packet rules processing phase

In order for the scheme with rule processing phase to function, the following steps must be followed. The scheme with rule processing phase of traffic filtering packets is presented in Fig.1.

III. RULE COMPRESSION

The filtering system must be designed so that certain types of packets are processed only by certain firewalls, ensuring that the reception domains of each firewall's firewall do not overlap. An independent rule set generated by the K-map algorithm is used here, as it allows free and fair distribution of rules among firewalls.

Metaprules are the general rules that unify the domain of each firewall. They define common characteristics of a packet that can match the rule of a particular firewall.

In order to have fewer constraints in rule allocation, an independent list of rules generated by the k-map algorithm is used. This algorithm takes as input the original list of access control rules and provides as output an equivalent list of fully independent rules [1,2]. The generated rule list consists only of ACCEPT rules (except the default DENY rule) and is semantically equivalent to the original one, which means that the solution for any resulting packet is the same for the original list or with k-map generated rules.

The output list of conflict-free rules contains some redundant rules. That's why it is set up in the optimization phase to merge the rules and remove the redundancy. Rule merging consists of grouping two rules R_x and R_y together if there exists $i \in [1,d]$, where d is the number of fields such that the corresponding fields F_{xi} and F_{yi} can be grouped into a single entry, while all rules other fields are equal. Redundancy removal consists of concatenating two rules having the same action with Domain $(R_x) \subset$ Domain (R_y). Removing redundancy and concatenation does not affect the behavior of the firewall, since the rules no longer conflict. The generated firewall is similar to the original firewall, but with a significantly reduced number of rules.

However, to generate meta-rules, we also need to remove the correlation between rules. For this purpose, we propose another optimization to remove partial redundancy and decompose the list of rules [3,4]. Two rules R_x and R_y are correlated if R_x matches some packets that match R_y and the latter matches some packets that match R_x. This means that Domain $(R_x) \not\subset$ Domain (R_y), Domain $(R_y) \not\subset$ Domain (R_x) and Domain $(R_x) \cap$ Domain $(R_y) \neq 0$. Since R_x and R_y have the same solution, they are considered partially redundant.

In some cases it is possible to aggregate redundant rules into a single rule $R_x \cup R_y$, while in other cases we have to remove the overlap between domains. If we have two rules R_x and R_y that are correlated, then we check for each $k \in 1, ... ,d$ if Domain $(F_{xk}) \subset$ Domain (F_{yk}), then we replace Domain (F_{yk})

with Domain (F_{yk})-Domain (F_{xk}) and R_x remains unchanged. The Flowchart algorithm of the traffic filtering packet rule compression is shown in Fig. 2.

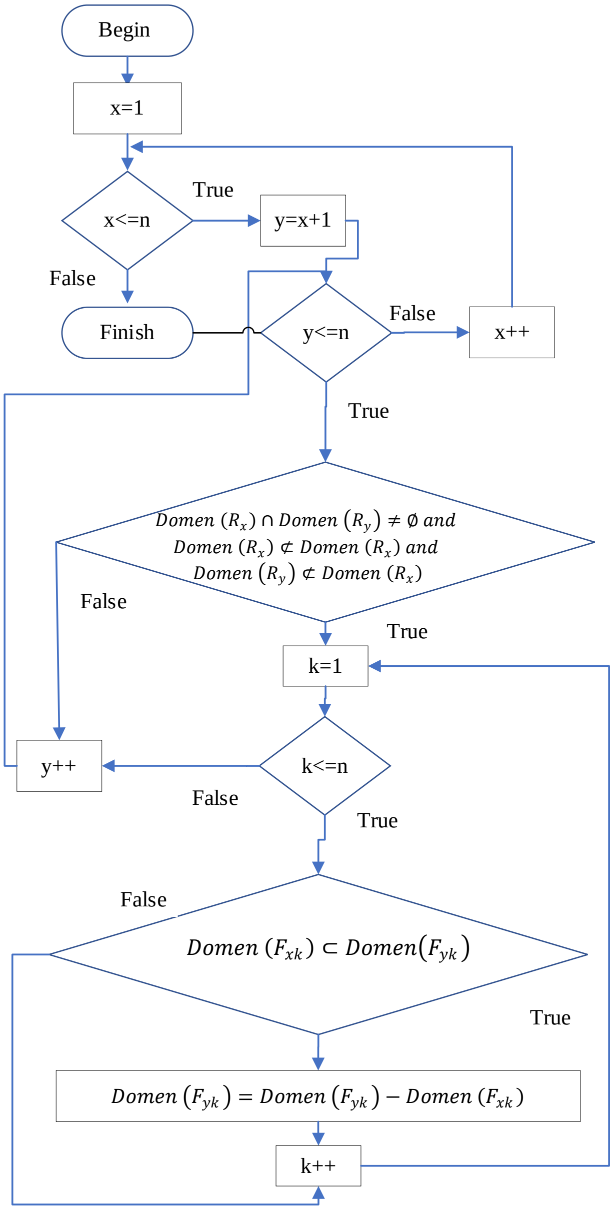

Fig.2. Flowchart algorithm of traffic filtering packet rule compression

Based on Flowchart algorithm of traffic filtering packet rule compression in table 1 is shown the time compression of packet filtering rules.

TABLE 1 TIME COMPRESSION OF TRAFFIC PACKET FILTERING RULES

Number of incoming packets	Packet travel time (milliseconds) t
1	1.5
5	46.20000000298023
7	330.6000000089407
23	420.20000000298023
53	1703.4000000059605

This processing is necessary to generate meta-rules. The more limited the scope of each rule is, the easier it will be to generalize the scope of the rule list. This avoids distributing two rules with overlapping domains to two different firewalls.

IV. DISSEMINATION OF THE RULE

The Flowchart algorithm for distributing traffic filtering packet rules is shown in Fig. 3.

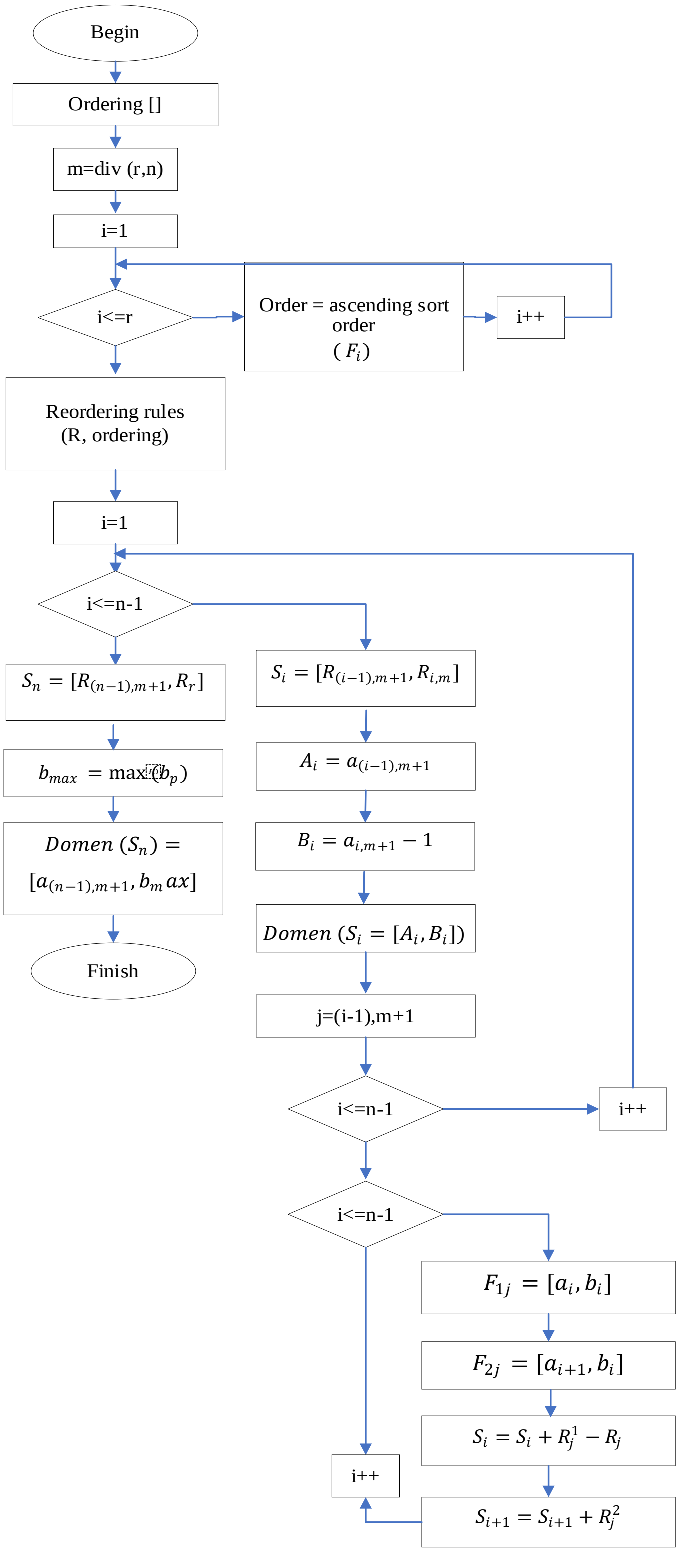

Fig.3. Flowchart algorithm for distributing traffic filtering packet rules

First the sorting of the field range starts, the Sort in ascending order function returns a list of sorted rule numbers. Then, based on this list, the rules are reordered by calling the Reorder Rules function. This is followed by dividing each $div(r, n)$ rule in another firewall represented by the list S. If the domain of a rule is not within the domain of its firewall, it is split into two rules and the new rules are reassigned. In this way all firewalls have non-overlapping domains. Metarules can be generated directly from each firewall's Domain (S) domain.

Based on Flowchart algorithm for distributing traffic filtering packet rules in table 2 is shown distribution of traffic filtering packet rules.

TABLE 2 DISTRIBUTION OF TRAFFIC FILTERING PACKET RULES

Incoming value N	Incoming value R	Collection B	Packet x	Packet travel time (milliseconds) t
2	3	1,2,3,4	3	0.5999999940395355
5	8	2,5,6,1	0	0.9000000059604645
7	15	4,2,6,3	1	0.5
11	3	2,5,8,4	1	0.7999999821186066
8	4	8,6,4,2	1	0.6000000238418579
3	7	1,5,7,2	2	0.6000000238418579

V. META PRINCIPLE GENERATION

The algorithm is used to determine whether the packet is categorized as class A, class B or class C of the class view and then accordingly sent to the corresponding firewall. The SendPacket () function is responsible for accepting the packet and the firewall as arguments and then checks the IP format and checks whether the IP is in string format or not and if not, converts it to that format [5,6]. This conversion to string format is done to avoid any other malicious code to be injected here which can be run in the backend of the architecture. The flowchart algorithm for generating traffic filtering packet metarules is shown in Fig.4.

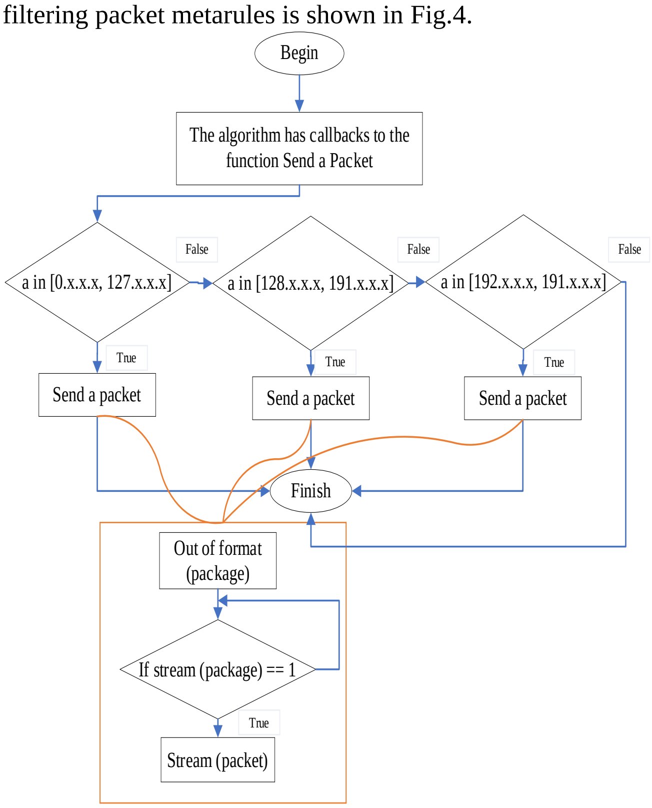

Fig.4. Flowchart algorithm generating meta rules for traffic filtering packets

Based on Flowchart algorithm generating meta rules for traffic filtering packets in Table.3 is shown the generating meta rules for traffic filtering packets.

TABLE 3 GENERATION META RULES FOR TRAFFIC FILTERING PACKETS

IP packet	IP packet (Packet 0 failed to arrive; Packet 1 arrived)	Packet travel time (milliseconds) t
0.0.0.0	0	1432.5
127.0.100.1	1	1794.5999999046326
0.100.100.1	1	1557.5999999046326
135.156.100.1	1	1485.2999999523163
160.125.255.100	0	1030.6000000238419
191.168.100.1	1	1668.2000000476837
192.168.100.101	0	1293.8999999761581
255.168.100.1	1	974.3999999761581

VI. GLOBAL CONSISTENCY RULES REFERENCES

Global Consistency Rules sets default disclaimer rules for the entire architecture so that the entire system is organized. Here, as you can see, if the rule was denied, then DENY(r) will return a value of 1, then the IP format is checked, and then a default deny rule is created [7]. The rule is sent to the packet distributor so that such packets are rejected before they even reach the firewalls. The flowchart algorithm for rule generation global traffic filtering consistency is described in Fig.5.

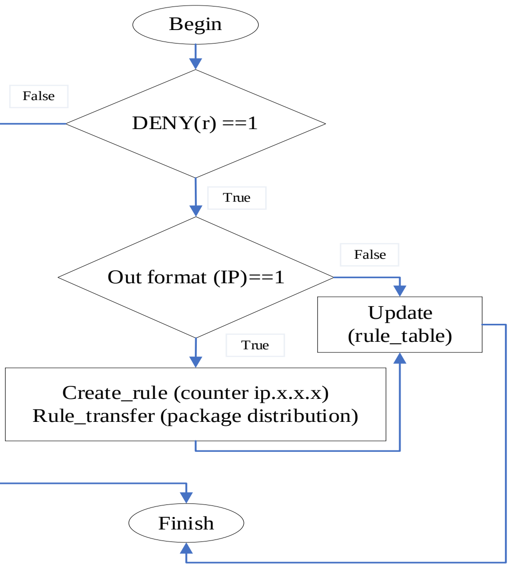

Fig.5. Flowchart algorithm rule generation global traffic filtering consistency

On the basis Flowchart algorithm rule generation global traffic filtering consistency in Table 4 is shown the rule generation global traffic filtering consistency

TABLE 4 THE RULE GENERATION GLOBAL TRAFFIC FILTERING CONSISTENCY

IP packet	IP packet (Packet 0 failed to arrive; Packet 1 arrived)	Packet travel time (milliseconds) t
0.0.0.0	1	4144.199999928474
127.156.100.156	0	1208.181936
10.100.100.10	1	1304.3999999761581
145.126.100.1	1	1445.8000000715256
172.125.255.250	0	1263.546505
181.168.100.1	1	1005.5
192.168.100.1	1	1110
255.168.100.1	1	1690.3000000715256

VII. HOT CACHING RULES

Here f_set is a list which is used to retrieve the rule tables of all the firewalls present in the architecture. Then we start looking at each of the rule tables and extract the hit frequency column for processing [8]. First, it is sorted the hit frequency in ascending order and then use the sort_relevant () function to sort the entire rule table by the sorted hit frequency column. This was a dynamic update of the firewall rule table according to the rules that have the maximum hit rate. The Flowchart algorithm of rule generation for hot caching traffic filtering is described in Fig.6.

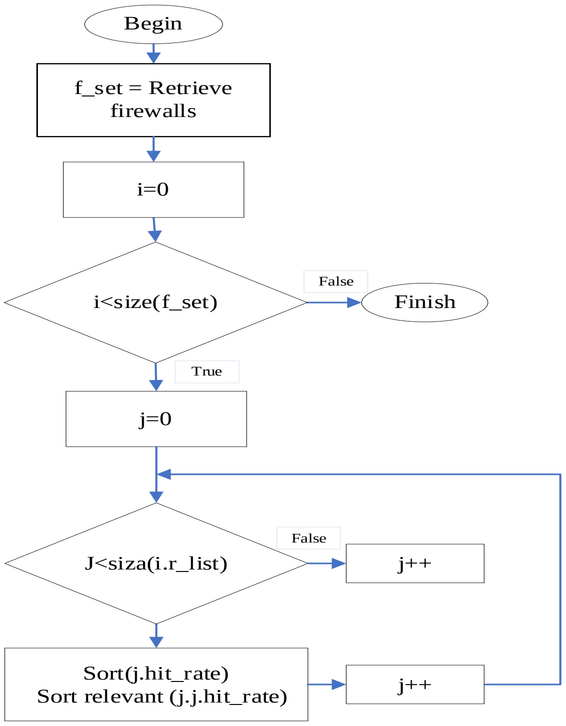

Fig.6. Flowchart algorithm of rule generation for hot caching traffic filtering

On the basis Flowchart algorithm of rule generation for hot caching traffic filtering in Table 5 is shown rule generation for hot caching traffic filtering

TABLE 5 RULE GENERATION FOR HOT CACHING TRAFFIC FILTERING

Number of incoming packets	Packet travel time (milliseconds) t
1	2350,70000004768
2	1226,79999995231
3	1477,29999995231
4	1379,39999997615
5	1613,79999995231
6	1407,90000009536
7	2722,29999995231
8	2133,39999997615
9	1018,50000000000

Based on the above algorithms, an architecture for optimizing traffic filtering rules is proposed in Fig.7.

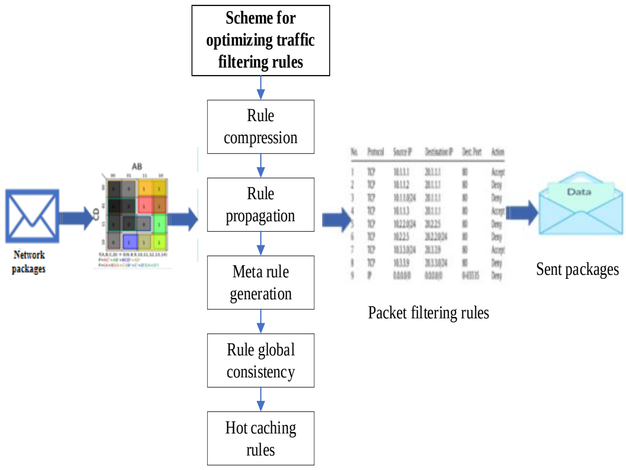

Fig.7. Architecture for optimizing traffic filtering rules

In conclusion, it should be noted the proposed architecture for optimizing traffic filtering rules reduces rule processing time and reduces the number of rules as the number of nodes on the firewall increases. Under optimizing, the number of rules is minimized by Spoofing attacks and false positives when determining a network attack.

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Algorithm for generating S-Box using trigonometric function

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***Abstract*— This article introduces based on trigonometric transformation algorithm for generating sorting-resistant S-boxes for use in robust cryptographic algorithms. The article highlights the importance of S-boxes in ensuring good diffusion of plaintext throughout ciphertext and the need for dynamism in S-box design. The article provides an overview of traditional S-box design methods and describes recent unconventional approaches, including an algorithm using linear trigonometric transformation to create S-boxes. The proposed algorithm is capable of efficiently generating S-boxes that can resist various cryptanalysis methods. The article provides a mathematical description of the function used in the algorithm and highlights the algorithm's solution space. The paper presented a single 16*x*16 table of S-box using trigonometric transformation and verified it against various cryptographic criteria.**

Keywords*— *s-box, block cipher, nonlinearity, generate s-box, trigonometric function, cryptography.

I. INTRODUCTION

Cryptographically strong encryption algorithms rely heavily on the S-box, a key component that introduces non-linearity into the system. The S-box Feistel or SP is a widely used standard in network-based symmetric encryption algorithms [1,2]. A robust cryptographic algorithm requires a strong S-box that can ensure good diffusion of the plaintext throughout the ciphertext, making it difficult to establish any discernible relationship between them. S-boxes can be static or dynamic and designing a safe S-box requires ensuring its dynamism. This can be achieved through two methods: using a key-dependent permutation table that changes the S-box based on the encryption key, or using a dynamically generated permutation table that is unique for each round of encryption. The effectiveness of an S-box can be evaluated by testing its resistance to certain attacks, such as linear and differential cryptanalysis. A safe S-box should not have linear or differential dependencies [3]. Essentially, cryptographic algorithms that pass these tests are more resistant to various attacks.

II. MATERIALS AND METHODS

Designing a robust S-box is essential in the development of secure encryption algorithms, as it plays a vital role in introducing non-linearity into the system and facilitating good diffusion of the plaintext throughout the ciphertext. Traditionally, S-boxes are calculated using various mathematical methods, but in recent years, new unconventional methods and algorithms have been developed for both static and dynamic S-boxes. In 2014, W. Zhang and E. Pasalic proposed two methods for constructing S-boxes with high algebraic and differential properties. More recently, in 2012 and 2020, Yong Wang, Kwok-Wo Wong, Chang Bing Lee, and Yang Lee developed an S-box design method based on Chaotic System and Genetic Algorithm. In 2020, Zhu, Ding, Xiao Jun Tong, Miao Zhang, and Zhu Wang proposed a new S-box manufacturing method based on chaotic system and its advanced design. In 2021, A.H. Zahid et al presented a simple and efficient dynamic and key-dependent algorithm for constructing S-boxes using linear trigonometric transformation. Also in 2021, G. Kim, H. Kim, Y. Heo, Y. Jeon, and J. Kim proposed a new method for generating S-boxes by collecting bitwise operations from an identity function. Despite the recent advancements in S-box design algorithms, the demand and interest in the development of cryptographic algorithms continue to increase, which necessitates the need for the development of durable S-box designs. As new attack techniques continue to emerge and the number of encryption processes in real-world applications continues to grow, designing a robust S-box remains a critical research area in cryptography [4-10].

III. S-BOX GENERATION USING LINEAR TRIGONOMETRIC TRANSFORMATION

This article introduces a novel algorithm for generating sorting-resistant S-blocks by utilizing trigonometric functions to construct S-boxes. The algorithm proposed in this study is capable of efficiently constructing S-boxes with a predetermined number of elements. The findings indicate that using trigonometric functions in this method, S-boxes can be created that can resist various cryptanalysis methods. The mathematical description of the function based on trigonometric transformation, which is used in the proposed algorithm, is provided as Equation (1) in reference [8]. The function presented in [8] has been enhanced by the inclusion of a parameter *y* that varies with the value of *x* and serves to further enhance the upper limit of nonlinearity achieved by the function. The study demonstrates that the proposed algorithm effectively addresses the challenge of designing reliable S-boxes, which is a crucial research area in cryptography, given the growing demand for secure cryptographic algorithms in real-world applications.

$$f(z) = \sin((A+B)\cdot x\cdot y\cdot z + C) \quad (1)$$

where $0 < x < 1,\ 0.5 < y < 2,\ \ 0 \le z \le (2^n - 1), B \in z$ and $A, C = \{1, 3, ..., 2^n - 1\}$

By randomly selecting variable values within specified ranges, the *A, B, C, x*, and *y* variables can be used to construct an S-box. A large number of S-box combinations can be achieved by changing these variables. When creating an *n=8* and *8x8* dynamic S-box, the maximum combinations for *A, B, C, x* and *y* are 128, 256, 128, 10^{15} and 10^{8}, respectively. In this case, Figure 1 illustrates the nonlinearity produced by the trigonometric transformation function at x=0.5150, y=0.8150, n=8, A=111, B=256, and C=133. With approximately 10^{29} possible combinations, this algorithm's solution space is vast, making careful evaluation necessary to ensure the production of effective S-boxes. The algorithm's vast solution space necessitates the identification of stable S-boxes by assessing their values against the criteria listed in Section V. To create S-boxes in the *8x8* form, *n=8*, and with random *x*, *y*, *A*, and *C* values within the algorithm's specified intervals, this method was employed.

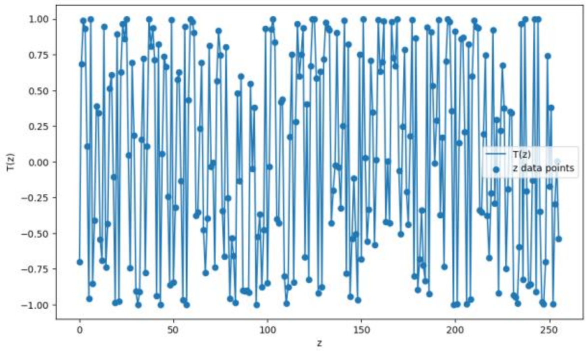

Fig. 1. The nonlinear graph was created when calculating the trigonometric function with the values *x=0.3134, y=1.3945, n=8, A=53, B=256, C=161*.

IV. ALGORITHM FOR GENERATING ROBUST S-BOXES BY TRIGONOMETRIC TRANSFORMATION.

The purpose of the algorithm for generating robust S-boxes by trigonometric transformation is to provide a method for constructing substitution boxes (S-boxes) that are resistant to various cryptanalytic attacks. S-boxes are a crucial component of modern symmetric-key cryptographic systems, as they transform input bits into output bits in a way that is difficult to reverse-engineer.

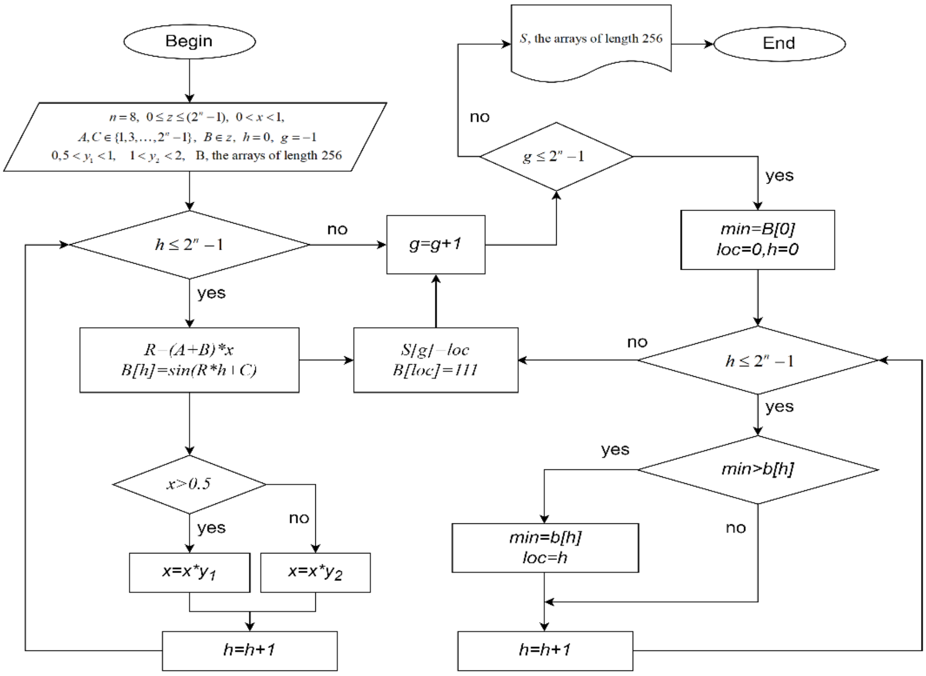

Fig. 2. Initial S-box generation algorithm based on trigonometric transformation.

The algorithm relies on a mathematical approach that involves using trigonometric functions to transform an initial S-box into a new S-box that has enhanced cryptographic properties. The process involves iterating through a series of trigonometric transformations, each of which modifies the original S-box to improve its resistance to various types of attacks. Our proposed algorithm was developed based on the algorithm given in [8]. The graphical representation of this algorithm is given in Figure 2.

Based on the algorithm shown in Figure 2, the following algorithm was developed and the S-Box values were calculated. The proposed S-Box generation algorithm consists of the following steps.

1. According to the algorithm in Fig. 2, its *A, C, x,* y_1 and y_2 values are randomly selected as 2 S-Box values.

2. The XOR operator is used to add the elements of the 1st order of S-Box values, resulting in the generation of a new value.

3. The value created in step 2 is added to array element *d* until the number of its elements is 256. If the number of *d* array elements is less than 256, it returns to step 1 and new S-Boxes are calculated.

4. If the value generated in step 2 exists in the d array in step 3, it is returned to step 1 and new S-Boxes are calculated.

5. The non-linearity of the resulting 256-element d array is calculated. If the non-linearity value does not meet the given cryptographic requirements, it goes to the 1st step of the algorithm and the process continues.

V. PERFORMANCE ANALYSIS OF PROPOSED S-BOX

Our study focuses on the development of an S-box for block ciphers by employing the approach based on trigonometric transformation. To evaluate the effectiveness of the algorithm, we implemented it in Python and subjected the resulting S-box to rigorous testing, including assessments for Nonlinearity, Strict Avalanche Criterion (SAC), Differential Uniformity (DU), and Linear Approximation Probability (LAP). The output S-Box of our algorithm is presented in Figure 3, while the non-linear plot of the S-Box is illustrated in Figure 4.

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	c7	ca	c2	fa	ce	c0	04	36	b1	d5	70	81	1e	71	3e	1c
1	97	e7	e3	8b	cf	67	5d	30	3f	f6	2b	06	48	2c	74	c3
2	29	cb	ed	a8	7a	ea	85	b2	b9	21	f8	6d	15	a3	80	42
3	d7	92	d9	1b	e5	bc	0d	1f	a9	79	bb	23	66	7d	b7	b3
4	0e	ec	a0	93	63	26	32	2e	01	ee	a5	e9	fc	ff	69	5a
5	7f	76	46	98	44	13	40	35	c9	47	aa	e6	f3	64	e8	19
6	f7	eb	05	9b	3a	4f	68	4c	90	8f	34	6c	45	f4	73	77
7	94	a7	ab	ad	08	4d	bd	24	54	fb	00	de	b0	e1	8a	33
8	9f	7c	50	dd	dc	62	22	16	96	82	fd	a4	17	03	0b	d1
9	4b	9d	e4	3d	0a	bf	89	df	3c	84	8d	0f	ac	c1	58	4a
A	f1	7b	83	d8	b4	ef	20	d3	2a	61	87	f2	53	c4	d6	c5
B	09	18	07	f9	fe	e2	75	41	d2	1d	c8	b6	37	4e	86	65
C	d0	7e	59	da	8c	5b	99	51	1a	12	af	cc	14	78	31	f5
D	10	8e	2f	72	c6	6e	6f	5f	95	55	02	b5	38	cd	d4	39
E	56	0c	27	5c	be	91	6b	52	28	57	b8	88	a1	e0	ba	f0
F	6a	a2	11	3b	ae	a6	43	60	db	9a	5e	49	2d	25	9c	9e

Fig. 3. Proposed S-box in values of hexadecimal.

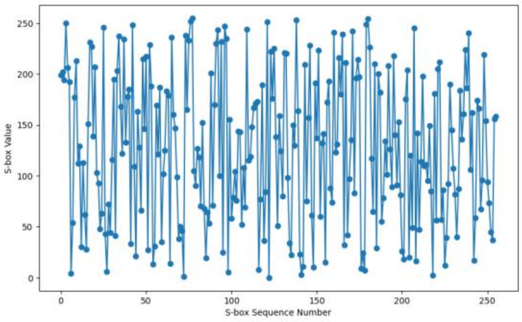

Fig. 4. Nonlinearity graph of the proposed S-box.

Nonlinearity

An 8 × 8 S-box creates a correspondence between an 8-bit input and an 8-bit output. If this correspondence follows a linear pattern, the S-box becomes susceptible to successful attacks on the encrypted data, hence, compromising the cryptographic strength. However, nonlinear mapping in the design of the S-box provides considerably stronger cryptographic strength, making it more resistant to such attacks. Carefully crafted S-boxes with nonlinear mappings act as a robust shield in cryptosystems that can resist linear cryptanalytic attacks. To calculate nonlinearity, the Walsh-Adamard substitution method, defined as (2), is utilized.

$$S_{\langle f \rangle}(\omega) = \sum_{x \in GF(2^n)} (-1)^{f(x) \oplus x \bullet \omega} \quad (2)$$

Here is the scalar product between $\omega \in GF(2^n)$, $x \bullet \omega$ x and ω in a finite field. The nonlinearity of an n × n S-box is computed using Equation (6)

$$N_f = 2^{n-1}\left(1 - 2^{-n} \max_{\omega \in GF(2^n)} \left| S_{\langle f \rangle}(\omega) \right| \right) \quad (6)$$

After computing the nonlinearity of the eight f_i $(1 \leq f_i \leq 8)$ Boolean functions involved in the proposed 8×8 S-box, we obtained impressive average values of 105.5. The individual values were 106, 104, 104, 104, 100, 110, 104, and 112, respectively. To evaluate the performance of this S-box, we compared it against some recently proposed chaos-based S-boxes in Tables I and II, which demonstrated its commendable performance outcomes. Compared to other S-boxes, our proposed S-box showed superior statistical results in terms of minimum, maximum, and average nonlinearity scores. It is crucial to have high nonlinearity scores for all eight Boolean functions in S-boxes as they help reduce the input-output correlation and improve the cryptographic strength of the S-box.

TABLE I. COMPARISON OF NONLINEARITY SCORES OF SOME 8×8 S-BOXES

S-box	**Nonlinearity**							
	1	2	3	4	5	6	7	8
Proposed	106	104	104	104	100	110	104	112
In [6]	108	108	108	108	108	108	108	108
In [7]	108	108	106	102	108	102	108	104
In [10]	108	106	108	106	104	106	104	106
In [11]	98	100	100	104	104	106	106	108

TABLE II. COMPARISON OF MIN, MAX, MEAN NONLINEARITY OF SOME 8×8 S-BOXES

S-box	**Nonlinearity**		
	Min	**Max**	**Mean**
Proposed	100	112	105,5
In [6]	108	108	108
In [7]	102	108	105
In [10]	104	108	106
In [11]	98	108	103

Strict avalanche criterion (SAC)

The Strict Avalanche Criterion (SAC) is a crucial property of cryptographic S-boxes, used to measure the sensitivity of output bits to changes in input bits. Webster and Tavares introduced the SAC criterion in 1986 [12], and it is widely used for evaluating the strength of cryptographic primitives. To assess an S-box's conformity to the SAC property, we can generate all possible input pairs that differ in one bit and compare the output pairs. The number of output bit differences between the pairs can then be counted and divided by the total number of output bits. If this value is at near 0.5 or 0.5, the S-box meets the SAC property.

Differential Probability (DP)

The differential probability quantifies the likelihood that a particular input difference yields a specific output difference. It is computed by dividing the count of input pairs resulting in the desired output difference by the total number of possible input pairs. Ideally, the S-box should exhibit differential uniformity, where an input differential Δx_i must mirror an output differential Δy_i with a single value, yielding a distinct reflection probability for each *i*. The differential convergence probability (DP), a gauge of differential uniformity, measures this property of a given S-box (4).

$$DP(\Delta x \to \Delta y) = \left(\frac{\#\{x \in X \mid S(x) \oplus S(x \oplus \Delta x) = \Delta y\}}{2^m} \right) \quad (4)$$

where x is the set of all possible input bit values and 2^m is the number of its elements.

Linear approximation probability (LAP)

The linear approximation probability (LAP) is a crucial property utilized in the analysis of S-box security in cryptographic systems. It assesses the likelihood of a linear approximation being valid for an S-box. A linear approximation is a linear function that mimics the behaviour of a non-linear function, such as an S-box. LAP gauges the degree to which this approximation holds for an S-box by measuring the probability of the output of the S-box satisfying a linear equation for a specific input difference. A linear approximation table is typically used to represent the LAP of an S-box. This table displays all possible input and output differences and the corresponding probability of a linear approximation being valid for each difference. A higher LAP value implies that the S-box is more vulnerable to linear attacks that can undermine its security. Conversely, a lower LAP value indicates a higher level of security. To enhance an S-box's security, it is crucial to increase its non-linearity and ensure that it complies with the strict avalanche criterion. Matsui's definition defines the linear convergence probability of an S-box based on the aforementioned criteria (5).

$$LAP = \max_{\Gamma x, \Gamma y \neq 0} \left| \frac{\#\{x \in X \mid x \bullet \Gamma x = S(x) \bullet \Gamma y\}}{2^m} - \frac{1}{2} \right| \quad (5)$$

where Γx and Γy are input and output masks, respectively; X is the set of all possible input bits, and 2^m is the number of its elements [13].

Fixed Points Analysis (FPA)

In cryptography, S-box fixed points refer to a condition where an S-box, or substitution box, maps a specific input to the same output value. In other words, when an S-box has a fixed point, the input value and output value are equal. S-box fixed points can pose a security risk for cryptographic systems as they can be exploited by attackers to break the encryption and gain access to sensitive information. To illustrate this, suppose that an attacker knows a plaintext message and its corresponding ciphertext. If the attacker also knows that the S-box used in the encryption process has a fixed point, they can use this information to potentially determine the key used for encryption. This is because the attacker can use the known plaintext and ciphertext to determine the input and output values of the fixed point. With this knowledge, the attacker can then use the fixed point to deduce the key used for encryption, thereby compromising the security of the system. To mitigate the risk posed by S-box fixed points, cryptographic designers typically use S-boxes that have no fixed points or have a limited number of fixed points. They achieve this by carefully selecting S-boxes that have desirable cryptographic properties such as high non-linearity, strict avalanche criterion, and resistance to differential and linear cryptanalysis. By using S-boxes with such properties, the risk of fixed points is significantly reduced, thereby enhancing the overall security of the cryptographic system.

Table III shows the results of testing the proposed S-box and others on the strict avalanche criterion (SAC), linear probability (LP), differential probability (DP) and Fixed Points Analysis (FPA).

TABLE III. COMPARISON OF SAC, LINEAR PROBABILITY (LP), DIFFERENTIAL PROBABILITY (DP), AND FIXED POINTS ANALYSIS (FPA) OF SOME 8×8 S-BOXES

S-Box	SAC	DP	LAP	FPA
Proposed	0.4922	10/256	0.1328	0
In [6]	0.5781	10/256	0.1416	1
In [7]	0.5019	10/256	0.0629	0
In [10]	0.4987	10/256	0.1316	0
In [11]	0.4972	12/256	0.1181	0

VI. CONCLUSION

To conclude, this paper emphasizes the significance of designing robust S-boxes for developing secure cryptographic algorithms. S-boxes play a vital role in introducing non-linearity into the system and ensuring an effective spread of the plaintext across the ciphertext. The paper has discussed both traditional and non-traditional methods for S-box design, including a linear trigonometric transformation algorithm. The S-box values presented in Figure 3 demonstrate impressive results, achieving a minimum of 100, a maximum of 112, and an average of 105.5 for Nonlinearity, with a SAC value of 0.4922, DP value of 10/256, LAP value of 0.1328, and FPA value of 0. These outcomes suggest that the proposed algorithm has the potential to be further enhanced and can efficiently generate S-boxes that can withstand various cryptanalysis methods.

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Estimating The Error Of Local Interpolation Spline Functions In The Class Of $W^1[a_1,b_1]$ Functions And Creating A Digital Processing Model Of Geophysical Signals

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Abstract: Today, various mathematical models are being developed in the scientific-methodological study of the problems arising in the industry and the industry, and these models are of great importance. Therefore, the use of spline functions, which are considered effective and important in the development of modern science and technology, is an urgent issue. One of the remarkable properties of the spline function is that it has been proven to have a number of advantages over the existing classical interpolation multipliers. In this work, we consider the error estimation and application of the local interpolation cubic spline function in $W^1[a_1,b_1]$, which is built on the basis of a linear combination of parabolas with 2 common points. In this paper, all error properties of local interpolation cubic spline functions are analyzed based on digital processing of geophysical signal obtained on the basis of several experimental data. The local interpolation error of the cubic spline functions in the derived area was evaluated and verified using graphs and numerical analysis based on specific examples.

Keywords— Spline function, signal processing geophysical signal, digital signal processing, interpolation.

I. INTRODUCTION

The local interpolation cubic spline functions are used in the digital processing of various geophysical, biomedical and many other signals, in the approximate calculations of regular, singular and Fure integrals, in the approximate solution of regular integral equations, singular integral equations and Fure integral equations. Some results in building formulas are given in [1-5]. With the help of such splines, it is possible to build digital signal processing models, build effective quadrature and cubic formulas. Such local splines include Hermite splines, which interpolate the function together with the derivatives of the given order, and Ryabenkov [1,4,7,9,12,13,16] splines, which interpolate the values of the function at the grid nodes. From [4, 7,9,12,13,16], we see that the order of maximum approximation to the Ryabenkov cubic spline is O(h^2). The local cubic spline considered below has a maximum approximation order of O(h^3), after which the interpolation process becomes saturated. Based on the construction procedure of the spline function with defect equal to 2 as given in [Scopus article link], we can determine the following from the conditions for determining α_1, α_2, α_3 and α_4 [2,8,11,17]:

$$\alpha_1+\alpha_3=1, \qquad \alpha_1+\alpha_2+\alpha_3+\alpha_4=1 \qquad (1)$$

determining that $\alpha_3=1-\alpha_1$, $\alpha_4=-\alpha_2$. from above [3,5,7].

After the condition of joining the first and second derivatives of splines $S'_i(x)$, $S'_{i+1}(x)$ and $S''_i(x)$, $S''_{i+1}(x)$ x_{i+1} at the node, after simplifications we have the following:

$$\alpha_1(\Delta^2 f_{i+1}-\Delta^2 f_{i-1})+\alpha_2\Delta^3 f_{i-1}=\Delta^3 f_i\,, \qquad (2)$$

$$\alpha_1(\Delta^4 f_{i-1})-\alpha_2(\Delta^2 f_{i-1}+\Delta f_i-\Delta f_{i+2})=\Delta^3 f_i. \qquad (3)$$

where Δ is the finite difference operator.

If we take the solutions of the system of equations (4)-(6) as $\alpha_1^*, \alpha_2^*, \alpha_3^*, \alpha_4^*$ then

$$S_3(x)=S_3(t)=(\alpha_1^*+\alpha_2^* t)y_i(t)+(\alpha_3^*+\alpha_4^* t)y_{i+1}(t)$$

the defect is a spline equal to 1. But there are complex rational functions depending on the coefficients $f_{i-1}, f_i, f_{i+1}, f_{i+2}, f_{i+3}$. Therefore, such a spline is inconvenient for practical use. If we take $\alpha_1=5/6$, $\alpha_2=-1$, we get $\alpha_3=1/6$, $\alpha_4=1$. These values satisfy conditions (1)-, (2)-, but do not satisfy equation (3). It follows that we have an interpolation spline with 2 defects in the section $[x_i,x_{i+1}]$.

$$S_3(f;x)=S_3(t)=(1-t)y_i(t)+ty_{i+1}(t). \qquad (4)$$

here:

$$\varphi_1(t)=\frac{11t^2}{12}-\frac{5t}{12}-\frac{t^3}{2} \qquad \varphi_2(t)=1-\frac{9t^2}{4}-\frac{t}{4}+\frac{3t^3}{2}$$

$$\varphi_3(t)=\frac{7t^2}{4}+\frac{3t}{4}-\frac{3t^3}{2} \qquad \varphi_4(t)=\frac{t^3}{2}-\frac{5t^2}{12}-\frac{t}{12}$$

$$t=(x-x_i)/h\,,\quad h=x_{i+1}-x_i\ [x_i,x_{i+1}]\ \ t\in[0,1]$$

[silka] maqollarda keltirilgan parobolik $y_i(t)$ va $y_{i+1}(t)$ tenglamalar ifodasini (4) tenglikka qo'yib, $[x_i,x_{i+1}]$ kesmada quyidagiga ega bo'lamiz:

$$S_3(f;x)=\sum_{j=0}^{3}\varphi_{j+1}(t)f(x_{i+j-1}). \qquad (5)$$

II. SOME KNOWN RESULTS AND AUXILIARY DEFINITIONS

One of the most widely used methods in electroresearch is the electroprofiling method. Electroprofiling is an exploration method based on measuring electrical resistance, in which changes in relative resistance of subsurface rocks are studied with devices of constant dimensions along given profile directions. In this method, the distance between the supply electrodes does not change during operation, which means to study the approximately constant thickness of the rocks under all points of the profile.

Let the mesh nodes be given in the section $[a,b]$: $\Delta: a = x_0 < x_1 < ... < x_N = b$. Here, P_m is a set of polynomials of degree no greater than m, and $C^k = C^k[a,b]$ is a class of functions with ordered continuous derivatives. $C^{-1}[a,b]$ is a class of continuous functions without discontinuity of the first type. The function $S_m(x) = S_{m,k}(x,\Delta)$ is called a polynomial spline of degree k $(0 \le k \le m-1)$ with defective $\{x_i\}$ nodes, if the following conditions hold [1,3,5,11,22]:

a) $S_m(x) \in P_m$ на $[x_i, x_{i+1}]$, $i = 0,1,...,N-1$;

b) $S_m(x) \in C^{m-k}[a,b].$

Suppose that the values of the function f(x) $f_i = f(x_i)$ at nodes xi of the DDD network are known. A spline $S_m(x)$ is said to be interpolated if the following conditions are met:

c) $S_m(x_i) = f_i, \;\; i = 0,1,...,N.$

A measurable function f(x) is said to be bounded on the section [a, b] if there exists μ such that the dimension of the set of points for which the condition $|f(x)| > \mu$ is fulfilled is zero [7,11]. The smallest of those satisfying this condition is defined as $\underset{x\in[a,b]}{\operatorname{ess\,sup}} |f(x)|$ $L_\infty[a,b]$ is a measurable and bounded space, and the norm in it is defined as follows:

$$\|f(x)\|_{L_\infty[a,b]} = \underset{x\in[a,b]}{\operatorname{ess\,sup}} |f(x)|.$$

The class of functions f(x) with an absolute continuous l-1 and l-order derivative in $L_\infty[a,b]$ on the interval [a, b] is defined as $W^l[a,b]$ [6].

Next, we apply the generalized version of the mean value theorem below. Let $a \le x_1 \le x_2 \le ... \le x_k \le b$ and λ_1, λ_2, λ_3,..., λ_k values have the same sign, and $f(x) \in C[a,b]$. So

$$\lambda_1 f(x_1) + \lambda_2 f(x_2) + ... \lambda_k f(x_k) = (\lambda_1 + \lambda_2 + ... + \lambda_k) f(\xi) \quad a \le \xi \le b. \tag{6}$$

We also use the Taylor series distribution:

$$f(x) = f(a) + ... + \frac{f^{(r-1)}(a)(x-a)^{r-1}}{(r-1)!} + \frac{1}{(r-1)!}\int_a^x (x-v)^{r-1} f^{(r)}(v)dv, \tag{7}$$

or

$$f(x) = f(a) + ... + \frac{f^{(r-1)}(a)(x-a)^{r-1}}{(r-1)!} + \frac{f^{(r)}(\eta)}{r!}(x-a)^r,$$

$$a \le \eta \le x,$$

(8)

These are valid for f(x)<W[a,b] and f(x)C[a,b], so Gelder's inequality also

$$\int_a^b |f(x)| \cdot |g(x)| dx \le \|f(x)\|_{L[a,b]} \|g(x)\|_\infty . \tag{8'}$$

III. Estimating the error of the local interpolation spline function in in the class of $W^1[a_1,b_1]$ functions.

A two-dimensional signal can be viewed as an ordered collection of one-dimensional signals. With this in mind, many of the principles and practices of one-dimensional signal processing in signal analysis and processing apply to two-dimensional signal processing.

$$R_N(f;x) = \sum_{j=0}^{3} \varphi_{j+1}(t) f(x_{i+j-1}) - f(x), \tag{9}$$

here

$$\varphi_1(t) = \frac{11t^2}{12} - \frac{5t}{12} - \frac{t^3}{2} \qquad \varphi_2(t) = 1 - \frac{9t^2}{4} - \frac{t}{4} + \frac{3t^3}{2}$$

$$\varphi_3(t) = \frac{7t^2}{4} + \frac{3t}{4} - \frac{3t^3}{2} \qquad \varphi_4(t) = \frac{t^3}{2} - \frac{5t^2}{12} - \frac{t}{12}$$

Theorem 1. For the error $R_N(f;x)$ of the cubic spline $S_3(f;x)$ determined in (9), it is reasonable to estimate as follows [6,7,19]:

$$\max_{a\le x\le b} |S_3^{(r)}(x) - f^{(r)}(x)| \le R_r, \quad r = 0,1,2,...$$

In this $a_1 = a - h, \;\; b_1 = b + h$ a R_r given in Table 1.

Table 1.

A class of functions	R_0	R_1	R_2
$W^1[a_1,b_1]$	$0{,}75hM_1$		

Proof. 1. We consider the proof of the theorem for the given classes.

For easy verification, the following equality holds:

$$\sum_{j=0}^{3} \phi_{j+1}(t) = 1, \tag{10}$$

In this case, let $f(x) \in W^1[a_1,b_1]$. Putting r=1, a=x, $x = x_{i+j-1}$ in the formula (7), we get the following:

$$f(x_{i+j-1}) = f(x) + \int_x^{x_{i+j-1}} f'(\vartheta)d\vartheta .$$

Applying this equality for j=0,1,2,3, we determine from (9).

$$R_N(f;x) = \sum_{j=0}^{3} \varphi_{j+1}(t)[f(x) + \int_x^{x_{i+j-1}} f'(\vartheta)d\vartheta] - f(x) .$$

and from that

$$R_N(f;x) = f(x)\sum_{j=0}^{3}\varphi_{j+1}(t) + \sum_{j=0}^{3}\varphi_{j+1}(t)\int_{x}^{x_{i+j-1}} f'(\vartheta)d\vartheta - f(x)$$

.

Applying equality (10) and using Gelder's inequality, we get:

$$|R_N(f;x)| = \left|\sum_{j=0}^{3}\varphi_{j+1}(t)\int_{x}^{x_{i+j-1}} f'(\vartheta)d\vartheta\right| \le \sum_{j=0}^{3}\left|\varphi_{j+1}(t)\int_{x}^{x_{i+j-1}} d\vartheta\right| \|f'(x)\|_\infty =$$

$$= M_1\sum_{j=0}^{3}\left|\phi_{j+1}(t)(x_{i+j-1}-x)\right|$$

$x_{i+j-1} - x = (j-1-t)h,$ for being

$$|R_N(f;x)| \le [|\phi_1(t)|(1+t) + |\phi_2(t)|t +$$

$$+|\phi_3(t)|(1-t) + |\phi_4(t)|(2-t)]M_1\cdot h$$

If we consider the pointers of $\varphi_i(t),\ \ i=\overline{1,4}$ s, we get the following

$$|R_N(f;x)| \le [-\phi_1(t)(1+t) + \phi_2(t)t + \phi_3(t)(1-t) - \phi_4(t)(2-t)]hM_1$$

It follows that:

$$|R_N(f;x)| \le t(1-t)g_2(t)M_1 h \le g_2\cdot hM_1,$$

$$g_2(t) = 2(1+2t-2t^2),\ \ g_2 = \max_{0\le t\le 1}\{2t(1-t)(1+2t-2t^2)\}.$$

Then,

$$\|R_N(f;x)\| \le 0,75M_1\cdot h\,. \qquad (11)$$

we will have [18,23,24].

IV. Application to Digital Signal Processing Based on the Considered Model.

Geophysical signal recovery presented in Table 2 through the considered cubic spline model was considered. Based on the above sequence, a third-order spline construction program with a defect equal to two was developed in the MATLAB environment and used in digital signal processing (Fig. 1). As we know, industry owners face many problems in receiving geophysical signals and transmitting waves. These problems are: deterioration of signal quality, addition of interference to the necessary information, insufficient reception of signals from certain areas. We can see in the following analysis and applications that the spline model seen above is effective in digital processing of signals with similar problems.

TABLE 2. AMPLITUDE VALUES OF GEOPHYSICAL SIGNALS OVER TIME.

№	Time, seconds	Amplitude, Hz	Spline	Error
1	1	0,0381	0,0381	0
2	1,1	0,038426	0,03856	0,000134
3	1,2	0,038873	0,03902	0,000147
4	1,3	0,039405	0,03948	0,000075
5	1,4	0,03999	0,03994	0,00005
6	1,5	0,040594	0,0404	0,000194
7	1,6	0,041182	0,04086	0,000322
8	1,7	0,04172	0,04132	0,0004
9	1,8	0,042175	0,04178	0,000395
10	1,9	0,042513	0,04224	0,000273
11	2	0,0427	0,0427	0
12	2,1	0,042729	0,04244	0,000289
13	2,2	0,042631	0,04218	0,000451
14	2,3	0,04243	0,04192	0,00051
15	2,4	0,04215	0,04166	0,00049
16	2,5	0,041813	0,0414	0,000413
17	2,6	0,041442	0,04114	0,000302
18	2,7	0,041063	0,04088	0,000183
19	2,8	0,040697	0,04062	0,000077
20	2,9	0,040368	0,04036	0,000008
21	3	0,0401	0,0401	0
			Max:	0,00451

In the next step, we will show the graphic representation of the above table in Figure 1

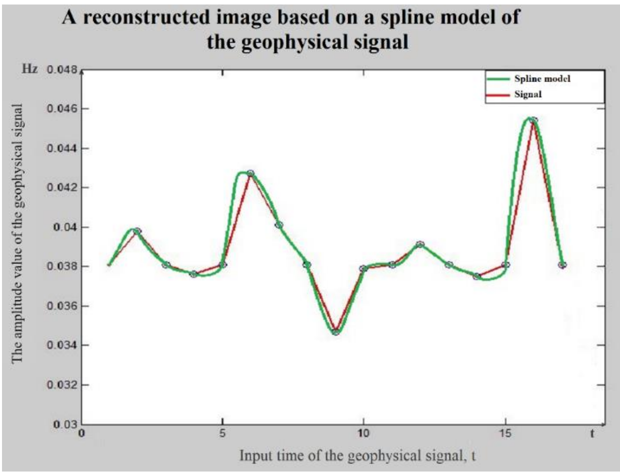

Figure 1. Plot of geophysical signal recovery based on constructed cubic spline function.

As can be seen from the above results, the digitally processed geophysical signal based on the model we proposed showed values equal to its real values, and in the future, in the study of problems in the object, conducting scientific and practical research on the results obtained directly through the Sline model, is the best way to achieve the expected result. [10,13,15,16,21,24].

Conclusion

In conclusion, it should be said that the theory of splines occupies an important place in the development trend of science, especially in solving practical problems. This is also reflected in the article. The development and use of effective and modern models in solving the problems arising in the issues of satisfying the material needs of the population, searching for underground mineral resources and their rational use is considered as one of the urgent problems of today. Also, from the results of this paper, we can see that their research using spline models is a very effective way to solve some of the above problems. If we talk directly about numbers, the result of restoration and digital processing of the geophysical signal obtained as an experiment is as follows: the maximum value of the absolute error of the obtained result is 4.5 * 10-4 Hz. It shows how accurate and effective the model works, and it encourages further study of spline functions, because every good and effective result obtained will serve the further development of science, the progress and future of mankind.

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Mathematical model of summarization of important information units in text documents

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Abstract - This article considers the issue of extracting relevant information units from a set of single-category text documents and summarizing them in the final document. Currently, scientific and practical research directions aimed at extracting important information from electronic information sources through keywords have been formed. These include Text Mining, NLP (Natural Language Processing), NER (Named Entity Recognition), ATS (Automatic Text Summarization). In the article, research methodologies in the literature aimed at processing text documents and forming a summary report or conclusion based on the important information in them are researched. Then, on the example of the Uzbek language, a mathematical model and system infrastructure for extracting and summarizing information units from electronic text documents will be developed.

Keywords—text formalization, document & fragment template, database, rules, information flow, ATS, NER, TextMining

I. Introduction

Currently, documents circulating through information systems, especially documents in EDMS systems, are stored in certain information custodians. Analyzing the content of the documents of this collection relies mainly on human visual observation and intelligence. For example, you can take the EDMS system of a large-scale organization or management body. In this system, the superior organization sends letters to subordinate organizations. There are many subordinate organizations. Lower organizations send a response to an incoming document to a higher organization. Usually, the responsible person(s) in the higher authority ***summarizes*** the response documents through mental work. That is, each answer opens the document individually using application programs (MS Word, Excel), copies the necessary information fragments into a summary document. This means that summarizing the main information units of all documents into one single file requires more time and human effort. Based on this problem, the development of an automatic report preparation tool in order to reduce human labor and ensure the integrity of information is an urgent issue. This includes automatic machine analysis of documents in a set of documents with a specific document template (template, layout) focused on a subject area, and a software tool that develops a report that summarizes the necessary information units in all documents.

A lot of scientific research work is being carried out aimed at extracting information through automatic analysis of documents. As a result, on their basis, the program applications were put into practice. In particular, the analysis shows that the research works determine the document templates, determine the document structure through templates, place the information in the database in the predetermined areas of the template documents, determine the structure of the tables in the document and retrieve the records in it, the text keywords database (KSB) through recognition and analysis of texts in natural language (NLP), transformation of pictorial documents into textual documents (text, table, picture, list, etc.) [10,11]

II. Analysis (KeyWords, NER, ATS)

Web resources on the Internet (eg, websites, user comments, news, blogs, social media networks, electronic newspapers, etc.) are huge sources of textual information. In addition, there is a large amount of textual content in the archives, such as news, novels, books, subject field work documents, references, transcription of dialogues, scientific articles. In particular, the large volume of electronic documents circulating and stored inside and outside the organization belonging to the sector is unique. The content of text documents on the Internet and other archives is growing rapidly. As a result, users spend a lot of time trying to find the information they are looking for. They can't even read and understand all the textual content of the search results. Most of the reviewed texts contain repetitive or irrelevant pieces of information. That is why the compilation and condensing of text resources is an urgent issue. Even if there are several documents in a single file directory with the same structure and a set template, manually summarizing these documents is a costly and time-consuming task. In practice, it is very difficult for humans to manually summarize this large amount of text data. Therefore, there is a strong demand for an automated system that extracts only the necessary information from information sources. Automatic text summarization (ATS) is the main solution to this dilemma.

To achieve this goal, it is necessary to find the necessary text and extract (extract) the information from the initially defined documents. Instead, this issue falls under the scope of Text Minig. Text Mining (text mining) is the process of extracting high-quality information from large volumes of text. Some methods of natural language processing (NLP-Natural Language Processing) such as tagging (marking) POS (Parts-Of-Speech), syntax analysis, N-grams, tokenization, etc. NER (Named Entity Recognition) is used. This includes tasks such as automatic keyword (KS) extraction and text summarization. KS extraction is the main stage of text summarization. Therefore, in this study, attention is paid to both methods [7,9].

Automatic KS extraction is the process of selecting words and phrases from a text document based on a model that can provide the main content of the document without any human intervention [1]. The goal of automatic KS extraction is to maximize the use of computing power and speed in solving the problem of information construction and recovery without the help of an additional human interpreter. The result is the process of extracting the most important features from the text of the document and gathering a summary of the original document. KS extraction methods focus on statistical information derived from features such as word location in a document, word frequency, and inverse document frequency. This information is used to support keywords, calculate trust, and generate keyword lists. The analysis of the literature shows that there are different methodologies used in the KS extraction process and different algorithms in each methodology (Figure 1). Also, KS extraction algorithms have been applied to various subject areas.

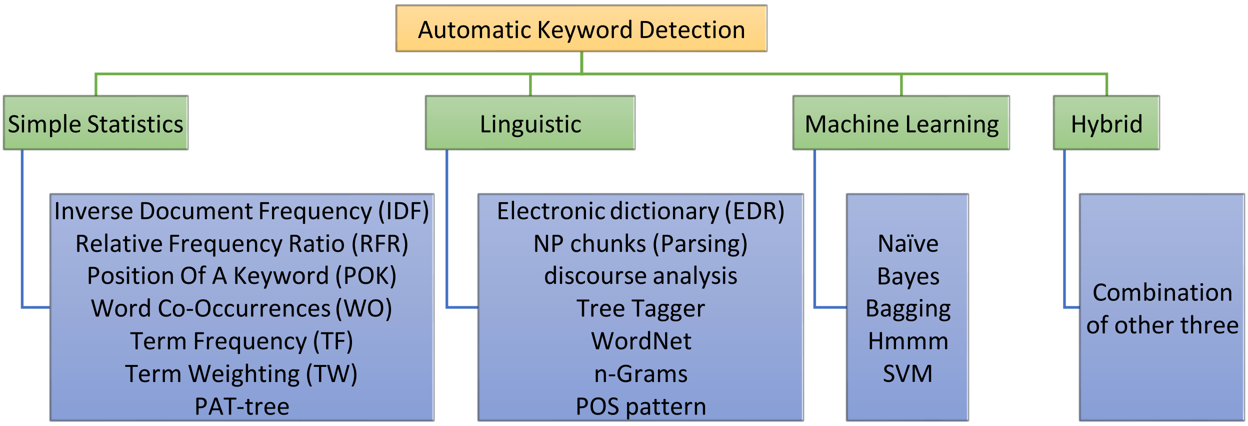

Figure 1. Automatic keyword retrieval classification

Text summarization is the process of extracting the most important information from the text into a reduced version for the user based on a specific task [2]. Usually the result is about 17% of the original text and contains all the information that can be obtained from reading the original article [3]. After analyzing large volumes of data, summarization is an effective and powerful way to gain a sufficient picture of all the data.

The main purpose of the automatic text summarization (ATS) system is to keep short information containing the main content of the input document in less space and with minimal duplication. In this case, users know the content of the document without having to read it completely, without spending a lot of time and effort through automatically generated summaries. An automatic generalization summary can be described as follows:

– summarization extracts the most important information from the source(s) while creating a reduced version of the original information for a given user(s) and task(s);

– A summary can be conventionally defined as a text consisting of one or more texts, conveying important information from the source text(s) and not more than half of the original text(s), and usually much less.

– The summary is shorter than the introduction and contains the most important information from the introduction. And usually it can be defined as a text that is much less than this amount.

The general architecture of the ATS system consists of the following tasks (Fig. 2):

– Pre-Processing: creating the structure of the original text using many linguistic methods, such as segmenting sentences, tokenizing words, removing stop words, tagging parts of speech, stemming;

– Processing (Processing): applying one of the text summarization approaches by applying one or more methods of turning the input document(s) into a summary;

– Post-Processing: Solving some of the problems in the generated sentences, such as resolving anaphoras (contiguous lines) and reordering selected sentences, before creating a final summary.

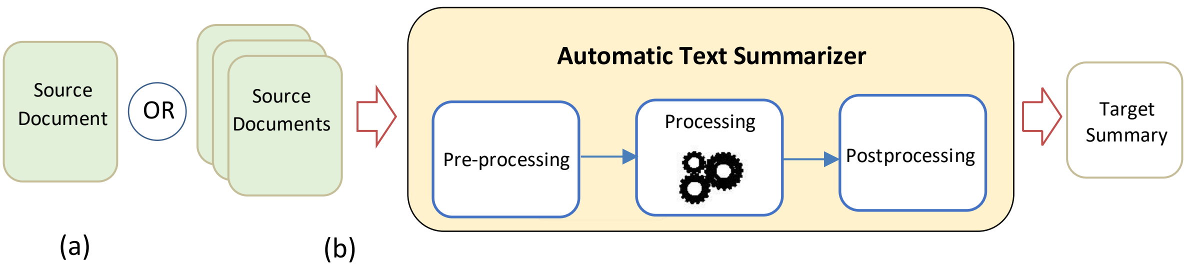

Figure 2. (a) Single-document or (b) Multi-document, automatic text summarizer.

ATS systems can be classified as single-document or multi-document summarization systems. The former infers from a single document, while the latter infers from a group of documents by reducing duplicates. ATS systems use one of extractive, abstract, or hybrid methods for text summarization. The extractive method selects the most important sentences from the input text and uses them to draw a conclusion. The abstract method represents the input text in an intermediate form, and then produces a conclusion with words and sentences that differ from the original text sentences. Unlike extractive summaries, abstract summaries consist of sentences that differ from those of the original document(s). A hybrid approach combines extractive and abstract approaches. Various methods of classification of ATS systems have been studied in the literature (Figure 3) [6].

ATS is one of the most challenging tasks in natural language processing (NLP) and artificial intelligence (AI) in general. ATS research began in 1958 with the automatic extraction of abstracts from journals and technical articles [5]. ATS poses many challenges to researchers, such as: 1) identifying the most informative segments in the input text to be included in the generated summary, 2) summarizing long single documents such as books, 3) summarizing multiple documents, 4) human evaluating a computer-generated summary without the need to compare the generated summary, 5) creating an abstract summary similar to a human-generated summary.

Text mining facilitates the extraction of knowledge and information from large resources. Text mine's goal is to enable the user to find the information they need efficiently. Text mining includes:

– Information retrieval (IR)

– Information extraction (IE)

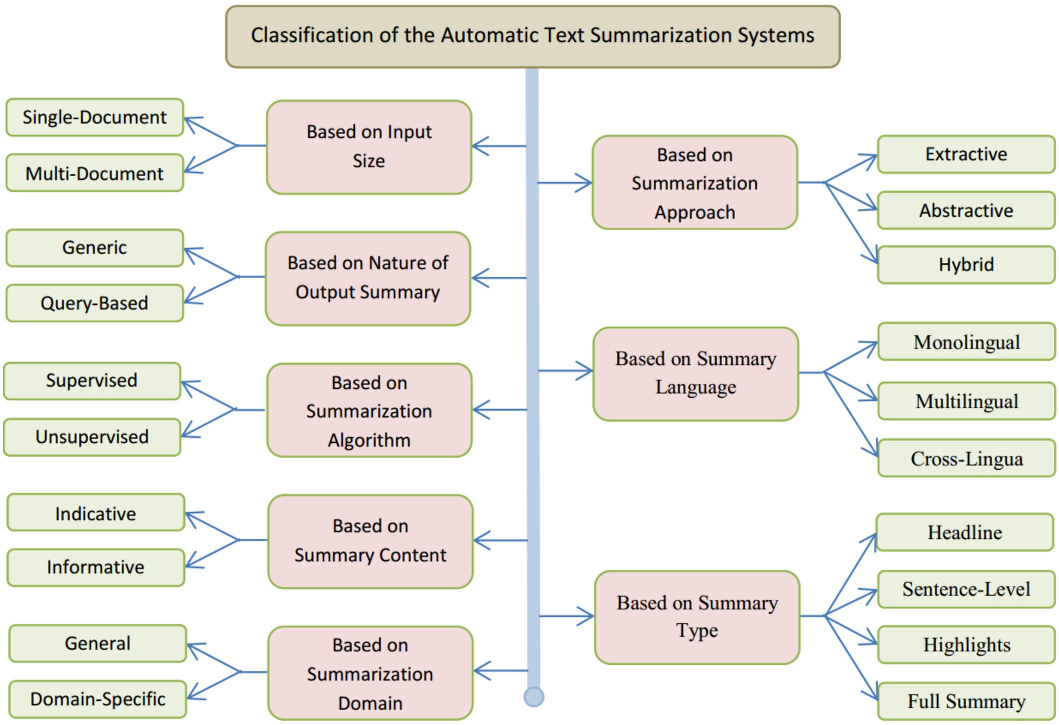

Figure 3. Classifications of the ATS systems.

While the task of information search is to collect and improve relevant documents, information retrieval provides specific information about certain types of subjects and relationships of interests. An IR system aims to extract important textual documents on a specific topic, while an IE system aims to extract predefined data types such as Named Entity and Relationships.

Named entity recognition (NER) is the problem of identifying named entities such as names of persons, organizations, time, location from a given data set or corpus. Named objects include specific subject area (medical, food) objects, user and other objects such as named objects defined in the corpus [8]. For example:

Text:

Kh.Kenjaev participated in the conference held in Tashkent TUIT in 2023 with 3 articles.

Output:

Kh.Kenjaev$_{\textbf{[Person]}}$ participated in the conference held in TUIT$_{\textbf{[Organization]}}$ in Tashkent$_{\textbf{[Location]}}$ in 2023$_{\textbf{[Time]}}$ with 3 articles.

There are three main methods of NER: *rule-based* approaches, *learning-based* approaches, and *hybrid* approaches.

Rule-based approaches consist of a set of rules manually developed by experts. The rules are based on syntactic-lexical patterns, linguistic and subject-subject knowledge. In order to achieve sufficient accuracy and high efficiency, rule-based recognition and classification systems of named objects are developed taking into account the specific characteristics of the subject area. Although these systems have some limitations, they are expensive, not portable, and subject-specific. In addition, these systems require human expertise for subject area knowledge and programming skills. Rules-based NER systems are designed for one subject area only and are not transferable to other subject areas.

Machine learning approaches deal with automatic learning using complex patterns and algorithms that make system decisions more efficient. Learning-based NER approaches fall into three categories: supervised; semi-controlled; uncontrolled.

Hybrid NER approaches are a combination of machine learning and rules. Hybrid systems are more accurate and flexible than other stand-alone systems using a unified learning approach.

Currently popular NER platforms include:

- GATE supports NER across many languages and domains out of the box, usable via a graphical interface and a Java API.
- OpenNLP includes rule-based and statistical named-entity recognition.
- SpaCy features fast statistical NER as well as an open-source named-entity visualizer.
- Transformers features token classification using deep learning models.

III. The Problem of Extracting Information from Documents Expressed in the Uzbek Language

Above, analytical information about automatic KS extraction from text documents, text summarization (ATS) and named object recognition (NER) systems was presented. Special mathematical-algorithmic methods, machine learning, deep learning and artificial intelligence tools are widely used in research [9]. However, there are few research works on extracting and summarizing the necessary information from complex structured text collection documents expressed in the natural language, especially Uzbek language, and the existing works have no specific specifications or are poorly developed.

Based on this, in order to realize the goal of creating an automatic report preparation tool based on the needs of the set of documents in this section, it is necessary to research the problematic tasks in the following sequence:

- Keyword database (objects, designations, subject field terms, etc.);
- Forming a base of templates, fragments and fragment extraction rules representing the structure of documents;
- Development of rules, mathematical models and algorithms for analyzing fragment records through KSB and extracting information units;
- Development of methods and algorithms for summarizing information arrays obtained from documents related to one field and their statistical processing;
- Infrastructure of software tool for automatic summarization of collection documents and IDEF models of information flow management in it;
- Software architecture, operating mechanism and its development.

In addition to the fact that these tasks are very coherent in terms of performance, especially the 1-4 links are mutually inseparable and complement each other. Now the essence of these tasks and the methods or mechanisms of solving them will be discussed in more detail.

Keyword database. NLP, DataMining, TextMining and machine learning algorithms are used to extract the necessary information units from the data of the text fragment recorded in the array. These algorithms for analyzing texts expressed in natural language rely on keywords (KS). Instead, various methods have been proposed for organizing a set of KS, searching for KS from the text and choosing the closest result, which mainly depends on the development of the research of the language in which the text is expressed and the scope of the subject area. In-depth consideration of how to solve the problem within the scope of the research from the point of view of human intelligence will clarify the formation of the CSB and the requirements for it.

Let's imagine that information-reports about one type of objects are given in the form of x_ia text document in Uzbek language. For example, information on the socio-economic conditions of citizens in neighborhoods. If we summarize the documents, the total number of citizens, low-income, entrepreneurs, self-employment, minors and unorganized youth, pensioners, unemployed, intellectuals are three key words related to the activities of the community. But these KS are not found uniformly in all x_i documents, they can be given with other words similar to synonyms that describe the relevant information. Based on these documents, it is necessary to prepare a report document Yas follows.

№	Mahalla name	Total population	Unemployed	Unorganized youth	Self-employment

When a person opens each document, he first focuses on the topic at the beginning of the page, extracts the name of the object (Mahalla) from it and copies it to Y document. Then, in order to determine the total population, KS, such as resident, maker, citizen, is searched from the document. Through the found KS, its indicator is determined based on the rules of sentence structure and copied to document Y. The process repeats for all the required parameters of KS and for all documents. If a KS is not found in some documents, the corresponding column is left blank. This generalization process is based on human intelligence and manual labor.

The process of summarizing the document on the basis of human intelligence can be seen from the example, that it is necessary to build a keyword database (KSB) representing types of objects and their names, terms related to the subject area, and indicators. This KSB is defined as:

$$KSB = \{L, O, P, T, B, R, Q\}, \quad (1)$$

here:

- $\boldsymbol{L} = \{l_1, l_2, \dots, l_{nl}\}$–object names collection *(Kegeili, Nukus, ...)*. An entity is a physical/virtual and existing organization/territory with a location address.
- $\boldsymbol{O} = \{o_1, o_2, \dots, o_{no}\}$- An entity is a physical/virtual and existing organization/territory with a location address *(district, mahalla, school...)*. The name of the object is determined from the document by the object type*;*
- $\boldsymbol{P} = \{p_1, p_2, p_3, \dots., p_{np}\}$- subject areas *(agriculture, public education)* ;
- $\boldsymbol{T} = \{t_1, t_2, \dots, t_{nt}\}$– The name of the object is determined from the document by the object type *(entrepreneur, unemployed, village, land, book, student, citizen, attendance, pension, water, summer,..);*
- $\boldsymbol{B} = \{b_1, b_2, \dots, b_{nb}\}$- terms (combination) related to object types and a set of its synonyms *(attendance (participation, coming to class..), student (student, student, listener,…), teacher (pedagogue, teacher, teacher, trainer, ...), ...);*
- $\boldsymbol{R} = \{r_1, r_2, \dots, r_{nr}\}$– numbers collection _ *(0,…, 9, one, two, … ten, hundred, thousand, million, billion, I, V. X, C…).*
- $\boldsymbol{Q} = \{q_1, q_2, \dots, q_{nq}\}$–abbreviations collection *(TUIT, KSU, NUUz, …)*

These designations are known as KSB. First, the object and its name are determined through KSB, then information units are extracted based on terms related to the selected subject area.

Database of document templates, fragments and fragment extraction rules . Nowadays, $H = (h_i)$ $(i = 1..nh)$there are many software tools for editing or reading text documents. They differ from each other by the file extension. In order to simplify the concept of template and fragment, a document with the extension *.doc, *.docx is taken as an example. Because the MS Word application has become very popular in recent times, the file structure of this application is complicated, along with the support of other text documents (import/export). That is, from a mathematical-algorithmic point of view, it is no exaggeration to say that the analysis of this file provides a very easy analysis of other extension files. So, now the necessary concepts are introduced:

Fragment. The elements that make up the document are conventionally called fragments. Fragments are divided into several types: headings, text, table, list, image. Text documents in organizational activities usually have a main document title, which defines the topic of the entire document. In some documents, the main title also consists of section headings. A *text fragment* is a document that provides information about relevant objects and subjects, and consists of several sentences, sentences from sentences, sentences from sentence fragments, sentence fragments from a sequence of words. The words are divided into categories corresponding to keywords related to the subject area, representing objects/subjects and indicators, dates and numbers, abbreviations, and non-important words. A *list fragment* is a sequence of texts of various objects (and indicators) listed in the document, which is called the main list. Lists have a literal name, usually given in the text by keywords such as "the following/this list". A document may contain several lists, and they are considered different fragments. Instead, each line of the main list consists of sublists, which in turn can cover sublists. Only the head and one level below it are listed in the work. A *table fragment* is a presentation of a collection of information about objects in an ordered form. A document can contain several tables and each table has its own name. The first line of the table is called the table title, and its columns contain the names of the index parameters of the objects. Starting from the second row of the table, all rows are called the body of the table, and in each row, the parameter indicators of a separate object are reflected in the corresponding column. For clarity, in the work, the cells of the tables are considered vertically and/or horizontally unattached. An *image fragment* is a special editing area of geometric shapes in the document, which includes object elements such as a picture. Images will have a name. Usually, the name is placed in the text below the image and is expressed by keywords such as "picture, shape, drawing".

Document template. A page of a text document is a style that contains the content (arrangement of elements) and design (styles, layout) of the document, and it is considered the starting point for creating a new document. Templates are different in terms of subject area, form, content structure, and content, such as the formation of reports on business processes of the organization. The popular standard document templates include personal reference, resume, application, power of attorney, contract, deed, biography, as well as special documents with different purpose and structure in the process of document circulation in the organization.

At the same time that electronic government systems, activity management and online service are being improved, electronic databases of natural language documentation templates have been put into practice in many countries. In particular, since April 1, 2021, "Legal Tech" - legal self-service information system has been launched in our republic (https://yurkhizmat.uz/). The document template is a broad concept, and in order to simplify the work, aspects such as page and layout parameters, header and footer are not considered.

Now, based on the presented concepts, mathematical designations are introduced to document templates and fragments. Fragments are defined as follows:

$$\Phi = \{\varphi_j\}, j = 0..4 \qquad (2)$$

where φ_0– title, φ_1– text, φ_2– list, φ_3– table, φ_4– image fragments.

Based on Φ, the **database templates** of document is expressed in this form.

$$A = \{A^i\}, i = 1..na,$$

$$A^i = \cup_{k=1}^{h} \langle \Phi_k^j \rangle, \Phi^j = \forall \varphi_j, \qquad (3)$$

where na- the number of templates, i - template type, h- the number of fragments in the template, k- is the sequence of occurrence of fragments in the document (ordinal number).

A **fragment database** is a set of rules for extracting $\forall \varphi_j$-fragments from a document. Usually, special characters or tags are used to separate fragments from the file structure of a document, and these separator characters are different in different file formats and extensions. Tags form a pair and consist of opening tags at the beginning and closing tags at the end of the fragment. For example, tags in an html file: <p>text</p>, <table>table</table>. Simple tags are presented here, and documents in other formats (MS Word) may contain more complex symbols. Fragment extraction rules are based on fragment tags respectively. The rules are written in a machine-readable language using special definitions for each φ_j-fragment and each file format. In general, the **fragment database is** expressed as follows:

$$\Psi = \{\varphi_j, file_k, tag_j, role_j\}, j = 0..4, k = 1,2, ... \quad (4)$$

where $file_k$ is the type of file format (docx, html, xml, etc.), tag is a pair of tags and special characters that separate the fragment, $role$ is the rules for extracting the fragment by tag. In the document format types section, the formation and rules of fragment tags are studied in a separate article.

For the purpose of linking fragment rules, as an example, the rules for φ_3 - tabular fragment can be given as follows:

If the document extension is html and there are opening-closing (<table>…</table>) tags of the tabular fragment, then this intermediate data should be extracted into the variable φ_3^0. Then, before the drop-down tag (<table>), check if there is a string (<p>…</p>), if this string contains keywords that represent the table, then the data of this string is φ_3^{name} o' be written to the variable. Let the table header be written to the φ_3^{header} array, and its rows to the φ_3^{body} matrix, using the function of extracting table data from φ_3^0.

Database of fragment templates. Above Ψ, only a fragment block is extracted from the document through. The quick extraction of information from these blocks that is close to the subject area is an important step. On the one hand, extracting information units based on KSB from the block text seems simple. From the research experience, it was decided that 1) it is necessary to create a separate fragment template base (FAB) for each a_i template fragments or a general document template base (UAB) for a set of documents under consideration and attach KSB to them. Because there are a lot of KS related to the object, firstly, machine operations increase, and secondly, some of them are required for the final report of the user.

Single-target FAB and UAB approaches differ in mechanism and complexity. In particular, FAB - attaching KSB for each fragment in advance increases the labor, if a fragment does not attach KSB, it will not be considered in the text analysis of the fragment. UAB - accounting document template is created in advance and appropriate KS is attached to the information units falling into its fragment fields. In both methods, KSs are inserted by the user into the fragment in the selected template. The FAB method is used in the work, and this fragment is called a keyword database (FKS). As an example, the structure of FKS can be given as in Figure 4. It is possible to select KS from existing KSB and enter other new keywords in fragments. Newly introduced KS are stored in a separate part of the FKS database, which will later be added to the main KSB.

So, based on the above, FKSB is expressed as follows:

$$\Omega = \{\varphi_j, a_i, \alpha_k, \beta_k\}, j = 0..4, k = 1,2, ... \quad (5)$$

where a_i is the selected template, $\alpha_k \subset KSB$ is the selected KS set, β_k is the newly introduced KS set, k is the order number of the FKS. A moderator can create an FKS for their reviewed documents and use it in subsequent reporting documents.

here _ a_i– the selected template, $\alpha_k \subset KSB$– the selected KS package, β_k– the newly entered KS package, k– FKS order number. A moderator can create an FKS for their reviewed documents and use it in subsequent reporting documents.

Extraction of information units from fragments. In the process of document analysis, a template is first selected for which the document is suitable. Then, fragments of the selected pattern are searched sequentially from the document. Extracting fragments from a document is performed using the following function:

$$\Theta(H_h, A_\varphi, \Psi_\varphi) \to X_i^{(j)}, \quad (6)$$

where H_h is the h-th document of the incoming set, A - selected template, Ψ- fragmentation rule, $X_i^{(j)}$- separated (j)-fragment block, the i-th occurrence of this fragment type.

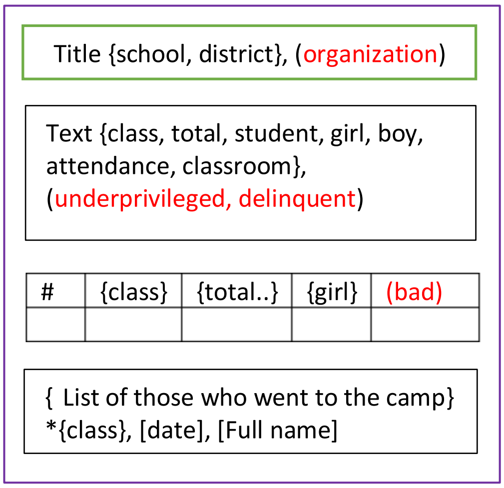

Figure 4. An example of the FKSB structure

Allocated blocks are written to the array as follows, depending on the fragment type:

$X^{(0)}$–title block (with all sentences) in fragment φ_0 of the document;

$X^{(1)}$- text block of the φ_1 fragment found in the template (with all sentences);

$X^{(2)} = (list^{name}, list^{body})$–list name and list block for φ_2 in the template;

$X^{(3)} = (table^{name}, table^{header}, table^{body})$- table data for φ_3;

$X^{(4)} = (image^{name}, image^{picture})$– fragment with image φ_4 in the template.

The information obtained for each of the fragments is recorded separately for the next stage in $X_i^{(j)}$ arrays, where (j) is type of fragment, i is order number. Separate Ψ-like algorithmic rules $\mathbf{\Gamma}$ are developed for processing block data of each type φ_i. It extracts information units from $X_i^{(j)}$ text blocks by FKSB. Since the number of rules for extracting these information units is large and large, this issue will be considered in a separate case. In general, the function of extracting information units is expressed as follows:

$$F\left(X_i^{(j)}, \Gamma^{(j)}, FKS\right) \to E_{k,h}^{(j),r}, r = 1,2,3, \ (7)$$

In general , the mathematical model of document fragmentation and extraction of information units is as follows:

$$H_h \xrightarrow{A_\varphi, \Psi_\varphi} X_i^{(j)} \xrightarrow{\Gamma^{(j)},\ KSB} E_{k,h}^{(j),r}, r = 1,2,3 \quad (8)$$

where $E^{(j),1}$ is the name of the information unit, $E^{(j),2}$ is the value of the information unit, $E^{(j),3}$ is the information format,

k is the number of received information units, (j) is the fragment type, h is the serial number of the current document.

Generalization of information arrays. Now the issue of summarizing information arrays obtained from the documents identified above will be considered. From the formula (8) $E_h^{(0)}$ is the information name of the title fragment of the *h-th* document in the current analysis, and the information units participate in summarizing the information units of other φ_j $(j = 1..4)$ fragments. Taking this into account, the model for forming a generalized reporting document (Δ) can be expressed as follows:

$$\Delta = \cup_{j=1}^{4} \cup_{h=1}^{nh} \Lambda^{(j)} \left(E^0 \bowtie E_{k,h}^{(j),r} \right), \tag{9}$$

where (j) is the type of fragment, nh is the number of documents in the analysis, $\Lambda^{(j)}$ is the function of summarizing information units corresponding to (j)-fragment together with E^0. The idea and result of $\Lambda^{(j)}$ operation are interpreted as follows:

$\Lambda^{(1)}$ – an automatic table is created from the information units extracted from the text block. In this case, the title of the table is built in the following order: in the 1st column, the symbol №, from the 2nd column, the name of the object(s) shown in E^0 is placed (*e.g.: school*), in the following columns, the key so shown in the φ_1 text fragment template is placed (e.g.: *total student*, *boys*, *gifted*, ...). According to the rows of the table after the header: the first column is ordinal number of the document (e.g.: 1), starting from column 2 is the value of the object(s) specified in E^0 (e.g.: *number 30*, ...), from the information units of key words taken from φ_1 text fragment are placed in the next columns. Each document falls into one row of the table. Also, if an information unit different from the previous one is found in the fragment φ_1 of the document in the analysis, then a new column is added to the table, the name of the information unit is written in the column header, and the value of the information unit is written in the corresponding line. If this fragment does not have an information unit from previous documents, the cell will be left empty.

$\Lambda^{(2)}$- tabular information units extracted from the table block are combined in the order of documents The sample table given in the φ_2 fragment template is copied to the summary document. The new row after this table header is concatenated by column and contains the value and name of the object(s) specified in E^0. Only the information units specified in the template are copied from the table fragment of the document being viewed in the next line to the appropriate columns.

$\Lambda^{(3)}$and $\Lambda^{(4)}$ are combined in the same order, but through specific actions, the appropriate fragment information units of the documents.

Above, the solution of the tasks, the integration of the implementation of the automatic report preparation tool based on the needs of the set of documents, was studied in detail from a mathematical point of view. As a result, KSB, φ_j – fragments, A^i – base of templates, Ψ – base of fragments, FKS, Ω – base of fragment templates, $\Theta \rightarrow X$ – function of extracting fragments from the document, $F \rightarrow E$ – function of extracting information units, Δ – a model of generalization of information arrays was developed.

Now the issue of creating a software tool that generates a report document based on the proposed mathematical basis of the collection documents is considered.

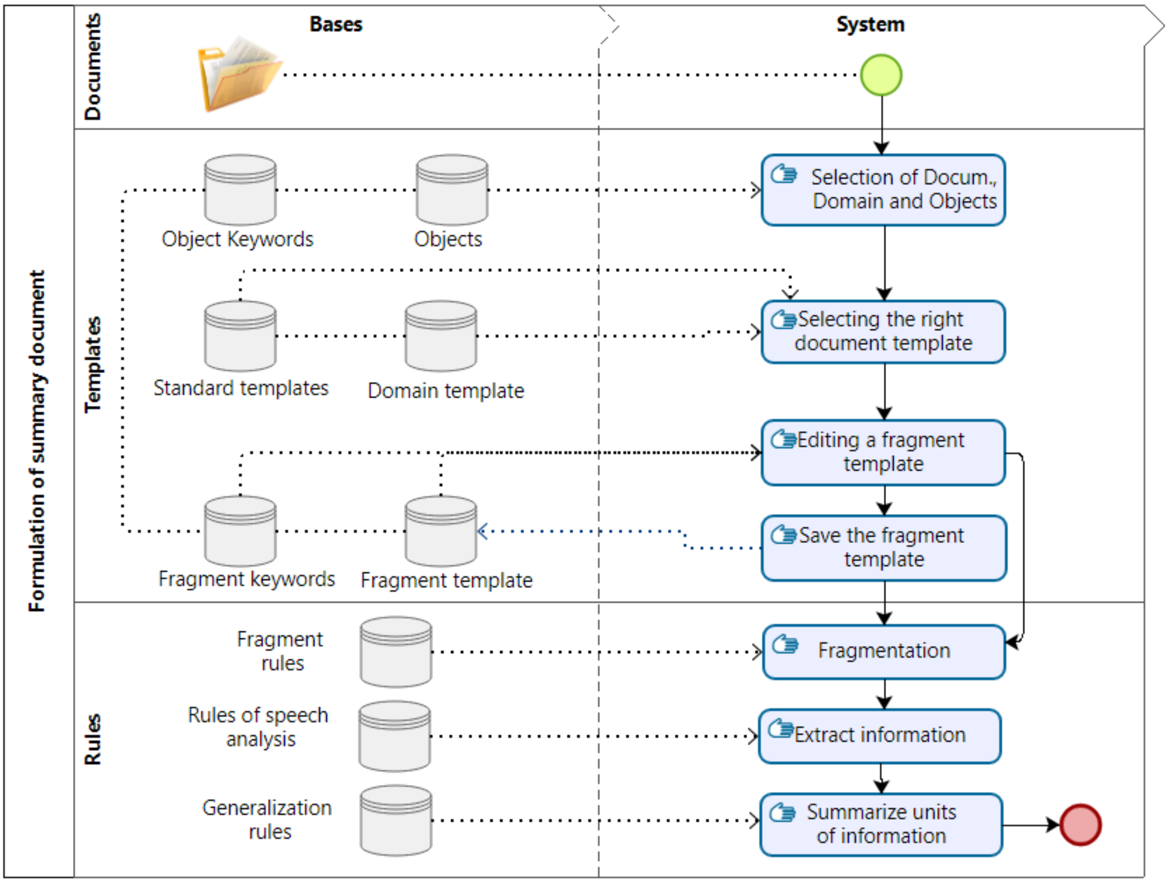

Figure 5. Architecture of a tool for summarizing information units of textual documents based on a model

Based on the needs of the set of documents, the information flow of the automatic reporting software and the infrastructure of the executed processes are proposed as shown in Figure 5. This infrastructure consists of information and knowledge bases and system architecture from the point of view of information flow. The database itself is divided into two parts: databases such as templates, fragments, keywords, and the knowledge base, which provides work with the document structure and information units in the model.

IV. Conclusion

In the article, the methods of KS extraction, text summarization and named object recognition, which are considered directions of automatic processing of text documents, which are in constant development, were studied. stages of tasks were studied. A new methodology for the sequence of tasks has been developed. As a result, a mathematical model and system infrastructure for extracting and summarizing information units from text documents in the Uzbek language was proposed.

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Cyber Security Issues and Approach Solutions in Virtual Education

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***Abstract*— This article discusses the importance of cybersecurity in protecting the vast expanse of the internet and highlights how the security of e-learning systems is often overlooked. Managing security in e-learning systems can be challenging, given the large number of users accessing them through multiple systems and networks. The article delves into cybersecurity issues related to e-learning systems and provides recommendations on how to effectively manage them.**

Keywords— Cyber security, e-Learning systems, cyber-attack, IT policies

I. Introduction

E-Learning systems utilize computing systems and the Internet to facilitate the acquisition of knowledge and skills. Despite their complex structure, these systems offer various benefits, including enhanced student satisfaction with training. Through the use of innovative educational technologies, e-Learning has provided participants with unparalleled opportunities to develop essential skills and knowledge. Nevertheless, these systems are vulnerable to cybercrime due to their use of the Internet. E-Learning systems are open, distributed, and interconnected, rendering personal, protected, or confidential information exposed to constant security risks [2].

E-learning systems such as WebCT, Moodle, and Blackboard are widely used and have undergone significant advancements in recent years. Information sharing, collaboration, and interdependence are the main components of e-learning systems. However, the sustainability of this system relies on ensuring the confidentiality, integrity, and availability of data. Security is a crucial issue in e-learning, and protecting against data manipulation, fraudulent user authentication, and privacy breaches are among the top concerns [1, 6, 7, 10].

The purpose of this article is to categorize the most important cyber security issues relevant to e-learning systems and provide an overview of countermeasures.

II. Education & Cyber security

The pandemic of 2020 clearly demonstrated the importance of distance learning. The use of interactive technologies made it possible not to interrupt the educational process during the exacerbation of the epidemiological situation. Along with understanding the power and potential of distance learning and digital technologies, there has also been an awareness of certain risks and threats [1, 4–6, 10, 12].

While recognizing the unique strengths of distance education, we will also dwell on its shortcomings. We present the above aspects in Table 1.

TABLE I. SWOT analysis for e-Learning

STRENGTHS
– Technological effectiveness – Availability and openness – Savings on the expenses accompanying face-to-face training process – Individual approach Development of independence – Opportunity to train different groups of the population
WEAKNESSES
– Weak development of information content – Weak equipment of the subjects of the educational process – Lack of live communication (personal communication) Poor control – Difficulties in assessment (low opportunities for assessment options) – The problem of verifying the identity of a student in an online lesson – Low level of cyber security – Insufficient level of technical equipment of all participants in the distance learning process

The modern education system requires the use of information systems and technologies to meet the needs of diverse students. This involves incorporating e-Learning, webinars, and other online digital content in addition to traditional classroom instruction. Building trust and promoting engagement among users is crucial in online learning systems. These systems can be categorized as either synchronous or asynchronous, depending on the method of implementation. Synchronous learning provides real-time interaction between students and mentors, while asynchronous learning enables participants to exchange information or ideas without being present at the same time as others.

Building digital trust. The higher education system is undergoing a transformation, with the advent of online education systems providing students with the opportunity to participate remotely. As students become more familiar with information systems and technology (IST), course providers are also improving their overall learning strategies. In the online learning process, both digital natives and digital immigrants need to feel confident about the ease of use, security, and protection of their personal data within the e-learning system. Moreover, it is crucial to ensure the security of students' bank details for payments and other available products. As major research universities conduct sensitive and commercially relevant research, cybercriminals are increasingly attracted to them. Hence, it is essential for everyone to prioritize the security of the university's information system.

BYOD. The use of personal devices in educational institutions, known as Bring Your Own Device (BYOD) policy, can lead to potential data protection issues as the device belongs to the user and not the institution. In addition to accessing the university network through computers located in specific computer rooms, students can also access it through their personal devices from various locations on or off campus. It is the responsibility of the university to ensure that the processing of personal data adheres to national and international Data Protection Act (DPA) principles of good information practice. The DPA law grants users clear rights to their personal data and imposes certain obligations on the organizations responsible for its processing. However, the BYOD policy may vary depending on the institution.

Security in learning management systems. Trust is not given much importance in traditional e-Learning systems as they do not meet the essential security requirements. Educational strategies are primarily designed and executed based on pedagogical principles, with security concerns often being overlooked. Consequently, various undesirable situations that can negatively impact the educational process and management may arise, including falsification of grades, identity fraud, interference with private conversations, altering dates, and mentors gaining access to students' personal information.

The researchers suggest using a security approach based on Public Key Infrastructure (PKI) models, which can fulfill several security requirements such as identity authentication, non-repudiation protection, and fault control [13]. PKI is based on public key cryptography, which provides authentication of the message sender and encrypts data on the internet. While conventional symmetric cryptography is commonly used for data encryption and decryption, it can create problems since the key is unique and key generation and exchange in the system can be problematic. In other words, if the key falls into the wrong hands, messages can be easily decrypted. Therefore, using public key cryptosystems is preferred on the internet.

Highest cyber security threats. With the fast-paced advancement of mobile devices and the growing desire for cutting-edge technology, their influence on society is expanding. This trend is generally positive, but it also increases the prevalence of malware due to outdated operating systems on devices receiving less attention than updated ones. This negative impact extends to the university network as well. Additionally, issues with device support systems, as well as their connections and interactions with the university system, may arise.

University students are among the most frequent users of social media, which can pose a risk for hosting and spreading malware. However, prohibiting access to social media sites altogether is not a viable solution. Instead, the focus should be on promptly detecting infected devices, securing the network, and safeguarding important data.

Virtualisation of desktops. Virtualization has become a popular and cost-effective strategy for many organizations, including universities. However, as more users switch to virtual environments, there are increased security threats to consider. It is essential to keep in mind that any device that is connected to the system can pose a potential risk.

Consumerisation of IT. The concept of consumerization of IT describes the trend in which individuals expect to use their personal devices, such as smartphones and tablets, to connect to corporate networks. Nowadays, many people are requesting that organizations allow them to use their own preferred and convenient devices. However, this can have an impact on networks that have already established policies, platforms and security measures in place to protect the security of company data.

III. Security threats, detection and protection

Electronic services, including e-learning, face similar challenges and share the same characteristics that require information sharing and distribution. As a result, their workflow is connected to the Internet, which is widely regarded as a network of risks [11]. In light of this, organizations must give more attention to security risk management, taking into account the various types and levels of threats and vulnerabilities. These can be classified into several categories, including:

- software attacks (viruses, trojans, worms, denial of service, macros),
- cyber espionage (advanced persistent threats (APT), social engineering),
- acts of theft (illegal equipment or information)
- intellectual property (piracy, copyright, infringement).

When we classify threats based on vulnerabilities, we examine the risks to each component of information security. For confidentiality attacks, we observe traits like cryptographic storage systems, data leakage, and direct links. Attacks on integrity involve buffer overflow, cross-site scripts, cross-site request forgery, injections, and executing malicious files. Authentication attacks include broken authentication and session management, and untrusted communication. Attacks on availability refer to denial of service [3, 8, 9].

TABLE II. The most serious threats

	THREATS	EXAMPLES
1	Deliberate software attacks	viruses, worms, macros, denial of service
2	Technical software failures and errors	bugs, coding problems, unknown loopholes

3	Acts of human error or failure	accidents, employee mistakes
4	Deliberate acts of espionage or trespass	unauthorised access and/or data collection
5	Deliberate acts of sabotage or vandalism	destruction of information or system
6	Technical hardware failures or errors	equipment failure
7	Deliberate acts of theft	illegal confiscation of equipment or information
8	Compromises to intellectual property	piracy, copyright, infringement
9	QoS deviations from service providers	power and WAN service issues
10	Technological obsolescence	antiquated or out-dated technologies
11	Deliberate acts of information extortion	blackmail for information disclosure

A threat can refer to an entity or situation that presents a danger. The use of password-based authentication systems has resulted in a rise in phishing attacks, which aim to steal confidential user information. Virtual learning environment providers and content distributors are primarily responsible for ensuring the security of the learning environment and safeguarding students' private information. The reliability of the educational environment is judged by the students themselves. Privacy and security concerns in virtual education have been prioritized based on user data, as illustrated in Fig. 1.

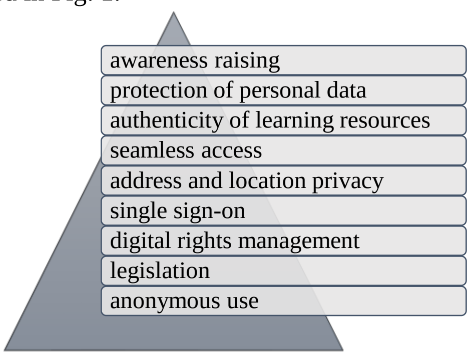

Fig. 1. Privacy and security issues in virtual education

There is a question regarding what steps can be taken to safeguard e-learning systems against security issues that are important (such as data manipulation, user authentication, and privacy). Here are some recommended tips to address these security concerns:

- Installing firewalls and anti-virus software
- Implementing Information Security Management (ISM)
- Improving authentication, authorization, confidentiality, and accountability
- Using digital right management and cryptography
- Training security professionals

Information Security Management (ISM) must be properly implemented to manage and mitigate risks and threats. It includes policies, processes, procedures, organizational structures and software/hardware functions.

IV. Developing a Security Management for e-Learning Systems

To ensure information security in educational institutions, it is important to adopt a corporate approach to risk management within existing governance structures. This means defining the control of information and classifying the threats faced by the institution, followed by adopting appropriate measures as a solution. All participants in the system must take responsibility for daily risk assessment, management, and reporting. It is also crucial for higher education institutions to be aware of their responsibilities in protecting institutional and research data and complying with national and international data protection laws. While most universities have different structures and levels of controls for managing confidential information, the lack of a general approach and management can create security issues.

The overall responsibility for network security within a university lies with network security providers, particularly network administrators. They are responsible for ensuring that information exchange between all parties is secure and for developing policies and procedures to counter any security threats. However, the role of the users in maintaining network and information security is also critical. Users must be able to accurately evaluate the importance of the information they possess, the level of security required, and avoid disclosing any confidential information to unauthorized parties.

To summarize the above, a good, effective and highly secure distance learning platform is long-term and reliable, and its use will serve both the users and the system administrators in the long run. Therefore, the distance learning platform containing the 9 steps shown in Fig. 2 below can be considered as a secure system.

1. *Develop a detailed plan*. Prior to starting the development of your e-Learning program, it is crucial to first establish your learning objectives, determine your intended audience, and select the appropriate Learning Management System (LMS) for your needs. The LMS serves as the backbone of your e-Learning initiative, enabling content delivery, progress monitoring, assessment management, and reporting on learner performance. Moreover, a reliable LMS must also provide a secure e-Learning environment that restricts access to authorized users only.

2. *Coordinate with your IT department*. When creating your e-Learning program, it is crucial to involve your IT department since they possess a wealth of experience in managing information. They can assist you in creating a secure Learning Management System (LMS) and identifying possible security threats.

3. *Require strong authentication*. To maintain a secure e-Learning environment, it is crucial to ensure that usernames and passwords are strong and not shared. The Learning Management System (LMS) should permit learners to modify their passwords at any time, and it is recommended to require password changes on a regular basis.

Moreover, in addition to strong passwords, the LMS should also offer the ability for learners to require further authentication when logging in from a new device. For instance, a user attempting to log in from a new computer may be prompted to provide a verification code sent to their mobile phone. This extra layer of security ensures that only authorized users have access to the e-Learning environment, even if the password is known to unauthorized individuals.

4. *Create clear compliance policies*. While safeguarding content from unauthorized access is important, protecting sensitive user data from misuse is even more critical. Learners may be hesitant to participate in your e-Learning program if they believe that their personal information could be compromised or utilized for illegitimate purposes. Furthermore, organizations that disregard data privacy regulations and laws could face hefty fines.

Therefore, it is essential to communicate your data protection policies clearly to your learners. You may provide a link to your privacy policy or include a statement on your login page, for example. Your Learning Management System (LMS) should allow you to customize settings that adhere to your industry-specific regulations.

5. *Perform a risk assessment*. The occurrence of cybersecurity threats and data breaches is on the rise, and they are not only more common but also more costly than in previous years. To prevent these expenses, it is important to conduct a risk assessment that will enable you to create a secure environment that reduces the risk of data breaches and unauthorized access to data.

For several organizations, the most significant security risk is internal, rather than external. It is crucial to conduct a comprehensive risk assessment of your e-Learning environment and identify any potential vulnerabilities. Your risk assessment should comprise an evaluation of your permissions structure and access control techniques, authentication techniques, device policies, monitoring policies, encryption methods, disaster recovery plan, and other factors. Additionally, the risk assessment will assist you in ensuring compliance by identifying security gaps and best practices.

6. *Maintain accurate records*. Maintaining records is another crucial aspect of compliance. Documentation and records are necessary for monitoring, reporting, and resolving compliance concerns. They can also serve as crucial evidence in legal proceedings. To ensure effective record-keeping, the use of state-of-the-art technology is necessary. By implementing best practices for data archiving, you can ensure the security and authenticity of your records. This will enable you to effortlessly manage your communication logs and search your repository for evidence, if necessary. Furthermore, these solutions can automate data retention, erasing emails after a specific period, which simplifies record-keeping and compliance.

7. *Encrypt data*. Your e-Learning platform should be completely encrypted to ensure that everything is shielded from unauthorized access, including data in transit and data at rest. It is important to choose an LMS that offers end-to-end encryption, which safeguards information as it moves between the user's browser and the server. Furthermore, your LMS should also encrypt data while it is stored on the server.

8. *Educate your employees*. Your workforce can be a vulnerable point in your security measures, with 85% of data breaches caused by human error, as per Tessian [2]. It is therefore essential to educate your employees on cybersecurity risks and best practices. By providing regular training and cybersecurity simulation exercises, you can keep your staff up to date on the latest information and identify those who may require additional training on cybersecurity best practices.

You should provide your learners with information on various cyber threats, such as phishing and ransomware attacks, and teach them how to recognize potential risks. Additionally, train them on how to identify phishing attempts and common social engineering tactics. It is vital to communicate that cybersecurity is a shared responsibility and that every employee plays a role in maintaining a secure environment.

9. *Perform updates and test regularly*. Continuing to maintain a secure e-Learning environment is crucial even after it has been built. Regular software updates must be performed and tested thoroughly to patch any security vulnerabilities and make the LMS and e-Learning environment more robust. Consistently testing the LMS and e-Learning environment can also help identify any security risks before they become a problem.

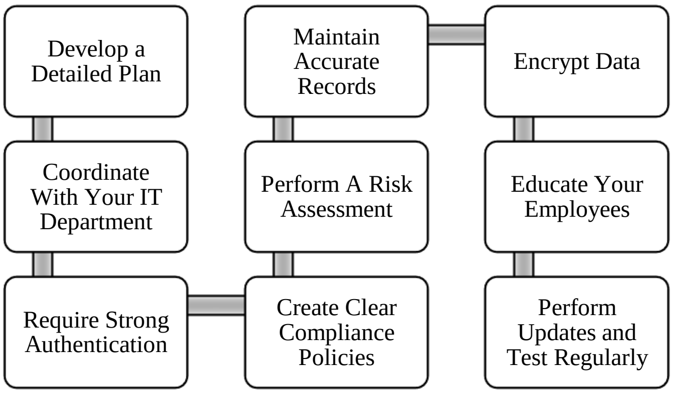

Fig. 2. Developing secure e-Learning environment

In addition, keeping your policies up to date is vital. Laws and regulations are continuously changing, so it is your responsibility to stay current. Even if the criteria have not changed, conducting regular audits can help detect potential issues before they become serious problems.

V. CONCLUSION

The growing interest in online education is likely to result in the creation of new virtual learning services, which could have a significant impact on traditional education practices. However, the need for flexibility, mobility, and scalability in e-learning can lead to various security challenges that make it difficult to manage and control data usage, storage, and handling both inside and outside the virtual classroom. This article explores the security concerns arising from e-learning and suggests solutions to address these issues.

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Solving the Problems of normalization of non-standard Words in the Uzbek Language Text

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***Abstract* – Text normalization holds a crucial role within text-to-speech systems, with a particular challenge lying in the differentiation of non-standard words. This research establishes a classification system for non-standard words by analyzing an extensive collection of Uzbek speech. A dual-phase method is suggested for enhancing non-standard words, involving initial categorization through finite state machines and subsequent subclass identification using maximum entropy classifiers. Through this approach, a remarkable 98.53% accuracy is attained during open testing. Empirical studies emphasize the efficacy of the non-standard word classification system, showcasing substantial advancements due to the implementation of maximum entropy classifiers.**

Keywords — artificial intelligence, machine learning, deep learning, speech, text to speech, non-standard words, FST, FSA, classification.

I. INTRODUCTION

Paraphrased: Text-to-speech (TTS) is the process of simulating human speech from a written text using machine learning techniques. The concept of speech synthesis dates back to the 18th century when the first rudimentary talking head systems attempted to mimic human voices, albeit with imperfections. Nowadays, there are numerous speech synthesizers worldwide that transform electronic text written in various languages into audible speech signals. The methods and tools used for this synthesis vary depending on the linguistic and phonetic characteristics of the chosen language. Presently, a key focus of research is improving the organization of speech synthesis and preprocessing of electronic texts to achieve a more accurate and natural linguistic expression in the selected language, ultimately aiming for speech signals that closely resemble natural human pronunciation [1].

Text normalization holds a critical role in text analysis within Text-to-Speech (TTS) systems. The Uzbek language encompasses numerous non-standard words, primarily because their characteristics elude standard dictionaries and "letter-to-sound" pronunciation rules [2, 3]. These non-standard terms necessitate transformation into their standard equivalents, a process referred to as text normalization. In English, non-standard words encompass numeral expressions, abbreviations, and even sentence segmentation, all integral components of text normalization. For Uzbek, the focus shifts to the normalization of non-Uzbek elements like numbers, symbols, and alphabets, adapting them to Uzbek forms. The conversion of non-standard words to appropriate standard counterparts varies based on local context and text genre, posing a complex challenge often likened to homograph detection [4, 5]. Nuance Vocalizer dedicates over 20% of its core application code to text normalization, reflecting its significance, and the framework continues to evolve with new input formats. Conventional text normalization approaches lean on straightforward rules, yet these tailored rules prove cumbersome to create, maintain, and adapt for emerging domains.

Conversely, the pursuit of homograph detection has witnessed the implementation of numerous machine learning methods, with decision trees and lists finding use in normalizing text, especially in English and Hindi, and notably in the Uzbek context. Text data undergoes classification and is harnessed in alignment with the support vector machine (SVM) classification algorithm [6]. Currently, there is a significant focus on researching the recognition and processing of Uzbek speech, resulting in numerous scientific publications. However, there is a notable lack of research in the area of synthesizing Uzbek electronic texts into speech signals and advancing computational linguistics for the Uzbek language. Specifically, there is insufficient exploration in text analysis and processing, representing texts in a syllabic format, identifying and rectifying grammatical errors in text, and developing real-time speech synthesis systems [7, 8, 9]. In this research, we delve into the comprehensive structure of TTS systems, including their various stages, descriptions, and sequences. Furthermore, we provide a classification of methods employed in text-to-speech systems. In the subsequent sections, we will delve deeper into these aspects to expand our knowledge and skills in this domain.

II. RELATED WORKS

The evolution of TTS systems has seen remarkable progress, with the initial synthesizers being mechanical devices capable of producing individual sounds or small segments of human speech, similar to musical instruments [10]. Among the methods used in TTS, one of the simplest yet effective approaches is the concatenative method. This method is detailed in works [11, 12], outlining the algorithm and presenting its outcomes in addressing speech synthesis challenges. The core principle of this method involves combining pre-recorded speech segments. However, it has notable drawbacks, including the requirement for substantial storage capacity and limited flexibility in modifying the sound. In the context of normalizing Uzbek text, the primary approach involves rule-based modules that operate prior to the word segmentation phase. This choice is made because Uzbek text often features variable spacing between words to accommodate different situations [13]. The prevailing approach to Uzbek text normalization relies on external rules, encompassing more than 15 distinct external rules, along with linguistic and discourse datasets. Scientific literature generally advocates for this rule-based Uzbek text normalization method [14].

Conversely, some researchers advocate for an integrated framework that combines word segmentation, named entity recognition, and the handling of nonstandard words. This holistic approach aims to streamline these processes within a unified structure [15]. The text normalization approach introduced in this research eliminates the need for a separate word segmentation process. Instead, it employs finite state machines to detect non-standard words within the text, undertaking an initial classification. Subsequently, maximum entropy classifiers are applied to achieve a more refined categorization of these non-standard words. Following a methodical analysis of a substantial TTS corpus, an exhaustive non-standard word taxonomy was formulated. This taxonomy serves as the foundation for a three-tier normalization procedure. The initial phase involves the utilization of finite state machines for detecting and provisionally categorizing non-standard words.

Subsequently, the application of maximum entropy classifiers refines the classification, while numerical state transducers aid in the generation of standard words. The non-standard word taxonomy stands as a cornerstone of the text normalization process. It establishes distinct categories for non-standard words, thus guiding their identification, classification, and subsequent modification. Notably, the Uzbek language’s textual content mainly entails the normalization of Arabic and Roman numerals, alongside specific symbols. The taxonomy itself encompasses 30 distinct numerical divisions (Table I).

TABLE I. TAXONOMY OF NON-STANDARD WORDS BASED ON INPUT FORMATS

Numbers	Numbers	1,2,3, ... and so on...
	point	1.29, 2000.9.10, 162.105.81.14, …
	defis	1998-2002, 2000-9-10, 4-3-2-1, …
	slesh	1/3, 2000/9/10, …
	pointer	10:15, 10:15:20, ...
	additions	%,s(ten thousand), adjectives,...
	range	100-200 Ď(100 dan 200 kishigacha), …
	others	‘99, ...
Symbols	-, /, :, ., ×, >, =,	
Others	URL, Email, Alphabets, …	

Table I furnishes a succinct overview of the non-standard word taxonomy. The initial classification of non-standard words hinges on their structural characteristics. Notably, within the algorithm, 95% of the 276 identified non-standard words belong to categories such as numerical strings, numeric strings accompanied by diverse character combinations (dot, hyphen, slash, colon), and numerical expressions featuring suffixed number strings, including Uzbek qualifiers. Another category pertains to characters, some of which possess multiple pronunciations. The normalization process for URLs and email addresses is straightforward [16]. Additionally, strings comprised of English alphabet characters are equipped with their corresponding Uzbek translations. Any other infrequent non-standard words are encompassed within the catch-all "Other" category. In total, the taxonomy encompasses 48 unique types of non-standard words presented in varying formats. Among these types, some exhibit distinct pronunciations, while others lack such distinctions.

III. SUBCLASS DISAMBIGUATION

The most cutting-edge techniques in the field of speech synthesis rely on deep learning approaches, as evidenced by research papers. These advanced speech synthesizers are trained using recorded speech data. Notable examples of deep learning-based synthesizers include WaveNet by Google DeepMind, Tacotron by Google, and DeepVoice by Baidu. Among these, the Tacotron model by Google is recognized as a modern and high-quality acoustic model. In fact, elaborates on a method based on the acoustic model belonging to the Tacotron2 family. Further scientific literature, as found in papers, provides insights into the ParallelWaveGAN neural vocoder, which represents the final stage in contemporary TTS systems. This vocoder plays a crucial role in converting the acoustic features obtained at the input of the acoustic model into a natural speech signal. Indeed, speech synthesis is a field with a long history of development, and over time, it has introduced numerous methods that vary in terms of the quality of the synthesized speech, algorithm complexity, and memory requirements [17]. ANSWs have different ways of pronunciation in different contexts. A subclass disambiguation process is needed to determine the true pronunciations in certain contexts. A maximum entropy classifier is built for each ANSW class.

A. *Maximum Entropy Classifier*

The maximum entropy framework agrees with everything that is known, but carefully avoids anything that is unknown. In other words, it estimates probabilities based on the principle of making as few assumptions as possible, under the constraints imposed. The probability distribution that satisfies the above property is the one with the highest entropy. It has an exponential form as in formula (1) below.

$$P\,(y|\,x) = \frac{1}{Z(x)}\exp\{\textstyle\sum_i \lambda_i f_i(x,y)\} \tag{1}$$

Where x is a history or context, y is the outcome or category, and Z (x) is a normalization function (2).

$$Z(x)\,\textstyle\sum_y \lambda_i f_i(x,y) \tag{2}$$

The features used in the maximum entropy framework are binary. Any useful evidence sources can be incorporated into the model as features, without conditional independence assumption. Here is an example of a feature function or indication function, which implies the fact that digit string “110” should be read digit by digit (3).

$$f_i(x,y) = \begin{cases} 1 & if\ y = dd, nsw = 110 \\ 0 & otherwise \end{cases} \tag{3}$$

The training of maximum entropy model is to learn parameters λ_i . Parameter estimation methods include Generalized. Iterative Scaling (GIS), Improved Iterative Scaling (IIS), L-BFGS and BLMVM, etc. Data smoothing methods include Gaussian prior, exponential prior, and inequality smoothing algorithm [17]. The fast parameter training method BLMVM and inequality smoothing algorithm are employed in our maximum entropy classifiers [18].

B. The Feature Templates

The set of classifiers have both public features and private features. Public features are shared by all classifiers while private features are designed specially for each classifier. Public Features, as follows, are n-gram Character features within window size (equals 4 here):

$$\begin{gathered}\textit{Uni-gram: } C_n\ (n=-4,-3,-2,-1,0,1,2,3,4)\\ \textit{Bi-gram: } C_nC_{n+1}\ (n=-4,-3,-2,-1,0,1,2,3)\\ \textit{Tri-gram: } C_nC_{n+1}C_{n+2}\ (n=-4,-3,-2,-1,0,1,2)\\ \textit{4-gram: } C_nC_{n+1}C_{n+2}C_{n+3}\ (n=-4,-3,-2,-1,0,1)\end{gathered} \tag{4}$$

Here, C_n can be a Chinese character, a digit string, an alphabet string, or a symbol (5).

$$C_n = \begin{cases} \text{num} & if\ \ n \neq 0 \wedge C_n\ is\ digits \\ C_n & otherwise \end{cases} \tag{5}$$

If Cn in context is a digit string, it is substituted by “num”, for a specific number may be not as indicative as the fact that it is a number. Private features include some heuristic information for specific classifiers. Take the classifier for NSW type “digits” as an example. Its private features are as follows:

- The number of digits in NSW If it begins with zero;
- If it is preceded with alphabets If it is followed with alphabets;
- While for NSW type “year”, private features are about the range of the number before “ٝ (year)”;

Standard word generation is the last module of text normalization.It is a generation step while former steps are analysis steps. The input of this module is NSW itself and its class tag. The output is its corresponding Chinese words. The conversion is a one-one correspondence and finite state transducers are applicable here.

IV. EXPERIMENTAL RESULTS

Experiments are designed to test the performance of NSWs detection and classification. For standard word generation is a determinate transformation, experiments here reflect the performance of the whole text normalization process. In the whole process, only the 6 maximum entropy classifiers for ANSWs need to be trained. For each classifier, the training set is composed of all occurrences of that type of ANSW in the People’sDaily Corpus. The training set sizes are ranging from 400 sentences to 4000 sentences. The closed test corpus is randomly extracted from the People’s Daily Corpus. It contains 6986 sentences and 13468 NSWs. Each sentence on average has 1.93 NSWs. The open test corpus is collected from the internet. Web pages are of various domains like sports, digital products, military and Bulletin Board System, etc. It contains 6007 sentences and 12219 NSWs. Each sentence on average has 2.03 NSWs. The percentage of BNSWs in the closed test corpus is 83.59%, while inthe open test corpus it is 74.77% (Table II).

TABLE II. DISTRIBUTION OF NSWS IN TEST CORPORA

	Sentences	NSWs	BNSWs	ANSWs
Closed	6986	13468	83.59%	16.41%
Open	6007	12219	74.77%	25.23%

Only if a NSW is correctly recognized and classified, it is counted as a correctly tagged NSW (5). Evaluation criteria are Precision (P), Recall (R) and F-score (F).

$$\begin{gathered} \mathrm{P} = \frac{\#correctly\ \ tagget\ \ NSW}{\#auto\ \ tagget\ \ NSW} \\ R = \frac{\#correctly\ \ tagget\ \ NSW}{\#real\ \ NSW} \\ F = \frac{2\times P\times R}{P+R} \end{gathered} \tag{5}$$

As the baseline, we use FSA for initial classification andsimply label ANSWs with their major subclass tags. In Table III, baseline (FSA) achieves F-scores of 96.99% in the closed test and 93.30% in the open test. BNSWs, which are always the majority ofNSWs, ensure a good baseline performance across domains.

TABLE III. OVERALL PERFORMANCE

	Closed (%)			Open (%)		
	P	*R*	*F*	*P*	*R*	*F*
FSA	96.99	96.99	96.99	93.30	93.30	93.30
FSA+ME	99.96	99.96	99.96	98.53	98.53	98.53

When Maximum Entropy (ME) classifiers are used for ANSWs, F-score gets improved by 2.79% in closed test and 5.23% in open test. It shows that ME is effective for NSWs disambiguation and the text normalization module in this paper adapts well to new domains. In Table III, precision equals to recall, which means that the number of auto-tagged NSWs equals to the number of real NSWs. Experiments prove that FSA detect all NSWs correctly. Errors are only introduced in the subclass disambiguation stage. The micro average precisions of subclass disambiguation in the closed test and open test are 99.73% and 94.23% respectively.

Uzbek adverbs, including adjectives and quantifiers, play a pivotal role in discerning the pronunciation of non-standard words, particularly those pertaining to quantity (Table IV).

Table V presents various response categories along with potential pronunciation alternatives. It becomes evident that certain non-standard words exhibit a considerable degree of ambiguity, requiring intrinsic and contextual information for accurate interpretation. Based on the aforementioned taxonomy, the text normalization procedure involves three distinct stages (Table V).

TABLE IV. EXAMPLES OF NON-STANDARD WORDS

Class of non-standard words	An example	Percent
Indicators	35 P inchi,nchi	55%
Wholes	100 $	8%
Interests	10%, 12.5%	6%
The date	27 oktabr	4%
Number and words	15 ming	3%
Number base	5 kg, 10 cm	2%
Years	5 yil	2%
Others	Win32	4%

TABLE V. EXAMPLES OF NON-STANDARD WORDS

Class of non-standard words	**An example**	**Percent**
Numbers	Number to number	2 ga 11 (2.11 metr)
	whole	110
	Vote	110
	Inliz alphabet	p2p
a-giper	year after year	1998-1999
	telephone	+99893 385 34 34
	number-number	737-200 (Boying737-200)
	number-number	200-300
	rate	2-3
	Subtract	100-1=99
Slesh	Fraction	1/3
	date	2001/01
Dominant	time	10:15 (10:15 soat)
	Step	10:15

In the initial step, a machine learning algorithm is employed to identify non-standard words within authentic text and execute preliminary categorization. At this point, the core non-standard word classification is achieved. Subsequently, for each categorized instance, the output from the initial classification phase is harnessed to determine the corresponding subclass. The refinement of subclasses is carried out using maximum entropy classifiers within the subclass refinement module. When a non-standard word receives a designated class tag, the Bounded state switcher facilitates its transformation into a standard word. The overall process flow is visually depicted in Fig. 1, while Fig. 2 and Fig. 3 provide comprehensive insights into its detailed workflow.

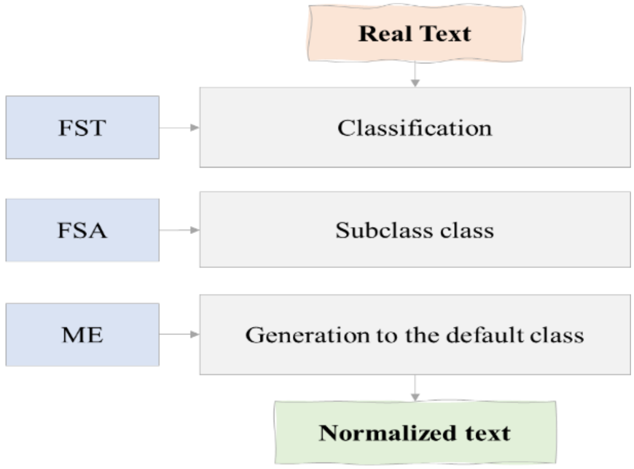

Fig. 1. Text normalization schemes

Speech processing, which we mentioned above, is one of the most pressing problems. Also, the results of the above research and the results of the work done are shown in the following figures (Fig. 2 and Fig. 3).

Fig. 2. System interface

Fig. 3. The result of using the program

V. CONCLUSION

This paper delivers an extensive examination of Uzbek text normalization, encompassing the creation of a non-standard word taxonomy from a substantial corpus. Through meticulous taxonomy evaluation, a dual-phase non-standard word classification method emerges, comprising preliminary classification through finite state automata and more advanced classification via maximum entropy classifiers. Empirical testing underscores the efficacy and adaptability of this approach, demonstrating its strong performance across diverse domains. Worth noting, this approach operates at the character level, negating the need for a separate word segmentation process.

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Construction Of Higher-Order Spline Functions, Digital Processing And Modeling Of Signals, And Their Comparative Analysis

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Abstract: In this work, numerical processing of signals using high-order spline models in the direction of the approximation theory of mathematical modeling, which plays an important role in the development of science, is considered one of the important and urgent issues, therefore, third-order, fifth-order, seventh-order Ryabenky spline models selected. We can also say that high-order Ryabenky spline models are effective and reliable mathematical models in digital signal processing. As an example, the functions obtained as an experiment and the initial values of the gastroenterological signal were obtained. Approximation of gastroenterological signals and functions, numerical processing of signals by obtained values, and results of comparative analysis are presented. From the results of the comparative analysis, it was analyzed that the results obtained in this study in digital processing of signals are better approximated by the seventh-order Ryabenky spline model among the results of digital processing of signals based on third-order, fifth-order, and seventh-order Ryabenky spline functions. The higher-order Ryabenky spline functions discussed in this paper can also be used in digital processing and processing of various medical and other signals.

Keywords— digital signal processing, spline models, medical signals, mathematic models, gastroenterological signals.

I. Introduction

Today, in the field of medicine, many studies are being conducted on monitoring human health and accurate and early diagnosis of diseases in patients. Ongoing research shows that medical signal processing, digital processing of signals can provide high-quality and effective diagnosis. It is emphasized that this is important and one of the most urgent issues of our time. Since the issue here is about human health, it encourages scientists to conduct non-stop research in medicine, modeling, modern technology and other fields. Among them, the researchers conducted in digital processing of signals are also considered important. The ongoing research is inextricably linked with many directions. For example: mathematical modeling, digital signal processing, medicine and several other fields. Analyzing such factors, the application of spline functions, which is considered an important and leading mathematical tool of approximation theory, ranks high in terms of relevance and today brings good results in several fields of science and technology. Many scientists have cited this in their research [8,10,13,15,16,18]. Therefore, the application of spline functions in solving the problems considered in this article is intended. In the next step, we will consider the construction and implementation of spline functions.

II. CONSTRUCTION OF HIGHER ORDER SPLINE FUNCTIONS

If the function under consideration is sufficiently smooth, then it is desirable to approximate it with splines of a higher degree so that the convergence is faster. For this purpose, the error of approximating the function by splines of the seventh degree of Ryaben'kiy has been investigated. Continuing the study, the splines of the seventh degree of Ryabensky were obtained [1,4,5,6].

In this paper, using quadrature formulas, we will calculate estimates of their error.

Let p>0 be a fixed integer, $f(x) \in C^q(-\infty,\infty)$and $f(x) = f(ih), (i = 0, \pm1, \pm2, \dots)$ the trace of a function on a uniform one-dimensional grid [4,5,9].

Ryaben'kii's papers describe the operator L that maps $f(ih)$ to the function Sph(x). defined everywhere and being an interpolation spline of degree 2p+1 of defect p+1. To estimate the error in the one-dimensional case with respect to the error $f(x)$ - Sph(x) and order derivatives, the following estimate follows:

$$\left|f^{(r)}(x) - S_{ph}^{(r)}(x)\right| \le h^{q-r} K(p)\, sup_x \left|f^{(q)}(x)\right|. \quad (1)$$

where the constant $k(p)$ depends only on p.

For any spline Sph(x) can be written explicitly in terms of the values of the function $f(ih)$, so it is convenient for applications. In contrast to Hermitian splines, these splines can also be used to approximate C[a,b] functions [2].

In the works of Sodolev and Ryaben'kiy, for $x_i, \le x \le x_{i+1}$ the following expression is given for the function Sph(x) [3,6]

$$S_{ph}(x) = \sum_{j=0}^{p} \sum_{k=0}^{p-j} \frac{(p+k)!}{k!j!p!} \left[a_{pj}(x_i) t^{j+k} (1-t)^{p+1} + (-1)^j a_{pj}(x_{i+1}) t^{p+1} (1-t)^{j+k}\right]. \quad (2)$$

Where: $t = \frac{x-x_i}{h}, a_{p0}(x_i) = f(x_i)$

$$a_{pj} = j! \sum_{k=j}^{p} \frac{\Delta f(x_i)}{k!} S(k,j) j \ge 1 \quad (3)$$

$S(k,j)$ Stirling numbers of the first kind.

Relationship between Newtonian and ordinary powers formulas

$$y^0 = y^{[0]}; y^n = \sum_{k=1}^{n} S(n,k) y^{[k]}, n = 1,2,\dots$$

$$y^{[0]} = y^{[n]}; y^n = \sum_{k=1}^{n} S(n,k) y^k, n = 1,2,\dots$$

where $S(n,k)$ and $S(k,j)$ are the so-called Sterling numbers of the first and second kind, respectively

Precisely the following identity

$y^k = \sum_{i=1}^{k} \frac{y^{[k]}}{i!} \Delta^i O^k$ (4)

where: $y^{[k]} = y(y-1)(y-2)\dots(y-k+1)$, $\Delta^i O^\alpha = \sum_{k=1}^{i} (-1)^{i-e} e_j{}^e e^k$

${y_{(n=3)}}^{[n]} = \sum_{k=1}^{n=3} S(n,k)\, y^k$; y $[k] = y(y-1)(y-2)\dots(y-k+1)$

n=1; $y^{[1]} = \sum_{k=1}^{1} S(1,1)\, y' = S(1,1)y' = y$

n=2; $y^{[2]} = \sum_{k=1}^{2} S(2,k)\, y^k = S(2,1)y + S(2,2)y^2 = y(y-1)$

n=3; $y^{[3]} = \sum_{k=1}^{3} S(3,k)\, y^k = S(3,1)y + S(3,2)y^2 + S(3,3)y^3 = y(y-1)(y-2)$

general view of Newtonian and ordinary powers [9,11,15,17]

$$y^{[k]} = S(k,1)y + S(k,2)y^2 + S(k,3)y^3 + \dots\dots + S(k,k-1)y^{k-1} + S(k,k)y^k$$

$$y^{[k]} = y(y-1)(y-2)(y-3)\dots(y-k+1)$$

$$y^{[k+1]} = y(y-1)(y-2)(y-3)\dots(y-k+1)(y-k)$$

$$y^{[k+1]} = S(k+1,1)y + S(k+1,2)y^2 + S(k+1,3)y^3 + \dots\dots + S(k+1,k)y^k + S(k+1,k+1)y^{k+1}$$

$$y^{[n]} = [\sum_{n=1}^{k} S(k,n)\, y^n = (S(k,1)y + S(k,2)y^2 \dots\dots + S(k,k-1)y^{k-1} + S(k,k)y^k)(y-k)(S(k,1)y + S(k,2)y^2 \dots\dots + S(k,k-1)y^{k-1} + S(k,k)y^k)(y-k)$$

$$S(0,0) = 0 \dots S(k,0) = 0 \dots S(k,k) = 1 \dots, k \geq 1$$
$$S(k+1,j) = S(k,j-1) - kS(k,j), j = 1,k$$

Recursive formula for calculating Stirling 1-kind:

$$\begin{cases} y^{[n]} - \text{newton wall} \\ y^n - \text{ordinary wall} \\ \left(\begin{array}{c}\text{connection between them inset connection between} \\ \text{numbers Stilngga of the 1st and 2nd kind}\end{array}\right) \end{cases}$$

$y^{[k]}$, $y^{[k]} = y(y-1)(y-2)(y-3)\dots(y-(k-1))$

$$y^{[0]} = y^0 = 1$$

$y[1] = y$

$$y^{[2]} = y(y-1) = y^2 - y$$

$y^{[3]} = y(y-1)(y-2) = (y^2 - y)(y-2) = y^3 - y^2 - 2y^2 + 2y = y^3 - 3y^2 + 2y =$

$$\sum_{k=1}^{3} S(n,k)\, y^k = S(3,3)y^3 + S(3,2)y^2 + S(3,1)$$
$$S(3,3) = 1, \rightleftarrows\rightleftarrows S(3,2) = -3, \quad S(3,1) = 2$$

$y^{[n]} = \sum_{k=1}^{n} S(n,k)\, y^k$ here the $S(n,k)$ is the Stirling number of the 1st kind

$y^n = \sum_{k=1}^{n} S(n,k)\, y^{[k]} = \sum_{k=1}^{n} \frac{\Delta^k O^n}{k!} y^{[k]}$ – here the $S(n,k)$ is the Stirling number of the 1st kind

$y^{[n]} = \sum_{k=1}^{n} S(n,k) y^k = S(n,1)y + S(n,2)y^2 + S(n,3)y^3 + \dots\dots + S(n,n)y^n$ here the $S(n,k)$ is the Stirling number of the 1st kind.

Example n=1

1. $y^{[1]} = \sum_{k=1}^{1} S(n,k)\, y^k = S(1,1)y'$

2. $y^{[1]} =$ y when comparing received $S(1,1)y^1 = y^1 \Rightarrow S(1,1) = 1$

n=2

$$y^{[2]} = y(y-1) = y^2 - y \quad (1)$$

$$y^{[2]} = \sum_{k=1}^{2} S(2,k) y^k = S(2,1)y + S(2,2)y^2 \quad (2)$$

$(1) = (2)$
$1y^2 - y = S(2,2)y^2 + s(2,1)y \Rightarrow S(2,2) = 1 \quad S(2,1) = -1$

n=3

$$y^{[3]} = \sum_{k=1}^{3} S(3,k)y^k = y(y-1)(y-2) = y^3 - 3y^2 + 2y \Rightarrow$$
$$\Rightarrow S(3,1) = 2;\ S(3,2) = -3;\ S(3,3) = 1$$
$$S(3,1)y + S(3,2)y^2 + S(3,3)y^3 \Rightarrow S(k,0) = 1; S(k,k) = 1$$
$$S(k+1,j) = S(k,j-1) - kS(k,j), \quad (j = \overline{1,k})$$

The spline of the third degree of Ryabenky [2,4,5,9], on the segment $[x_i; x_{i+1}]$

$S_3(x) = \phi_1(t)f(x_i) + \phi_2(t)f(x_{i+1}) + \phi_3(t)f(x_{i+2})$. (5)

here: $\phi_1(t) = (1-t)^2(1+t)$,
$\phi_2(t) = t(1+2t-2t^2)$,
$\phi_3(t) = -t^2(1-t)$

p=1

$$S_{1h}(x) = \sum_{j=0}^{1}\sum_{k=0}^{1-j} \frac{(1+k)!}{k!\,j!\,1!}\left(a_{1j}(x_i)t^{j+k}(1-t)^{1+1} + (-1)^j a_{1j}(x_{i+1})t^{1+1}(1-t)^{j+k}\right) =$$

$$= \sum_{k=0}^{1} \frac{(1+k)!}{k!\,1!\,1!}(a_{10}(x_i)t^{0+k}(1-t)^2 + (-1)^0 a_{10}(x_{i+1})t^2(1-t)^k) +$$

$$+ \sum_{k=01}^{1-0} \frac{1!}{1!\,0!\,1!}(a_{11}(x_i)t^{1+0}(1-t)^2 + (-1)^1 a_{11}(x_{i+1})t^2(1-t)^{1+0}) =$$

$$= \frac{1!}{0!\,1!\,1!}(a_{10}(x_i)t^0(1-t)^2 + (-1)^0 a_{10}(x_{i+1})t^2(1-t)^0) +$$

$$+ \frac{2!}{1!\,1!\,1!}\left(a_{10}(x_i)t(1-t)^2 + (-1)^0 a_{10}(x_{i+1})t^2(1-t)\right) +$$

$$+a_{11}(x_i)t(1-t)^2 - a_{11}(x_{i+1})t^2(1-t) =$$
$$= a_{10}(x_i)(1-t)^2 + a_{10}(x_{i+1})t^2 + 2a_{10}(x_i)t(1-t)^2 + 2a_{10}(x_{i+1})t^2(1-t) +$$
$$+a_{11}(x_i)t(1-t)^2 - a_{11}(x_{i+1})t^2(1-t) =$$
$$= a_{10}(x_i)(1-t)^2(1+2t) + a_{10}(x_{i+1})t^2(3-2t) + a_{11}(x_i)t(1-t)^2 -$$
$$-a_{11}(x_{i+1})t^2(1-t)$$
$$t = S_{1h}(x) = a_{10}(x_i)(1-t)^2(1+2t) + a_{10}(x_{i+1})t^2(3-2t) +$$
$$= a_{11}(x_i)t(1-t)^2 - a_{11}(x_{i+1})t^2(1-t)$$
$$a_{10}(x_i) = f(x_i), \Delta f(x_i) = f(x_{i+1}) - f(x_i)$$
$$a_{11}(x_i) = 1!\sum_{k=1}^{1}\frac{\Delta f(x_i)}{1!}S(1,1) = f(x_{i+1}) - f(x_i), S(1,1) = 1$$
$$a_{11}(x_{i+1}) = f(x_{i+2}) - f(x_{i+1})$$
$$S_{1h}(x) - S_3(x) = f(x_i)(1-t)^2(1+2t) + f(x_{i+1})t^2(3-2t) +$$
$$+\big(f(x_{i+1}) - f(x_i)\big) + (1-t)^2 - \big(f(x_{i+2}) - f(x_{i+1})\big)t^2(1-t) =$$
$$= ((1-t)^2(1+2t)t(1-t)^2)f(x_i) + \big(t^2(3-2t) + t(1-t)^2 + t^2(1-t)\big)f(x_{i+1}) -$$
$$-t^2(1-t)f(x_{i+2}) = \phi_1(t)f(x_i) + \phi_2(t)f(x_{i+1}) + \phi_3(t)f(x_{i+2})$$
$$\phi_1(t) = (1-t)^2(1+t), \qquad \phi_2(t) = t(1+2t-2t^2), \qquad \phi_3(t) = -t^2(1-t)$$

III. COMPARATIVE ANALYSIS OF DIGITAL SIGNAL PROCESSING USING HIGHER ORDER SPLINE FUNCTIONS.

Above, we considered the construction of the third-order Ryabenikov spline function[4,5,9,21], and thus the 5th and 7th-order models of this spline function were also constructed. The constructed models are shown in Figure 1 in the Maple program. Now we will consider the application and comparative analysis of 3rd, 5th and 7th order Ryabenikov spline functions to gastroenterological signals [17,19,20,22,23].

$$SR_3(x) = h\sum_{i=1}^{N} f(ih) + \frac{5}{12}h\big(f(0) - f(1)\big) + \frac{1}{12}h\big(f(h) - f(1+h)\big)$$

here: $f(x), x = ih, i = 1\ldots N$ (6)

$$SR_5(x) = h\sum_{i=1}^{N} f(ih) + \frac{43}{120}h\big(f(0) - f(1)\big) + \frac{1}{5}h\big(f(h) - f(1+h)\big) - -\frac{7}{120}h\big(f(2h) - f(1+2h)\big)$$

here: $f(x), x = ih, i = 1\ldots N$ (7)

$$SR_7(x) = h\sum_{i=1}^{N} f(ih) + \frac{549}{1680}h\big(f(0) - f(1)\big) + \frac{523}{1680}h\big(f(h) - f(1+h)\big) - -\frac{313}{1680}h\big(f(2h) - f(1+2h)\big) + \frac{81}{1680}h\big(f(3h) - f(3+h)\big)$$

here: $f(x), x = ih, i = 1\ldots N$ (8)

Table 1 presents the comparative analysis results of the $f(x) = x^7$ function selected as an experiment on the basis of the spline functions of the 3rd, 5th, and 7th orders given above with integral values at different values of N.

Table 1

N	f(x)	SR3(x)	SR5(x)	SR7(x)	f(x)-SR3(x)	f(x)-SR5(x)	f(x)-SR7(x)
10	0,125	0,12289827	0,12310161	0,1239654	2,10E-03	1,90E-03	1,03E-03
20	0,125	0,12476026	0,124847401	0,124955721	2,40E-04	1,53E-04	4,43E-05
30	0,125	0,1249311	0,124961806	0,12499238	6,89E-05	3,82E-05	7,62E-06
40	0,125	0,12497137	0,124985271	0,124997755	2,86E-05	1,47E-05	2,24E-06
50	0,125	0,12498548	0,124992869	0,12499912	1,45E-05	7,13E-06	8,801E-07
60	0,125	0,12499165	0,124996028	0,124999588	8,35E-06	3,97E-06	4,121E-07
70	0,125	0,12499476	0,124997567	0,124999782	5,24E-06	2,43E-06	2,177E-07
80	0,125	0,1249965	0,124998404	0,124999874	3,50E-06	1,60E-06	1,256E-07
90	0,125	0,12499755	0,124998898	0,124999226	2,45E-06	1,10E-06	7,742E-07
100	0,125	0,12499822	0,124999207	0,124999497	1,78E-06	7,9302E-07	5,029E-07

As can be seen from the table above, the results obtained using higher-order spline functions are very close to the results of the function obtained as an experiment. This means that the application of the selected model in the field of medicine will give us good results. In the next section, we consider the application of the model to gastroenterological and codeological signals and their comparative analysis. It is known to us that in the field of cordiology, it is very important to accurately calculate the value of the heartbeat amplitude in monitoring human health and diagnosing heart diseases. Gastroenterological signals are also of great importance in determining the diseases of the human internal organs and in evaluating the effect and process of the treatment procedures applied to them. Table 2 presents the values of gastroenterological signals and their comparative analysis restored on the basis of the higher-order spline function.

Table 2.

N	*f(x)*	*SR3(x)*	*SR5(x)*	*SR7(x)*	*f(x)-SR3(x)*	*f(x)-SR5(x)*	*f(x)-SR7(x)*
10	0,25	0,24975	0,2499	0,25	2,50E-04	1,00E-04	0
20	0,25	0,24996875	0,2499875	0,25	3,13E-05	1,25E-05	0
30	0,25	0,24999074	0,249996296	0,25	9,26E-06	3,70E-06	1E-15
40	0,25	0,24999609	0,249998438	0,25	3,91E-06	1,56E-06	1E-15
50	0,25	0,249998	0,2499992	0,25	2,00E-06	0,0000008	1E-15
60	0,25	0,24999884	0,249999537	0,25	1,16E-06	4,62963E-07	0
70	0,25	0,24999927	0,249999708	0,25	7,28863E-07	2,91545E-07	0
80	0,25	0,24999951	0,249999805	0,25	4,88281E-07	1,95313E-07	0
90	0,25	0,24999966	0,249999863	0,25	3,42936E-07	1,37174E-07	1E-15
100	0,25	0,24999975	0,2499999	0,25	0,00000025	0,0000001	0

From the results obtained from Table 2, it can be seen that from the higher-order spline functions, the seventh-order spline function returned the values for which the values of the function were the least different from the true values. So digital processing of signals through this model gives good results in the considered medical field. You can see this from the results in the table above.

Conclusion

In this article, we considered the construction of spline functions of the third, fifth, and seventh degrees. In addition, a comparative analysis was conducted with the function values obtained as an experiment. Based on the obtained results, the effectiveness of the considered model was evaluated, its application to gastroenterological signals and a comparative analysis was presented. From the obtained results, the maximum value of the differences of the results obtained by the spline function of the third degree from the actual values was equal to 2.5E-04, and in the spline function of the fifth degree, it was equal to 1.0E-04. Among the considered models, the spline with the highest efficiency and accuracy is the seventh-order spline function, and it is not difficult to see this from the obtained results. This is of great importance in digital processing of medical signals.

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MEASURE OF COMPACTNESS FOR ANALYSE DATASET

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Abstract. The article dedicated to finding measure of compactness, and analyze dataset with using compactness. For finding measure of compactness , we search for hidden regularities from sociology database. In this way we need consider n-p full task and it will be 2^n combinations. To solve this task, we use heuristic way with using binary matrix. In the article we use invariant methods which find measure of compactness of dataset. Our survey were taken from korean, uzbek peoples and we obtained a result from this dataset.

Keywords: object, set, class, feature, nominal, quantitative, space, similarity matrix.

1 Introduction

Generalizing ability applies to the main indicators characterizing the quality of recognition algorithms [1]. This ability is manifested in the ability to determine affiliation objects to classes that the algorithm did not see in the learning process. Hypothesis Verification compactness is the basis of many criteria and methods of the theory of pattern recognition. So, in [1] the compactness profile is described for calculating the generalizing ability of families of algorithms having of infinite capacity in the space VC (Vapnik – Chervonenkis) [2]. For determining affiliation the arbitrariness of an arbitrary admissible object to classes when using such families of algorithms move must store the entire sample in memory. Representative of the family with infinite capacity is the "nearest neighbor" algorithm(BS). For practical purposes, when calculating the generalizing ability, it is enough to use local properties (local restrictions) of object samples [1]. The local constraint in [3] can be considered the proposed N.G. Zagoruyko compactness index, determined by the number of objects-standards of minimum coverage, in which the recognition of class objects is fixed sampling was correct. In addition to the compactness indicator, candidates for inclusion in the set of local constraints are the number of noise objects, the dimension of the feature space, the set of objects around locks (subsets of boundary objects) of classes [4] by a given metric. Interest is the limiting value of dimension, above which the compactness index [3] increases. The set of features that defines the limit value is considered as informative for the proximity measure used. Dimension above the limit leads to erosion of the similarities between sampling objects.

There is a need to introduce a new measure of compactness with dimensional quantities with values in [0, 1]. The values of these quantities are required to analyze how the actual structure of the training sample is different(by a given measure of proximity) from the ideal for recognition. An ideal structure is considered in which the number of reference objects of the minimum coverage is equal to the number of classes. The measure of compactness can be used to compare metrics and transformations of attribute space in relation to “better” on fixed samples of objects. Analysis of the structure of samples is based on the use of the properties of this relationship. The analysis technique is focused on quantitative indicators calculated by the results of dividing class objects into disjoint groups [4]. The guarantee of the uniqueness of the partition by the number of groups and the composition of their objects is the stability of the algorithm used. The influence of noise objects on the indicators of the generalizing ability of algorithms has been repeatedly considered in scientific publications. An extensive list of works in [5] provides an overview of various 38 methods for detecting and removing noise objects. Most of these methods are focused on use of the BS rule. The recognition quality according to the BS rule substantially depends on the sensitivity of the metric to the dimension of the attribute space. The change in dimension is associated with the selection of informative features, and with the transition to the description of objects in space from latent features. In [4, 6], it was proposed to use two types of rules for hierarchical agglomerative grouping of initial features as a toolkit for transition to latent features. The first type is focused on the sequential combination of two signs into one by non-linear mapping of their values on the numerical axis. Grouping according to the rules of the second type is based on values of the stability criterion of objects by a given metric in a two class recognition problem. For each group of attributes, a generalized assessment of the object is calculated. Methods that implement two types of hierarchical grouping rules can be identified as non-linear and linear. Nonlinear methods are invariant to the scale of feature measurements. In linear methods, the invariance property is absent. The sequence of formation of groups and latent features based on them according to two types of rules determines the order by relation of the degree of informativeness. The informativeness of the feature is calculated as the extremum of the criterion dividing its (feature) values into disjoint intervals in the form of checking the degree of truth of a hypothesis: The sets of features values in the description of objects from different classes with the number of intervals equal to the number of classes do not intersect with each other.

In this paper, non-empty classes (sets) of metrics are considered, the cluster structures of training samples for which coincide (are equivalent) in the number of groups and the composition of the objects included in them.

Information on the cluster structure allows sequential selection of objects of standards of minimum coverage, in each of which a local metric is defined. The method for calculating the weights of local metrics is similar to that used in the FRiS STOLP method [3]. To evaluate the generalizing ability of the BS method algorithms, it is proposed to use a criterion, the values of which are calculated depending on the dimension and composition of the set of features, the number of removed noise objects and the number of objects of the minimum coverage standards. Assessment by criterion was used to demonstrate the sustainability of the selection of informative features with cross validation method on random samples. Additionally, in this article we will mention our results.

2 Methodology.On splitting class objects into disjoint groups

The use of a partially trained sample (PTS) for setting grouping conditions is described in [7]. An example of a condition is the indication of a subset of pairs of sample objects that, when split, should not fall into one group. Belonging to disjoint classes serves a source of additional information for the study of cluster structure using various proximity measures. The main ideas of the method given below are presented in [4]. The aims of splitting class objects into disjoint groups are:

- calculation and analysis of compactness values of class objects and the sample as a whole;
- search for the minimum coverage of the training sample with reference objects.

The recognition problem in the standard setting is considered. It is believed that the set of objects $E_0 = \{S_1, S_2, ..., S_m\}$ divided by $l\,(l > 2)$ disjoint subsets (classes) $K_1, K_2, ..., K_l,\ E_0 = \bigcup_{i=1}^{l} K_i$. Objects are described using a set of n heterogeneous attributes $(N) = \{S_1, S_2, ..., S_m\},\ \xi$ value which is measured in interval scales, $(n - \xi)$ - in nominal. The metric $\rho\ (x, y)$ is given on the set of objects E_0.

We denote by $L(E_0, \rho)$ the subset of boundary objects of classes defined on E_0 by the metric $\rho\ (x, y)$. Objects $S_i,\ S_j \in K_t,\ t = 1, 2, ..., l$ are considered related $S_i \leftrightarrow S_j$, if $\{S \in L(E_0, \rho) \mid \rho(S, S_i) < r_i\ and\ \rho(S, S_j) < r_j\} \neq \varnothing$ where $r_i(r_j)$ distance to the nearest object from $S_i(S_j)$ from $CK_t(CK_t = E_0 \setminus K_t)$ by metric $\rho\ (x, y)$. The set $G_{tv} = \{S_{v1}, S_{v2}, ..., S_{vc}\},\ c \geq 2,\ G_{tv} \subset K_t, v < |K_t|$ represents an area (group) with related objects in class K_t, if for any $S_{vi}, S_{vj} \in G_{tv}$ there exists a path $S_{vi} \leftrightarrow S_{vj} \leftrightarrow ... \leftrightarrow S_{vj}$. An object $S_i \in K_t,\ t = 1, \dots, l$ belongs to a group of one element and is considered unconnected if it does not exist paths $S_i \leftrightarrow S_j,$ for no one object $S_j \neq S_i.\ S_j \in K_t$. It is required to determine the minimum number of disjoint groups of connected and unrelated objects for each class $K_t,\ t = 1, \dots, l$. This problem can be considered in an alternative setting (without specifying features) if a square proximity matrix $\{a_{ij}\}\ m \times m$ between m objects and a vector $F = \{f_1, f_2, ..., f_m\},\ f_i \in \{1, 2, ..., l\}$, belonging of the objects to the $K_1, K_2, ..., K_l$. Vector F serves as additional information for specifying grouping conditions. When determining the minimum number of groups of connected and unrelated class objects, $L(E_0, \rho)$ is used - a subset of the boundary objects (shell) of classes by the given metric ρ and a description of objects in the new space from binary signs. To distinguish the class shell for each $S_i \in K_t,\ t = 1, \dots, l$, a sequence ordered by $\rho\ (x, y)$ is constructed

$$S_{i_0}, S_{i_1}, ..., S_{i_{m-1}},\ S_i = S_{i_0}. \tag{1}$$

Let $S_{i_\beta} \in CK_t$ be the object closest to S_i from (1), not belonging to the class K_t. Denote by $O(S_i)$ a neighborhood of radius $r_i = \rho\left(S_i, S_{i_\beta}\right)$ centered in S_i that includes all objects for which $\rho\left(S_i, S_\tau\right) < r_i,\ \tau = 1, ..., \beta - 1$. In $O(S_i)$ there is always a nonempty subset of objects

$$\Delta_i = \left\{ S_{i_\alpha} \in O(S_i) \mid \rho(S_{i_\beta}, S_{i_\alpha}) = \min_{S_{i_\tau} \in O(S_i)} \rho(S_{i_\beta}, S_{i_\tau}) \right\}. \quad (2)$$

By (2), the belonging of objects to the class shell is defined as $L(E_0, \rho) = \bigcup_{i=1}^{m} \Delta_i.$

The set of shell objects from $CK_t \cap L(E_0, \rho)$ is denoted by $L_t(E_0, \rho) = \left\{ S^1, S^2, ..., S^\pi \right\}, \ \pi \geq 1.$ The value $\pi = 1$ uniquely determines the inclusion of all objects of the class in one group. For $\pi \geq 1$ we transform the description of each object $S_i \in S_\mu \vee S_\eta \ in \ S_i = (y_{i1}, y_{i2}, ..., y_{i\pi})$ where

$$y_{ij} = \begin{cases} 1, \ \rho(S_i, S^j) < r_i \\ 0, \ \rho(S_i, S^j) \geq r_i \end{cases} \quad (3)$$

Let, according to (3), a description of objects of the class K_t in a new (binary) attribute space be obtained, $\Omega = K_t$, and θ - is the number of disjoint groups of objects, $S_\mu \vee S_\eta$, $S_\mu \wedge S_\eta$- accordingly, the operations of disjunction and conjunction by binary signs of objects $S_\mu, S_\eta \in K_t$. The step-by-step algorithm for splitting objects $K_t$into disjoint groups $G_1, ... G_\theta$is as follows.

Step 1: $\theta = 0$

Step 2: Select Object $S \in \Omega$, θ = θ + 1, $Z = S$, $G_\theta = \emptyset$

Step3: Make a choice S=Ω end $S \wedge Z = true$, Ω = Ω\S, $G_\theta = G_\theta \cup S, Z = Z \vee S$ till

$\{S \in \Omega | S \wedge Z = true\} \neq \emptyset$

Step 4: if $\Omega \neq \emptyset$ then goto step 2

Step5: the end

Partitioning of E_0 objects into disjoint groups according to the algorithm described above is used to find the minimum coverage [4] of the training sample by objects by standards. Denote by $R_s = \rho(S, \bar{S})$ the distance from the object $S \in K_t$ to the nearest object $\bar{S}$ from the class $(\bar{S} \in CK_t)$ opposite to K_t, by δ is the minimum number of disjoint groups of connected and unconnected objects of classes on E_0.

We order the objects of each group $G_u \cap K_t$, $u = 1, ... , \delta$ t=1,…,l according to the set of values $\{R_s\}_{s \in G_u}$. As a measure of proximity between $S \in G_u, u = 1, ... , \delta$, and an arbitrary admissible object S' , a weighted distance over the local metric $(S, S') = \rho(S, S')/R_S$. The decision on whether S' belongs to one of the classes $K_1, ... K_i$ is made according to the rule: $S' \in K_t$ if

$$d(S_\mu, S') = min_{S_j \in E_0} d(S_j, S') and \ S_\mu \in K_t \ and \ d(S_\mu, S') \neq min_{S_j \in CK_t} d(S_j, S') (4)$$

According to the principle of *sequential exclusion* used in the search for coverage, the sample $E_0$is divided into two subsets: the set of standards $E_{ed}$and the control set E_k, $E_0 = E_{ed} \cup E_k$. At the beginning of the process $E_{ed} = E_0, E_k = \emptyset$. Sorting by values from $\{R_s\}_{s \in G_u}, u = 1, ..., \delta$is used to determine the candidate for removal from the number of reference objects by the group G_u. The idea of selection consists to the find the minimum number of standards at which the recognition algorithm by (4) remains correct (without errors recognizing objects) on E_0. We assume that the numbering of groups of objects reflects the order $|G_1| \geq \cdots \geq |G_\delta|$ and the group $G_p, p = 1, ..., \delta$ δ did not select reference objects. E_{ed}deletion candidates are sequentially selected starting from $S \in G_p$with a minimum $R_S$value. If the inclusion of S in $E_k$violates the correctness of the decision rule (4), then S returns to the set E_{ed}.

3 Realization of the concept. On compactness measures in recognition problems with a teacher

Compactness measures are claimed for evaluating the generalizing ability of recognition algorithms. When calculating the estimates, the results of the search and removal of noise objects, the selection of informative feature sets, the number of reference objects of the minimum coverage of training samples are used. Consider the method of forming a set of noise objects whose power depends on the verification of the conditions proposed below.

Let be $S_K \in K_i, \rho(S_k, S_r) = min_{S_j \in CK_i} \rho(S_k, S_j)$ and $Z = |\{S_\mu \in K_i | \rho(S_k, S_\mu) < \rho(S_k, S_r)\}|$. Denote by $D_i(D_i \in CK_i$ the set of noise objects of class K_i. The object $S_r \in CK_i$ is included in D_i and is considered as noise if the condition is satisfied:

$$\frac{ZZ-\lambda}{|K_i|} > \frac{1}{m-|K_i|} \tag{5}$$

where $ZZ = |\{S_\mu \in K_i | \rho(S_r, S_k) < \rho(S_p, S_k) < \rho(S_\eta, S_k)|\} |\lambda| < min_{1 \le i \le l} |K_i|, \rho(S_\eta, S_k) = min_{S_j \in CK_{i\{S_r\}}} \rho(S_j, S_k)$. The values Z and Z + ZZ can be considered as the number of representatives of the class K_i in the hypersphere centered in $S_K \in K_i$ respectively, before and after the removal of the noise object S_r. The selection of objects of training samples, under certain restrictions, helps to increase the generalizing ability of recognition algorithms. It is believed that the generalizing ability of the algorithm is improved if it is allowed to make mistakes on the determined objects of the sample. In our case as such objects from , $\cup_{i=1}^{l} D_i$.

Let the representatives of the class be divided by the minimum number μ of disjoint groups of objects according to the algorithm from above mentioned, $\min m_{ij} = |G_{ij}|, j = 1, \dots, \mu, \sum_{j=1}^{\mu} m_{ij} = m_i$. To analyze the results of dividing the class K_i into disjoint groups, taking into account their number, representativeness (by the number of objects) and removal of noise objects, it is proposed to use such a structural characteristic as compactness estimation:

$$\Theta_i = \frac{\sum_{j=1}^{\mu} m_{ij}^2}{m_i^2} \tag{6}$$

Obviously, the set of admissible values of Θ_i by (6) lies in the interval $\left[\frac{1}{m_i}, 1\right]$. If the group G_{i1} contains all objects from $K_i \cap \left(E_0 \setminus \cup_{j=1}^{l} D_j\right)$ then $\Theta_i = 1$. The average estimate of the compactness of the training sample as a whole is made taking into account the fraction of $(\frac{E_0 \setminus \cup_{i=1}^{l} D_j}{m})$ noise objects excluded from consideration according to (5) as

$$R(E_0, \rho) = \left(\frac{E_0 \setminus \cup_{i=1}^{l} D_j}{m}\right) \frac{\sum_{i=1}^{l} m_i \Theta_i}{E_0 \setminus \cup_{i=1}^{l} D_j} = \frac{\sum_{i=1}^{l} m_i \Theta_i}{m} \tag{7}$$

Values (6) and (7) indirectly indicate the homogeneity (heterogeneity) of the structure of the training sample. The closer the similarity of the groups in terms of the number of class objects included in them, the closer the value of (6) - to $\frac{1}{m_i}$, and (7)- to $\frac{1}{m}$. Obviously, the number and composition of noise objects depend both on the value of parameter λ in (5) and on sets of features in the description of objects. The problem of implementing computational procedures is to coordinate the selection of informative features and the removal of noise objects. Let the structure of class objects in the sample E_0 be calculated by the grouping algorithm from above mentioned. We denote by Sh (λ, X (k)) the number of noise objects E_0 determined depending on the value of λ according to (5) on the set of features X (k) ⊂ X (n), CF is the number of reference objects of the minimum coverage of the training sample, from which Sh (λ, X (k)) noise objects are removed. Since it is impossible to obtain an exact solution to the problem of selecting informative features without enumerating all their combinations taking into account the removal of noise objects, in practice it is recommended to use various heuristic methods. Regardless of the methods used, the quality of the selection of informative features is proposed to be determined by checking two conditions:

- when removing noise objects Sh (λ, X (k)) from E0, the indicator of the minimum coverage of the sample with reference objects

$$F(X(k), \lambda) = \left(\frac{m - Sh(\lambda, X(k))}{m}\right)\left(\frac{m - Sh(\lambda, X(k))}{CF}\right) \tag{8}$$

tends to the maximum allowable value $\frac{m}{l}$;

- product of the number of reference objects of the minimum coverage by the dimension of the attribute space

$$\frac{k*CF}{m - Sh(\lambda, X(k))} \to min_{E_0} \tag{9}$$

The first condition (8) is necessary to assess the compactness of the coverage of the sample with standard objects, the second (9) - to assess the complexity of the calculations.

To search for informative sets {X (k) | X (k) ⊂ X (n)} two criteria are proposed. Both criteria clearly do not use the number of reference objects of the minimum CF coverage. The number of noise objects Sh (λ, X (k)) according to (5) is calculated by a fixed value of λ. Such λ for all sets X (k) ⊂ X (n), k ≥ 2, is defined as

$$\lambda = arg\ max_{0\le|\eta|<min_{1\le i\le l}|K_i|}F(X(n),\eta) \quad (10)$$

The use of (10) is based on the assumption that the probability of selecting informative feature sets with a higher compactness in (8) is close to zero for λ other than (10). In the first (in the order of presentation) criteria, the results of covering sample objects with hyperspheres are taken into account, taking into account the removal of noise objects, in the second, compactness estimates are used according to (7) based on the property of connectivity over objects of class shells. Let $O(S_i, X(k))(1 \le k < n)$ be the neighborhood of the object, $S_i \in E_0 \cap K_j, j = 1, \dots, l$, defined as $O(S_i, X(k)) = \{S \in K_j | \rho(S, \overline{S_i})\}$, where $\overline{S_i} \in CK_j$is the object closest to S_i by the metric ρ (x, y) from the complement to the class K_j by the set of attributes X (k). We define the estimate $S_i \in E_0$ on X (k) as

$$Z(S_i, X(k)) = max_{S_i\in O(S,X(k))}|O(S, X(k))|. \quad (11)$$

The attribute $x_d \in X(n)$ is a candidate for inclusion in the set X (k) if

$$\sum_{S_i\in T} Z(S_i, X(k+1)) > \sum_{S_i\in T} Z(S_i, X(k)), \quad (12)$$

where $X(k+1) = X(k) \cup \{x_d\}, T \subset E_0$.

Let P denote the subset of feature indices from X (n); D_j(P) is the set of noise objects of class Kj according to (5) on the set $\{x_a\}_{a\in P}$ at the value λ, calculated according to (10). Step-by-step selection of informative feature sets using (11) and (12) is implemented as follows.

Step 1: Choice $i_1, j_1 \in \{1, \dots, n\}$. P=$\{i_1, j_1\}$.

Step 2: Pick out $\cup_{j=1}^{l} D_j(P)$ by (5) to $\{x_a\}_{a\in P}$. $T = E_0 \setminus \cup_{j=1}^{l} D_j(P)$. Calculate $\theta(P) = \{\theta_i(P)\}_1^m$ by $\{x_a\}_{a\in P}$, $\theta_i(P) = \{S_\mu,\ S_i \in K_j | \rho(S_i, S_\mu) < r_i,\ r_i = min_{S_t\in CK_j\cap T}\rho(S_i, S_t)\}$.

Step 3: $u = 0; Z(P) = \{z_i(P)\}_l^m, where\ z_i(P) = max_{S_i\in\theta_j(P)}|\theta_j(P)|. Y = 0.$

For all $v \in \{1, \dots, n\}\setminus P$ pick out

$\cup_{j=1}^{l} D_j(P \cup \{v\})$ by (5) at $\{x_a\}_{a\in P\cup\{v\}}$, $T = E_0 \setminus \cup_{j=1}^{l} D_j(P \cup \{v\})$, $C = \sum_{S_i\in T} z_i(P)$,

calculate $\theta(P \cup \{v\}) = \{\theta_i(P \cup \{v\})\}_1^m$ by $\{x_a\}_{a\in P\cup\{v\}}$, where $\theta_i(P \cup \{v\} = \left\{S_\mu, S_i \in K_j \middle| \rho(S_i, S_\mu) < r_i, r_i = min_{S_t\in CK_j\cap T}\rho(S_i, S_t)\right\}$;

calculate $Z(P \cup \{v\}) = \{z_i(P \cup \{v\})\}_1^m$, where $z_i(P \cup \{v\}) = max_{S_i\in\theta_j(P\cup\{v\})}|\theta_j(P \cup \{v\})|, N = \sum_{S_i\in T} z_i(P \cup \{v\})$.

If N>C and N>Y then Y=N, $u = v$

Step 4: If Y>0, then $= P \cup \{u\}$, go to 2.

Step 5: Output P.

Step 6: the end.

Denote by P the subset of feature indices from X (n); $D_j(P)$ is the set of noise objects of class $K_j$according to (5) on the set $\{x_a\}_{a\in P}$ with value λ calculated according to (10). A step-by-step selection of informative feature sets using (11) and (12) is implemented . To compare informative sets obtained by different criteria, it is recommended to use (8) and (9).

Computational experiment. For a given training set $E_0 = \{S_1, \dots, S_m\}$, consisting of representatives l disjoint classes of objects . It is believed that each object $S_i \in E_0$ is described by n nominal features.

We choose a one sociology dataset which determines nationality (uzbek or korean). The features of dataset are questions of surveys. The values of feature means the answers of the question. In our dataset there are 100 objects and 25 features. The last feature in our dataset is class of object.

We fix one metric from the equivalence class Ψ and assume that it is basic for a computational experiment. When calculating the measure of proximity between objects, the Zhuravlev metric was used as the base

$$\rho(x, y) = \sum_{i\in I}|x_i - y_i| + \sum_{i\in J}\begin{cases}1, x_i \ne y_i\\0, x_i = y_i\end{cases} \quad (14)$$

where $I, J \subset \{1, \dots, 20\}$ - are sets of numbers of quantitative and nominal features, respectively.

Firstly, we determined shell objects, which is subset of boundary objects. As a result, 64 objects from 100 objects in dataset are taken as a shell object, after that, we built y_{ij} binary matrix:

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0--1 1 0 0 0 0 0 1 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1--1 1 1 0 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
2--0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
3--0 1 0 1 0 0 0 1 0 0 0 1 1 0 0 1 1 1 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
4--0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
5--0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
6--0 0 0 1 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
7--0 0 0 1 1 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
8--0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
9--0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
10--1 0 0 0 0 0 1 1 1 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
11--1 0 0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
12--0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
13--0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
14--0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
15--0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
16--0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
17--0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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21--0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
22--0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
23--0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
24--0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
25--0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
26--0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
27--0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
28--0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
29--0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
30--0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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In addition, i can say that, our binary matrix is symmetric as to main diagonal. After that, we grouped objects of classes. Groups of first class:

{0,1,10,11,19,49,3,24,31,35,45,47,15,21,16,18,20,29,37,6,7,17,23,28,46,2,4,32,38,39,40,34,5,8,25,26,30,33,43,9,12,27,44,22,42,41,36}, {13}, {14}, {48} – number of groups=4

Groups of second class:

{50,52,83,60,65,70,72,73,93,96,97,55,78,79,94,54,62,63,76,92,66,81,69,59,90,95,51,53,58,88,67,89,98,57,74,64,75,77,87,91,68,56,82,85,86,71}, {61}, {80}, {84}, {99} – number of groups=5

Finally, we found compactness of both classes: 0,8848 and 0,848 respectively. It can be seen that, compactness of classes are almost equal and good grade. As a result, our found compactness measures show that, our dataset is good to take experiments because, compactness measure is close to 1.

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Model and numerical algorithm for investigation of the transfer and diffusion of aerosol particles in the atmosphere taking into account the capture of particles by vegetation elements*

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***Abstract*—In this paper, a mathematical model and a numerical algorithm are developed for the process of transfer and diffusion of harmful substances, which take into account the wind speed in three directions and the rate of deposition of aerosol particles on the underlying surface, as well as the capture of particles by vegetation elements, which plays a significant role in the dynamics of the object of study. To integrate the task, an implicit finite-difference scheme and an algorithm with the second order of approximation have been developed in time and space variables, with the help of which can be used to carry out numerical calculations on a computer system, on the basis of which it is possible to investigate and predict the ecological state of the industrial region under consideration.**

***Index Terms*—approximation, transport and diffusion, atmosphere, harmful aerosols, numerical algorithm**

I. Introduction

At present, the problems of environmental pollution with hazardous chemicals in the industrialized regions of the globe have become sharply aggravated. By the 21st century, human's technogenic impact on the biosphere and individual geocomponents (atmosphere, hydrosphere, lithosphere and communities of living organisms) has reached enormous proportions. Anthropogenic emissions and discharges are increasing from year to year. They also contain new components that are even more toxic which lead to a violation of the stability of the biosphere, to its destruction. The ecological state of the Earth's biosphere is assessed as a global crisis. The intensive growth of human economic activity, while ignoring the possibilities of nature and the laws of its development, has led to the need to solve one of the pressing problems on a global scale. This problem is related to the tasks of protecting the environment, water resources and underground resources from technogenic factors and negative anthropogenic impacts that directly affect the ecological state of the surface layer of the atmosphere and atmospheric air quality. Conducting comprehensive research, monitoring, forecasting and analysis of the process of the spread of impurities in the atmosphere, in soil and groundwater are among the most urgent tasks in the problem of environmental protection. The solution of these problems is associated with taking into consiferation many factors that affect the dispersion of impurities in the atmosphere, soil and groundwater. These include anthropogenic and meteorological conditions, type of source, properties of impurities, etc. The problems of modeling the transfer and diffusion of harmful substances are studied in scientific schools created under the guidance of foreign scientists J.W. Deardorff, M. Germano, U. Piomelli, L.C. Berselli, G.S. Winckelmans, W.C. Reynolds, T. Iversen., T.E. Nordeng, R. Lange, M. Pekar, G.I. Marchuk, V.V. Penenko, A.E. Aloyan, L.T. Matveeva, V.P. Dimnikova, I.E Naatsa, I.A. Kibelya, L.N. Gutman and others.

In the work [1], for monitoring, forecasting and making managerial decisions to protect the environment of industrial regions, a mathematical model was developed that describes the process of propagation of active aerosol particles emitted from production facilities, which involves weather and climatic factors, forward and reverse reaction rates and the reaction rate decomposition of the mixture by a chemical reaction.

A model, a numerical algorithm, and a software tool was developed by the authors of the work [2] for research, forecasting, and monitoring, as well as for assessing the ecological state of the atmosphere and the underlying surface of the region under consideration by passive and active impurities, which take into account the main parameters and disturbances that affect the object as a whole. A system of nonlinear differential equations in partial derivatives was obtained to determine the speed of movement of aerosol particles under the action of an air flow, which estimate the main physical and mechanical properties of aerosol particles, which play an important role in the process under consideration.

The papers [3]–[5] solved the problem related to monitoring and forecasting the ecological state of the air basin of industrial regions, where there is often a violation of the balance of the sanitary norm of the environment, due to a large amount of emissions of harmful substances into the atmosphere. The authors of the article, when developing a mathematical model of the transfer and diffusion process, calculated existing factors such as soil erosion, which, with unstable air mass stratification, is essential: - Change the concentration of harmful substances in the atmosphere; - Change the speed of movement of the air mass of the atmosphere in three directions over time; - Change the diffusion coefficient and the vertical turbulent mixing coefficient for stable and unstable stratification; - Change the direction of the wind with time per day, depending on the orography of the area; - Change the coefficient of interaction, which depends on the characteristics of the underlying surface of the earth and the orography of the area. Numerical calculations were carried out in a computer system, the results of which are presented in the form of graphical objects. A model of the process of distribution of industrial emissions in the atmosphere was developed in the article [6]–[8], taking into consideration the deposition rate of fine particles, which is described using a multidimensional differential equation in partial derivatives with appropriate initial and boundary conditions. For the numerical solution of the problem, the method of splitting by physical processes was used: transport, diffusion and absorption of harmful particles, as well as an implicit finite-difference scheme in time with the second order of accuracy. Although the above works have obtained significant results of a fundamental and applied nature, they do not consider the spread of harmful substances, considering the heterogeneity and roughness of the earth's surface: vegetation cover, forest belt, high-rise residential and industrial facilities.

II. Formulation of the problem

With considering the above, we figure on a mathematical model that describes based on the law of hydromechanics in order to study the process of transfer and diffusion of aerosol particles in the atmosphere, including the essential parameters u, ν, ω - the components of the wind speed in directions, x, y, z, respectively, as well as the orography of the area under consideration:

$$\begin{gathered}\frac{\partial\theta}{\partial t} + u\frac{\partial\theta}{\partial x} + v\frac{\partial\theta}{\partial y} + (w - w_g)\frac{\partial\theta}{\partial z} + \sigma\theta + \alpha\theta = \\ = \mu\frac{\partial^2\theta}{\partial x^2} + \mu\frac{\partial^2\theta}{\partial y^2} + \frac{\partial}{\partial z}\left(\kappa\frac{\partial\theta}{\partial z}\right) + \delta Q\end{gathered} \tag{1}$$

with the corresponding initial and boundary conditions:

$$\left.\theta\right|_{t=0} = \theta^0; \tag{2}$$

$$-\mu\left.\frac{\partial\theta}{\partial x}\right|_{x=0} = \xi\left(\theta_E - \theta\right); \mu\left.\frac{\partial\theta}{\partial x}\right|_{x=Lx} = \xi\left(\theta_E - \theta\right); \tag{3}$$

$$-\mu\left.\frac{\partial\theta}{\partial y}\right|_{y=0} = \xi\left(\theta_E - \theta\right); \mu\left.\frac{\partial\theta}{\partial y}\right|_{y=L_y} = \xi\left(\theta_E - \theta\right); \tag{4}$$

$$-\kappa\left.\frac{\partial\theta}{\partial z}\right|_{z=0} = \left(\beta\theta - f_0\right); \kappa\left.\frac{\partial\theta}{\partial z}\right|_{z=H_z} = \xi\left(\theta_E - \theta\right); \tag{5}$$

Where there is θ - the concentration of harmful substances in the atmosphere; t is time; θ^0 – primary concentration of harmful substances in the atmosphere; θ_E - is the concentration entering through the boundaries of the area under consideration; $x,\ y,\ z$ - coordinate system; u, ν, ω - wind speed in three directions; w_g- is the particle settling rate; σ - coefficient of absorption of harmful substances in the atmosphere; $\alpha\left(z\right)$ - coefficient characterizing the capture of particles by vegetation elements; $\mu,\ \kappa$ are the diffusion and turbulence coefficients; Q - is the power of the source; δ - is the Dirac function; ξ - is the mass transfer coefficient across the calculation boundaries; β - is the coefficient of particle interaction with the underlying surface.

III. Solving method

Further, for the numerical integration of problem (1)-(5), we introduce the notation.

$$\bar{w} = w - w_g; \theta = e^{\frac{ux+vy}{2\mu} + \frac{\bar{w}z}{2\kappa}}\tilde{\theta} \tag{6}$$

and substituting relation (6) into equation (1) and simplifying like terms, we end up with the following:

$$\frac{\partial\tilde{\theta}}{\partial t} + \sigma_1\tilde{\theta} = \mu\frac{\partial^2\tilde{\theta}}{\partial x^2} + \mu\frac{\partial^2\tilde{\theta}}{\partial y^2} + \frac{\partial}{\partial z}\left(\kappa\frac{\partial\tilde{\theta}}{\partial z}\right) + e_1\delta Q \tag{7}$$

Here $\sigma_1 = \frac{\kappa u^2 + \kappa v^2 + \mu\bar{w}^2 + 4\sigma\mu\kappa + 4\alpha\mu\kappa}{4\mu\kappa}$; $e_1 = e^{-\left(\frac{ux+vy}{2\mu} + \frac{\bar{w}z}{2\kappa}\right)}$;

The initial and boundary conditions for (7), respectively, are as follows:

$$\left.\tilde{\theta}\right|_{t=0} = \tilde{\theta}^0; \tag{8}$$

$$-\mu\left.\frac{\partial\tilde{\theta}}{\partial x}\right|_{x=0} = \xi\left(e_1\theta_E - \tilde{\theta}\right); \mu\left.\frac{\partial\tilde{\theta}}{\partial x}\right|_{x=L_x} = \xi\left(e_1\theta_E - \tilde{\theta}\right); \tag{9}$$

$$-\mu\left.\frac{\partial\tilde{\theta}}{\partial y}\right|_{y=0} = \xi\left(e_1\theta_E - \tilde{\theta}\right); \mu\left.\frac{\partial\tilde{\theta}}{\partial y}\right|_{y=L_y} = \xi\left(e_1\theta_E - \tilde{\theta}\right); \tag{10}$$

$$-\kappa\left.\frac{\partial\tilde{\theta}}{\partial z}\right|_{z=0} = \left(\beta\tilde{\theta} - e_1 f_0\right); \kappa\left.\frac{\partial\tilde{\theta}}{\partial z}\right|_{z=H_z} = \xi\left(e_1\theta_E - \tilde{\theta}\right). \tag{11}$$

To simplify the solution, we consider equations (7)-(11) in a rectangular $D = (0 \le x \le L_x,\ 0 \le y \le L_y,\ 0 \le z \le H_z)$ area and assume that the source of pollution is in the surface layer of the earth. For the numerical solution of problem (7)-(11), we cover the change field with an unknown grid corresponding to the steps, taking into consideration the boundary conditions:

$$\Omega_{xyzt} = \left\{(x_i = i\Delta x,\ y_j = j\Delta y, z_k = k\Delta z,\ \ \tau_n = n\ \Delta t);\right. \\ \left. i = \overline{1, N_x};\ \ j = \overline{1, M_y},\ \ k = \overline{1, L_z},\ n = \overline{0, N_t},\ \ \Delta t = \tfrac{1}{N_t}\right\}.$$

We use an implicit difference scheme to ensure a high order of approximation in terms of time and space variables, as well as the stability of the calculation process, we obtain a finite difference scheme: In the direction of the Ox:

$$\frac{\tilde{\theta}^{n+1/3}_{i,j,k}-\tilde{\theta}^{n}_{i,j,k}}{\Delta t/3}+\sigma_1\tilde{\theta}^{n+1/3}_{i,j,k}=$$
$$=\frac{\mu}{\Delta x^2}\left(\tilde{\theta}^{n+1/3}_{i+1,j,k}-2\tilde{\theta}^{n+1/3}_{i,j,k}+\tilde{\theta}^{n+1/3}_{i-1,j,k}\right)+$$
$$+\frac{\mu}{\Delta y^2}\left(\tilde{\theta}^{n}_{i,j+1,k}-2\tilde{\theta}^{n}_{i,j,k}+\tilde{\theta}^{n}_{i,j-1,k}\right)+$$
$$+\frac{1}{\Delta z^2}\left(\begin{array}{c} l\kappa_{k+0,5}\tilde{\theta}^{n}_{i,j,k+1}- \\ -\left(\kappa_{k-0,5}+\kappa_{k+0,5}\right)\tilde{\theta}^{n}_{i,j,k}+ \\ +\kappa_{k-0,5}\tilde{\theta}^{n}_{i,j,k-1}\end{array}\right)+$$
$$+\frac{1}{3}e_1\delta_{i,j,k}Q.$$

We tear off the brackets and grouping similar terms of the equation, we get:

$$\begin{gathered}\tfrac{\mu}{\Delta x^2}\tilde{\theta}^{n+1/3}_{i-1,j,k}-\left(\tfrac{3}{\Delta t}+\sigma_1+\tfrac{2\mu}{\Delta x^2}\right)\tilde{\theta}^{n+1/3}_{i,j,k}+\tfrac{\mu}{\Delta x^2}\tilde{\theta}^{n+1/3}_{i+1,j,k}=\\ =-\left(\left(\tfrac{3}{\Delta t}-\tfrac{2\mu}{\Delta y^2}-\tfrac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2}\right)\tilde{\theta}^{n}_{i,j,k}+\tfrac{\mu}{\Delta y^2}\tilde{\theta}^{n}_{i,j-1,k}+\right.\\ \left.+\tfrac{\mu}{\Delta y^2}\tilde{\theta}^{n}_{i,j+1,k}+\tfrac{\kappa_{k-0,5}}{\Delta z^2}\tilde{\theta}^{n}_{i,j,k-1}+\tfrac{\kappa_{k+0,5}}{\Delta z^2}\tilde{\theta}^{n}_{i,j,k+1}+\tfrac{1}{3}e_1\delta_{i,j,k}Q\right).\end{gathered} \tag{12}$$

To simplify the above equation, we introduce the following notation:

$a_{i,j,k}=\frac{\mu}{\Delta x^2};\ b_{i,j,k}=\frac{3}{\Delta t}+\sigma_1+\frac{2\mu}{\Delta x^2};\ c_{i,j,k}=\frac{\mu}{\Delta x^2};$

$$d_{i,j,k}=\left(\frac{3}{\Delta t}-\frac{2\mu}{\Delta y^2}-\frac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2}\right)\tilde{\theta}^{n}_{i,j,k}+$$
$$\frac{\mu}{\Delta y^2}\tilde{\theta}^{n}_{i,j-1,k}+\frac{\mu}{\Delta y^2}\tilde{\theta}^{n}_{i,j+1,k}+\frac{\kappa_{k-0,5}}{\Delta z^2}\tilde{\theta}^{n}_{i,j,k-1}+$$
$$+\frac{\kappa_{k+0,5}}{\Delta z^2}\tilde{\theta}^{n}_{i,j,k+1}+\frac{1}{3}e_1\delta_{i,j,k}Q.$$

We write equation (12) as a system of tridiagonal linear algebraic equations using the above notation:

$$a_{i,j,k}\tilde{\theta}^{n+1/3}_{i-1,j,k}-b_{i,j,k}\tilde{\theta}^{n+1/3}_{i,j,k}+$$
$$+c_{i,j,k}\tilde{\theta}^{n+1/3}_{i+1,j,k}=-d_{i,j,k}.$$

We also approximate the first part of the boundary condition (9) with the second order of accuracy:

$$-\mu\frac{-3\tilde{\theta}^{n+1/3}_{0,j,k}+4\tilde{\theta}^{n+1/3}_{1,j,k}-\tilde{\theta}^{n+1/3}_{2,j,k}}{2\Delta x}=\xi e_1\theta_E-\xi\tilde{\theta}^{n+1/3}_{0,j,k}$$

or

$$\begin{gathered}3\mu\tilde{\theta}^{n+1/3}_{0,j,k}-4\mu\tilde{\theta}^{n+1/3}_{1,j,k}+\mu\tilde{\theta}^{n+1/3}_{2,j,k}=\\ 2\Delta xe_1\xi\theta_E-2\Delta x\xi\tilde{\theta}^{n+1/3}_{0,j,k}.\end{gathered} \tag{13}$$

From the resulting tridiagonal system of linear algebraic equations

$$a_{1,j,k}\tilde{\theta}^{n+1/3}_{0,j,k}-b_{1,j,k}\tilde{\theta}^{n+1/3}_{1,j,k}+c_{1,j,k}\tilde{\theta}^{n+1/3}_{2,j,k}=-d_{1,j,k}$$

find $\tilde{\theta}^{n+1/3}_{2,j,k}$ as follows:

$$\tilde{\theta}^{n+1/3}_{2,j,k}=-\frac{a_{1,j,k}}{c_{1,j,k}}\tilde{\theta}^{n+1/3}_{0,j,k}+\frac{b_{1,j,k}}{c_{1,j,k}}\tilde{\theta}^{n+1/3}_{1,j,k}-\frac{d_{1,j,k}}{c_{1,j,k}}. \tag{14}$$

$\theta^{n+2/3}_{i,2,k}$ in equation (14) we substitute in (13) and get the following:

$$3\mu\tilde{\theta}^{n+1/3}_{0,j,k}-4\mu\tilde{\theta}^{n+1/3}_{1,j,k}-\frac{a_{1,j,k}}{c_{1,j,k}}\mu\tilde{\theta}^{n+1/3}_{0,j,k}+$$
$$+\frac{b_{1,j,k}}{c_{1,j,k}}\mu\tilde{\theta}^{n+1/3}_{1,j,k}-\frac{d_{1,j,k}}{c_{1,j,k}}\mu=$$
$$=2\Delta xe_1\xi\theta_E-2\Delta x\xi\tilde{\theta}^{n+1/3}_{0,j,k};$$

or

$$\begin{gathered}\left(3\mu+\frac{a_{1,j,k}}{c_{1,j,k}}\mu+2\Delta x\xi\right)\tilde{\theta}^{n+1/3}_{0,j,k}=\\ =\left(4\mu-\frac{b_{1,j,k}}{c_{1,j,k}}\mu\right)\tilde{\theta}^{n+1/3}_{1,j,k}+\\ +\frac{d_{1,j,k}}{c_{1,j,k}}\mu+2\Delta xe_1\xi\theta_E;\end{gathered} \tag{15}$$

As a result, we find $\tilde{\theta}^{n+1/3}_{0,j,k}$ from equation (15):

$$\begin{gathered}\tilde{\theta}^{n+1/3}_{0,j,k}=\frac{4\mu c_{1,j,k}-b_{1,j,k}\mu}{3\mu c_{1,j,k}-a_{1,j,k}\mu+2\Delta x\xi}\tilde{\theta}^{n+1/3}_{1,j,k}+\\ +\frac{d_{1,j,k}+2\Delta x\xi c_{1,j,k}e_1\theta_E}{3\mu c_{1,j,k}-a_{1,j,k}\mu+2\Delta x\xi}.\end{gathered} \tag{16}$$

Using the given formulas (16), we find the values of the sweep coefficients $\alpha_{0,j,k}$ and $\beta_{0,j,k}$:

$$\begin{gathered}\alpha_{0,j,k}=\frac{4\mu c_{1,j,k}-b_{1,j,k}\mu}{3\mu c_{1,j,k}-a_{1,j,k}\mu+2\Delta x\xi};\\ \beta_{0,j,k}=\frac{d_{1,j,k}+2\Delta x\xi c_{1,j,k}e_1\theta_E}{3\mu c_{1,j,k}-a_{1,j,k}\mu+2\Delta x\xi}.\end{gathered} \tag{17}$$

We also approximate the second part of the boundary condition (9):

$$\mu\frac{\tilde{\theta}^{n+1/3}_{N-2,j,k}-4\tilde{\theta}^{n+1/3}_{N-1,j,k}+3\tilde{\theta}^{n+1/3}_{N,j,k}}{2\Delta x}=$$
$$=\xi e_1\theta_E-\xi\tilde{\theta}^{n+1/3}_{N,j,k}$$

or

$$\begin{gathered}\mu\tilde{\theta}^{n+1/3}_{N-2,j,k}-4\mu\tilde{\theta}^{n+1/3}_{N-1,j,k}+3\mu\tilde{\theta}^{n+1/3}_{N,j,k}=\\ =2\Delta xe_1\xi\theta_E-2\Delta x\xi\tilde{\theta}^{n+1/3}_{N,j,k}.\end{gathered} \tag{18}$$

Sequentially applying the sweep method for N, N-1 and N-2 , we find $\tilde{\theta}^{n+1/3}_{N-1,j,k}$ and $\tilde{\theta}^{n+1/3}_{N-2,j,k}$

$$\tilde{\theta}^{n+1/3}_{N-1,j,k}=\alpha_{N-1,j,k}\tilde{\theta}^{n+1/3}_{N,j,k}+\beta_{N-1,j,k}; \tag{19}$$

$$\begin{gathered}\tilde{\theta}^{n+1/3}_{N-2,j,k}=\alpha_{N-2,j,k}\tilde{\theta}^{n+1/3}_{N-1,j,k}+\beta_{N-2,j,k}=\\ =\alpha_{N-2,j,k}\left(\alpha_{N-1,j,k}\tilde{\theta}^{n+1/3}_{N,j,k}+\beta_{N-1,j,k}\right)+\\ +\beta_{N-2,j,k}=\alpha_{N-2,j,k}\alpha_{N-1,j,k}\tilde{\theta}^{n+1/3}_{N,j,k}+\\ +\alpha_{N-2,j,k}\beta_{N-1,j,k}+\beta_{N-2,j,k}.\end{gathered} \tag{20}$$

Substituting $\tilde{\theta}^{n+1/3}_{N-1,\,j,\,k}$ and $\tilde{\theta}^{n+1/3}_{N-2,\,j,\,k}$ from (19) and (20) in equation (18) we find $\tilde{\theta}^{n+1/3}_{N,\,j,\,k}$:

$$\begin{gathered}\alpha_{N-2,\,j,\,k}\alpha_{N-1,\,j,\,k}\mu\tilde{\theta}^{n+1/3}_{N,\,j,\,k}+\alpha_{N-2,\,j,\,k}\beta_{N-1,\,j,\,k}\mu+\\ +\beta_{N-2,\,j,\,k}\mu-4\alpha_{N-1,\,j,\,k}\mu\tilde{\theta}^{n+1/3}_{N,\,j,\,k}-\\ -4\beta_{N-1,\,j,\,k}\mu+3\mu\tilde{\theta}^{n+1/3}_{N,\,j,\,k}=\\ =2\Delta x e_1\xi\theta_E-2\Delta x\xi\tilde{\theta}^{n+1/3}_{N,\,j,\,k};\end{gathered}$$

$$\begin{aligned}\tilde{\theta}^{n+1/3}_{N,\,j,\,k}=&\frac{2\Delta x e_1\xi\theta_E}{2\Delta x\xi+(\alpha_{N-2,\,j,\,k}\alpha_{N-1,\,j,\,k}-4\alpha_{N-1,\,j,\,k}+3)\,\mu}-\\ &-\frac{(\beta_{N-2,\,j,\,k}+\alpha_{N-2,\,j,\,k}\beta_{N-1,\,j,\,k}-4\beta_{N-1,\,j,\,k})\,\mu}{2\Delta x\xi+(\alpha_{N-2,\,j,\,k}\alpha_{N-1,\,j,\,k}-4\alpha_{N-1,\,j,\,k}+3)\,\mu}.\end{aligned}\tag{21}$$

In the reverse course of the sweep in succession, the values of the concentrations are determined $\tilde{\theta}^{n+1/3}_{N-1,\,j,\,k}$,$\tilde{\theta}^{n+1/3}_{N-2,\,j,\,k}$, ..., $\tilde{\theta}^{n+1/3}_{0,\,j,\,k}$ are in the following form:
$\tilde{\theta}^{n+1/3}_{i,\,j,\,k}=\alpha_{i,\,j,\,k}\tilde{\theta}^{n+1/3}_{i+1,\,j,\,k}+\beta_{i,\,j,\,k};$
$i=\overline{N-1,\,0},\ j=\overline{1,\,M-1},\ k=\overline{1,\,L-1}.$
Applying the above procedures in the direction Oy and we have the following:

$$\bar{a}_{i,\,j,\,k}\tilde{\theta}^{n+2/3}_{i,\,j-1,\,k}-\bar{b}_{i,\,j,\,k}\tilde{\theta}^{n+2/3}_{i,\,j,\,k}+\bar{c}_{i,\,j,\,k}\tilde{\theta}^{n+2/3}_{i,\,j+1,\,k}=-\bar{d}_{i,\,j,\,k}.$$

Here

$$\bar{a}_{i,\,j,\,k}=\frac{\mu}{\Delta y^2};\quad \bar{b}_{i,\,j,\,k}=\frac{3}{\Delta t}+\sigma_1+\frac{2\mu}{\Delta y^2};\quad \bar{c}_{i,\,j,\,k}=\frac{\mu}{\Delta y^2};$$

$$\begin{gathered}\bar{d}_{i,\,j,\,k}=\left(\frac{3}{\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2}\right)\tilde{\theta}^{n+1/3}_{i,\,j,\,k}+\\ \frac{\mu}{\Delta x^2}\tilde{\theta}^{n+1/3}_{i-1,\,j,\,k}+\frac{\mu}{\Delta x^2}\tilde{\theta}^{n+1/3}_{i+1,\,j,\,k}+\\ +\frac{\kappa_{k-0,5}}{\Delta z^2}\tilde{\theta}^{n+1/3}_{i,\,j,\,k-1}+\frac{\kappa_{k+0,5}}{\Delta z^2}\tilde{\theta}^{n+1/3}_{i,\,j,\,k+1}+\\ +\frac{1}{3}e_1\delta_{i,\,j,\,k}Q.\end{gathered}$$

$$\begin{gathered}\bar{\alpha}_{i,\,0,\,k}=\frac{4\mu\bar{c}_{i,\,1,\,k}-\bar{b}_{i,\,1,\,k}\mu}{3\mu\bar{c}_{i,\,1,\,k}-\bar{a}_{i,\,1,\,k}\mu+2\Delta y\xi};\\ \bar{\beta}_{i,\,0,\,k}=\frac{\bar{d}_{i,\,1,\,k}+2\Delta y e_1\bar{c}_{i,\,1,\,k}\xi\theta_E}{3\mu\bar{c}_{i,\,1,\,k}-\bar{a}_{i,\,1,\,k}\mu+2\Delta y\xi}.\end{gathered}\tag{22}$$

$$\begin{aligned}\tilde{\theta}^{n+2/3}_{i,\,M,\,k}=&\frac{2\Delta y e_1\xi\theta_E}{2\Delta y\xi+(\bar{\alpha}_{i,\,M-2,\,k}\bar{\alpha}_{i,\,M-1,\,k}-4\bar{\alpha}_{i,\,M-1,\,k}+3)\,\mu}-\\ &-\frac{\left(\bar{\beta}_{i,\,M-2,\,k}+\bar{\alpha}_{i,\,M-2,\,k}\bar{\beta}_{i,\,M-1,\,k}-4\bar{\beta}_{i,\,M-1,\,k}\right)\mu}{2\Delta y\xi+(\bar{\alpha}_{i,\,M-2,\,k}\bar{\alpha}_{i,\,M-1,\,k}-4\bar{\alpha}_{i,\,M-1,\,k}+3)\,\mu}.\end{aligned}\tag{23}$$

Similarly, applying the above procedures in the direction of Oz, we get the following:

$$\bar{\bar{a}}_{i,\,j,\,k}\tilde{\theta}^{n+1}_{i,\,j,\,k-1}-\bar{\bar{b}}_{i,\,j,\,k}\tilde{\theta}^{n+1}_{i,\,j,\,k}+\bar{\bar{c}}_{i,\,j,\,k}\tilde{\theta}^{n+1}_{i,\,j,\,k+1}=-\bar{\bar{d}}_{i,\,j,\,k}.$$

Here

$$\bar{\bar{a}}_{i,\,j,\,k}=\frac{\kappa_{k-0,5}}{\Delta z^2};$$

$$\bar{\bar{b}}_{i,\,j,\,k}=\frac{3}{\Delta t}+\sigma_1+\frac{\kappa_{k-0,5}+\kappa_{k+0,5}}{\Delta z^2};$$

$$\bar{\bar{c}}_{i,\,j,\,k}=\frac{\kappa_{k+0,5}}{\Delta z^2};$$

$$\begin{gathered}\bar{\bar{d}}_{i,\,j,\,k}=\left(\frac{3}{\Delta t}-\frac{2\mu}{\Delta x^2}-\frac{2\mu}{\Delta y^2}\right)\tilde{\theta}^{n+2/3}_{i,\,j,\,k}+\frac{\mu}{\Delta x^2}\tilde{\theta}^{n+2/3}_{i-1,\,j,\,k}+\\ +\frac{\mu}{\Delta x^2}\tilde{\theta}^{n+2/3}_{i+1,\,j,\,k}+\frac{\mu}{\Delta y^2}\tilde{\theta}^{n+2/3}_{i,\,j-1,\,k}+\\ +\frac{\mu}{\Delta y^2}\tilde{\theta}^{n+2/3}_{i,\,j+1,\,k}+\frac{1}{3}e_1\delta_{i,\,j,\,k}Q^{n+1},\end{gathered}$$

$$\begin{gathered}\bar{\bar{\alpha}}_{i,\,j,\,0}=\frac{4\kappa_1\bar{\bar{c}}_{i,\,j,\,1}-\bar{\bar{b}}_{i,\,j,\,1}\kappa_1}{3\kappa_1\bar{\bar{c}}_{i,\,j,\,1}-\bar{\bar{a}}_{i,\,j,\,1}\kappa_1-2\Delta z\beta};\\ \bar{\bar{\beta}}_{i,\,j,\,0}=\frac{\bar{\bar{d}}_{i,\,j,\,1}\kappa_1+2e_1\Delta z\bar{\bar{c}}_{i,\,j,\,1}f}{3\kappa_1\bar{\bar{c}}_{i,\,j,\,1}-\bar{\bar{a}}_{i,\,j,\,1}\kappa_1-2\Delta z\beta}.\end{gathered}\tag{24}$$

$$\begin{aligned}\tilde{\theta}^{n+1}_{i,\,j,\,L}=&\frac{2\Delta z e_1\xi\theta_E}{2\Delta z\xi+(\bar{\bar{\alpha}}_{i,\,j,\,L-2}\bar{\bar{\alpha}}_{i,\,j,\,L-1}-4\bar{\bar{\alpha}}_{i,\,j,\,L-1}+3)\,\kappa_L}-\\ &-\frac{\left(\bar{\bar{\beta}}_{i,\,j,\,L-2}+\bar{\bar{\alpha}}_{i,\,j,\,L-2}\bar{\bar{\beta}}_{i,\,j,\,L-1}-4\bar{\bar{\beta}}_{i,\,j,\,L-1}\right)\kappa_L}{2\Delta z\xi+(\bar{\bar{\alpha}}_{i,\,j,\,L-2}\bar{\bar{\alpha}}_{i,\,j,\,L-1}-4\bar{\bar{\alpha}}_{i,\,j,\,L-1}+3)\,\kappa_L}.\end{aligned}\tag{25}$$

As a result, a mathematical model and a numerical algorithm were obtained for monitoring and predicting the process of the spread of harmful substances in the atmosphere, considering the heterogeneity and roughness of the earth's surface: vegetation cover, forest belt, high-rise residential and industrial facilities.

IV. Computational Experiment and Discussion of Results

Computational experiments were carried out to study the process of transfer and diffusion of harmful substances in the atmosphere, taking into account the heterogeneity and roughness of the earth's surface: vegetation cover, forest belts, high-rise residential and industrial facilities. As follows from the results of the numerical calculations, the dynamics of changes in the concentration of harmful substances in the atmosphere significantly depends on the wind speed in the surface layer of the atmosphere (Fig. 1). From the dynamics of the transfer of pollutants in the atmosphere, it can be seen (Fig. 2, 3) that, depending on the change in the direction and speed of the wind, the concentration of pollutants in the atmosphere and the area of their transfer change over time.

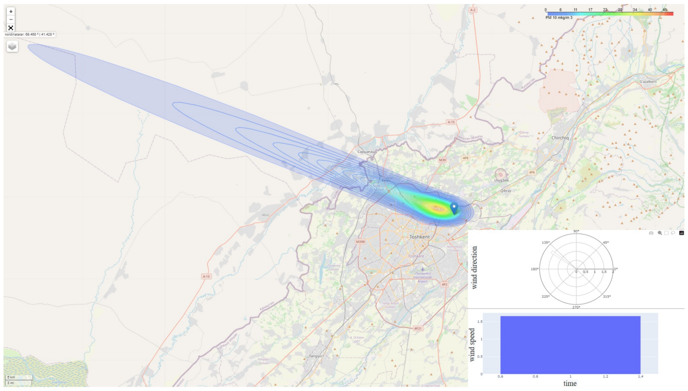

Fig. 1. Dynamics of transfer and diffusion of aerosol particles in the atmosphere at Q = 1000 mg/m3; H=50 m; u=1.5 m/s; t = 1 h.

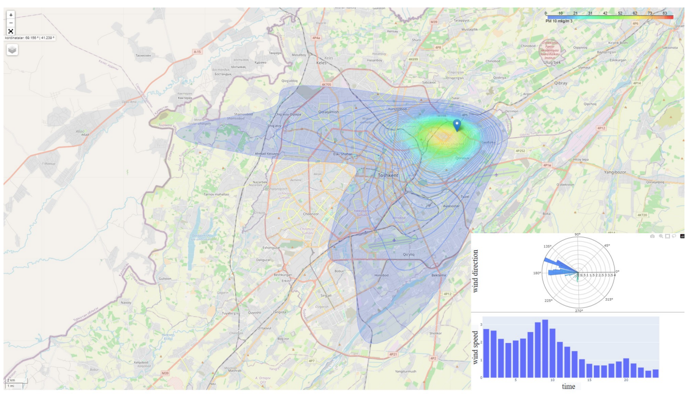

Fig. 2. Dynamics of transfer and diffusion of aerosol particles in the atmosphere at Q = 1000 mg/m3; H=100 m; t = 24 h; u=3.5 m/s.

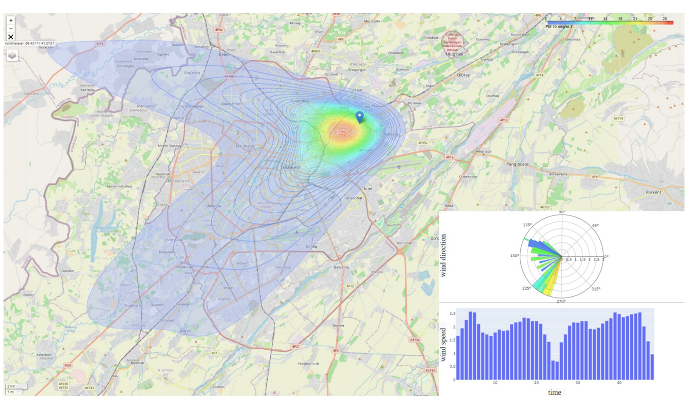

Fig. 3. Dynamics of transfer and diffusion of aerosol particles in the atmosphere at Q = 1000 mg/m3; H=100 m; t = 48 h; u=3 m/s.

V. Conclusions

A mathematical model has been developed to monitor and predict the concentration of pollutants in the atmosphere of the region under consideration, that takes into consideration the wind speed in three directions and the rate of deposition of aerosol particles on the underlying surface, as well as the capture of particles by vegetation elements, which plays a significant role in the dynamics of the process. Thus, in this work, a numerical algorithm has been developed for solving the problem (1)-(5) with the second order of approximation in time and space variables. By software implementation of the developed model and algorithm, it is possible to carry out SE on a computer to study and predict the ecological state of the industrial regions under consideration.

It can be seen from the figures 1,2,3 that the change in the concentration of aerosols in the atmosphere depends significantly on the actual change in wind speed by day, the coefficient characterizing the capture of particles by vegetation elements and the horizontal diffusion coefficient, as well as the vertical turbulence coefficient. The concentration of pollutants in the surface layer of the atmosphere changes over time depending on the actual wind speeds.

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Content Based Recommendation Systems: an overview

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***Abstract*—In this article, today information library systems are one of the main sources of providing information needs of the population and they have many users. Information-library systems have a large amount of valuable information resources and have established an information search service for users to find the necessary literature. As you know, search engines receive queries and return results that are considered relevant. As a result, the user again faces the problem of finding what he needs from among the many information sources provided. Currently, in several information systems, recommendation systems based on artificial intelligence are effectively used to recommend objects. In information library systems, high efficiency can be achieved by determining the information needs of users and recommending appropriate literature. For this, the information needs of library users should be determined by analyzing information about their age, interests, level of knowledge in a certain area, previous requests, profession, etc. By introducing recommendation systems in information library systems, it is possible to ease the work of librarians, increase the speed and accuracy of finding the necessary information source, and increase the efficiency of management and the level of satisfying the information needs of the population.**

Keywords—information, intelligent search, users, artificial intelligence, information needs, recommender system.

I. INTRODUCTION

The use of content and book reviews for recommendatory purposes dates back to 1999. Mooney and Roy extracted book metadata from Amazon, such as title, authors, summaries, reviews, comments, and similar authors, titles, and terms. When the last three functions based on collaborative filtering are removed, the performance of collaborative filtering is greatly reduced. This system represented books as bags of words and used a binary classifier based on Naive Bayes [1, 2, 3]. The metadata of the book is expanded by Kapusuzoglu and Oguduku, who use an extended ontology. For example, if an ontology has a domain author, its extended ontology will include author awards and other publications. The system characterizes books as a relational database (several tables connected by foreign keys). To work with new ontologies, extended forms of cosine and Euclidean similarity measurements are proposed. The experiments are carried out on 2791 server magazines of an online bookstore. They show that stretched ontologies improve the accuracy of recommendations over standard ontologies, especially the proposed Euclidean distance.

II. RECOMMENDATIONS BASED ON THE TEXT CONTENT OF BOOKS

Of the more than thirty recommender systems surveyed, only a few take into account the actual text of the books. WHA proposed a content-based stylometry method. The book is represented in two ways: as a vector of words extracted using the latent dirichlet distribution, or as a normalized vector of style characteristics, in particular, vocabulary richness, document length, bigrams of parts of speech, and most frequently occurring words in the book. Rocchio's algorithm has been adapted to detect the most important features of stylometry for the reader. Experiments with the LitRec dataset have shown that combining a content-based stylometric system with collaborative filtering performs better than a separate collaborative filtering or content-based system. When comparing different representations of books, the hidden themes of the dirichlet distribution showed the best results [3, 4].

The widespread adoption of e-book readers introduces another level of book recommendations. E-books allow you to use the digitized text of the book. Given the entire text of an e-book, Zhang and Chou recommend authors and e-booksafter obtaining the name of the user's favorite author. The system builds a four-level tree for each author with their background information (such as education and political opinions) at the highest level, followed by the author's books, the pages of each book, and the paragraphs on each page at the next three levels. . This hierarchical structure wasproposed to solve the problem of spatial distribution. The problem arises when sequences of words are processed without considering their context. For example, if one is working with bags of words, "computer", "science" and "school" are treated as separate terms even though they occur as a trigram.

To deal with tree structures, Zhang and Chow adopted a multi-layer self-organizing map (MLSOM). Book recommendation systems use the last three levels to measurethe similarity between two books. Author recommendation systems use all levels to find similar authors. The dataset retrieved from Project Gutenberg contained the text of 10,500 books and 3,868 author information items. There are no users or ratings in this dataset. The purpose of the experiment is to “assess the relevance of two books”. If the requested book has similar genres to the found book, this is considered a relevant recommendation. This system is reported to outperform other content-based systems using Latent Semantic Indexing, Latent Dirichlet Allocation, and PLSA; however, the hidden dirichlet allocation gives similarperformance [3, 7, 8].

Givon and Lavrenko address the problem of cold start of elements; the system includes social tags. Each book is characterized by vectors tf-idf (term frequency - reciprocal document frequency) of social tags (extracted from the book cataloging website, LibraryThing3) and book tags (extracted from the entire text of the book). For new books that don't have social tags available, a relevance model is used toexamine book tags to predict social tags. A comparison is made between item-based collaborative filtering, user-based collaborative filtering, and a combination of collaborative filtering and a relevancy model. The pure relevance model produces results similar to those of collaborative filtering systems. Also, book recommendations are no different, whether they're on real or perceived social tags.

Linguistic elements contain many syntactic, lexical, stylistic and artistic elements. In addition, we have illustrated the factors that play a role in making accurate recommendations. Our proposed system based on author identification does not require author demographic information such as, which is not always available. Also, unlike our Content based systems are designed and evaluated to provide individualized recommendations to each user. Pera and Ng include writing style in combination with other factors in book recommendation systems. However, the writing style was learned from the point of view of the reviewers and not automatically from the book's textual content. Book reviews, of which there are not alwaysmany (if any), depend on the bias of users and the level of judgment [5, 6].

III. Text element Recommendations

The main approach in book search engines is to use the word set method, which creates book representations based on term frequency. In this case, cosine similarity is often used to find the most similar book representations. The vector space model was used to search for similar books based on their descriptions in rather than their actual text. Other popular information retrieval approaches using topic modeling techniques are also used in text element recommendations. Topic modeling techniques learn latent topics from a corpus in which a mixture of topics characterizes each document. One method is Latent Semantic Indexing (LSI) also called Latent Semantic Analysis (LSA). Latent semantic indexing performs singularvalue decomposition (SVD), which is a dimensionality reduction technique, on a set of documents to learn the contextual meanings of words. Subsequently, latent semantic indexing presents documents (whether previously seen or new) in a "semantic space" where corresponding documents are considered similar. Latent Dirichlet Allocation (LDA) presents a document as a mixture of topics and measures the degree to which a word is related to each of the topics. It is assumed that the document is related to a limited number of topics and that the topic has a limited number of recurring terms. Topic models have helped evaluate preferences in many recommender systems. For example, recommendations were based on topics extracted from movie plots, articles, and online course curricula.

A more recent modern approach is paragraph 2vec, also called Doc2vec, which was proposed by Le and Mikolov to provide a fixed size representation for documents regardless of their length. In recommender systems, Doc2vec has been used by Gupta and Varma and Wang to recommend research papers and answers in Q&A systems, respectively. All methods in this subsection are considered basic.

IV. Social recommender systems and user-generated content

Social recommendation systems use posts, relationships, tags, and other content found on social networks to make suggestions. Recommendations from friends are more trusted than other users. This type of recommender system usually complements other recommender systems to solve a new user problem. The next three subsections present recommender systems using book cataloging networks, social networks, and general book reviews.

V. Recommendations for book cataloging platforms

One system developed by Pera benefits from LibraryThing, a social book cataloging site. It allows users to form friendships as well as catalog and tag books. The proposed system measures the similarity between books cataloged/liked by the target user and books cataloged/liked by his friends. Similarity is calculated in two ways. First, because each book in LibraryThing has a tag cloud attached to it, the system finds the similarity of the books represented by the tags using a word correlation matrix. Second, it calculates the strength of friendships as it measures the similarity between the tags assigned by the user and their friends. The book rating is based on a single rating calculated using the joint product of the similarity values of the two methods. To evaluate the system, the raters' data is extracted from LibraryThing and the results are compared against the Amazon and LibraryThing recommendation lists; they are vastly superior to both [9, 10].

Tags are also integrated into a system that finds similar books in the user's friends list. Books are considered similar if they share one or more tags with friends, or when friends rate them highly. The system goes further by measuring the trustworthiness of the user's friends. The most trusted friend is the one with the most tags in common. As in the evaluation, the recommendations of this system are superior to those of Amazon and LibraryThing.

Users in are represented as nodes in a network, and trust between them is calculated using inference and propagation. When users consider buying books, they request recommendations from their neighbors, who in turn relay the request to their neighbors. Alternatively, the user may receive suggestions from a content-based system. Books in the system are also embodied as nodes, linked due to the similarity of their content.

To the best of our knowledge, none of the book readers use social media other than book cataloging websites. In addition, previous social book recommendation systems have been based on the use of tags and as well as friend lists. Thus, the topic model-based book recommendation component is the first social book recommendation system that automatically extracts user interests from general social networks and matches them with book topics.

VI. RECOMMENDATIONS BASED ON SOCIAL MEDIA

Social networks have become an excellent resource for “warming up” a user’s cold start. In addition to using Facebook friend lists analyzed user demographics and user- liked pages. Nair solved a new user problem by analyzing the target user's tweets and identifying which movie genres she likes. The cosine similarity between the tweet and the movie plot is calculated. If the similarity is greater than 0.5, the movie genre is added to the user's favorite genres. Later, films of the most common genres are recommended. Based on topics learned from Twitter user accounts, recommender systems can suggest hashtags and friends. The topic-based book recommendation component, on the other hand, solves a new user problem by using tweets to recommend non- Twitter items (such as non-hashtags).

To provide news guidance, Abel treat the user profile as a request; The k most similar candidate news articles are recommended. User profiles are made up of three elements: hashtags, entities, and topics. A concept is scored by counting the number of times a user mentions it (for example, #technology = 5). The OpenCalais framework is used to define the names of people, places, and other entities in addition to topics; there is a limit to 18 different topics (for example, politics or sports). All articles posted by 1,619 Twitter users in the last week of observation are considered candidates for recommendation. Entity-based user profiles received the highest accuracy.

Chen suggest a recommendation URL based on Twitter. Cosine similarity is calculated between user profiles and URL topics, and the system recommends the URL elements with the highest scores. The personal profile and the subscriber profile for each user are built from words. For the URL, a set of words is also created from the terms found in the tweets that include the URL. In a field experiment, 44 participants rated recommended URLs. The best performance was 72.1% accuracy when the recommender system used its own profiles and candidate URLs from FoF (Followee-of-Followees) [6, 9].

Unlike work which searches for news-related and narrow lists of entities and categories, the topic model-based book recommendation component is dynamic. . and represents the dominant topics discussed by the user without looking for predefined concepts. The proposed system does not require entity recognition or development of ontologies. Moreover, our system focuses on a limited number of topics frequently discussed by the user, and this makes it easy to enrich the topics, for example, with word embedding. The recommendation of news using Twitter may require the analysis of hashtags and entities such as names and places that may correspond to rapidly changing news. Literary books, however, may include broad aspects that are not primarily about names and actions.

VII. RECOMMENDATIONS BASED ON USER TEXTS

Many readers share their opinions about books on the Internet. Such views provide an opportunity to explore the user's preferences in detail. In the study discussed in this section, books are ranked based on the similarity of their reviews and keyword matching (set in advance). In each book preferred by a user, a thematic map is created based on the description of the book and user reviews. A topic map is a form of ontology built using TM-Gen that represents extracted text as a map. Many natural language processing techniques are applied before extraction, including morphological analysis and named entity recognition. All subject maps of the user's favorite books are combined and compared with candidate books with the same representation. The system is evaluated using the BookCrossing dataset. It produces fewer errors than some implemented modern systems. In a series of recommender systems for beginning readers, book recommendations are based on four factors: readability and content similarity, topics, and attractive terms. The user's readability level is measured and compared to a set of candidate books.

To measure readability, TRoL and ReLAT are used to determine the level of a book without an excerpt. For content similarity, publicly available book summaries are presented as word packs, and similarity is calculated using word correlation coefficients (WCF). The similarity of topics depends on the subject headings of the Library of Congress (LCSH). To find the similarity of the thematic distribution of books, a vector space model is created and the similarity between the vectors is calculated. In a significant number of book-related LCSHs are penalized as they entail content complexity. Finally, in order to analyze the attractive terms of books, refer to the literature with recommendations for readers and identify six aspects of books: characterization, frame, writing language and style, tempo, special themes, plot, and tone. Usually, the attractive terms associated with each book can be obtained from reader recommendations from databases such as NoveList Plus, which require paid access. Therefore, in this paper, attractive terms are taken from reader feedback automatically collected from websites such as Amazon.com, Bertrams.com, Bookfinder4u.com, Bookmooch.com, Dogobooks.com, and Fishpond.com. The 124 predefined terms, classified into each of the six dimensions, are extracted from surveys, as Pera and Ng explain in detail. The similarity of vectors of attractive terms of the book of favorites and books of candidates is calculated. The recommendation system in takes into account illustrations on book covers. It uses the open source computer vision library (OpenCV) to check the similarity of covers, which are freely available through the Google Books API and LibraryThing. Pera and Ng extend the recommender system it includes readability level and content similarity by including readability similarity, which is simply element-based collaborative filtering. The similarity scores above are combined using multiple linear regression in CombMNZ in Borda scoring. These systems are compared with other popular recommender systems such as Amazon and Goodreads, or with previous versions of the system. For comparison and additional qualitative analysis, assessors evaluate the system using Amazon Mechanical Turk [10].

VIII. CONCLUSION

The reviews of a particular user can be extracted to find out their detailed interests. To make individual book recommendations, Priyanka analyzes each user's reviews. The sentiment of each review is evaluated only by counting the occurrence of positive and negative words. A matrix is created for each user. Its rows and columns represent books and features extracted from user reviews. For example, one column could be "understandable", which could have a positive, negative, or neutral value in each row (book). The sentiment of the overall value of the function is calculated. The approach has not been evaluated and its performance has not been reported. Sohail apply a non-automated book recommendation method based on opinion analysis. To find top-rated computer science books, reviews are used. Seven categories of characteristics are analyzed, each of which is assigned a weight. The weights are summed up and the books are redistributed accordingly.

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E-mail Filtering Methods and Their Comparative Analysis

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***Abstract*— In this paper e-mail messages, spam message statistics, programs that send e-mail messages, spam and phishing messages, types of spam messages, e-mail filtering methods, comparative analysis of filtering methods, advantages and disadvantages of these methods, comparative analysis of available features in e-mail filtering methods.**

Keywords*— E-mail, filtering, spam, phishing, spammer, email spam, social media spam, forum spam, spam distributed through comments on websites, catalogs and mailing lists, sms spam, email traffic, E-mail filtering, Filter by list, Filter by keywords, Heuristic filtering, Filtering based on Bayesian network, Cooperation filter, Filter by query – answer, Support vector machine filtering.

I. Introduction

Nowadays, with the development of information and communication systems, the need of using electronic information is increasing and almost all the countries of the world are maintaining e-mail exchange system and the flow of e-mail between organizations is increasing day by day. E-mail is the only e-mail exchange system recognized by all the countries of the world. There are other types of email exchange systems but other systems are not recognized in all countries.

II. Main Part

E-mail is a technology that allows real-time exchange of e-mail over computer networks, i.e., receiving and sending e-mail. Modern e-mail works over the Internet or computer networks. Anyone who knows how to work on a computer can open a free e-mail account and use it freely. For this purpose, it is enough to register on one of the portals providing e-mail service [1] . After registration, e-mail can be accessed from any computer connected to the Internet. There are many such portals. The most famous of them are:

http://mail.yandex.ru;
http://www. u mail.u z ;
http://mail.rambler.ru;
http://mail.google.com;
http://mail.yahoo.com;
http://www.mail.ru .

The advantages of e-mail are that the address name is easy to remember and files can be sent in any format. It can be noted quite fast and reliable delivery of messages, ease of use and similar features [2] .

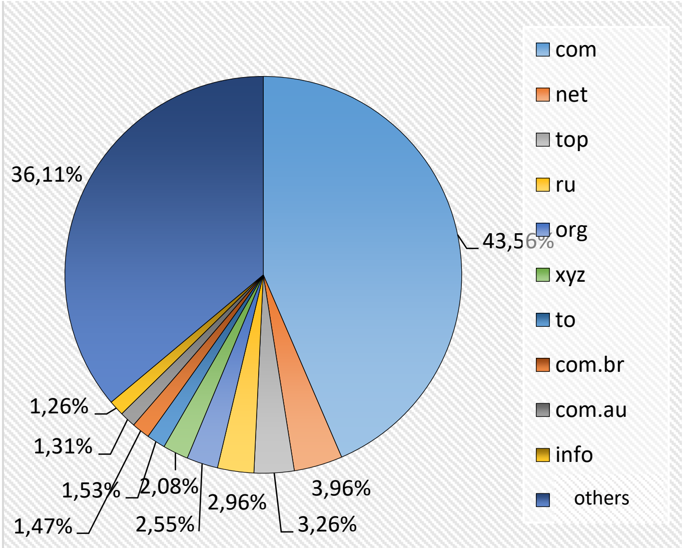

Fig. 1. Top level domains are where more spam and phishing pages are located

The disadvantages of e-mail are the massive spread of advertisements and viruses, the limitation of message size, and the possibility of its use for malicious purposes if an unauthorized person gets into the mailbox.

In the last decade, spam e-mail links have become a serious problem for e-mail users [3]. A large number of spam messages are sent to users' e-mail accounts every day. Most of the spam is sent to private e-mail addresses. Spam accounts for 78% of all messages sent. According to the Message Abuse Task Force, 88-92% of all emails were sent in the first half of 2010. As of 2020, spam accounted for 50.37% of email traffic, down 6.14% from 2019. Most of the spam, 21.27%, came from Russia. Kaspersky Lab 184, 435, 643 malicious links detected. Mail antiviruses often detected messages containing malware of the Trojan.Win32.Agentb family . Anti-phishing system blocked 434898635 attempts to go to fake resources. 18.12% of online stores are frequently subjected to phishing attacks [4] . This is why email filtering is important.

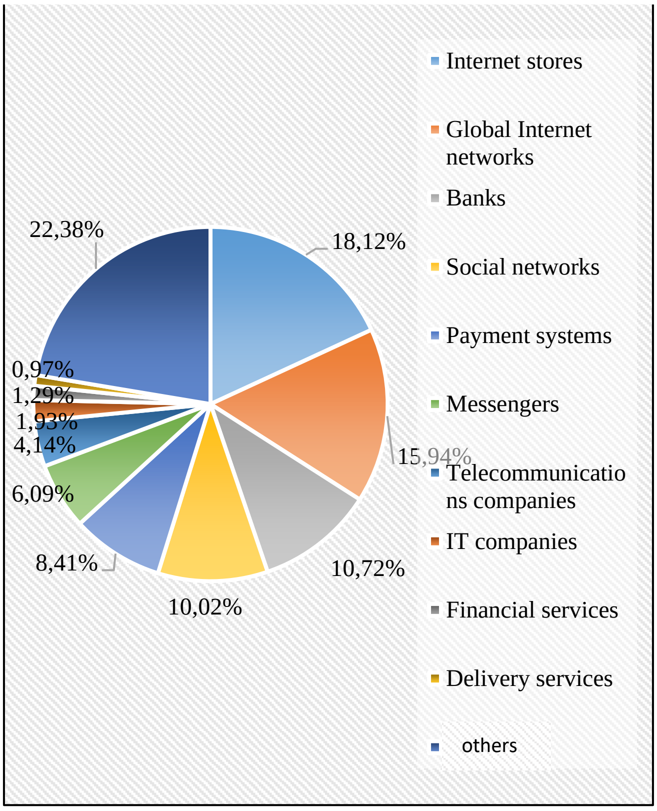

Fig. 2. Distribution of organizations attacked by spammers

Spam is the systematic transmission of commercial electronic messages by individuals who conceal or falsify their true identities. In a broader sense, it is an electronic document sent to an e-mail address as an advertisement from an unknown person or organization. There can also be spam messages on a local network. The bad side of spam is that it fills users' inboxes with unwanted messages. This, in turn, wastes purchased traffic to open unwanted messages. If the number of spam messages is too high and the interval between incoming spam messages is too short, it will cause the mail server to crash and overload the Internet channel. Spam messages have the following forms:

- email spam (EPS);
- social media spam (ITS);
- forum spam (FS);
- spam (SSHC) distributed through comments on websites;
- catalogs and mailing lists (KBS) ;
- sms spam (SS).

People or organizations that send spam are called spammers. With the help of spam message, there is an opportunity to increase the counter that counts the visitors to the social page and through this you can see the revenue. This is why anti-spam filters are installed when creating a website. An example of this is the introduction of a CAPTCHA system when writing comments. This will allow you to control whether the person leaving the message is a human or a robot. Essentially, spam is sent to users through a script, an algorithm is created, and it becomes public.

Email spam is a type of email spam that consists of messages sent to a large number of recipients via email. Clicking on a link in a spam message can redirect the user to a phishing website or a site that hosts malware. Spam e-mail may contain malware in the form of embedded scripts or other executable files. Spam detection usually involves a large number of links in an email. Most spam filtering approaches currently in use focus on a classification method where text messages are the primary content. Classified spam messages may consist of neutral words [5].

Spam not only harms the majority of email users, but also puts a strain on an organization's information systems infrastructure and causes a decrease in the efficiency of information systems [5].

E-mail filtering is the process of analyzing incoming e-mail messages in real time according to specified criteria and depending on the result of the analysis, the e-mail message is accepted or rejected. It is mainly used in the process of

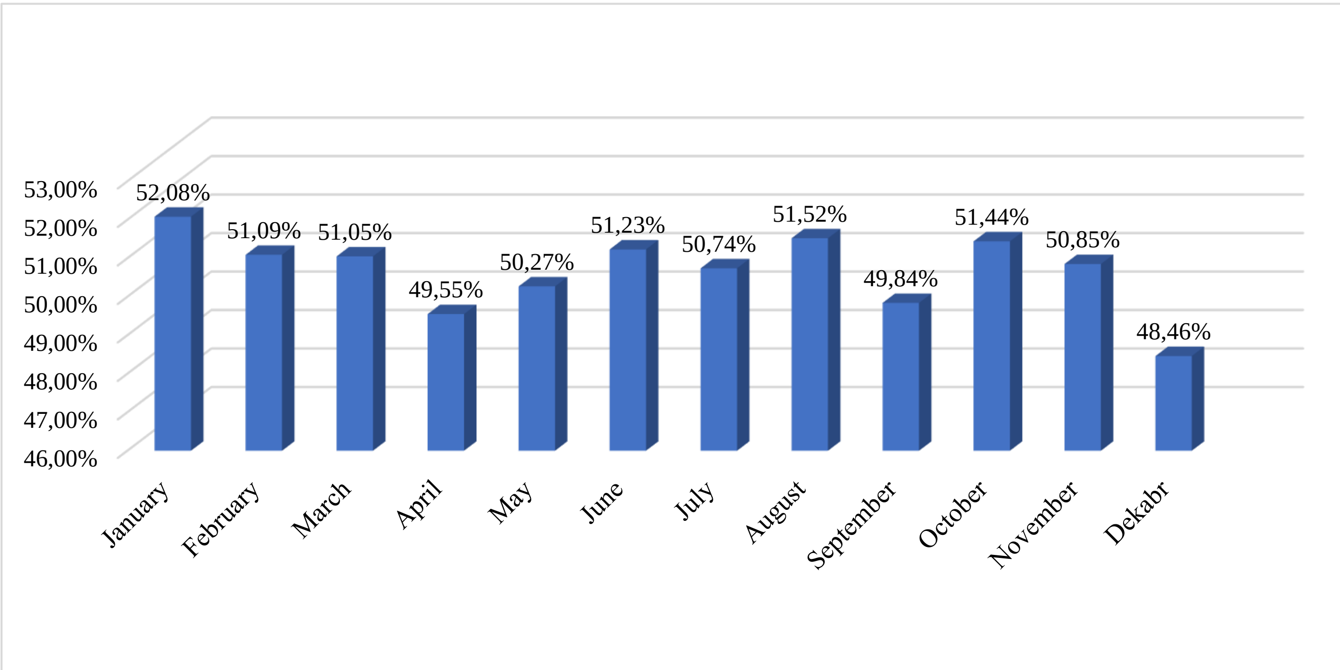

Fig. 3. The share of spam in global email traffic in 2020.

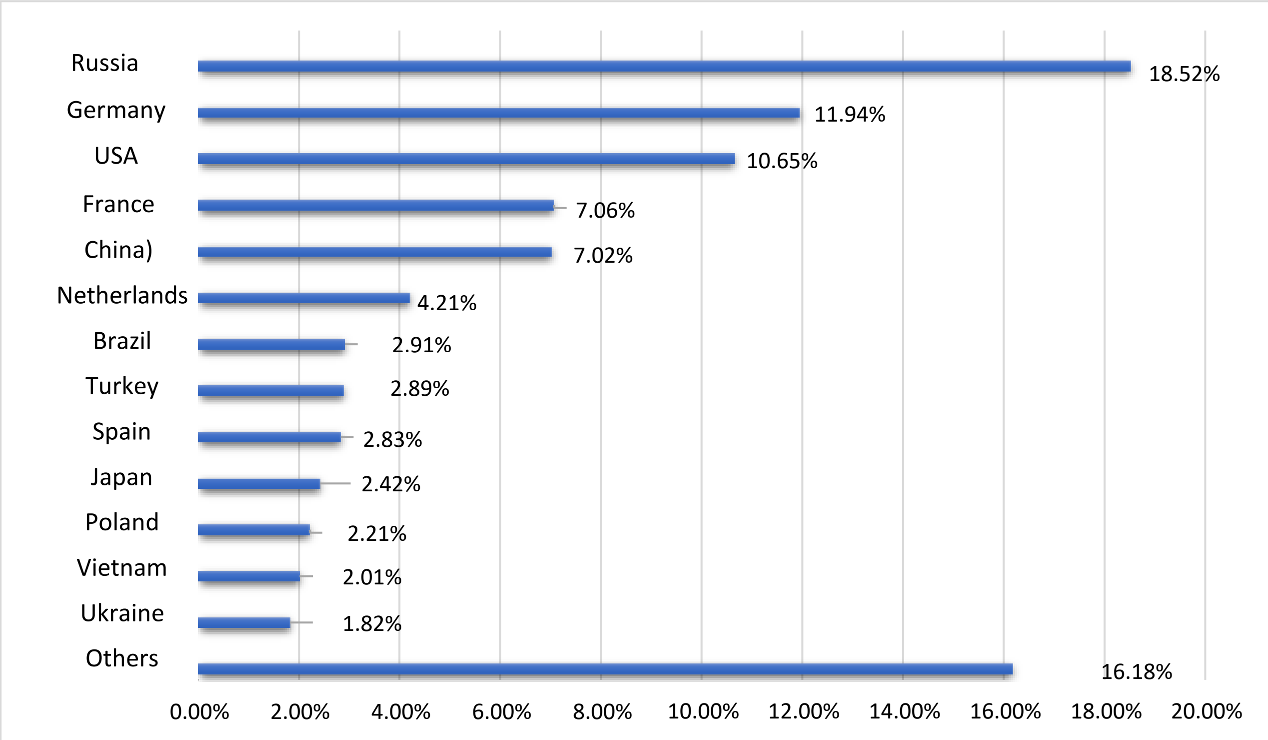

Fig. 4. Percentage of spam messages sent worldwide.

automatic processing of incoming e-mail messages, but filtering is also used besides anti-spam method to add human factor to both e-mail messages and outgoing messages [6].

TABLE I. ANALYSIS OF EMAIL FILTERING METHODS.

№	Name of method	Classification	Advantage	Disadvantage
1.	Filter by list	List-based filters are a way to stop spam by classifying senders as spammers or trusted users, blocking or allowing their messages depending on the situation. It has the following representations: - A blacklist is a list of IP addresses or email addresses that have previously been used for spam emails; - It is a real-time list of black holes. works like a traditional blacklist but requires less maintenance; - a whitelist blocks spam using systems that are almost the exact opposite of a blacklist; - - a gray list is a list that rejects a message from a previously unknown user and sends an error message to the current server.	When an incoming message arrives, the spam filter checks to see if the IP address or e-mail address is blacklisted; if not, the message will be considered spam and deleted.	While blacklists ensure that certain spammers don't get to a user's email, they can also misidentify users as spammers.
2.	Filter by keywords	It performs keyword-based filtering, that is, it blocks a message with a specific keyword and adds the email address from which the message was sent to the list of addresses that send suspicious content. If there is an increased flow of messages from that address, it will block the address completely.	message spam can effectively detect spam by identifying keywords that occur frequently in messages.	It takes time for IT staff to keep the filter list of blocked words up to date.
3.	Heuristic filtering	Instead of blocking messages containing	Heuristic filters work quickly, minimizing	Aggressively tuned heuristic filters can cause false positives if

№	Name of method	Classification	Advantage	Disadvantage
		keywords, consider a few terms in the email. Heuristic filters scan the content of incoming mail and implement a mechanism to score words or phrases. Suspicious words commonly found in spam emails get high scores, while words found in normal emails get low scores. It then summarizes and calculates all the scores. If a message gets a certain score (set by the anti-spam application administrator) or higher, the filter will consider it spam and block it. Messages with a rating lower than the specified score will be delivered to the user.	email interception, and are quite efficient to install and configure.	a legitimate user sends an email containing certain words.
4.	Filtering based on Bayesian network	A filtering method based on the laws of mathematical probability to determine whether or not e-mail messages are spam. A Bayesian filter scans email content to determine which incoming messages are classified as spam, and then compares the text to a two-word list to calculate the probability that the message is spam. For example, if the word "Valium" occurs 62 times in a spam message and 3 times in normal emails, there is a 95% probability that an incoming email containing the word "Valium" is spam.	Bayesian filter constantly creates its own list of words based on the messages received by an individual user, it becomes more effective the more often it is used.	method requires a learning period to work properly, you will have to be patient and manually delete a few unsatisfactory messages beforehand.
5.	Cooperation filter	It uses a message-based approach to combat spam by collecting information from millions of e-mail users around the world. This system can flag incoming e-mail as spam or non-spam, and the information collected is sent to a central database.	In partnership Because gi's filtering system includes a huge base of active users, it can quickly, sometimes in minutes, quell spam epidemics.	If a large number of spammers group together and pretend to be legitimate users of the system, they will lead to decreased accuracy due to mislabeling of spam messages.
6.	Filter by query - answer	A method that requires the sender to perform a task before delivering an email, i.e. when a user sends an email to someone using the request/response filter, they receive a reply email asking them to enter a code or access a website in a specified form. . Email will be sent if this task is completed successfully. In other cases, it is blocked.	The method is that it can only be solved by a human being, not by a computer or an artificial intelligence system.	Request/Response Filter E-newsletters to which the user subscribes because these messages are usually sent by automated programs .
7.	Support vector mashine filtering	Performs message filtering using statistical learning techniques. Determines a threshold that divides messages into 2 categories based on the received data. These limits will consist of spam and non-spam messages.	The accuracy level is high, easily filtering even complex cases	Due to the large number of comparable factors, the speed of performance is low.

Email filters are commonly used to detect and remove viruses or spam from incoming email messages. In some organizations, as a result of employee non-compliance with established regulations and laws, spam messages spread to the organization's local or corporate network. Users are encouraged to use email filters to sort messages into folders based on subject or other criteria. Mail filters are installed by the user as a stand-alone program or as part of an e-mail program. In e-mail programs, users can easily create programs that automatically filter mail according to selected criteria. Most e-mail programs have automatic spam filtering. Internet service providers can also install mail filters on their mail agents as a service to their customers. Because of the growing threat of fraudulent Web sites, ISPs filter URLs in e-mail messages to prevent threats from malicious attackers. Email filters can handle inbound and outbound traffic. Includes a system for filtering incoming e-mail messages or a process for scanning messages from the Internet for users protected from legitimate interception [9]. Outbound e-mail filtering involves rescanning e-mail messages from local users to prevent potentially harmful messages from being delivered to other users on the Internet. One method of outbound e-mail filtering commonly used by Internet service providers is transparent SMTP (Simple Mail Transfer Protocol) proxying, in which e-mail traffic is intercepted and filtered through transparent proxy servers on the network. Enterprises are increasingly using email filtering software to protect their employees and IT. E-mail filtering programs are developed based on the following methods (Table 1).

These cited methods have different indications in terms of mechanism of action, built-in features, method accuracy, reliability, cost, social acceptability, etc. To determine which method is more effective in filtering email messages, a comparative analysis based on several features is needed. The selected features should be available in the information systems used [7]. As spammers continue to develop new ways to bypass e-mail filters, the methods used for e-mail filtering also need to be continuously improved and a combination of methods incorporating additional features should be utilized. The email filtering methods mentioned above have a number of features and their comparative analysis is as follows (Table 2).

TABLE II. A COMPARATIVE ANALYSIS OF AVAILABLE FEATURES IN EMAIL FILTERING METHODS

Filtering method / Advantages	Filter by list	Filter by keywords	Heuristic filtering	Filtering based on Bayesian network	Cooperation filter	Filter by query - answer	Support vector machine filtering o
Convenience	+	-	-	+	-	-	+
Universality	+	-	+	-	-	-	+
Fulfillment	-	+	+	+	+	+	+
Accumulation	-	-	-	-	-	-	-
Waste of time	+	+	-	+	+	-	+
Non-repeatability	-	-	-	+	-	+	+
Deception	-	-	-	-	+	+	+
Accuracy	+	-	-	+	+	+	+
Cost	+	+	-	-	-	-	-
Social recognition	+	+	+	-	+	+	-

None of the e-mail filtering methods currently in use is comprehensive and cannot be. Because it is clear that these characteristics change according to the requirements of the information system. Therefore, it is reasonable to use the following comparative analysis to determine the effectiveness of the methods. This takes the most common types of spam messages and compares them according to whether the methods are able to detect these types of spam or not [8]. The method that is able to detect the most common types of spam will have the property of adapting to the environment. Because spam messages propagate differently in different environments. A method that filters email messages and detects spam by adapting to the distribution environment is categorized as a large-scale and multifunctional method. The effectiveness of the large-scale and multifunctional method is high.

TABLE III. COMPARATIVE ANALYSIS OF SPAM DETECTION METHODS BY TYPE (SPAM DETECTION YES OR NO).

Spam message type / Filtering method	Action	EPS	FS	SSHC	KBS	SS
Filter by list	YES	NO	NO	YES	NO	YES
Filter by keywords	YES	NO	NO	NO	YES	YES
Heuristic filtering	YES	YES	NO	YES	NO	NO
Filtering based on Bayesian network	YES	YES	NO	YES	YES	YES
Cooperation filter	YES	NO	YES	YES	NO	YES
Filter by query - answer	YES	NO	YES	NO	YES	NO
Support vector mashine filtering	YES	YES	YES	YES	YES	YES

CONCLUSION

E-mail filtering reduces the load on the company's information system and also allows you to detect spam messages. The absence of overload on the organization's internal servers increases the speed of the servers. Almost every organization has a separate mail server for email messages, and hundreds of messages arriving on these servers are handled by ISPs. The environment also plays an important role in email filtering. When all the users in an organization conduct their work online, it is necessary to use a hybrid program that combines several methods at the same time. The main reason for this is that when spam emails are detected, it is necessary to update the spam email databases or keep updating the addresses of the spammers sending spam emails while checking the list or content. That is why it is necessary to use hybrid software in filtering e-mail messages. By comparative analysis of email filtering methods on different characteristics, parameters and environments, it is found that the method is versatile and feature rich. By comparative analysis it is found that the efficiency of basis vector method is high but all the experts know that the speed of this method is low, t. large number of comparable factors in basis vector method. Improvements in this method can increase the reliability and speed of e-mail filtering and spam detection software. To do this, first of all, it is necessary to define the criteria needed to filter e-mail messages.

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Adaptive Control for A New 4D Chaotic Wing Attractors with Multistability and Offset Boosting

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***Abstract*— This article explores a novel four-dimensional autonomous deterministic chaotic system controlled by a single parameter. Intriguingly, by fine-tuning that parameter, a spectrum of behaviours is observed, encompassing quasi-periodic oscillations, chaos, and hyper-chaos. A coexistence of a blend of both 3D torus and chaotic attractors is presented, which is rare to find in recent existing works. Both the homogeneous and heterogeneous multistabilities and the offset-boosting are investigated. The output chaotic signal is being validated in MATLAB Simulink. Here, chaotic signal control has been successfully attained using the adaptive control strategy using Lyapunov's secondary stability method.**

***Keywords*— torus, coexistence, multistability, offset boosting, chaos control**

I. Introduction

Chaotic systems have gained significant attention in recent decades for their wide-ranging theoretical and practical uses. They find applications in diverse areas like secure communication, neural networks, lasers, nonlinear circuits, chemical reactors, mobile robots, financial systems, and more [1,2].

Furthermore, nonlinear systems exhibit another crucial characteristic known as IC-dependent coexisting attractors, often referred to as "coexistence". Multistability occurs as multiple stable states coexist (even four to six attractors) under the influence of varying system parameters and initial conditions [3]. Currently, research into offset-boosting is a prominent area in chaos-related studies, driven by its notable relevance in secure communication applications [4, 5].

Chaos control introduces an input control for stabilizing unstable equilibria, utilizing a blend of active and adaptive control, along with a synergy of nonlinear and linear feedback mechanisms [6–9]. Instances of actual procedures requiring operation within pre-defined scenarios include managing missile trajectories in military applications, overseeing temperature and pressure control in industrial settings, and in the refinement of satellite orbits and within the realm of space applications, which have increased focus on devising track control methods for chaotic models. From some recent literature survey (TABLE I), we have identified some key features where we can improve further:

TABLE I. Comparision with recent prior arts

Ref.	**Existence of both flow and Attractor Merging**	**Homogeneous and heterogeneous multistability**	**Initial offset-boosting**	**Chaos control**
[10](2022)	Not discussed	Not discussed	No	No
[11](2023)	Not discussed	Not discussed	No	Yes
[12](2023)	Not discussed	Not discussed	No	Yes
[13](2022)	Not discussed	Not discussed	Yes	No
Our work	Yes	Yes	Yes	yes

In comparison to existing chaotic systems, we have studied the following distinctive characteristics in this paper:

1. A new autonomous four-dimensional chaotic system showcases a blend of torus and chaotic attractors. Its behaviour undergoes scrutiny through bifurcation diagrams, phase portraits, and Lyapunov exponent plots.
2. By fine-tuning a control parameter a, a series of dynamic behaviours like chaos, hyperchaos, quasi-periodic oscillations, and offset boosting, homogeneous and heterogeneous multistabilities are shown here and verified by the help of phase portrait, Lyapunov and bifurcation diagram.
3. Demonstrating the output signal of the system using off-the-shelf components, a Simulink-based approach is employed to validate the feasibility of the proposed chaotic model.
4. Chaos control has been successfully attained through the implementation of the adaptive control strategy using Lyapunov's secondary stability method and numerical simulations and validated the efficacy of the control strategy for the system.

II. New 4D Chaotic System

A new 4D chaotic system is proposed as follows

$$
\begin{aligned}
\frac{dx}{dt} &= ay + 0.01xz \\
\frac{dy}{dt} &= -\,2x + 14yz \\
\frac{dz}{dt} &= 0.9 - 0.5w^2 - y^2 \\
\frac{dw}{dt} &= -z
\end{aligned}
\tag{1}
$$

where, x, y, z, w are the state variables. The number of positive Lyapunov exponents as one- represents chaotic, two and more represent hyperchaotic. Fig. 1. illustrates chaotic states with $a = 1$ and sensitive dependence on the initial condition $(0.2, 0.2, 0.2, 0.2)$.

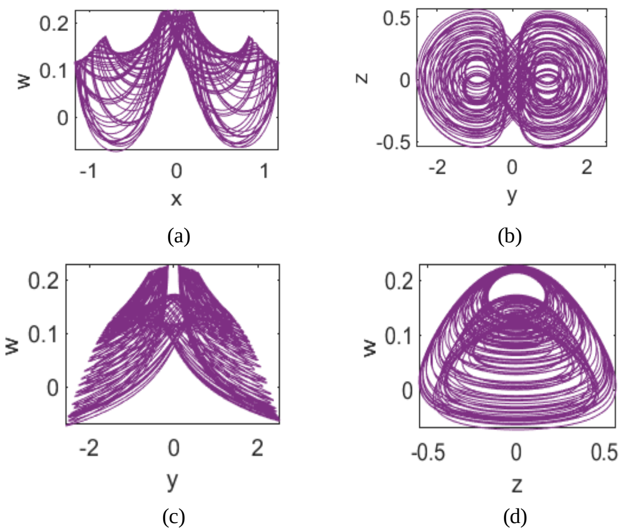


Fig. 1. Chaotic attractors for $a = 1$ and initial values $(0.2, 0.2, 0.2, 0.2)$: on planes (a) $x - w$, (b) $y - z$, (c) $y - w$, *and* (d) z - w.

III. Analysis of System Dynamic Characteristics

A. *Variation in Parameter a and its Effect on System Dynamics*

The dynamics of the system (1) are analysed when the control parameter a is varied. The initial conditions (IC) are fixed In Fig. 2, we can see the impact of parameter a (ranging from 10 to 20) on the behaviour of the system. In Fig. 2, Lyapunov exponents reveal chaotic, hyperchaotic, and quasi-periodic oscillations, while the bifurcation diagram illustrates how these oscillations occur as we vary the parameter a. Fig. 3. illustrates typical phase orbits of the system under variable a.

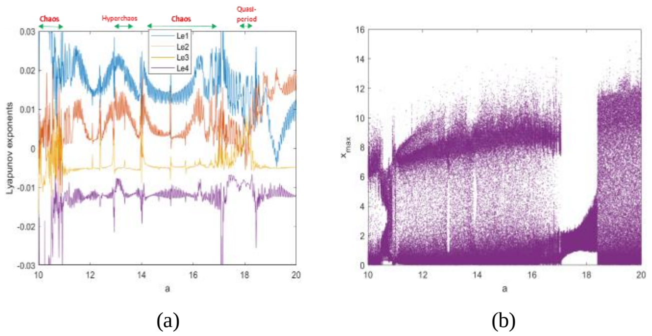


Fig. 2. The dynamic behaviours with IC = $(0.2, 0.2, 0.2, 0.2)$, $a \in [10, 20]$: (a) Lyapunov exponent plot; (b) bifurcation plot of the state variable *x*.

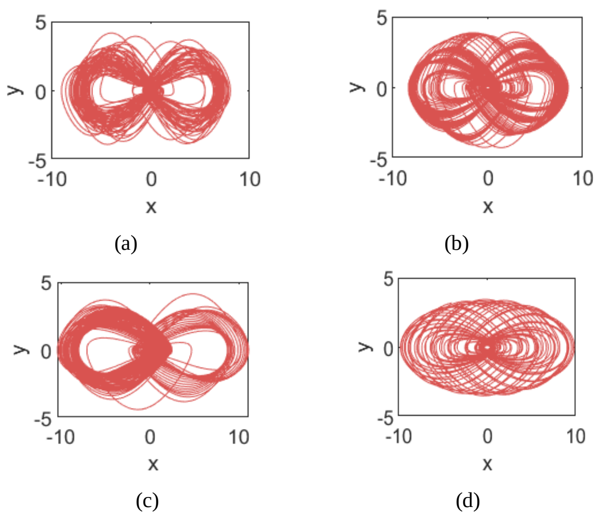
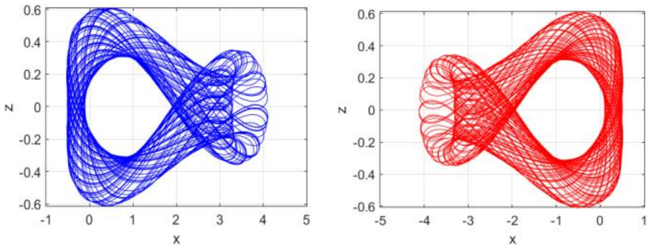


Fig. 3. Typical phase trajectory with initial values $(0.2, 0.2, 0.2, 0.2)$ for various parameters a : (a) $a = 10.20$; (b) $a = 13.5$; (c) $a = 18.02$; (d) $a = 18.62$.

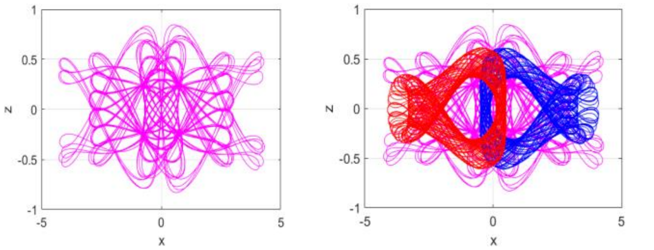
B. *Co-existence of both Chaotic Attractors and Flows*

The proposed system shows many complex dynamics, like hyper-chaos, chaos and quasi-periodic attractors as well as flow. Several coexisting attractors or flows are presented, indicating multistability. With different initial values with fixing the parameter $a = 5$, the system exhibits a blend of torus and chaotic attractors. Homogeneous and heterogeneous coexistence of both chaotic attractor and flow are studied here (Fig. 4).

By fixing the parameter $a = 5$, and taking the initial values $(x, y, z, w) = (0.1, 0.2, 0.3, 0.2)$, the system (1) produces an asymmetrical or heterogeneous chaos on *x*–*z* plane (Fig. 4(a)). In this case, four Lyapunov exponents are $L1 = 0.0418, L2 = 0, L3 = 0$, and $L4 = -0.01$. Fig. 4(b) illustrates an asymmetrical chaos about the *z*-axis with initial values $(x, y, z, w) = (-0.1, 0.2, -0.4, 0.2)$. For this case, Lyapunov exponents are $L1 = 0.012, L2 = 0, L3 = 0,$ and $L4 = -0.0236$. Further choosing the same parameters and taking initial values $(x, y, z, w) = (0.008, 0.014, 0.14, 0.09)$ a symmetrical or homogeneous chaotic attractor is appeared in Fig. 4(c). Here four Lyapunov exponents are $L1 = 0.09, L2 = -0.013, L3 = -0.018,$ and $L4 = -0.06$. Fig. 4(d) depicts the coexistence of different homogeneous or heterogeneous chaotic structures together under parameters $a = 5$ and its confirm the multistability characteristics of the system.



(a) (b)

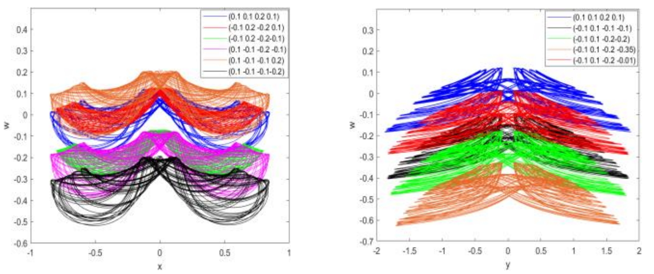


(c) (d)

Fig. 4. Coexistence of multiple chaotic behaviours of system (1) for $a = 5$, (a) asymmetric chaotic torus; (b) asymmetric chaotic torus; (c) symmetric chaotic attractors ; (d) coexistence of both heterogeneous and homogeneous chaotic dynamics triggered by initial values (a), (b) and (c).

C. *Offset-Boosting Behavior*

The proposed chaotic system exhibits an interesting characteristic, known as initial offset boosting. This characteristic becomes apparent when observing the evolution of initial conditions. By altering the initial conditions while keeping the other parameters constant, the multiple attractors are maintained. Fig. 5(a) depicts the phase portraits on the x-w plane, it is observed that they move in parallel to the w-axis at $a = 1$. Similarly, in Fig. 5(b), the phase trajectories on the y-w plane also move in parallel to the w-axis. Furthermore, Fig. 5(a) demonstrates both shifting and wing variations in the phase-portrait diagrams, due to different initial conditions. This initial offset-boosting characteristic with multistability is a distinct feature of the proposed system (1).



(a) (b)

Fig. 5. Offset-boosting on planes (a) *x-w* and (b) *y-w* for fixed $a = 1$ with different initial conditions.

IV. Modelling in MATLAB Simulink :

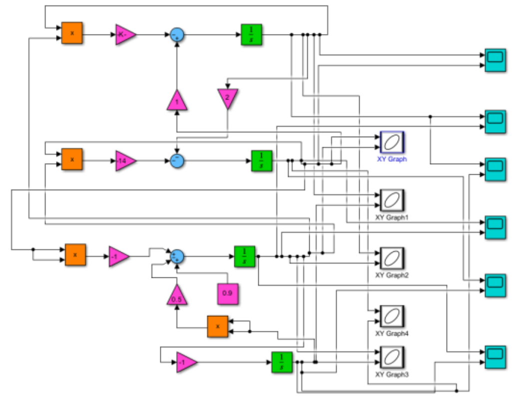


Fig. 6. Simulink simulation model of the proposed chaotic system

Simulink, a powerful simulation toolbox, offers modules that facilitate the construction of dynamic simulations for chaotic systems. By leveraging these modules, researchers can accurately model and analyse the complex behaviour exhibited by chaotic systems. With Simulink's extensive library of blocks and functions, it becomes possible to represent the nonlinear dynamics and intricate relationships inherent in chaotic systems. These blocks can be interconnected to form a comprehensive simulation model, capturing the behaviour of the system over time.

Simulink's integration with MATLAB provides access to advanced mathematical functions and algorithms, enabling the implementation of various chaos-generating equations or systems. By incorporating these equations into Simulink models, one can generate a time domain plot for different signals that exhibit chaotic properties. Additionally, Simulink offers visualization capabilities that allow users to observe and analyse the evolution of chaotic systems in real time. Plots, graphs, animations and hardware implementation can be generated from simulation outputs, aiding in the comprehension and interpretation of the system's complex dynamics. The modular nature of Simulink simplifies the process of modifying and experimenting with different parameters, initial conditions, or system configurations. Overall, Simulink's simulation toolbox serves as a valuable tool for constructing and analysing dynamic simulations of chaotic systems.

Here Runge–Kutta method is used, using the ode45 function, with a tolerance of 10^{-9}, with a sample step of 1 and simulating 120 seconds. The initial value is set as $(0.2,0.2,0.2,0.2)$. Fig. 6. Depicts the simulation model of the proposed system.

In Fig. 6, the adder is represented by blue modules, the multiplier is represented by the orange module and the gain is represented by the magenta module, that is, the control parameter and coefficient of the system. The optimal parameters of the system are set as $a = 1$ and the green one represents the four state spaces. The black and cyan modules are used to represent the six output sequences of the system. Fig. 7 depicts the phase portraits and their respective time series plots of the chaotic signals from the Simulink model.

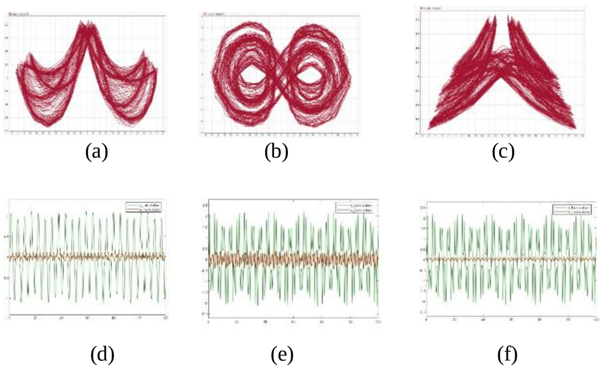


Fig.7. Similar chaotic nature and respective time domain plots as system (1) from the Simulink modelling for $a = 1$ and initial values $(0.2, 0.2, 0.2, 0.2)$.

V. ADAPTIVE CONTROL FOR CHAOTIC SIGNAL

A. Analytical Solution Approach

Chaos management of the newly introduced chaotic signals is explored employing an adaptive control approach. Consequently, the chaotic system (1) undergoes modification to transform into

$$\frac{dx}{dt} = ay + 0.01xz + u_1$$
$$\frac{dy}{dt} = -2x + 14yz + u_2 \qquad (2)$$
$$\frac{dz}{dt} = 0.9 - 0.5w^2 - y^2 + u_3$$
$$\frac{dx}{dt} = -z + u_4$$

Here, u_1, u_2, u_3 and u_4 denote the proposed adaptive control inputs aimed at stabilizing the chaotic dynamics of system (1). The primary approach of the adaptive controller involves creating control signals u_1, u_2, u_3 and u_4 aiming to counteract the inherent nonlinearity within the analysed chaotic system (2). This action is geared towards prompting the system to exhibit a response similar to that of a linear system, establishing a stable equilibrium point at $(0,0,0,0)$. In alignment with this, the configuration of u_1, u_2, u_3 and u_4 are presented as follows

$$u_1 = -\tilde{a}\, y - 0.01xz - \delta_1 x$$
$$u_2 = 2x - 14yz - \delta_2 y \qquad (3)$$
$$u_3 = -0.9 + 0.5w^2 + y^2 - \delta_3 z$$
$$u_4 = z - \delta_4 w$$

In this scenario, we have positive constants u_1, u_2, u_3 and u_4 representing linear feedback gains. The symbol $\tilde{a}$, symbolizes the estimated parameter to coefficient a. When equation (3) is inserted into equation (2), it defines the following controlled system at play:

$$\dot{x} = (a - \tilde{a})y - \delta_1 x$$
$$\dot{y} = -\delta_2 y \qquad (4)$$
$$\dot{z} = -\delta_3 z$$
$$\dot{w} = -\delta_4 w$$

When the estimated parameters $\tilde{a}$ align with the system's actual parameters a, equation (4) transforms into

$\dot{x} = -\delta_1 x$, $\dot{y} = -\delta_2 y$, $\dot{z} = -\delta_3 z$ and $\dot{w} = -\delta_4 w$. This allows us to represent the parameter estimation error as follows:

$$e = a - \tilde{a} \qquad (5)$$

Referring to equation (5), the derivatives of the parameter estimation errors can be stated as follows:

$$\dot{e} = -\dot{\tilde{a}} \qquad (6)$$

By inserting equation (5) into equation (4), we obtain:

$$\dot{x} = ey - \delta_1 x$$
$$\dot{y} = -\delta_2 y \qquad (7)$$
$$\dot{z} = -\delta_3 z$$
$$\dot{w} = -\delta_4 w$$

To derive the control law for adapting parameter estimations, let's establish a Lyapunov positive definite function, denoted as $v_1(x, y, z, w, e)$, within the controlled chaotic system described by equation (7):

$$v_1(x, y, z, w, e) = \frac{1}{2}\left(x^2 + y^2 + z^2 + w^2 + e^2\right) \qquad (8)$$

When we differentiate the established Lyapunov function $v_1(x, y, z, w, e)$, we obtain:

$$\dot{v}_1(x, y, z, w, e) = x\dot{x} + y\dot{y} + z\dot{z} + w\dot{w} + e\dot{e} \qquad (9)$$

By employing equations (6) and (7), we can eliminate $\dot{x}, \dot{y}, \dot{z}, \dot{w}$ and $\dot{e}$ from equation (9), resulting in:

$$\dot{v}_1(x, y, z, w, e) = \left(-\delta_1 x^2 - \delta_2 y^2 - \delta_3 z^2 - \delta_4 w^2 - e\left(\dot{\tilde{a}} - xy\right)\right) \qquad (10)$$

From equation (10), the parameter estimation law can be determined as follows:

$$\dot{\tilde{a}} = xy + \xi\left(a - \dot{\tilde{a}}\right) \qquad (11)$$

Here, ξ represents positive constants. Considering the formulated estimation law in equation (11), the derivative of the Lyapunov function $v_1(x, y, z, w, e)$ can be expressed as a definitively negative function, as follows:

$$\dot{v}_1(x, y, z, w, e) = -\left(\delta_1 x^2 + \delta_2 y^2 + \delta_3 z^2 + \delta_4 w^2 + \xi e^2\right) \qquad (12)$$

By applying Lyapunov's second method for stability, the system states $x(t), y(t), z(t), w(t)$ and $e(t)$ converges exponentially to zero.

B. Simulated Numerical Analysis

The recommended controller's performance is evaluated through computer simulations. As depicted in Fig. 8 (a–c), the chaotic behaviours are observed in an uncontrolled manner for the parameter $(a = 1)$. Figure 8(a) displays a time series pattern for chaotic nature. Fig. 8(b) and 8(c) represent the chaotic attractors of (1), on 2D (x,y) and 3d

(x, y, z) planes respectively. The transformation of chaotic solutions into trivial fixed points, is observed in this research. Figure 8(d–f) depicts the achievement of controlling chaotic signals within a concise time frame, showcasing the efficacy of the obtained outcomes. The numerical simulation outcomes are generated utilizing MATLAB.

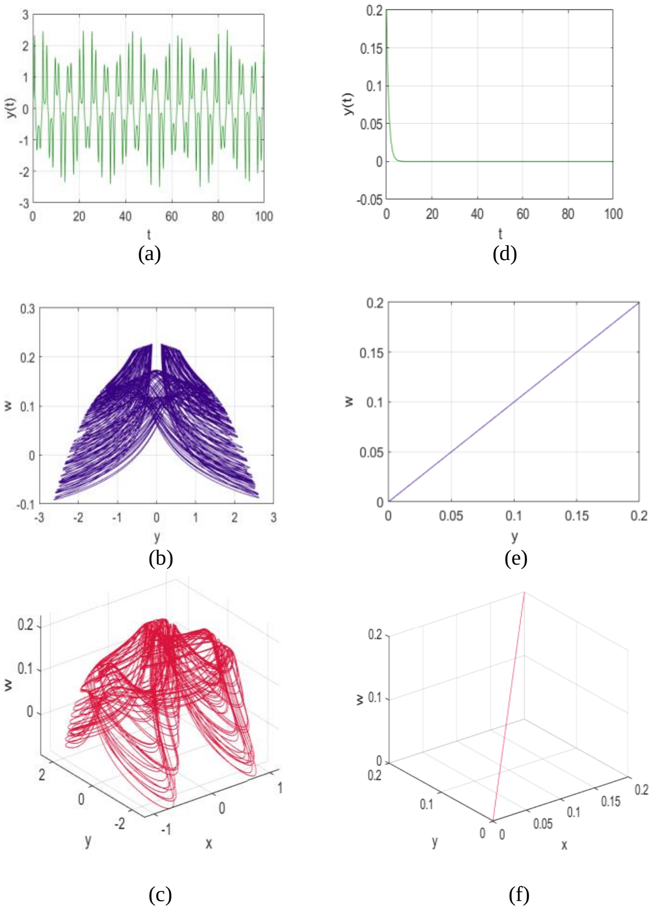


Fig.8. Visualization of numerical evolution of chaotic system: (a–c) without chaos control and (d–f) with chaos control.

VI. Conclusions

This study presents a unique four-dimensional chaotic system controlled by the parameter 'a'. By using MATLAB simulations, it uncovers various chaotic behaviours, including unique co-existing torus as well as attractors. The standout feature is how the system can display both 3D tori with different patterns i.e., both heterogeneous and homogeneous coexistence and offset boosting behaviours , setting it apart from existing works. The system's signal is validated using MATLAB Simulink. A significant aspect of this study is its ability to control chaos, which stands out. To achieve this, adaptive control strategies inspired by Lyapunov's second method are employed. Our numerical verification shows that when the controller is being used, the chaotic behaviour decreases. This strategy holds promise in various fields like secure communication, weather prediction, cryptography, finance, and biology.

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The Organization as a Named Entity: Detection and Tone Analysis in Uzbek Texts

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***Abstract*— This study introduces an innovative algorithm designed to automatically identify and analyze mentions of organizational entities within Uzbek texts. Leveraging a lexicon-based approach, the method first isolates company or business names using specific linguistic indicators such as capitalization and the presence of standard business affixes (e.g., OOO, IP, AO). Following this identification process, sentiment analysis is employed to discern the tonality of the context in which these entities are mentioned — categorizing them as positive, negative, or neutral. This is achieved by assessing the volume and nature of adjectives and adverbs within surrounding sentences. The findings of the research present insights into the frequency of mentions for each organization and the predominance of either positive or negative sentiments associated with them. This research not only advances the understanding of organizational mentions in the Uzbek linguistic landscape but also provides a foundational tool for stakeholders to gauge corporate reputation from textual data. The proposed methodology has potential implications for media monitoring, market research, and reputation management.**

Keywords*— Organizational mentions, Uzbek texts, lexicon-based approach, sentiment analysis, corporate reputation, linguistic indicators, textual data, media monitoring, market research, reputation management

I. Introduction

In today's information age, textual data from various sources, including news articles, social media platforms, and business reports, has become an invaluable resource for comprehending organizational dynamics and their public perception[1]. With the proliferation of such data, the need for robust and effective computational methods to extract and analyze relevant information has grown exponentially[2]. The Uzbek linguistic landscape, although rich and diverse, has remained relatively under-researched in this context[3], particularly in terms of processing and analyzing mentions of organizational entities and their associated sentiments.

The significance of recognizing organizational mentions within textual data cannot be overstated. For stakeholders, ranging from corporate executives to investors, understanding how an organization is being portrayed in various textual sources provides critical insights[4]. These insights can influence decision-making, strategic communication efforts, and reputation management. Similarly, sentiment analysis offers a refined perspective by evaluating not just the occurrence of mentions but also the tone associated with them – whether positive, negative, or neutral[5].

Historically, much of the computational linguistic research concerning named entity recognition (NER) and sentiment analysis has been concentrated around major languages like English, Mandarin, or Spanish[6]. Yet, regional languages, such as Uzbek, play pivotal roles in local business ecosystems, policy-making, and socio-cultural dialogues[7]. Therefore, developing tailored algorithms for such languages is not just an academic exercise but a practical necessity[8].

The lexicon-based approach, while traditional, offers unique advantages in terms of stability and transparency over other methods such as machine learning[9]. Utilizing a predefined lexicon for identifying specific terms, in this case, organizational names, allows for controlled precision[10]. Furthermore, by employing specific linguistic indicators like business affixes or capitalization patterns, the chances of accurately identifying the intended entities increase[11]. Yet, the challenge lies in delineating the diverse ways organizations might be referred to and ensuring that the lexicon captures this variety.

Following entity recognition, sentiment analysis seeks to evaluate the emotional tone surrounding the identified entities[12]. This analysis, while seemingly straightforward, is laden with complexities, especially when transitioning from one language or cultural context to another. Word choices, idioms, and linguistic structures that signal positivity in one culture might be neutral or even negative in another[13].

This paper, therefore, addresses the twin challenges of recognizing organizational mentions and assessing their associated sentiments within the framework of the Uzbek language[14]. By marrying the lexicon-based approach with sentiment analysis techniques tailored for Uzbek, this study aims to pave the way for a nuanced understanding of corporate reputation within the Uzbek linguistic milieu[15]. Additionally, it strives to provide a foundation upon which further linguistic and computational research can be built, enhancing the depth and breadth of text analysis capabilities in the region[16].

II. Key Elements of Uzbek Grammar for Text Analysis

To facilitate the development of an algorithm proficient in identifying organizational mentions and interpreting sentiment in the Uzbek language, a thorough understanding of the specific components of Uzbek grammar and syntax[17] is crucial. Despite the dearth of extensive research on computational linguistics applied to Uzbek, the language has a complex grammatical structure that cannot be ignored.

Uzbek is classified as an agglutinative language[18]. This nature profoundly affects both NER and sentiment analysis. For instance, in the proposed lexicon-based algorithm, the agglutinative formation of words like "Toshkentshik", meaning a person from Tashkent could be a significant determinant of the sentiment tone, especially if preceded or followed by adjectives or adverbs of a specific emotional tenor[].

The importance of case markings in Uzbek is another vital consideration. For example, consider the phrase "Kompaniyaga yaxshi", meaning 'good for the company'. Here, the case marking "-ga" indicates a beneficial relationship, thereby influencing sentiment. Overlooking this could lead to incorrect sentiment classification, as the algorithm might simply focus on the occurrence of the positive word "yaxshi" without considering its relationship to the entity "Kompaniya".

Different registers of the language—formal and colloquial—also come into play. A formal statement like "Shirkat muvaffaqiyatli ishlamoqda", meaning 'The company is operating successfully' conveys a neutral or positive tone that stakeholders might perceive differently from a more colloquially framed statement.

Moreover, the relatively free word order in Uzbek syntax must also be taken into account. For example, both "Shirkat yaxshi" and "Yaxshi shirkat" translate to 'Good company', but the positioning of the adjective and noun can be switched without altering the basic meaning. The proposed algorithm must, therefore, be contextually robust to accurately identify entities and gauge sentiments irrespective of the syntactic arrangement.

To summarize, a detailed understanding of the grammatical and syntactical components of the Uzbek language is crucial for the proposed lexicon-based algorithm's effectiveness in NER and sentiment analysis. This section serves as a fundamental backdrop for the methodologies and algorithmic strategies that will be discussed subsequently.

III. Related Works

Sentiment analysis in the Uzbek language remains relatively underexplored. Contributing factors to this scarcity include limitations such as insufficient linguistic tools, a lack of annotated text corpora, and computational constraints. These have collectively curtailed in-depth research in this specialized domain. An important work in this area [18] focuses specifically on sentiment analysis, scrutinizing consumer feedback in the restaurant sector. This study is noteworthy for assembling a specialized dataset for the Uzbek language, a Turkic language often constrained by limited resources. The authors employ a broad spectrum of computational techniques, including logistic regression, support vector machines, and various neural network architectures. Their approach encompasses data collection, preprocessing, and performance evaluation, achieving a commendable 91% accuracy with the best-performing model through tailored preprocessing techniques for agglutinative languages.

However, it is crucial to distinguish between the objectives of this existing research and the goals of the current study. While the referenced work concentrates solely on sentiment analysis in the Uzbek language, our paper broadens the scope to include NER specifically targeting organizational mentions. The prevalent reliance on machine learning in existing research, while powerful, necessitates a resource-intensive pipeline including extensive annotated data. Contrary to this, the current study proposes a lexicon-based methodology that leverages dictionaries, offering a potentially more resource-efficient alternative. This lexicon-driven strategy seems particularly well-suited for languages like Uzbek, which feature unique syntactic and morphological characteristics. Therefore, by adopting a lexicon-based approach for both sentiment analysis and NER, this research aims to address gaps in existing studies and offer a more comprehensive analytical tool for organizational reputation assessment within the Uzbek linguistic context.

The development of sentiment analysis resources for Turkic languages received a notable contribution through a study [19], which pioneered the creation of a Dictionary of Kazakh Sentiment Words. This work employed a rule-based approach, utilizing an emotional word dictionary specifically designed for the Kazakh language. Drawing upon morphological rules and an ontological model, the study outlined various moods present in Kazakh texts. Through a meticulous investigation, the authors identified key parts of speech that are critical in establishing text polarity and sentiment, eventually identifying phrases that significantly contribute to the overall sentiment of a text.

While this existing research offers a valuable framework for sentiment analysis in the Kazakh language, it's crucial to distinguish its scope from that of the current study. The primary focus of the referenced research is sentiment analysis, whereas our study aims to expand into the NER, specifically targeting organizational mentions in the Uzbek language. Although both Kazakh and Uzbek belong to the Turkic language family, the unique morphological and syntactic attributes of Uzbek necessitate a bespoke approach tailored specifically for it. Thus, despite the similarities and the potential applicability of the rule-based approach outlined in the Kazakh study, the peculiarities of the Uzbek language require a more customized methodology. Our proposed lexicon-based approach aims to serve this need, capitalizing on extensive dictionaries and linguistic rules specifically designed for Uzbek. In doing so, this research seeks to address the unique challenges posed by the Uzbek language, offering a robust method for both sentiment analysis and NER tailored to its specific linguistic idiosyncrasies.

The research outlined in study [20] merits attention for its rigorous application of both traditional machine learning and contemporary deep learning techniques for sentiment classification in the Uzbek language. Both approaches are reported to offer commendable levels of accuracy. However, the study is somewhat limited in its methodological exposition; it offers only cursory insights into dataset selection and other crucial factors that might impact the generalizability of their results.

It is noteworthy that the authors were able to attain accurate sentiment classification within the Uzbek language using machine learning models. However, their approach primarily focuses on sentiment analysis, leaving room for further exploration in other Natural Language Processing (NLP) tasks. Specifically, their study does not delve into Named Entity Recognition, which forms the crux of our research.

Further, the absence of benchmarking against other methodologies, including lexicographic or hybrid approaches, leaves open the question of whether other techniques might be more or equally effective, particularly in a language as complex and nuanced as Uzbek. The Uzbek language, with its unique morphological and syntactic intricacies, offers a ripe ground for exploration beyond just sentiment analysis, extending into the NER and beyond.

Our study, therefore, seeks to fill this gap by focusing on the task of recognizing organizational mentions in Uzbek texts. We propose a lexicon-based approach, tailored to cater to the idiosyncrasies of the Uzbek language, in order to capture the nuanced ways organizations are mentioned. The methodology aims not just to identify these mentions but also to contextualize them, providing a rich landscape for understanding organizational dynamics and their public perception. Thus, our work complements existing research by adding a new dimension to text analysis in the Uzbek language, extending the scope from sentiment analysis to the NER specific to organizations.

IV. Proposed Algorithms

The first part of the proposed algorithm aims to recognize organizational entities within the text. The algorithm employs a two-tiered approach for identifying such entities. Initially, it relies on a curated lexicon comprising over 1,000 company names, both global and specific to the Uzbek market. If the entity exists within this pre-established lexicon, it is promptly recognized.

In the absence of a lexicon match, the algorithm transitions to a pattern-based recognition technique. It scans for key prefixes such as "MChJ," "XK," "OK," and e.g., coupled with the presence of capitalization, to identify potential organizational names within the text. This dual-approach ensures that even without a comprehensive lexicon, the system retains the ability to identify newer or less-known organizational entities.

The second component of the algorithm focuses on sentiment analysis of sentences where the organizational entities are mentioned. The algorithm utilizes a dictionary of adjectives and adverbs (e.g., "good," "bad," "expensive," etc.) to evaluate the sentiment carried in each sentence.

To account for intensity modulators, words such as "very," "strongly," and "weakly" are also considered. Each sentence is assigned a sentiment score based on the cumulative polarity of individual words, adjusted for any intensity modulators.

Finally, the algorithm calculates the overall sentiment of the text by aggregating the sentiment scores of individual sentences. The text is then classified as either positive, negative, or neutral based on which type of sentences are most frequently occurring.

The two components are integrated into a cohesive framework. After the identification of organizational entities, the corresponding sentences are subjected to sentiment analysis. This provides a comprehensive view, enabling stakeholders to discern not only the frequency of mentions but also the tonality associated with each organizational entity.

By marrying Named Entity Recognition with Sentiment Analysis tailored to the unique linguistic landscape of the Uzbek language, the proposed algorithm aims to provide a nuanced understanding of public perception towards organizations. This algorithm offers a robust tool for various applications, including market research, reputation management, and sociopolitical analysis. In Fig.1 algorithm's work is shown.

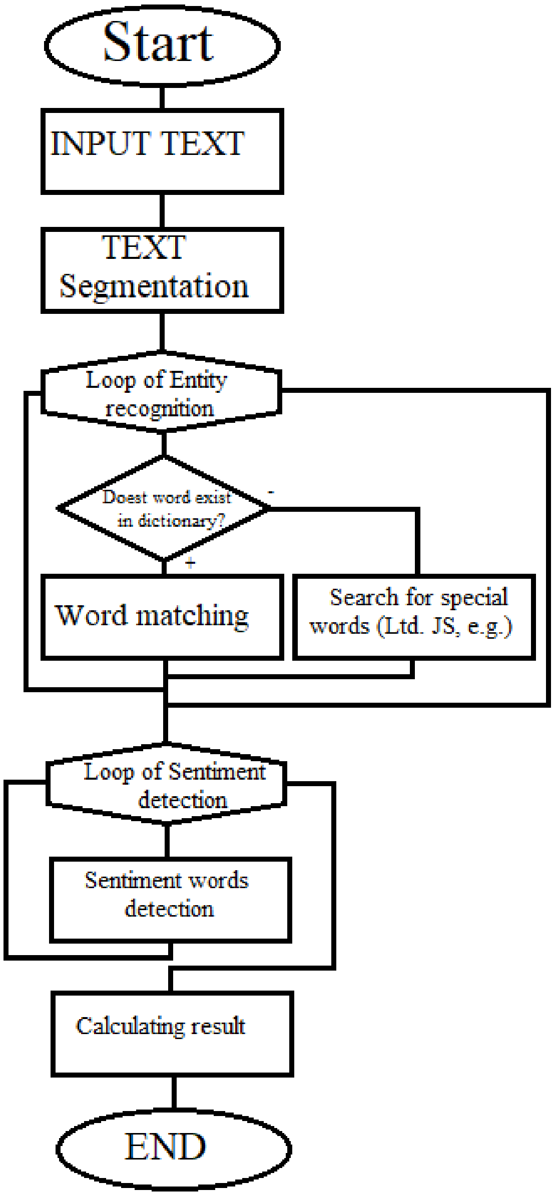

Fig. 1. Scheme of the algorithm's work.

V. Results of the Algorithms' Work

The algorithm was rigorously evaluated using a corpus of 1,000 heterogeneous sentences, stratified into four distinct test groups, each containing 250 sentences. Groups 1 and 2 were primarily allocated for the evaluation of named entity recognition, while Groups 3 and 4 were designed to assess sentiment analysis performance.

Group 1: This group comprised sentences where the names of organizations are present in our curated lexicon of companies, and sentiment words are also included from a predetermined lexicon. The algorithm demonstrated an efficacy rate of 100% in accurately identifying both named entities and sentiments within this group.

Group 2: This set contained sentences wherein the organizational names are not indexed in the company lexicon but include known sentiment words. The algorithm resorted to prefix-based identification using acronyms like "MChJ", "YATT", etc., to recognize companies. The performance rate for this group was 92%. One limitation observed was the algorithm's sensitivity to the placement of prefixes; for example, it identifies "Bundyod Buildings MChJ" as an organization, but fails to do so when the arrangement is "MChJ Bundyod Buildings".

Group 3: This group exclusively contained sentences with organizational names and sentiment words that are both present in the lexicons. The algorithm achieved an accuracy rate of 100%.

Group 4: This group consisted of sentences with organizational names from the lexicon, but with sentiment words not indexed in our lexicon. In such cases, the algorithm employed morphological analysis to attain a performance rate of 96%. The discrepancies arose mainly from morphological transformations that resulted in semantic inversions, such as converting "yaxshimas" (not good) to "yaxshi" (good).

Overall, the algorithm exhibited strong performance metrics across both named entity recognition and sentiment analysis. However, it's crucial to acknowledge the necessity for continuous lexicon updates to maintain the algorithm's accuracy and robustness. The performance limitations underline the importance of future research aimed at refining these initial promising results.

TABLE I. RESULTS OF THE ALGORITHM

№	**Tested Sentences Quantity**	**% of correctly analyzed Sentences**	**Quantity of correctly analyzed Sentences**
1	**250**	**100**	**250**
2	**250**	**92**	**231**
3	**250**	**100**	**250**
4	**250**	**96**	**239**

VI. CONCLUSION

The present research embarked on a comprehensive investigation of named entity recognition and sentiment analysis within the context of the Uzbek language. Recognizing the significant limitations and gaps in existing research—most of which primarily focused on machine learning approaches and sentiment analysis—this study proposed a novel algorithm tailored for the specific linguistic intricacies of the Uzbek language.

The algorithm employs a dual-method strategy for organizational named entity recognition. Firstly, it utilizes a curated lexicon of over 1,000 known company names to identify entities within a text. Secondly, in the absence of a lexicon match, it resorts to pattern-based identification, taking into account specific prefixes and capitalization patterns inherent to organizational names.

Moreover, the sentiment analysis component of the algorithm introduces a robust technique that employs a lexicon of adjectives and adverbs to evaluate the sentiment of individual sentences. The framework takes into consideration the intensity modulators, offering a more nuanced understanding of the textual sentiment.

The integrated framework holds significant promise for multiple applications, including but not limited to market research, public relations, and sociolinguistic studies. The tailored approach to the linguistic challenges posed by the Uzbek language offers a feasible alternative to resource-intensive machine learning methodologies.

However, the study is not without its limitations. Future research may expand the lexicon and adjust the algorithm to factor in idiomatic expressions or cultural references for more accurate sentiment identification. Also, a comparative study with other Turkic languages may yield valuable insights into the commonalities and disparities in linguistic structures, which can be instrumental in refining the algorithm further.

In summary, this paper serves as a stepping stone for more extensive research in the areas of named entity recognition and sentiment analysis in resource-scarce and morphologically rich languages like Uzbek. Through its lexicographic focus, the study aims to plug existing gaps in the literature, offering a methodologically sound and linguistically sensitive tool for textual analysis.

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Context-based Automatic Correction for the Uzbek Language

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***Abstract* – Correcting spelling mistakes in texts written in Uzbek is one of the important problems to be solved in natural language processing (NLP) tasks. In this research, a rule method for automatic spelling correction based on context-based and machine learning algorithm for Uzbek texts is presented. The method combines a noisy channel model with hidden markov models to correct a given word. This study differs from other studies by also considering the contextual information of the word within the sentence. The proposed method aims to integrate with other word-based spelling correction models.**

Keywords* — *speech, machine learning, deep learning, NLP, HMM, noise signal.

I. Introduction

One of the primary obstacles in the realm of natural language processing involves dealing with inaccuracies within textual content. To facilitate research in natural language processing concerning such texts, the initial phase involves the identification and rectification of these inaccuracies. Historically, the predominant approach for addressing errors within text, which mainly encompassed deletions, insertions, and substitutions, was extensively employed to tackle the occurrence of unfamiliar words [1]. This procedure is widely adopted as a preliminary stage in all applications of natural language processing, including tasks like machine translation. The most prevalent methods for checking word spelling rely on a dictionary comprising both word-level and character-level data. These spell checking mechanisms employ a dictionary to deduce the accurate word choice, taking into consideration factors like word frequencies, typographical errors based on keyboard proximity (such as replacing 'n' with 'm'), and phonetic or cognitive errors (Fig.1)

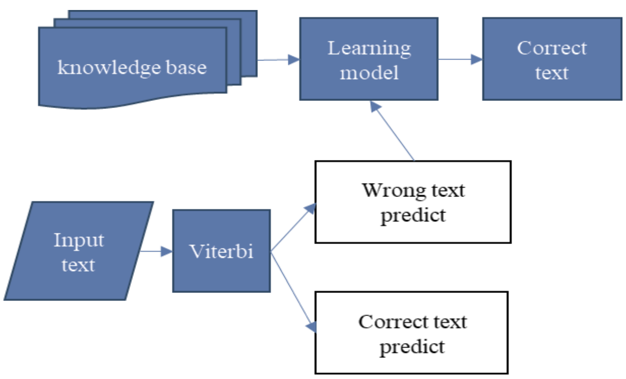

Fig 1. Proposed model architecture

The majority of these suggested editing models disregard context and solely assess the word in isolation [2]. However, this research introduces a model designed to identify misspelled words while considering not only the word itself but also its adjacent words when generating potential replacements. The diagram outlining the structure of the implemented model is displayed in Fig. 1. In this study, the initial phase involves training the model using a Hidden Markov Model (HMM).

The written sentence is then checked simultaneously using the Viterbi algorithm. If there are no misspelled words in the sentence, no action is taken, if there are misspelled words, candidate words are determined by the Viterbi algorithm and the probability of the sentence is determined. the candidate words that maximize will be correct. The Viterbi algorithm is specified as a word. So, in effect, the Viterbi algorithm has been revised to work in a context-sensitive manner.

II. Related Works

When delving into the existing literature, it becomes evident that there exists a scarcity of studies focusing on spelling correction within the Uzbek language [3]. Prior research has explored various approaches, including the utilization of language morphological structure, language modeling, algorithms based on minimum edit distance, and measures of text similarity. Some of these studies have put forth methods for suggesting potential replacements for misspelled words. A notable example is the rule-based approach proposed by Left Hand and Oflazer. In their model, rules are formulated using a root term alongside an additional dictionary. This approach involves the analysis of words through a morpheme analyzer, coupled with the examination of Turkish phoneme and morpheme rules via finite state machines. This process aims to determine the correctness of a given word. Many of these investigations primarily revolve around the detection of errors without delving into the aspect of error correction [4, 5]. Among these endeavors, research has employed Oflazer's finite state machines to recognize words and distinguish correct from incorrect ones, considering a certain degree of proximity. This degree of proximity is defined by the spelling difference between the accurate term and the erroneous one, encompassing the count of letter deletions, additions, and substitutions [5].

Numerous instances of models employing n-gram and minimum edit distance algorithms can be found in the context of agglutinative languages such as Uzbek [6, 7]. What sets these models apart from other investigations is their utilization of n-grams (n, n-1, n-2) that vary based on the length of the word. A specific study leveraged syllabic n-gram frequencies to detect misspelled words. In this research, statistics regarding monogram, bigram, and trigram frequencies were extracted from five distinct datasets. The proposed model takes individual words from the text as input and applies a classification process, categorizing words into "true" or "false" based on their probability distribution. Importantly, this model's function is solely to determine the accuracy or inaccuracy of the provided words, without suggesting the correct replacement for any erroneous terms [8, 9].

Furthermore, an additional model centered around n-grams was put forth. In the initial phase of this model, language-specific n-grams are derived through the utilization of an extensive dataset. However, it's important to note that even with a substantial dataset, certain n-grams might not be included. Consequently, if a word cannot be located within the n-grams, regardless of the dataset's size, it is deemed to be correctly spelled. When dealing with misspelled words, the erroneous term is cross-referenced with the dictionary and juxtaposed against language-specific words. [10, 11] Through this comparison, a potential correct word is identified and chosen.

A. *The proposed model*

In this research endeavor, we introduce a spelling correction model that employs Hidden Markov Models (HMMs) to ascertain the accurate rendition of a misspelled word, taking contextual cues into account. The constructed model comprises three distinct components. The initial component is responsible for detecting misspelled words and determining their accurate variants within a given dataset, utilizing a word-centric approach [12, 13]. The second component involves the incorporation of the HMM model, which plays a pivotal role in the overall process. The third and final component is responsible for selecting the most appropriate correct form from potential candidate options within the context of a sentence. This selection process is carried out through the utilization of the Viterbi algorithm.

B. *Detecting misspelled words*

In order to detect misspelled words in a dataset, it is necessary to search the entire ma to find the misspelled words and their correct forms. The data set is transmitted via Viterbi. Examples of misspelled words identified by the model and their correct forms are listed in Table I.

TABLE I. MISWRITTEN WORDS AND THEIR CORRECT FORMS

Wrong words	**Suggestive forms of correctly spelled words**
oogan	olgan, osgan, ochgan, otgan, …
aamoq	ahmoq, anglamoq, aldamoq, asramoq, …
bo'lopti	bo'lyapti, bo'layapti, …

C. *Hidden Markov model.*

A hidden Markov model has hidden and observed states. In our proposed Markov model for the spelling correction process, hidden states correspond to correct forms of misspelled words and observed states correspond to misspelled words:

- p(wi) initial probabilities : the probability of starting sentence with the correct word wi;
- transition probability p(wi+1|wi) : the probability that the word wi+1 appears after the word wi;
- emission probability p(x|wi) : the probability that a correctly spelled word wi is incorrectly spelled as x;

Here, the transition probability is obtained by the Laplace-corrected condition of the maximum likelihood calculated on the training data set, and the Noisy Channel model proposed by scientists Brill and Moore is used for the emission probability.

D. *A noisy channel model*

According to the noisy channel model, passing through a noisy communication channel results in a misspelled word when a correct word is "misspelled". in the candidate's words:

$$\omega = argmax\ P(x|\omega)P(\omega)\ \omega\epsilon C \qquad (1)$$

Where P(x|w) is the channel model, P(w) is the prior probability, and C is the candidate correct form fitted for the misspelled word x. In this study, only the channel model of the Noisy Channel Model is used to estimate the emission probability in the Hidden Markov Model, and the prior information is ignored. Four confusion matrices are used to calculate the channel model (Fig. 2 and Fig. 3):

- del[x,y] : number (xy written as x)
- ins[x,y] : number (x written as xy)
- sub[x,y] : number (written as x y)
- trans[x,y] : number (written as xy yx)

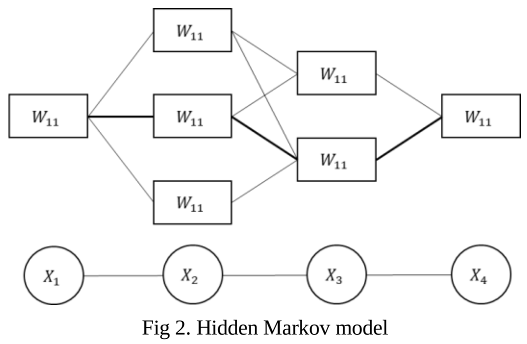

Fig 2. Hidden Markov model

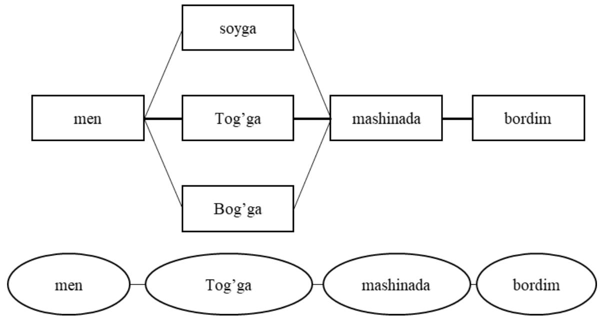

Fig. 3. Schematic of the Viterbi firing algorithm

Here, del, ins, sub, and trans represent the operations of deleting, adding, replacing with another character, or replacing two characters in a row. According to these procedures, the emission probability is calculated using Formula 2.

$$p(x|w) = \begin{cases} \frac{del\,[x_{i-1}w_i]}{count\,[x_{i-1}w_i]} & if\ deletion \\ \frac{ins[x_{i-i}w_i]}{count\,[w_{i-1}]} & if\ insertion \\ \frac{sub\,[x_i w_i]}{count\,[w_i]} & if\ substitution \\ \frac{trans\,[w_i w_{i+1}]}{count\,[w_i w_{i+1}]} & if\ transposition \end{cases} \quad (2)$$

Here, x represents the misspelled word and w represents the correct form. If xi or wi is the i in the word. shows the character. In the formula, count [xi−1wi] gives the number of subrows xi−1wi, count [wi−1] gives the number of wi−1, count [wi] gives the number of wi, and count [wiwi+1] gives the number of subrows wiwi+1.

E. Viterbi algorithm

In this work, the Viterbi algorithm is used to predict the most accurate possible form of misspelled words for a given sentence. The Viterbi algorithm is presented in Fig. 3.

The algorithm consists of two steps: In the first step, the most probable probability of the sequence of words is calculated, in the second step, starting from the end, it is found in the following way to find the most probable sentence that maximizes the probability of the sentence. posterior indices are the probabilities of incorrect words. There are correct forms [14].

F. Algorithm

The order of operations for the whole process is given in Algorithm. The algorithm has 2 functions. The first function takes a data set as input. The function detects misspelled words by passing all words in the data set through Viterbi and obtains candidate words for the specified words. The initial, transition, and emission probabilities required for the HMM model are calculated on the dataset. The second function takes a written sentence as input. The words in the sentence are passed through Viterbi, if there is a misspelled word, the candidate words for these words are determined by Viterbi, and Viterbi is applied to these candidate words, and the sentence is maximized candidate words in the correct form [15]. As a result, the correct form is returned by correcting the sentence.

III. Experimental results

A. Data collection

In this research, firstly, the dataset is used to remove the wrong words. The dataset is a combination of 4 datasets. 3 of them are collected from Uzbek newspapers, and one from Internet pages. This dataset contains a total of 423 million words (word tokens). The dataset was chosen for this study because there is no other very large dataset for the Uzbek language. However, the fact that this dataset consists of newspapers and websites, meaning that the words are frequently used in everyday speech, makes the dataset valuable for this study. 602,462 invalid words were removed from the dataset using Mainspring.

B. Results

The model we propose in this study is that the correct form of a word varies according to its context. And Viterbi chooses the first one from the list of candidates and writes the wrong word correctly (Table II).

TABLE II. RESULT

Model	Accuracy (%)
N gramm model	75%
Viterbi+HMM	89%
RNN	56%

When examining the data set, it appears that this is not always the correct choice. Examples of words that got correct for the wrong word but did not come first in the candidate forms are given in Table II. 200 misspelled words removed from the data set to evaluate a context-based model built to find the correct form of a misspelled word added to the containing sentence. When choosing these words, attention was paid to the fact that they received several morphemes.

The success of the model is based on accuracy. Accuracy is the ratio of correctly corrected words to all incorrectly corrected words. Our results are compared with the works of Viterbi and RNN et al. When calculating the correctness of the Viterbi algorithm, the correct form is checked first. Accuracy results are presented in Table I. It is observed that our proposed model performs better than the other two models. When the results are checked, it is observed that Viterbi included the correct form in the list of candidates for misspelled words, but did not return it as the first form. Unlike Viterbi, because we look at the context, more suitable candidates can be selected instead of the first candidate returned. Misspelled words selected from the data set, candidate forms returned from Viterbi are listed in Table II. Shapes found to be correct as a result of the Viterbi algorithm are written in bold in the Table II.

IV. Conclusion

In this work, a context-based spelling correction model for Turkish is proposed in contrast to other Turkish spelling correction works. To select the correct form of a misspelled word among the correct forms obtained from the word-based model, the model searches for the form that maximizes the likelihood of the sentence given the context. The developed model can be combined with other word-based models.

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Mathematical modeling of the process of magnetelastic deformation of anisotropic plates in a thin complex form

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***Abstract*— The article is devoted to the mathematical modeling of the process of geometrical nonlinear deformation of magnetoelastic anisotropic plates with a complex structural shape. A mathematical model and a calculation algorithm of the process of geometric nonlinear deformation of thin plates of complex shape under the influence of an electromagnetic field is developed. In solving the researched problem, computational experiments are performed for plates made of different materials (isotropic, anisotropic) with different boundary conditions, positive results are obtained and analyzed. In addition, the construction of the boundary equation of the investigated complex area using the R-function method (RFM) is considered.**

Keywords*— Mathematical model, isotropic and anisotropic plate, geometric nonlinearity, Hamilton-Ostrogradsky variational principle, Kirgof-Liav hypothesis, Cauchy relation, computational algorithm, iteration, Bubnov-Galerkin method, R-function method (RFM).

I. Introduction

In recent years, many studies have been devoted to the study of deformation stress states of plates and shells, and these issues have not lost their relevance even now. The reason is that plates and shells form structural elements of modern equipment in various fields. The shapes of the elements of this device are complex, and the mechanical properties of the materials used are inhomogeneous and anisotropic.

Optimizing modern constructions and carrying out work such as calculation and design requires that these elements be durable and reliable in operation for a long time, and this, in turn, presents researchers with the problem of automating all classification issues. Problems of this type differ not only in physical parameters, but also in the constructive form of the field under study. Therefore, one of the most important tasks is to study the processes of geometric nonlinear deformation, taking into account the anisotropic properties of plates with a complex structural shape under the influence of an electromagnetic field.

II. 1 Mathematical modeling

Based on the Hamilton-Ostrogradsky variational principle, using Cauchy's relations, Hooke's law and Maxwell's electromagnetic tensor, a mathematical model of a thin anisotropic plate placed is developed in an electromagnetic field in the form of a system of differential equations with initial and boundary conditions for displacement [1-3, 12-14].

A thin anisotropic plate of flexible thickness h placed in an electromagnetic field is made of conductive material, and electromagnetic forces are given in advance. External current and charges are assumed to be absent [1-3]. The plate is located in the Cartesian coordinate system x, y, z so that x, y overlaps with the middle plane.

When developing the equation of motion of the plate, the following Kirchhoff-Liav hypothesis is used as the change laws of displacement [1, 12-14]:

$$u_1(x,y,z) = u - z\frac{\partial w}{\partial x}, u_2(x,y,z) = v - z\frac{\partial w}{\partial y}, u_3(x,y,z) = w. \quad (1)$$

Here: $u, v, w-$ displacements.

Mathematical model of the problem. An overview of the Hamilton-Ostrogradsky variational principle [1, 12-14]:

$$\int_t (\delta K - \delta\Pi + \delta A)dt = 0. \quad (2)$$

Here: $\delta-$-variation derivative; $K-$kinetic energy; $\Pi-$ potential energy; $A-$ external volume and work done by surface forces.

Based on the Hamilton-Ostrogradsky variational principle (2) above, we calculate the change of kinetic and potential energy and the work done by external forces. As a result, a geometrical nonlinear mathematical model with initial and boundary conditions for anisotropic flexible thin plates located in the following (3) - (5) electromagnetic field is formed [1-3]:

$$\begin{cases} -\rho h\frac{\partial^2 u}{\partial t^2} + \frac{\partial N_{11}}{\partial x} + \frac{1}{2}\frac{\partial N_{12}}{\partial y} + N_x + R_x + q_x + T_{zx} = 0, \\ -\rho h\frac{\partial^2 v}{\partial t^2} + \frac{1}{2}\frac{\partial N_{12}}{\partial x} + \frac{\partial N_{22}}{\partial y} + N_y + R_y + q_y + T_{zy} = 0, \\ -\rho h\frac{\partial^2 w}{\partial t^2} + \frac{\partial}{\partial x}(N_{11}\frac{\partial w}{\partial x} + \frac{1}{2}N_{12}\frac{\partial w}{\partial y}) + \frac{\partial}{\partial y}(\frac{1}{2}N_{12}\frac{\partial w}{\partial x} + N_{22}\frac{\partial w}{\partial y}) + \\ + \frac{\partial^2 M_{11}}{\partial x^2} + \frac{\partial^2 M_{12}}{\partial x \partial y} + \frac{\partial^2 M_{22}}{\partial y^2} + N_z + R_z + q_z + T_{zz} = 0. \end{cases} \quad (3)$$

Initial conditions:

$$\rho h \frac{\partial u}{\partial t}\delta u\bigg|_t = 0, \rho h \frac{\partial v}{\partial t}\delta v\bigg|_t = 0, \rho h \frac{\partial w}{\partial t}\delta w\bigg|_t = 0,$$
$$\rho \frac{h^3}{12}\frac{\partial^2 w}{\partial t \partial x}\delta w\bigg|_x\bigg|_t = 0, \ \rho \frac{h^3}{12}\frac{\partial^2 w}{\partial t \partial y}\delta w\bigg|_y\bigg|_t = 0. \tag{4}$$

The boundary condition is:

$$\begin{cases} N_{11}\delta u|_x = 0, \ \frac{1}{2}N_{12}\delta v\Big|_x = 0, \ -M_{11}\delta\frac{\partial w}{\partial x}\Big|_x = 0, \ -\frac{1}{2}M_{12}\delta\frac{\partial w}{\partial y}\Big|_x = 0, \\ \left[N_{11}\frac{\partial w}{\partial x} + \frac{1}{2}N_{12}\frac{\partial w}{\partial y} - \frac{\partial M_{11}}{\partial x} - \frac{1}{2}\frac{\partial M_{12}}{\partial y}\right]\delta w\Big|_x = 0, \\ \left[\left(N_{Px}+N_{Txx}\right)\delta u + \left(N_{Py}+N_{Txy}\right)\delta v + \left(N_{Pz}+N_{Txz}\right)\delta w\right]\Big|_x = 0, \\ N_{22}\delta v|_y = 0, \ \frac{1}{2}N_{12}\delta u|_y = 0, \ -M_{22}\delta\frac{\partial w}{\partial y}\Big|_y = 0, \ -\frac{1}{2}M_{12}\delta\frac{\partial w}{\partial x}\Big|_y = 0, \\ \left[N_{22}\frac{\partial w}{\partial y} + \frac{1}{2}N_{12}\frac{\partial w}{\partial x} - \frac{\partial M_{22}}{\partial y} - \frac{1}{2}\frac{\partial M_{12}}{\partial x}\right]\delta w\Big|_y = 0, \\ \left[\left(N_{Fx}+N_{Tyx}\right)\delta u + \left(N_{Fy}+N_{Tyy}\right)\delta v + \left(N_{Fz}+N_{Tyz}\right)\delta w\right]\Big|_y = 0. \end{cases} \tag{5}$$

Here: $u, v, w -$ displacements; $\rho -$ the density of the plate material; $h -$ plate thickness; M_{11}, M_{22}, M_{12} - bending and twisting moments; N_{11}, N_{22}, N_{12} - normal and impact forces; $N_x, N_y, N_z, R_x, R_y, R_z -$ volume forces organizers; $T_{zx}, T_{zy}, T_{zz}, q_x, q_y, q_z -$ organizers of t-surface forces; $N_{Px}, N_{Py}, N_{Pz}, N_{Fx}, N_{Fy}, N_{Fz}, N_{Txx}, N_{Txy}, N_{Txz}, N_{Tyx}, N_{Tyy}, N_{Tyz} -$ the organizers of the contour forces.

Determination of bending and twisting moments, normal and impact forces. Now we determine the problem of electromagnetic elasticity of thin anisotropic plates (3)-(5) in the nonlinear mathematical model M_{11}, M_{22}, M_{12} - bending and twisting moments and N_{11}, N_{22}, N_{12} - normal and impact forces. Taking into account the anisotropic materiality of the plate we are studying Hooke's law is expressed as follows [2, 3, 13]:

$$\begin{aligned} \sigma_{11} &= B_{11}\varepsilon_{11} + B_{12}\varepsilon_{22} + B_{16}\varepsilon_{12}, \\ \sigma_{22} &= B_{12}\varepsilon_{11} + B_{22}\varepsilon_{22} + B_{26}\varepsilon_{12}, \\ \sigma_{12} &= B_{16}\varepsilon_{11} + B_{26}\varepsilon_{22} + B_{66}\varepsilon_{12}. \end{aligned} \tag{6}$$

Here: $\varepsilon_{11}, \varepsilon_{12}, \varepsilon_{22} -$ deformation tensor components; $\sigma_{11}, \sigma_{12}, \sigma_{22} -$ tension tensor components; $B_{ij}\left(i, j = 1,2,6\right) -$ constants are expressed by $a_{ij}\left(i, j = 1,2,6\right)$ (elastic coefficients of plate material) as follows [2,3]:

$$B_{11} = \frac{a_{22}a_{66} - a_{26}^2}{\Delta}, \quad B_{12} = \frac{a_{16}a_{26} - a_{12}a_{66}}{\Delta}, \quad B_{22} = \frac{a_{11}a_{66} - a_{16}^2}{\Delta},$$
$$B_{16} = \frac{a_{12}a_{26} - a_{22}a_{16}}{\Delta}, \quad B_{26} = \frac{a_{12}a_{16} - a_{11}a_{26}}{\Delta}, \quad B_{66} = \frac{a_{11}a_{22} - a_{12}^2}{\Delta},$$
$$\Delta = \left(a_{11}a_{22} - a_{12}^2\right)a_{66} + 2a_{12}a_{16}a_{26} - a_{11}a_{26}^2 - a_{22}a_{16}^2. \tag{7}$$

In this case, the plate under study is an anisotropic material, which in turn can be an orthotropic or transversal-isotropic material.

If it is an orthotropic material, then $a_{ij}\left(i, j = 1,2,6\right) -$ the elastic coefficients of the plate material will be as follows [2,3]:

$$a_{11} = \frac{1}{E_1}, \ a_{22} = \frac{1}{E_2}, \ a_{12} = -\frac{\nu_{12}}{E_2} = -\frac{\nu_{21}}{E_1} = -\frac{\nu_2}{E_2} = -\frac{\nu_1}{E_1}, \tag{8}$$
$$a_{66} = \frac{1}{G_{12}}, \ a_{16} = 0, \ a_{26} = 0; \ \nu_1 = \nu_{21}, \ \nu_2 = \nu_{12}.$$

So, based on (8), if we find $B_{ij}\left(i, j = 1,2,6\right)$ by formulas (7):

$$B_{11} = \frac{E_1}{1-\nu_1\nu_2}, \ B_{22} = \frac{E_2}{1-\nu_1\nu_2}, \ B_{12} = \frac{\nu_2 E_1}{1-\nu_1\nu_2} = \frac{\nu_1 E_2}{1-\nu_1\nu_2}, \tag{9}$$
$$B_{66} = G_{12}, B_{16} = B_{26} = 0.$$

If the material is transversally isotropic, the $E = E_1 = E_2, \ G = G_{12}, \ \nu = \nu_1 = \nu_{21} = \nu_2 = \nu_{12}$ equalities for the parameters in (8) are appropriate, and according to the formulas (7) $B_{ij}\left(i, j = 1,2,6\right)$ are expressed as follows [2, 3]:

$$B_{11} = B_{22} = \frac{E}{1-\nu^2}, \quad B_{12} = \frac{\nu E}{1-\nu^2},$$
$$B_{66} = G = \frac{E}{2(1-\nu)}, \quad B_{16} = B_{26} = 0. \tag{10}$$

Here: $E, E_1, E_2 -$ yung module; $\nu, \nu_1, \nu_2, \nu_{12}, \nu_{21} -$ Poisson's ratio; $G, G_{12} -$ displacement module.

(1) Taking into account the Kirchhoff-Liav hypothesis, (6) is defined as follows:

$$\sigma_{11} = B_{11}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{12}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{16}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right),$$
$$\sigma_{22} = B_{12}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{22}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{26}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right),$$
$$\sigma_{12} = B_{16}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{26}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{66}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right).$$

Based on the above, moments and forces are determined as follows:

$$N_{11} = h\left[B_{11}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{12}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{16}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)\right],$$
$$N_{22} = h\left[B_{12}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{22}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{26}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)\right],$$
$$N_{12} = h\left[B_{16}\left(\frac{\partial u}{\partial x} + \frac{1}{2}\left(\frac{\partial w}{\partial x}\right)^2\right) + B_{26}\left(\frac{\partial v}{\partial y} + \frac{1}{2}\left(\frac{\partial w}{\partial y}\right)^2\right) + B_{66}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right)\right]. \tag{11}$$

$$M_{11} = -\frac{h^3}{12}\left(B_{11}\frac{\partial^2 w}{\partial x^2} + 2B_{16}\frac{\partial^2 w}{\partial x \partial y} + B_{12}\frac{\partial^2 w}{\partial y^2}\right),$$
$$M_{22} = -\frac{h^3}{12}\left(B_{12}\frac{\partial^2 w}{\partial x^2} + 2B_{26}\frac{\partial^2 w}{\partial x \partial y} + B_{22}\frac{\partial^2 w}{\partial y^2}\right), \tag{12}$$
$$M_{12} = -\frac{h^3}{12}\left(B_{16}\frac{\partial^2 w}{\partial x^2} + 2B_{66}\frac{\partial^2 w}{\partial x \partial y} + B_{26}\frac{\partial^2 w}{\partial y^2}\right).$$

Now, we will substitute the determined (12) - (13) moments and forces (3) - (5) with the unknown values of $N_{11}, N_{22}, N_{12}, M_{11}, M_{22}, M_{12}$ in the mathematical model. The nonlinear terms in the equations of motion are then moved to the right-hand side of the equation and grouped. As a result, it appears that it is convenient to use computational methods to solve the researched problem [8 - 16].

III. COMPUTATIONAL ALGORITHM OF NUMERICAL SOLUTION OF THE PROBLEM

In order to numerically solve the problems (3) - (5) presented above, a computational algorithm was developed that uses the analytical R-function method (RFM), the Newmark method, the variational Bubnov-Galerkin method, and a number of numerical methods for magneto-elastic plates with a complex structural shape. [5-6, 9-10]. The problem-solving process consists of the following steps:

1. Application of the linearization method in solving systems of differential equations with nonlinear partial derivatives.

2. Construction of a sequence of coordinate functions corresponding to the given boundary conditions (structures of solutions) using V.L. Rvachev's R-function method (RFM).

3. Discretization with respect to spatial variables, discrete equations, that is, construction of discrete equations using the Newmark method and the Bubnov-Galerkin variational method.

4. Solving discrete equations and finding unknown components of structures of solutions.

5. Identify unknown functions. Determination of tangential and normal displacements of the middle surface of the plate.

When solving the problem using iterative numerical methods based on the above steps, the functions $u_i(x,y,t), v_i(x,y,t)$ and $w_i(x,y,t)$ are determined for each iteration.

The iteration step continues until condition $\max\{|u_i - u_{i-1}|, |v_i - v_{i-1}|, |w_i - w_{i-1}|\} \le \varepsilon$ is met. Here $\varepsilon -$ is the fixed precision.

IV. COMPUTATIONAL EXPERIMENTS

As an example, let's consider a plate of complex shape, which is used in the production of transformers and is under the influence of electromagnetic field forces (Fig. 1).

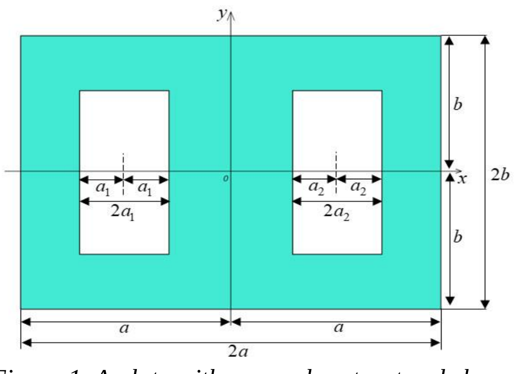

Figure 1. A plate with a complex structural shape.

The analytical equation of a thin plate of complex shape is obtained by the R-function method. In this case, the transition from logical functions to the construction of analytical equations is carried out on the basis of RFM, using the following formulas [5-6]:

$$f_1 \wedge_\alpha f_2 \equiv \frac{1}{1+\alpha}\left(f_1 + f_2 - \sqrt{f_1^2 + f_2^2 - 2\alpha f_1 f_2}\right), \quad f_1 \vee_\alpha f_2 \equiv \frac{1}{1+\alpha}\left(f_1 + f_2 + \sqrt{f_1^2 + f_2^2 - 2\alpha f_1 f_2}\right). \tag{14}$$

Here, the $\alpha \equiv \alpha(x,y)$-function is located on the surface of $-1 < \alpha \le 1$. In particular, we get $\alpha = 0$.

Then the boundary equation of the complex field given in Figure 1 above is expressed in the form of (15), i.e.:

$$\Omega = f_{12} \wedge f_{34} \wedge f_{56}. \tag{15}$$

Here:

$$f_{12} = f_1 \wedge f_2 = a^2 - x^2 + b^2 - y^2 - \sqrt{\left(a^2 - x^2\right)^2 + \left(b^2 - y^2\right)^2} \ge 0,$$

$$f_1 = \left(a^2 - x^2\right) \ge 0, \quad f_2 = \left(b^2 - y^2\right) \ge 0;$$

$$f_{34} = f_3 \wedge f_4 = \left(x - \frac{a}{2}\right)^2 - a_1^2 + y^2 - b_1^2 - \sqrt{\left(\left(x - \frac{a}{2}\right)^2 - a_1^2\right)^2 + \left(y^2 - b_1^2\right)^2} \ge 0,$$

$$f_3 = \left(\left(x - \frac{a}{2}\right)^2 - a_1^2\right) \ge 0, \quad f_4 = \left(y^2 - b_1^2\right) \ge 0;$$

$$f_{56} = f_5 \wedge f_6 = \left(x + \frac{a}{2}\right)^2 - a_2^2 + y^2 - b_2^2 - \sqrt{\left(\left(x + \frac{a}{2}\right)^2 - a_2^2\right)^2 + \left(y^2 - b_2^2\right)^2} \ge 0,$$

$$f_5 = \left(\left(x + \frac{a}{2}\right)^2 - a_2^2\right) \ge 0, \quad f_6 = \left(y^2 - b_2^2\right) \ge 0.$$

Now, we study the process of geometrical nonlinear deformation of thin complex-shaped magnetoelastic plates. In this study, the change of deformation states under the influence of electromagnetic field forces when the plate with rigidly fixed boundaries is isotropic (copper) or anisotropic (anisotropic copper) was studied [7], that is, numerical results of the displacement function $w(x,y,t)$ at $x = [-2;2], y = 0, t = 0.2$ values along the Oz axis were obtained (Table 1).

Table 1. Numerical results of electromagnetoelastic states of isotropic and anisotropic plates.

x	**(Is)** w	**(Anis)** w	x	**(Is)** w	**(Anis)** w
-2	0	0	2	0	0
-1,9	0,000676	0,000429	1,9	0,000676	0,000429
-1,8	0,001972	0,001254	1,8	0,001972	0,001254
-1,7	0,001881	0,001197	1,7	0,001881	0,001197
-1,6	0,000693	0,000442	1,6	0,000693	0,000442
-1,5	0	0	1,5	0	0
-0,5	0	0	0,5	0	0
-0,4	0,000479	0,000312	0,4	0,000479	0,000312
-0,3	0,001662	0,001083	0,3	0,001662	0,001083
-0,2	0,003054	0,001993	0,2	0,003054	0,001993
-0,1	0,004143	0,002705	0,1	0,004143	0,002705
0	0,004551	0,002972	0	0,004551	0,002972

The process of geometric nonlinear deformation of thin isotropic and anisotropic plates of complex structural shape under the influence of electromagnetic field forces was also analyzed with graphical results (Fig. 2) [9-15]:

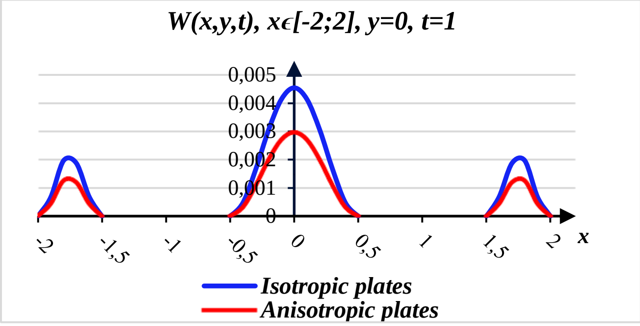

Figure 2. Graphical analysis of magnetoelastic states of isotropic and anisotropic plates.

V. Analysis of Results

The results of the study show that when the plate is anisotropic, it bends less than when it is isotropic. It should be noted that research of such issues is important to ensure durability, reliability and long-term serviceability of these thin plate-shaped structural elements under the influence of an electromagnetic field.

Conclusion

In this scientific research work, the processes of geometric nonlinear deformation of thin isotropic and anisotropic plates of complex structural shape, taking into account electromagnetic field forces, were studied.

In this, the effects of the electromagnetic field on the geometrically nonlinear deformation-stress state of a thin anisotropic plate with a magnetoelastic complex structural form were studied, a mathematical model of this problem and a calculation algorithm were developed.Computational experiments were conducted to solve the problem of magnetoelastic geometrical nonlinear deformation of thin plates with a complex structural shape.

The numerical results obtained from the calculations were presented in tabular form, and graphical images were provided for their analysis. The developed mathematical model, calculation algorithm and the results obtained from solving the problem can be used in the research processes of similar problems in the future [16-21].

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Unleashing the Potential of Technology: Enhancing Efficiency and Productivity in Business Operations

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***Abstract*— An automated system for trading and logistics is an innovative solution that optimizes business processes. It automates inventory, orders, and deliveries management, ensures efficient logistics, and facilitates information exchange with partners. The system enables the generation of reports and analytics, as well as forecasting demand and optimizing inventory levels. As a result, it enhances companies' operational efficiency, improves customer service, and reduces costs. Implementing this system provides a solid foundation for sustainable development in a competitive environment.**

***Keywords*— Innovation system, economic development, trade, development, transport systems**

I. Introduction

Trade is one of the most important sectors of the global economy. It encompasses the sale of goods and services and includes processes such as procurement, storage, and distribution of goods to meet consumer needs. Consumers are provided with products with specific characteristics and quality that match their needs and requirements in terms of location, time, and cost [1-6].

Trade can be divided into retail and wholesale. Retail trade involves selling goods to end consumers in stores, online shops, supermarkets, etc., while wholesale trade caters to large customers such as shops, companies, and enterprises [1-8].

Retail trade develops due to population growth, advancements in internet technology, changing consumer needs, and improved economic conditions [2-3]. Wholesale trade, on the other hand, develops as a result of increased production and the complexity of organizing their own logistics [1-3]. With the development of the global economy and the accessibility of the global market, the role of logistics in trade is becoming increasingly significant [3-9].

Logistics in trade is responsible f or managing the flow of goods from the manufacturer to the end consumer. It encompasses processes such as transportation, warehousing, packaging, inventory management, and supply chain managemen [6-10]. The goal of logistics is to ensure efficient and timely delivery of goods, minimize costs, and optimize processes within and between companies [7-10].

In trade, there are numerous factors that require attention to logistics management. Firstly, trading companies face various challenges such as increasing sales volumes, seasonal demand, increased demand for specific products, changing consumer preferences, and fast delivery times [2-7]. Logistic planning and coordination become key factors for successful product realization and meeting customer needs [9-11].

Secondly, globalization and border expansion bring new opportunities and challenges in trade[1-4] . Companies have to deal with the need to organize international deliveries, manage long logistics chains, and comply with the customs regulations of different countries. In this context, effective logistics becomes an integral part of success in global trade [11-12].

In the development of the trade and associated logistics industry, there are several problems that can be effectively addressed to accomplish tasks and reduce costs. One of the problems is the interaction between company departments, which often relies on paper-based documents, leading to inefficiency [7-16]. This approach slows down various processes, requires a significant amount of time for document creation, handling, and processing, as well as continuous financial expenses. Electronic document management optimizes business processes, reduces costs, and mitigates human factors issues such as data loss or physical damage, as electronic documents can be securely protected, for example, via encryption [14-20]. The key advantages of electronic document management are the ability to transfer and store documents organized through software [13,14].

Let's consider the challenge of manual inventory management. Systematic inventory management involves solving a wide range of tasks, such as controlling goods, accurately representing product movements, determining the most profitable assortment, planning purchases, conducting inventories, providing accurate profit data representation, and more [11-18]. Incorporating automated systems for inventory management is the most effective option since high product turnover involves processes that are challenging to control manually [17-26]. Modern software products can include various functional solutions, such as order processing, warehouse accounting, supplier order generation, analytical reporting, customer database management, and more [4-9].

In addition to the internal organizational interaction problem, another issue lies in the interaction with suppliers, which often occurs through various social media platforms and emails, leading to errors, delays, and potential problems with quality control [16-27]. Interaction is a crucial element of a company's efficiency and success, and achieving it requires developing and implementing strategies and programs for effective collaboration [3-11].

Technological innovations in logistics play a crucial role in trade. Automation of warehouse operations, e-commerce, the use of order management systems and supply chain tracking all contribute to process improvement and enhance operational efficiency in trade [1-5]. In conclusion, the link between trade and logistics is inseparable. Companies that invest in logistics gain a competitive advantage in the market as they can offer more efficient and reliable delivery of goods to their customers [5-8]. Consequently, logistics plays a vital role in the successful operations of trading companies, ensuring their growth and development on an international level [8-14].

II. System requirements

System requirements are a description of functional and non-functional characteristics that must be implemented in a software or hardware-software complex to meet the needs of users or companies [13-19]. They help determine what the system should do and what qualitative characteristics it should have.

Among the main system requirements, the following can be highlighted:

- Functional requirements define what the system should do and what its capabilities are. They describe specific functions and tasks that the system should perform. For example, functional requirements may include the ability to register users, add information, search a database, etc.
- Non-functional requirements define system characteristics such as performance, security, reliability, availability, and usability. For example, a non-functional requirement may dictate that the system should process up to 2000 requests per second or comply with certain security standards.
- Interface requirements define how users will interact with the system, what interface elements should be present, and how they should work. For example, an interface requirement may specify that the system should have an intuitively understandable user interface with the ability to scale the font.
- Performance requirements define the required speed and capacity of the system, its ability to process data and calculations. For example, a performance requirement may prescribe that the system should process a certain number of transactions per unit of time.

It is important to consider that system requirements should be clear, measurable, and achievable to ensure successful development and operation of the system [24-27].

Analyzing the requirements of multiple companies in this field, the following main requirements can be identified:

- Integration of all operations: The system must combine functions of accounting for goods, orders, supplies, shipments, and tracking of goods at all stages of supply.
- Warehouse management: The system must have the ability to track and control the availability of goods in the warehouse, notify of supply shortages, optimize warehouse space, and manage the inventory process.
- Order management and generation: The system should automate the process of order generation and processing from customers, including calculating the cost of the order, checking the availability of goods in the warehouse, and managing the delivery process.
- Tracking and routing of cargoes: The system should provide the ability to track goods at all stages of delivery - from the point of dispatch to delivery, and also optimize delivery routes to reduce costs and increase efficiency.
- Integration with partners and suppliers: The system should allow exchanging data on orders, supplies, and shipments with suppliers, logistics companies, and other partners for more effective supply chain management.
- Analytics and reporting: The system should provide the ability to analyze data on sales, inventory, product popularity, and other factors for making informed decisions, as well as generate reports for monitoring and planning.
- Data security: The system should ensure protection of confidential customer data, orders, and payments, as well as data recovery.
- Flexibility and scalability: The system should be flexible and easily scalable to be adaptable to different types of businesses and company scales.
- User-friendly interface and training: The system should be intuitive and have a user-friendly interface, as well as provide employee training feature for quick learning and efficient use.

III. System purpose

The developed system will be a powerful instrumental solution capable of transforming complex and chaotic processes into convenient and efficient work [21-30]. It is designed to optimize various aspects of the business, ranging from inventory management to control of goods transportation [13-19].

The system will easily integrate with major accounting and management systems, allowing for supply management and automatic order processing. It will provide information on available inventory, forecast demand, and control storage time and turnover of goods [28-36].

One of the main advantages of this system is the ability to significantly reduce storage and processing costs. It allows for the optimization of processes and avoids unnecessary expenses [21-23].

Furthermore, the system is capable of improving customer service by ensuring prompt order processing and timely delivery of goods [32-34]. It automatically matches orders with available inventory and helps prioritize deliveries to meet the needs of the most demanding customers.

Regardless of the size of the enterprise, this system can be easily implemented and adapted. It is suitable for large companies with complex logistics networks as well as small and medium-sized enterprises that want to increase their efficiency and competitiveness [15-32].

In conclusion, the developed system for automation in trade and logistics helps businesses achieve high efficiency and accuracy in their operations, reduce costs, and improve customer service. It is an integral part of modern business and will help you succeed in the field of trade and logistics [26-36].

IV. System development

The system should be implemented using modern development technologies, with mechanisms for data backup and recovery, system scalability, and adaptability to changes in company business processes. Figure 1 depicts the software architecture of the system [26-33].

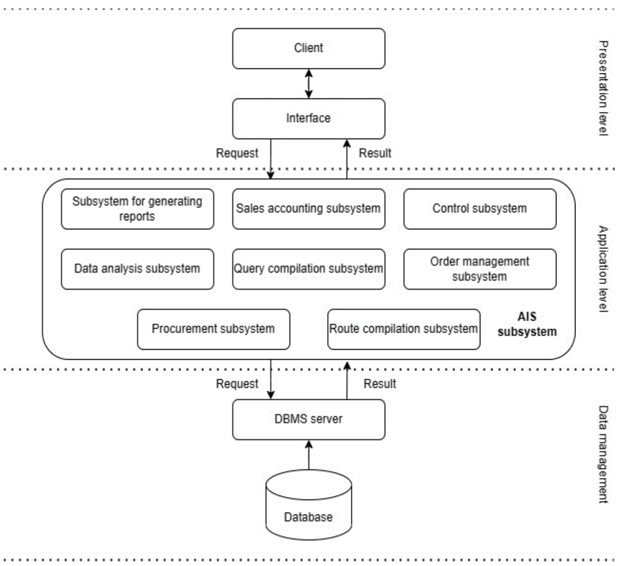

Fig. 1. Software architecture of the system.

The software architecture consists of three levels: presentation, business logic or application level, and data management. The presentation level includes everything related to user interaction, such as button clicks, mouse movement, etc. This level provides user interaction and data visualization in the interface [23-25]. The business logic or application level includes rules, algorithms for application response to user actions or internal events, and data processing rules. Data management includes storing, retrieving, modifying, and deleting data related to the application's business tasks, and it includes databases for clients, suppliers, products, and transportation. The server-side of the application ensures secure data transmission [24-37].

The system must implement functions described in use cases. Each use case diagram describes the functionality of one subsystem. A use case represents a functional unit expressed as a transaction between an actor and the system. It describes a sequence of actions performed by the system to achieve a useful result for the user. An actor refers to a user of the system (a person or another system) [37-39].

The use case model of the system consists of all the actors in the system and various use cases through which the actors interact with the system, thus describing the system's functional behavior. It also shows the relationships between use cases, deepening our understanding of the system [25-37].

The first step in modeling use cases is to create a list of system actors. Then, the system behavior is described, i.e., how users interact with the system by performing certain action sequences to achieve specific goals [31-40]. Use case mockups represent graphical representations of the system's capabilities and functionality. Mockups are an important element of system architecture as they allow visualizing various actions and data flows that occur in the system in a specific use case. Let's consider some examples of mockups for our system [23-29].

In Figure 2, a layout of a product report is presented. The product report layout represents a graphical or visual representation of data and information about goods or products.

It is a specially designed design that allows for a clear and convenient presentation of all necessary details about the products. The product report layout is an important tool in business as it allows for the control of information about all available and accessible goods, as well as those in the stages of manufacturing, delivery, or sale. The key elements that can be included in the product report layout include the following [37-41]:

- Product name and code: This helps identify the product and track its status and movement.
- Quantity of the product: Information about the quantity of the available or accessible goods, as well as the quantity sold, shipped, or returned.
- Price of the product: Indication of the unit cost of the product or the total cost of the available goods.
- Status of the product: Display of the status of the product, such as "in stock," "sold," "on sale," etc.

The product report layout can be used as an internal inventory management tool within a company or provided to customers or partners as an informational tool. It helps ensure transparency and efficiency in inventory management and improves planning and decision-making [12-16].

Warehouse		Total							
Code	Nomenclature	Remains		Purchases			Sales		
Trading floor		Quantity	The amount	Price	Quantity	The amount	Price	Quantity	The amount
134	Product 1	352	15765	352	80	80000	2000	75	15000

Fig. 2. Product repirt layout.

Another example of a layout is presented in Figure 3.

Order date	Route		Type of transport	Currency	Delivery status
20.01.2023	Country 2	Country 1	air	50000	Delivered
19.02.2023	Country 1	Country 2	auto	30000	On the way

Fig. 3. Layout of the delivery report.

A layout of a delivery report is a preliminary design or template of a report that presents information about the process of delivering goods or services. It provides the opportunity to visually organize and present delivery data in a convenient and understandable format [14-25].

A delivery report layout may include the following information:

- Delivery dates: specifying the dates when the goods or services were delivered.
- Customer details: containing the customer's contact information, including name, address, and contact details.
- Product or service details: describing the goods or services that were delivered, including their name, quantity, cost, and other related data.
- Delivery terms: indicating the delivery methods, delivery time, possible restrictions, and providing information on agreements with the customer.
- Delivery status information: reflecting the current delivery status, including the delivery date, confirmation of receipt or any other relevant data.

A delivery report layout can be presented in the form of a table, charts, diagrams, or other visual elements to easily view and analyze delivery information. It can be used as an internal tool for the delivery department, as well as an external document for customers or partners to showcase the delivery progress and ensure transparency in the process [32-37].

V. Conclusion

In conclusion, the developed automated system for the trade and logistics industry represents an innovative solution that significantly simplifies and optimizes business processes in this sector [9-16].

The system provides automation of goods accounting, orders, and deliveries, as well as efficient logistics, allowing companies to track and control all stages of supply. Thanks to the system's integration with various online platforms and partners, it ensures fast and reliable exchange of information between supply chain participants [34-39].

The system also enables automatic report generation and analytics, which helps companies make informed decisions based on up-to-date information. Moreover, by applying modern technologies and machine learning algorithms, the system offers demand forecasting and inventory optimization, preventing downtime and reducing costs [13-21].

As a result, the automated system for the trade and logistics industry has a wide range of functionalities that help companies increase their efficiency, improve customer service, and reduce costs. Implementing this system will be a reliable step towards sustainable and successful development in the modern competitive environment [12-20].

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Mathematical modeling of nonlinear processes of electromagnetic elastic thin plates of complex configuration

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***Abstract*— The article a mathematical model based on the Hamilton-Ostrogradsky variational principle is presented, using the Kirchhoff-Law hypothesis, the mathematical model in three-dimensional form is transformed into a two-dimensional model. To solve the problem, a computational algorithm was developed, for which practical software tools was created, computational experiments were conducted, and the results obtained were analyzed.**

Keywords*— *Mathematical modeling, Hamilton-Ostrogradsky principle, Maxwell's electromagnetic tensor, magneto elastic thin plate of complex configuration.

I. Introduction

The development and widespread use of structural elements in the form of thin plates and shells of complex configuration based on nonlinear patterns are relevant in the world. At the same time, the issues of modeling the processes of the influence of electromagnetic fields on the deformation of thin electrically conductive bodies, the development of a new generation of algorithms and software tools for modeling by the R-function method of the solution structure corresponding to the basic boundary conditions of magneto elastic plates and shells of complex configuration are of particular importance.

Several scientists in the world have conducted research on the theory of electrical conductivity of electromagnetic fields. Including S.A.Ambartsumyan, G.E.Bagdasaryan, M.V.Belubekyan, V.L.Rvachev, L.V.Kurpa, L.V.Molchenko, I.T.Selezov, M.R.Korotkina, Academician V.Q.Qobulov, academician X.A.Rakhmatulin, professor Sh.A.Nazirov, T.Yuldashev, R. Indiaminov, F.M.Nuraliev conducted many studies and achieved significant results.

Many studies available in this field are mainly limited to solving linear and nonlinear problems for elastic plates of symmetrical classical (circle, square, rectangle) shape. However, according to the results of the study, there are no studies related to the theory of nonlinearity for electrically conductive complex structurally symmetrical shaped plates under the influence of an electromagnetic field.

In this study, the bending of a thin plate under the influence of external forces, taking into account the processes of geometric nonlinear deformation of the magneto elastic plate. In this case, a thin plate of complex structural shape is taken as a solid body, and the problem of bending of a thin plate is solved, taking into account the effect of electromagnetic forces generated on it by an electromagnetic field.

II. Development a mathematical model

A mathematical model of the process of nonlinear deformation of a magnetoelastic plate is built on the principle of Hamilton-Ostrogradsky variation. It uses the Kirchhoff-Law hypothesis, the Cauchy relationship, the Lorentz force of Hooke's law, and Maxwell's view of the electromagnetic tensor [1].

$$\int_t (\delta K - \delta \Pi + \delta A) dt = 0 \qquad (1)$$

where: t - time, the product of variation, K – kinetic energy, Π – potential energy, A – the work done by external volumetric and surface forces.

According to the Kirchhoff-Law hypothesis, there is no deformation of a thin plate along the Z coordinate axis, and the displacement projections of the middle plane of the plate are expressed as follows:

$$\begin{aligned} u_1 &= u(x,y,t) - z\frac{\partial w}{\partial x}, \\ u_2 &= v(x,y,t) - z\frac{\partial w}{\partial y}, \\ u_3 &= w(x,y,t) \end{aligned} \qquad (2)$$

where: the displacement of the middle plane of the thin plate along the coordinate (x, y, z) axes .

Instead of the kinetic energy displacements, the values of formula 2 are given, and the following formula is formed as a result of fractional integration and similar terms compression.

$$\delta K = \int_x \int_y \left\{ \rho h \frac{\partial u}{\partial t}\delta u + \rho h \frac{\partial v}{\partial t}\delta v + \rho h \frac{\partial w}{\partial t}\delta w \right\} dydx \Bigg|_t -$$

$$-\iiint_{t\,x\,y}\left\{\rho h\frac{\partial^2 u}{\partial t^2}\delta u+\rho h\frac{\partial^2 v}{\partial t^2}\delta v+\rho h\frac{\partial^2 w}{\partial t^2}\delta w\right\}dydxdt.$$

where body density, V - the volume of the body.

To calculate the potential energy variation, the geometric nonlinear representation of the body deformation is first calculated. In this case, using the Cauchy relationship and the Kirchhoff-Law hypothesis, the nonlinear appearance of the deformation is expressed as follows:

$$\begin{cases}\varepsilon_{xx}=\dfrac{\partial u}{\partial x}-z\dfrac{\partial^2 w}{\partial x^2}+\dfrac{1}{2}\dfrac{\partial w}{\partial x}\cdot\dfrac{\partial w}{\partial x},\\ \varepsilon_{yy}=\dfrac{\partial v}{\partial y}-z\dfrac{\partial^2 w}{\partial y^2}+\dfrac{1}{2}\dfrac{\partial w}{\partial y}\cdot\dfrac{\partial w}{\partial y},\\ \varepsilon_{xy}=\dfrac{\partial u}{\partial y}+\dfrac{\partial v}{\partial x}-2z\dfrac{\partial^2 w}{\partial x\partial y}+\dfrac{\partial w}{\partial x}\dfrac{\partial w}{\partial y}.\end{cases}\quad(3)$$

where the deformation coefficients of the plate [8].

As mentioned above, based on the Kirchhoff-Law hypothesis, the potential energy of a thin plate is expressed as follows:

$$\delta\Pi=\int_y\left\{N_{xx}\delta u-M_{xx}\delta\frac{\partial w}{\partial x}-\frac{\partial M_{xx}}{\partial x}\delta w+N_{xx}\frac{\partial w}{\partial x}\delta w+\right.$$
$$\left.+N_{xy}\delta v-M_{xy}\delta\frac{\partial w}{\partial y}-\frac{\partial M_{xy}}{\partial y}\delta w+N_{xy}\frac{\partial w}{\partial y}\delta w\right\}dy\Bigg|_x+$$
$$\int_x\left\{N_{yy}\delta v-M_{yy}\delta\frac{\partial w}{\partial y}-\frac{\partial M_{yy}}{\partial y}\delta w+N_{yy}\frac{\partial w}{\partial y}\delta w+\right.$$
$$\left.+N_{xy}\delta u-\frac{\partial M_{xy}}{\partial x}\delta w-M_{xy}\delta\frac{\partial w}{\partial x}+N_{xy}\frac{\partial w}{\partial x}\delta w\right\}dx\Bigg|_y-$$
$$-\iint_{x\,y}\left\{\frac{\partial^2 M_{xx}}{\partial x^2}\delta w+2\frac{\partial^2 M_{xy}}{\partial x\partial y}\delta w+\frac{\partial^2 M_{yy}}{\partial y^2}\delta w+\right.$$
$$+\frac{\partial N_{xx}}{\partial x}\delta u+\frac{\partial N_{xy}}{\partial y}\delta u+\frac{\partial N_{yy}}{\partial y}\delta v+\frac{\partial N_{xy}}{\partial x}\delta v+$$
$$\left.+\left(\frac{\partial N_{xx}}{\partial x}+\frac{\partial N_{xy}}{\partial y}\right)\frac{\partial w}{\partial x}+\left(\frac{\partial N_{yy}}{\partial y}+\frac{\partial N_{xy}}{\partial x}\right)\frac{\partial w}{\partial y}\right\}dydx.$$

where N_{xx}, N_{yy}, N_{xy} – are the normal and shear forces along the thickness of the plate. M_{xx}, M_{yy}, M_{xy} – are the bending and torsional moments of the plate.

An overview of the variation of work performed by external forces, taking into account electromagnetic forces:

$$\int_t\delta Adt=\iint_{t\,v}\left[(X+\rho K_x)\delta u_1+(Y+\rho K_y)\delta u_2+(Z+\rho K_z)\delta u_3\right]dVdt+$$
$$+\iiint_{t\,y\,x}\left[(q_x+T_{zx})\delta u_1+(q_y+T_{zy})\delta u_2+(q_z+T_{zz})\delta u_3\right]dxdydt+$$
$$+\iiint_{t\,y\,z}\left[(P_x+T_{xx})\delta u_1+(P_y+T_{xy})\delta u_2+(P_z+T_{xz})\delta u_3\right]dzdydt+$$
$$+\iiint_{t\,x\,z}\left[(F_x+T_{yx})\delta u_1+(F_y+T_{yy})\delta u_2+(F_z+T_{yz})\delta u_3\right]dzdxdt$$

where $X, Y, Z, \rho K_x, \rho K_y, \rho K_z$ – the generating volume forces, $q_x, q_y, q_z, T_{zx}, T_{zy}, T_{zz}$ – the surface forces, $P_x, P_y, P_z, T_{xx}, T_{xy}, T_{xz}, F_x, F_y, F_z, T_{yy}, T_{yz}, T_{zx}$, – the generating contour forces.

In the calculation of electromagnetic forces, the electromagnetic forces applied to a thin plate are determined using the Maxwell electromagnetic tensor view [2].

$$R=\rho K=\frac{1}{4\pi}(\mathrm{rot}(\mathrm{rot}(\mathrm{U\,x\,H})))\,\mathrm{x\,H}$$

III. Computational algorithm of numerical solution of the problem

Algorithm for calculating the geometric nonlinear deformation processes of electromagnetic thin plates [4]:

1. Construction of solution structures corresponding to limit conditions
2. Construction of discrete equations with respect to spatial variables
3. Solving discrete equations and finding unknown components of solution structures.
4. Determining the normal displacements of the middle surface of the plate

To calculate the unknowns in the equation of motion using the given algorithm, the unknown displacement coefficients are determined using a combination of the Bubnov-Galerkin method of variation, the Gaussian square method, the Gaussian method Nyumark and the iteration method.

The limit equation of a magnetoelastic plate of complex configuration is constructed by the R-function [3].

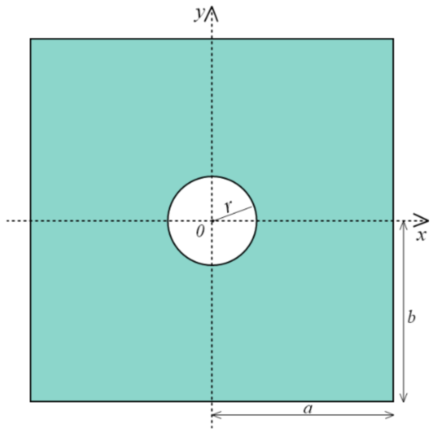

Figure 1. Magnetic plate with complex configuration.

$$f_1=\frac{(a^2-x^2)}{2a}\geq 0,\ f_2=\frac{(b^2-y^2)}{2b}\geq 0,$$
$$f_3=\frac{(x^2+y^2-r^2)}{2r}\geq 0,\ \omega=(f_1\wedge f_2)\wedge f_3.$$

where f_1, f_2, f_3 – the functions representing the field. ω – a normalized function representing the field.

$$u|_\Gamma = 0, \quad v|_\Gamma = 0, \quad w|_\Gamma = 0, \quad \frac{\partial w}{\partial n}\Big|_\Gamma = 0$$

where $n-$ the external normal falling on the surface of the plate, Γ - the limit of the sphere.

The structure of solutions built according to a given limit condition [4]:

$$u = \omega\Phi_1, \quad v = \omega\Phi_2 \quad w = \omega^2\Phi_3.$$

Limit conditions for rigidly configured plate configurations [5]:

Φ_1, Φ_2, Φ_3 -- unknown components.

$$\Phi_1 = \sum_{i=1}^{N} c_i(t)\phi_i(x,y), \ \Phi_2 = \sum_{j=1}^{N} c_j(t)\phi_j(x,y),$$

$$\Phi_3 = \sum_{k=1}^{N} c_k(t)\chi_k(x,y), u = \omega\sum_{i=1}^{N} c_i(t)\varphi_i(x,y),$$

$$v = \omega\sum_{j=1}^{N} c_j(t)\phi_j(x,y), \ w = \omega^2\sum_{k=1}^{N} c_k(t)\chi_k(x,y).$$

where $c_i -$ the unknown coefficients of the structure of the solutions, and $\varphi_i, \phi_j, \chi_k -$ some known polynomial functions [6].

The iteration method is used to find the displacements $u_i(x,y,t), v_i(x,y,t), w_i(x,y,t)$ of the middle surface of the plate Y from the system of equations formed, and a numerical solution is obtained [8].

The effect of electromagnetic field forces on the process of geometric nonlinear deformation of a thin plate was analyzed by obtaining numerical values of $w_i(x,y,t)$ the displacement function when the thin plate is exposed to electromagnetic field forces and without taking into account the effect of field forces (Table 1). At the same time, the difference between the maximum displacement points was 19%. This graph is shown through Figure 2 [7].

table 1

x	*The effect of electromagnetic field forces has not been considered* $w_i(x,y)$	*When exposed to electromagnetic field forces*
-1	0	0
-0.9	0.000013	0.00002
-0.8	0.00010	0.000143
-0.7	0.000228	0.000309
-0.6	0.000285	0.000373
-0.5	0.000232	0.000295
-0.4	0.000119	0.000149
-0.3	0.000028	0.000035
-0.2	0	0
0.2	0	0
0.3	0.000028	0.000035
0.4	0.000119	0.000149
0.5	0.000232	0.000295
0.6	0.000285	0.000373
0.7	0.000228	0.000309
0.8	0.00010	0.000143
0.9	0.000013	0.00002
1	0	0

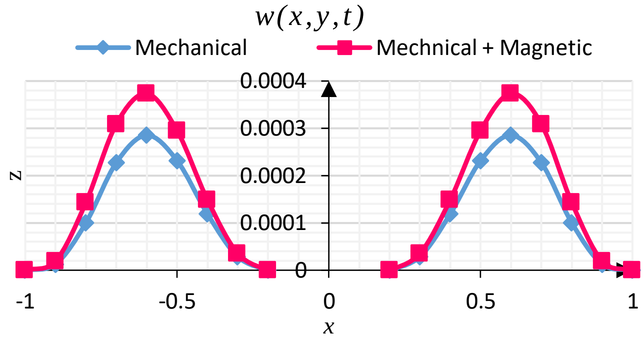

Figure 2. The effect of electromagnetic field forces on a thin plate of complex shape.

In the next experiment, a study performed on the thickness *h* of a thin plate of complex configuration, and numerical results and graphical representation (Figure 3) show that the plate bending values increase when the plate thickness *h* value is small. The geometric and mechanical parameters obtained in the computational experiment are as follows:

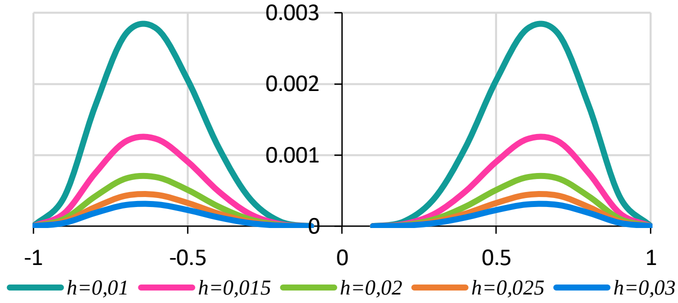

Figure 3. Experiment on plate thickness.

Numerical results and graphical images (Fig. 4) were obtained by conducting experiments on the radius *r* of a thin plate of fine complex shape (Fig. 1). The obtained results show that when the inner cut radius r of the plate is small, the bending values of the thin plate under the influence of external forces increase [9].

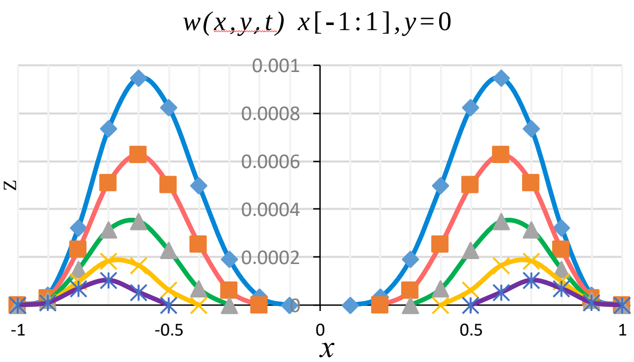

Figure 4. An experiment on the radii of a complex shaped plate

Deformation calculations of a magneto elastic plate with a complex configuration were studied for the second symmetric field shown in Figure 5 below, and the following numerical results (table 2) and graphs (Figure 5) were obtained [10].

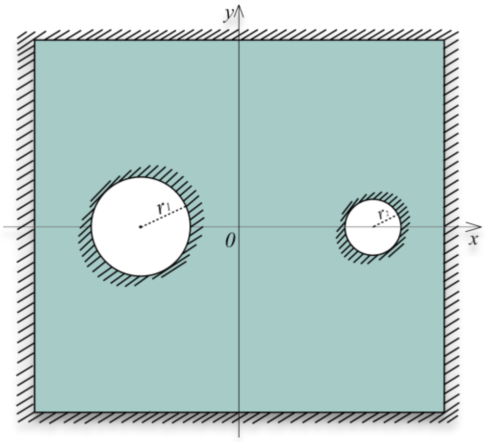

Figure 5. Magneto elastic plate with nonsymmetrical complex configuration.

An analytical equation was constructed for the applied asymmetric complex field of the *R*-function (Fig. 5) and was expressed by the following formula 4. This is a graph of the bending along the coordinate axis of an asymmetrical complex shaped magneto elastic plate shown in Figure 6.

$$\omega = (f_1 \wedge f_2) \wedge f_3 \wedge f_4 \qquad (4)$$

here

$$f_1 = \frac{(a^2 - x^2)}{2a} \geq 0, \; f_2 = \frac{(b^2 - y^2)}{2b} \geq 0,$$

$$f_3 = \frac{((x-a_1)^2 + y^2 - r^2)}{2r} \geq 0, \; f_4 = \frac{((x+a_2)^2 + y^2 - r^2)}{2r} \geq 0,$$

Geometric-mechanical parameters in computational experiments [11]:

$$a = 1,\, b = 1, a_1 = 0.5, a_6 = 0.55, h = 0.01,\, r_1 = 0.1, r_2 = 0.1,$$

$$\nu = 0.3,\, q = 1,\, H_x = H_y = H_z = 10к Э, E = 10^{11}\; H / м^2.$$

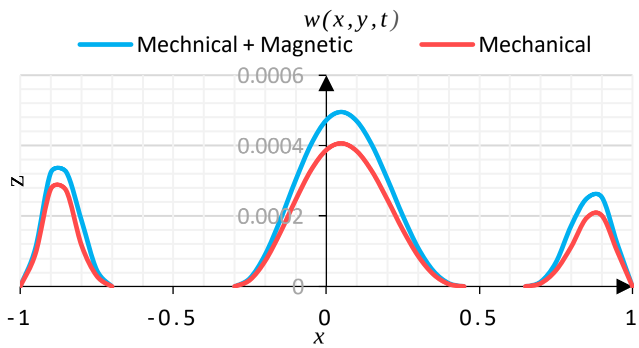

Figure 6. Bending of a magnetoelastic thin plate with an asymmetrical complex configuration.

In figure 11 the conical results of the bending along the axis of a complex shaped magnetoelastic plate (Table 2) and a graphical representation are showed (Figure 7).

Table.2

x	y	*w(x,y,t) function values when not affected by electromagnetic field forces*	*w(x,y,t) function values under the influence of electromagnetic field forces*
-1	0	0	0
-0.95	0	0.00009	0.00011
-0.9	0	0.00030	0.00038
-0.85	0	0.00027	0.00037
-0.8	0	0.00012	0.00019
-0.75	0	0.00003	0.00005
-0.7	0	0	0
-0.3	0	0	0
-0.25	0	0.00002	0.00002
-0.2	0	0.00007	0.00009
-0.15	0	0.00015	0.00019
-0.1	0	0.00025	0.00030
-0.5	0	0.00033	0.00040
0	0	0.00039	0.00047
0.5	0	0.00041	0.00050
0.1	0	0.00038	0.00047
0.15	0	0.00033	0.00040
0.2	0	0.00025	0.00030
0.25	0	0.00016	0.00020
0.3	0	0.00009	0.00011
0.35	0	0.00003	0.00004
0.4	0	0.00001	0.00001
0.45	0	0	0
0.65	0	0	0
0.7	0	0.00001	0.00001
0.75	0	0.00005	0.00007
0.8	0	0.00011	0.00017
0.85	0	0.00018	0.00029
0.9	0	0.00020	0.00032
0.95	0	0.00010	0.00012
1	0	0	0

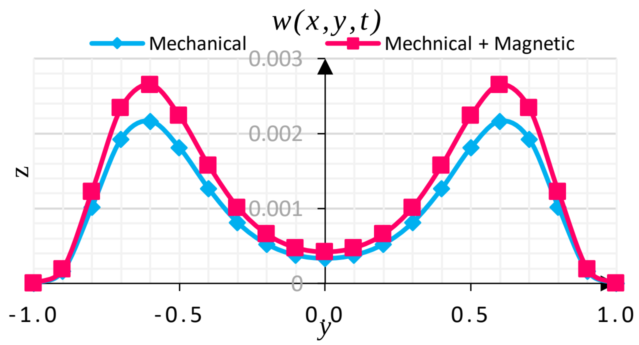

Figure 7. Bending of a magneto elastic thin plate with a complex configuration along the Oy axis.

CONCLUSION

In this research paper, the processes of geometric nonlinear deformation of thin plates of complex configuration, taking into account the forces of the electromagnetic field, were studied. In this case, the effects of the electromagnetic field on the geometrically nonlinear deformation- voltage state of a thin plate of electromagnetic complex configuration were studied;

a new mathematical model of the task of vibration of thin plates of complex structural shape located in the electromagnetic field was built. Computational algorithms have been developed to solve the task. A practical software tool has been developed to conduct computational experiments; in the process of calculating a thin plate of complex configuration, two complex-shaped symmetrical and asymmetric spheres were constructed and experiments were performed on them;

the numerical results obtained in the calculation were expressed in tabular form, and graphical images were provided for their analysis; in the future the results presented in this research work can be used as a basis for solving similar problems.

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Spectral analysis of muscle activity - an experimental investigation

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Abstract – This article explores the methods of spectral analysis for muscle activity biosignals and presents experimental results. The research introduces a novel approach to this analysis, aiming to determine specific characteristics of muscle biosignals. Using the proposed method, muscle biosignals were recorded and processed during athletes' training sessions.

Keywords – biosignal, EMG, electromyography, parameter, frequency spectrum, segment, monitoring, signal processing, feature extraction, filtering, spectral analysis, feature vector.

I. Introduction

Today, computer systems pervade every facet of our lives, including medicine. The modernization of our country's medical sector demands such integration. Medical devices, diagnostic tools, and testing equipment increasingly rely on computer systems for operation and control.

Biological signals, acquired through various means, undergo analysis to extract pivotal information. Standard techniques for signal analysis, like filtering, digitization, processing, and storage, are applicable to many biological signals.

By processing electromyography (EMG) signals, specific outcomes become attainable. The digitization of received data is paramount given its varied nature and transmission methods. For example, data might be relayed through Bluetooth, Wi-Fi, or multiple ports, taking forms such as packets, text, graphics, or files.

Electromyography (EMG) measures electrical activity produced by muscle fibers during contraction, leading to electromyogram (EMG) signals. These signals are indicative of muscle tension [1,2]. EMG signals are essential in numerous clinical and biomedical applications, from identifying muscular abnormalities to monitoring muscle activity.

EMG signals primarily serve to:

– Pinpoint the timing of muscle activation.
– Gauge the force muscles produce.
– Examine muscle fatigue through the signal's frequency spectrum.

These uses underscore the multifaceted nature of EMG signals. The first focuses on the exact timing of muscle activation – vital for grasping motor control and coordination. The second quantifies muscle force, essential in biomechanics and rehabilitation. Lastly, frequency spectrum analysis of EMG signals assesses muscle fatigue, shedding light on muscle conditions during extended or intense activities.

EMG signals are useful in diagnostic walking laboratories and are used by trained clinicians for tasks like biofeedback and ergonomic assessments. Their significance as biosignals spans biomechanics, motor management, neuromuscular physiology, movement disorders, postural control, and physiotherapy (Reaz et al., 2006). Clinical applications, such as gait analysis and coordination studies, necessitate the precise pinpointing of muscle activation timing and duration. Clinical specialists often favor visual inspection, granting a thorough signal evaluation. Additionally, algorithm speed becomes pivotal for specific applications, as does maintaining accuracy (Merlo et al., 2003).

Detecting voluntary muscle contractions is a crucial aspect of EMG processing. Its applications range from biomechanics to clinical diagnostics, rehabilitation tool development, and more. Through precise detection and analysis of these contractions via EMG, one can glean insights into human body mechanics, decipher movement patterns, muscle functions, and performance. Additionally, EMG-based diagnostics offer insights into muscle disorders, motor control deficits, and neuromuscular conditions. Data derived from EMG processing is paramount for creating efficient rehabilitation tools and interventions, enabling the formulation of tailored treatment plans and progress monitoring.

II. Methods and Algorithms for Processing Biosignals

The clinical assessment of a patient involves multiple stages, each with its distinct objective. Paraclinical techniques, like electromyography (EMG), supplement this process by providing additional data that bolsters the confidence in clinical hypotheses. Evaluating the efficacy of treatments and tracking disease progression are essential to pinpointing the specific type of pain or pathology. Throughout these stages, the primary goal of an EMG study remains to amass detailed information in the most efficient timeframe.

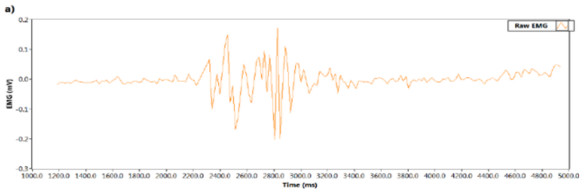

Figure 1. Appearance of the EMG signal (a signal recorded as a result of a single contraction and expansion of the biceps muscle).

Biosignals can be categorized based on multiple characteristics, including waveform and statistical structure. A primary distinction is between continuous and discrete signals. A continuous signal, represented as X(t), varies as a function of continuous time 't'. Typically, signals derived from biological events are continuous [3].

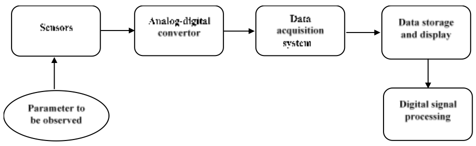

Figure 2. Block scheme of signal analysis.

Rohit Gupta and Ravinder Agarwal Method

The analysis of the electromyographic (EMG) signal adopts a block scheme comprising the following stages [4,5]:

– **EMG Signal Acquisition:** Contemporary hardware is employed to record the EMG signal, capturing the muscles' electrical activity.

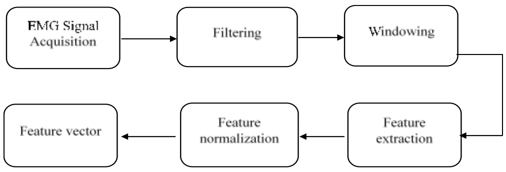

Figure 3. Block scheme of EMG analysis

– **Filtering:** The acquired EMG signal undergoes filtering to eliminate extraneous noise and artifacts, thereby improving the signal's quality.
– **Windowing:** The refined signal is divided into smaller sections or "windows", making it conducive for more in-depth analysis and processing.
– **Feature Extraction:** Specific characteristics of the EMG signal, such as amplitude, frequency, and time-domain traits, are extracted. These details furnish invaluable insights into the nature of muscle activity.
– **Feature Normalization:** To guarantee uniformity and comparability across diverse signals or individuals, the extracted attributes are normalized. This step considers variations in signal amplitude and other potential factors.
– **Feature Vector Formation:** By amalgamating the normalized features, a feature vector is formulated. This vector becomes the foundation for the subsequent phases of EMG signal analysis and interpretation.

The biosignals from muscle activity, once processed, were subjected to analytical scrutiny using the method proposed by Rohit Gupta and Ravinder Agarwal. This analysis leveraged a suite of machine learning algorithms, namely Decision Tree (DT), k-Nearest Neighbor (kNN), Artificial Neural Network (ANN), Support Vector Machine (SVM), and Linear Discriminant Analysis (LDA) [4,5,15].

H. Jaffer and H. Ghaeb's study focused on devising a system for diagnosing neuromuscular disorders by analyzing muscle activity biosignals [6].

Figure 4. Block scheme of the analysis of muscle activity biosignals.

The block scheme for electromyographic (EMG) signal analysis encompasses the following stages:

– **Recorded EMG:** The electromyographic signal is captured through specialized sensors that detect the electrical activity of muscles.
– **Conventional Filtering:** The acquired EMG signal is subjected to specific filtering techniques, such as DC removal and band-limit filtering (typically in the 50-150 Hz range). These filtration methods aim to improve the quality and clarity of the biosignals for subsequent analysis.
– **Feature Extraction:** Distinctive features are extracted from the biosignals to provide meaningful insights. Within the realm of EMG signal analysis, standard features encompass muscle fatigue (ascertained using the Fast Fourier Transform - FFT), signal power, and electrochemical delay characteristics.

The studies by the previously mentioned scientists were meticulously reviewed, culminating in the proposition of a dedicated algorithm for analyzing muscle activity biosignals, as depicted in [Fig 5].

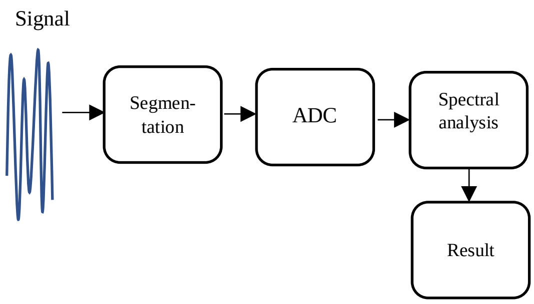

Figure 5. Block scheme of the spectral analysis of muscle activity biosignals.

The block scheme for the spectral analysis of muscle activity biosignals comprises the following stages:

- **Analog-to-Digital Conversion:** The biosignals of muscle activity undergo conversion from analog to digital form using an analog-to-digital converter. For this purpose, the study employed the BTSFreeEMG sensor, which is equipped with both an analog-digital converter and a primary filter.
- **Segmentation:** The biosignals are divided into smaller segments to facilitate subsequent analysis. Based on empirical research and analytical experiments, a segmentation length of 200ms and a sliding section of 100ms were identified as optimal parameters.
- **Spectral Analysis:** At this juncture, the biosignals are assessed in the frequency domain. Techniques such as the Periodogram and Welch methods are utilized, yielding amplitude-frequency parameters that shed light on the signals' frequency content.
- Result Presentation: The insights gleaned from the feature extraction process are visualized using graphs and tables, offering a holistic overview of the research findings.

To effectively execute and analyze our research objectives, setting up organized experiments was crucial. In this investigation, exercises were conducted with varying weights, specifically 1 kg, 3 kg, 5 kg, and 7 kg. Each weight was subjected to a testing duration spanning 5 weeks.

The Welch's method offers an avenue to quantify the spectral power density. By employing this technique, one can discern and study fluctuations in the spectral power density of the acquired signal.

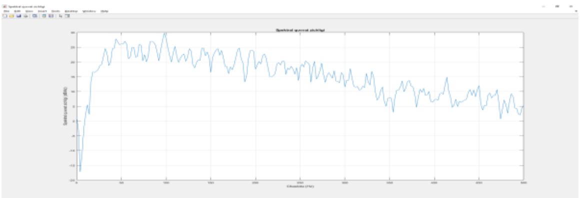

Figure 6. Power Spectrum Density.

A graph is instrumental in illustrating the Power Spectrum Density (PSD) in relation to its corresponding wavelength. Such a visual depiction elucidates the distribution of energy over varied wavelengths, granting a deeper understanding of the signal's spectral attributes.

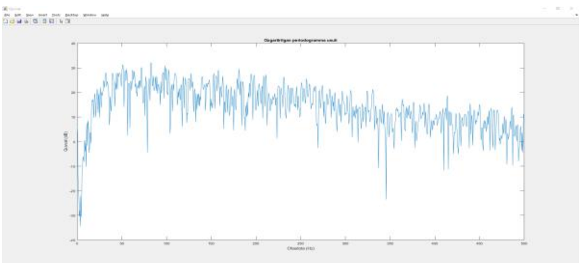

Figure 7. Graphical representation of signal's power.

Both the periodogram and Welch methods offer different modification capabilities. Specifically, the periodogram accommodates a range of alterations. Figure 7 showcases the energy output as interpreted by the fast Fourier transform via a periodogram.

III. Results and Discussion

The study's findings stem from the recorded and analyzed biosignals during the athlete's 35-day exercise regimen. This time frame facilitated the monitoring of shifts in the athlete's physiological and medical conditions and performance fluctuations. The results are depicted in Table 1, Figure 8, and Figure 9.

As illustrated in Table 2, the variations in power are graphically depicted in Figures 10 and 11.

TABLE I. Results Obtained By The Welch Method

	Week 1	*Week 2*	*Week 3*	*Week 4*	*Week 5*
1 kg	0,99	3,23	3,25	3,34	4,32
3 kg	3,64	4,56	4,59	6,06	6,07
5 kg	7,62	8,11	8,99	9,48	11,47
7 kg	7,61	9,5	9,5	9,68	11,68
9 kg	14,86	15,06	15,45	16,07	16,09

TABLE II. Results Obtained By The Periodogramm Method

	1 kg	*3 kg*	*5 kg*	*7 kg*	*9 kg*
Week 1	0,08	2,65	6,33	7,43	13,47
Week 2	1,06	3,09	7,33	8,83	14,15
Week 3	2,20	3,15	8,15	9,58	14,39
Week 4	2,23	4,23	8,66	10,67	15,11
Week 5	2,48	5,19	9,49	11,08	15,17

The periodogram method is adept at revealing power variations within muscle activity biosignals. For this study, weights of 1 kg, 3 kg, 5 kg, 7 kg, and 9 kg were employed. Across a span of 5 weeks, the power shifts in muscle activity biosignals were chronicled during exercises using the specified weights. The outcomes of the experiment were encouraging, demonstrating significant power alterations. Comprehensive data on these power transitions can be found in Table 2. The exercise recordings for each weight were undertaken over 5 days weekly.

Experiments were conducted to record power changes in the biosignals of human biceps brachii muscle activity using weights of 1 kg, 3 kg, 5 kg, 7 kg, and 9 kg. These findings hold considerable importance for tracking both the physical and biological states of athletes during training sessions. By employing the methods described, it is possible to efficiently capture and monitor analytical results, drawing from informative parameters within the biosignals of muscle activity.

The research underscores that tailored exercises designed to bolster the health and physical development of athletes can proactively address potential challenges they might encounter in their future endeavors.

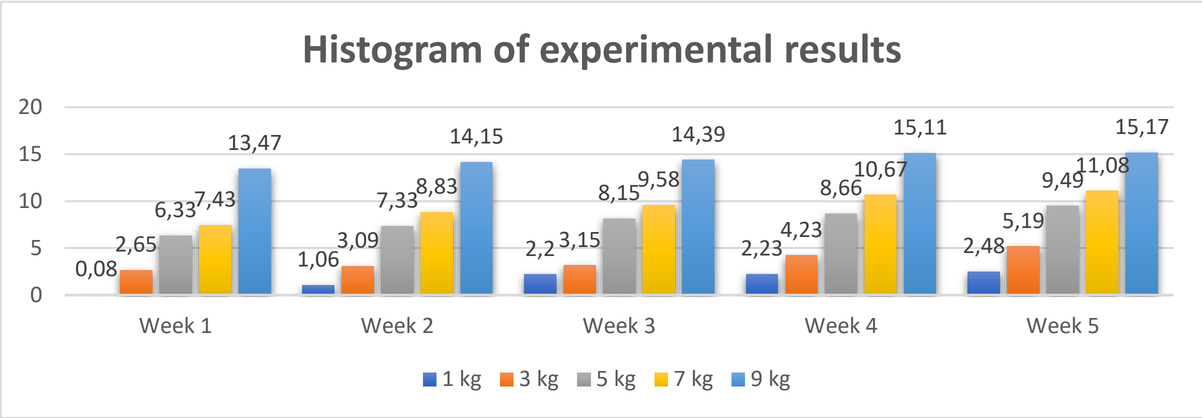

Figure 8. Results from the application of the Welch method in the experimental study.

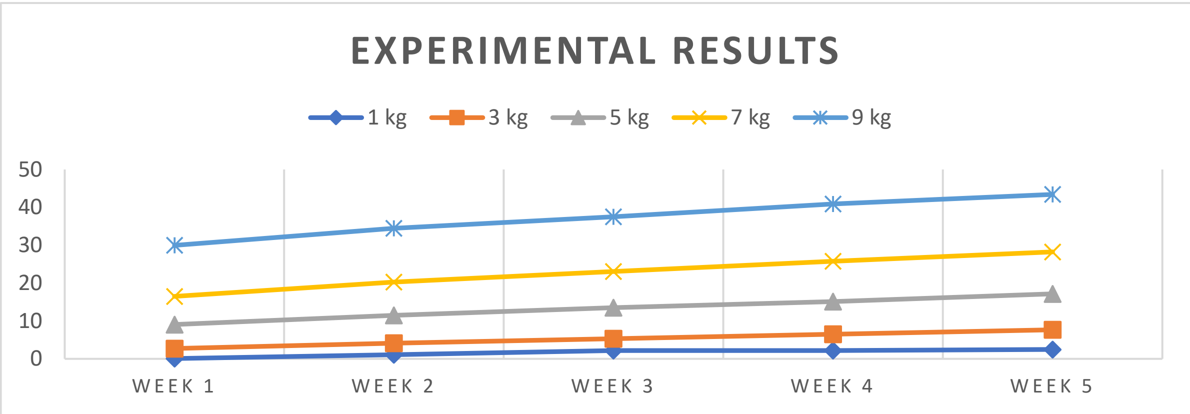

Figure 9. Graphical visualization illustrating the outcomes of the Welch method.

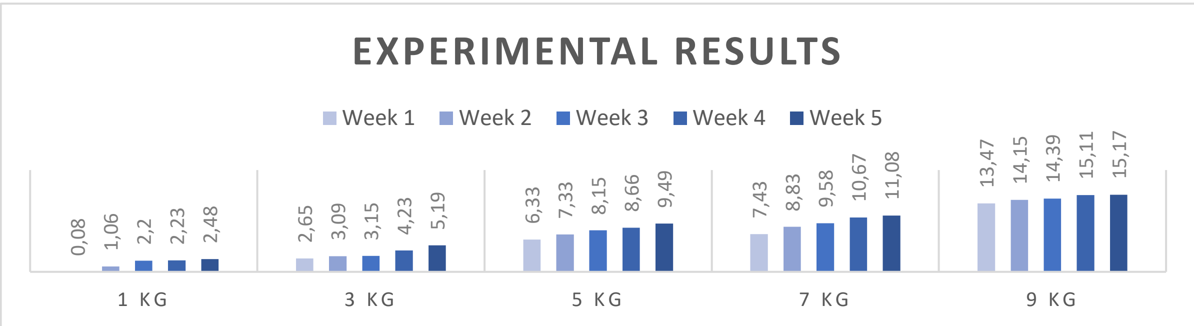

Figure 10. Graphical depiction of outcomes obtained using the Periodogram method in the experiment.

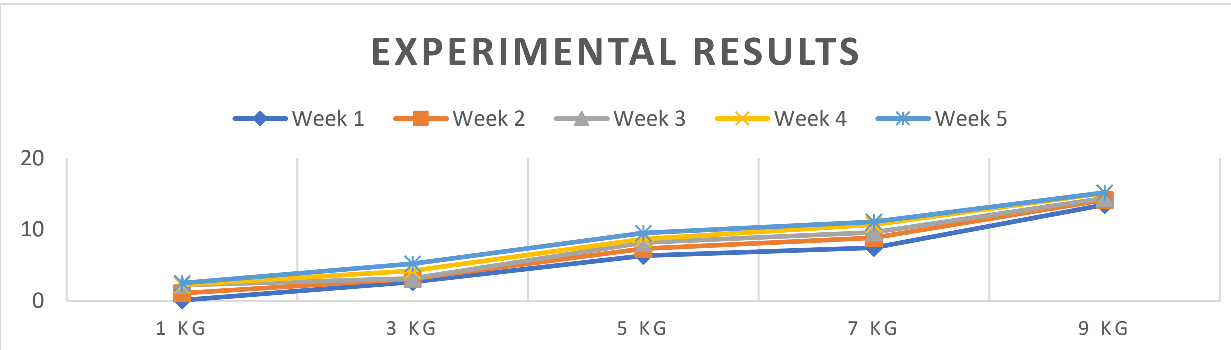

Figure 11. Visualization illustrating the analysis conducted using the Periodogram method.

Conclusion

This paper delves into the examination of algorithms employed in the medical domain for the analysis of biological signals. Our experiments underscore the profound influence of rehabilitative and analytical algorithms within the realm of sports. Notably, tailored exercises crafted for athletes or individuals undergoing rehabilitation can effectively track their physiological transitions and furnish them with consistent workout regimes.

The analysis extended to various facets of muscle activity biosignals, emphasizing the intrinsic features linked to them. Techniques for feature reduction and selection pinpointed the most salient and informative characteristics. Grounded in this scrutiny, algorithms were crafted to discern the prime features that showcase superior accuracy and efficacy in deciphering muscle activity biosignals.

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Image enhancement method using Hamacher t-conorm for breast cancer detection in mammograms

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***Abstract*— The primary and secondary indications of a breast tumor can be distinguished by mammography. Mammography helps to reduce the number of pointless biopsies and costly tests performed on healthy women while also allowing for the early detection of malignant tumors. To identify areas of pathological breast tumors, this research study addresses how to improve the quality of mammography images using the Hamacher t-conorm approach. A simple fuzzy set's membership function is ambiguous, therefore it falls inside an interval range with upper and lower membership levels. As a result, compared to the first type of fuzzy set, a second type of fuzzy set more effectively and differently depicts uncertainty.**

Keywords—*image enhancement, mammogram, type II fuzzy set, Hamacher t-conorm, breast cancer, image processing.*

I. INTRODUCTION

Along with the rapid development of the medical field, the accuracy of diagnosing oncological diseases, especially breast cancer based on mammography images, is increasing. According to analysts of Vantage Market Research [8], the market size of software products for the analysis of medical images will reach 5.97 billion dollars by 2028, and the annual growth rate for this period will be 7.9 percent. It is expected that the demand for computer-aided diagnosis software products will increase in the fields of oncological diseases, including breast cancer, orthopedics, dentistry, urology, neurology, and other medical fields. The growth of this market is driven by advances in medical imaging systems and related image analysis technologies, growing public and private investment in the medical imaging market, increased use of MRI and CT equipment due to chronic diseases, and more computerized diagnostic software related to the formation of complexes.

Improving the quality of mammography images. Medical image analysis methods and algorithms play a crucial role in the early detection and diagnosis of breast cancer. These methods help mammography radiologists interpret mammography images by accurately delineating tumor areas, quantifying tumor markers, and providing important information for clinical decision-making. The first step in analyzing medical images is to improve the quality of the obtained images.

Mammography imaging is medical imaging that focuses on viewing breast tissue using a low-dose x-ray system [1-4]. There are two types of mammogram imaging: digital mammogram and screen-film mammography. Screen-film mammography (SFM) involves traditional analog mammography films. Typically, the SFM background contains labels and markers, which are considered noise and should be removed [15-16]. Digital mammograms are also called full-field digital mammography (FFDM-Full-Field Digital Mammography). Additionally, you may find mammography images in a variety of formats, including LJPG (Lossless JPEG), JPEG (Joint Photographic Experts Group), DI-COM (Digital Imaging and Communications in Medicine), PGM (Portable Gray Map), and TIFF (Tag Image File Format). Two standing-view X-rays from both sides of each breast should be taken. It is necessary to look at four images of both breasts. The names of these four images are left/right craniocaudal and left/right mediolateral oblique views. Breast cancer can be diagnosed correctly in 83–95% of instances with mammography, which has a high level of accuracy [3]. Usually, the examination of the mammary gland is carried out in 2 standard projections perpendicular to each other, in the right and side projections. Mammography distinguishes primary and secondary signs of mammary tumors. The primary sign of cancer is the presence of a tumor shadow and microcalcifications, the tumor shadow may be irregularly shaped like a star or amoeba, with unclear, ill-defined borders, and radially scattered areas.

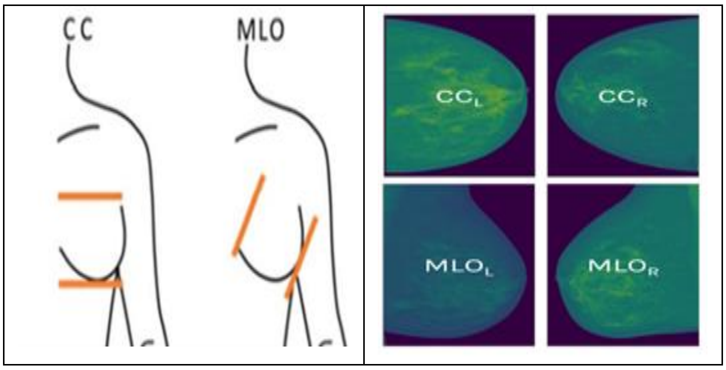

Fig 1. Four views of mammograms (bilateral craniocaudal and mediolateral oblique views).

Problems that arise during initial processing:
- the incompleteness of the set of medical images;
- non-fulfillment of the requirements for image clarity, brightness, and contrast level when taking images through devices;
- In the images taken by the devices, the special features of some systems partially or completely block the main parts of the image;
- The background in the images should not be separated from the main part.

Issues with segmenting mammography pictures include:
Anomaly detection in mammographic image segmentation is influenced by several factors[10-14]. As follows:

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1. Pixel sizes: In mammography images, the pixel sizes of tumor borders in the breast area are smaller than 200 μm or higher than 800 μm, it is not appropriate to classify these tumors based on available textural features. However, pixel sizes for 400 μm×800 μm are recommended for the classifier such as Bayesian in tumor classification of mammographic images;

2. Integration scale: The large pixel size of mammography images increases the calculation time, and the small pixel size reduces the effectiveness of textural analysis methods. Therefore, the recommended pixel resolution of mammography images should be optimal;

3. Pre-processing methods and character normalization: Pre-processing of mammography images changes their textural analysis methods, i.e. gray level value in the image, and character normalization affects classification accuracy. In the set of numerical values of texture markers, they are normalized to prevent large values from dominating small values.

In the past few years, numerous scholars have suggested various image enhancement methods to address low-quality images [6]. The literature review discusses a variety of strategies [7]. Fuzzy techniques, in particular the second type of fuzzy sets (also known as ultra fuzzy sets), are crucial for the creation of novel algorithms since they may effectively eliminate grayness inaccuracy as non-linear knowledge-based procedures. The primary idea behind ultra-fuzziness is to use the first type of fuzzy set to remove uncertainty from fuzzy systems. The local statistics of the fuzzified image are computed after digital mammography has been fuzzified using a second type of fuzzy set. The Hamacher t-conorm is then calculated after determining the upper and lower limits. Digital mammograms were obtained from Samarkand Regional Oncology Service and "ZARMED PRATIKSHA Hospital Groups" LLC.

II. Significance Of The System

In the article, the Hamacher t-conorm method of the second type of fuzzy set is studied in the stage of mammogram image enhancement to identify pathological breast tumor areas. Breast cancer early detection using a second type of fuzzy set is analyzed and compared with the Otsu threshold method. The literature is analyzed in the third part of this research paper, the methodology is in the fourth part, Part V includes the final results of our research, and conclusions are discussed in the last part.

III. Literature Survey

In medicine, one of the problems of increasing the speed and accuracy of diagnosis using artificial intelligence and computer vision is to identify tumors that were not detected in the basic examination based on the image of human body parts and classify the tumor into malignant or benign classes [7]. Today, tumors in various parts of a person are identified mainly based on the analysis of medical images. Nowadays, the analysis of research conducted in the field of processing and analysis of medical images shows that the accuracy of segmentation and diagnosis of breast tumor areas based on mammography images in different environments in real conditions is not high [8]. In this regard, the improvement of the methods and algorithms of pre-processing, segmentation, identification of tumor areas, evaluation, and identification of types by real conditions on medical images is considered one of the current practical issues. Artifact and noise removal and contrast enhancement are pre-processing stages in mammographic medical images. A unique approach [3] has been proposed for the early clarifying of breast tumors by enhancing microcalcification regions in mammographic medical images using hybrid neuro-fuzzy set methods [4], multilevel image thresholding is combined with an adaptive plant augmentation algorithm (APPA) using type II fuzzy sets. Authors in [5] suggested a two-step fuzzy set theoretic thresholding method that uses an uncertainty measure to calculate an appropriate threshold value and assess picture uncertainty. Fuzzy-coarse feature selection using the membership function was proposed in [9]. The Ant-Miner and Weka tools are used in conjunction with the chosen attributes to categorize the irregularities. The results of the experimental research demonstrate that the suggested strategy increases the accuracy of mammography categorization. T.Chaira [9] discovered how to use intuitionistic fuzzy set theory to analyze and characterize the inherent ambiguity and vagueness in medical imaging. In the context of contrast enhancement and segmentation, where the performance is shown to be significantly superior, It is shown that the intuitionistic fuzzy system theory is useful for analyzing medical images. The study [10] introduces a novel thresholding method that treats thresholds as type II fuzzy sets. Additionally, experimental findings with laser cladding photos are offered, along with a brand-new way to assess ultra-fuzziness. CH.V. Narayana and others introduced the Relative Fuzzy Membership Degree (RFMD), which takes into consideration the spatial correlation between the image's pixels, and others [11]. They also suggest a brand-new thresholding method that combines a two-dimensional histogram with a local average gray value calculated by RFMD and ultra fuzziness from the gray values of the pixels. A digital mammography-enhancing technique for microcalcification clusters is presented by Letizia Vivona and colleagues [12]. Enhancement based on fuzzy set rules can represent better knowledge than traditional histogram equalization enhancement techniques. It is recommended to improve the contrast of medical images using the second type of fuzzy set theory [14]. Although uncertainty is taken into account as a component of membership in fuzzy set theory, the second type of fuzzy set takes a more in-depth look at membership function uncertainty. The threshold algorithm proposed by Tizhoosh [10] received some recommendations from H. Bustince et al. [15]. It was possible to improve the contrast of color and grayscale images while preserving brightness and delivering natural hues by developing a better algorithm based on a second kind of fuzzy set. The suggested method produces better images by utilizing new higher and lower bands, a modified Hamacher t-conorm, and a transform-based gamma correction method[16].

IV. Methodology

Images as fuzzy sets. The fact that fuzzy logic gives us a potent mathematical framework for representing and processing expert knowledge is the main reason why one should look at the possibilities of fuzzy techniques for image processing. The idea of linguistic variables and the ambiguous if-then rules are crucial in this situation. By leveraging expert knowledge, fuzzy inference engines can be created, enabling processing that is similar to that of a human. Entropy can be used to determine how fuzzy a set is. The membership degree of any value in the discourse universe can be estimated using any fuzzy membership function [9]. The linear index of fuzziness γ_l for an $m \times n$ image subset $A \subseteq Z$ with L gray levels $g \in [0, L-1]$, the histogram $h(g)$, and the membership function can be defined as follows:

$$\gamma_l\ (A) = \frac{2}{mn}\sum_{g=0}^{L-1} h(g) \times \min[\mu_A(g), 1-\mu_A(g)]$$

For the spatial case, the fuzziness can be determined as follows:

$$\gamma_l\ (A) = \frac{2}{mn}\sum_{i=1}^{m-1}\sum_{j=1}^{n-1} \min[\mu_A(g_{ij}), 1-\mu_A(g_{ij})]$$

It is necessary to develop a suitable membership function $\mu_A(g)$ to measure the global or local image fuzziness:

$$\mu(g) = \begin{cases} 0, & g \le g_{min}\ or\ \ g \ge g_{max}, \\ L(g) = (\frac{g-g_{min}}{T-g_{min}})^{\alpha}, & g_{min} \le g \le T, \\ R(g) = (\frac{g_{max}-g}{g_{min}-T})^{\beta}, & T \le g \le g_{max}, \end{cases}$$

here g is the gray level, g_{min} and g_{max} are the minimum and maximum gray levels and $T \in [0, L-1]$ is a suitable constant. Since we often aim to segment the image using a single, ideally fuzzy number, using a fuzzy number appears more natural (a unique threshold for the entire image).

The second type of fuzzy set. The second kind of fuzzy set might be useful when it is difficult to agree on specific membership components because of the membership values. This is due to some ambiguity about the position, shape, or other elements. The second kind of fuzzy set considers an additional degree of freedom to better describe the uncertainty when the membership functions are fuzzy. A second type of fuzzy set is produced by blurring the first type of fuzzy set.

Description. A second kind of fuzzy set $\tilde{A}$ is defined by a second type membership function $\mu_{\tilde{A}}(x,u)$, where $x \in X$ and $u \in J_x \subseteq [0,1]$.

$$\tilde{A} = \{((x,u), \mu_{\tilde{A}}\ (x,u)) | \forall x \in X, \forall u \in J_x \subseteq [0,1]\}$$

In which $0 \le \mu_{\tilde{A}}\ (x,u) \le 1$. $\tilde{A}$ can also be expressed in the usual notation of fuzzy set as:

$$\tilde{A} = \int_{x \in X} \int_{u \in J_x} \frac{\mu_{\tilde{A}}\ (x,u)}{(x,u)}, \qquad J_x \subseteq [0,1]$$

where the double integral represents the union over all x and u. A second form of fuzzy set can be defined more concretely as follows:

$$\tilde{A} = \{((x, \mu_U(x), \mu_L(x)) | \forall x \in X$$

$$\mu_L(x) \le \mu(x) \le \mu_U(x), u \in [0,1])\}$$

Hedges are usually offered in pairs, with each one being a variation on the original phrase that is diagonally different. A language hedge and its reciprocal value could therefore be used to express the footprint of uncertainty. As a result, the higher and lower belonging values can be explained as follows:

$$\mu_U(x) = [\mu(x)]^{1/\alpha}$$

$$\mu_L(x) = [\mu(x)]^{\alpha}$$

where $\alpha \in (1, \infty)$. In the experiments, $\alpha \in (1, 2]$ has been used because $\alpha > 2$ is usually not meaningful for image data. The amount of contrast enhancement is controlled by the α parameter, in that it should satisfy $0 < \alpha \le 1$, where a greater value results in further amelioration.

Step1. The upper membership degree $\mu_U(x)$ of the initial membership function μ is calculated:

$$\mu_U(x) = [\mu(x)]^{0.5},$$

Step 2. The lower membership degree $\mu_L(x)$ of the initial membership function μ is calculated:

$$\mu_L(x) = [\mu(x)]^2 \ .$$

In the second type of fuzzy set rule, parameter α is determined in a heuristic way to fulfill the requirement of the condition for $0 < \alpha \le 1$ that was verified experimentally. Numerous studies have shown that superior contrast enhancement occurs when $\alpha > 0.6$.

Fuzzy t-conorm. Simple set theory can be extended to include the same union, intersection, and complement operators in multivalued logic, so a fuzzy set is an extension of a simple set. These operators are called T norms (t) and t co-norms (t^*) in fuzzy group theory. Many standards and norms have been published to date by authors such as Hamacher, Yager, Dombi, Weber, and others. These operators fall into one of two categories: (i) conditional operators with min or max terms, or (ii) algebraic operators that are purely algebraic and do not have min or max terms. Hamacher proposed t-norm and t-conorm without any min or max operations in algebra [9].

$H_\gamma(x,y) = \frac{x.y}{\gamma+(1-\gamma).(x+y-x.y)}, \gamma > 0$ is a t-norm reducing generator as:

$$f_\gamma(x) = \frac{1}{\gamma} ln \frac{\gamma+(1-\gamma).x}{x} \text{ and } f_\gamma^{-1}(y) = \frac{\gamma.e^{-\gamma.y}}{1-(1-\gamma).e^{-\gamma.y}}$$

and $H_\gamma^*(x,y) = \frac{x+y-x.y-(1-\gamma)xy}{1-(1-\gamma).xy}$

is a t -conorm with raising generator:

$$g_\gamma(x) = \frac{1}{\gamma} ln \frac{\gamma+(1-\gamma).(1-x)}{1-x} \text{ and } g_\gamma^{-1}(y) = \frac{1-e^{-\gamma.y}}{1-(1-\gamma).e^{-\gamma.y}}$$

V. Experimental Results

TABLE1. EXPERIMENTAL RESULTS OF DIGITAL MAMMOGRAPHY THRESHOLDING.

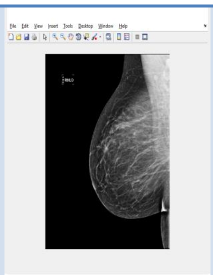
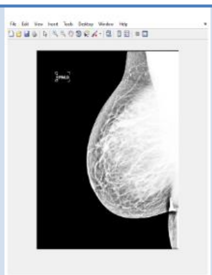
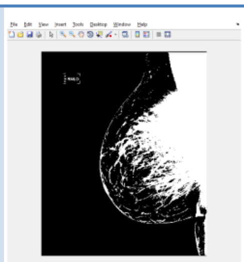
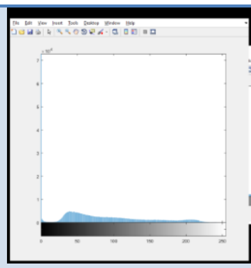
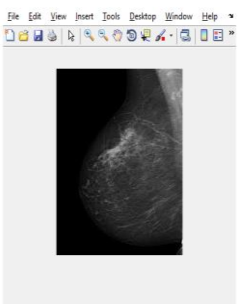
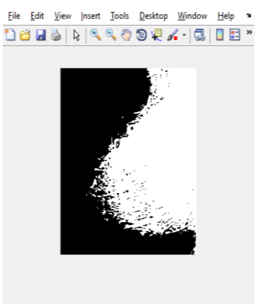
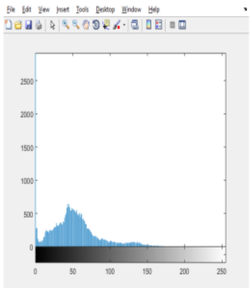
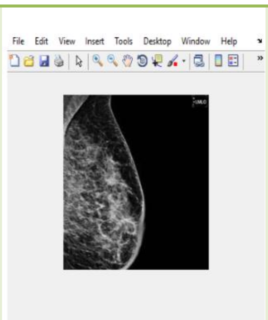
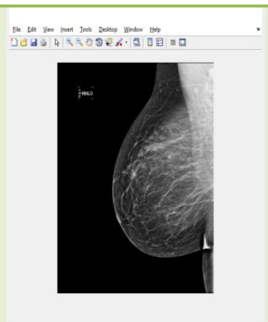
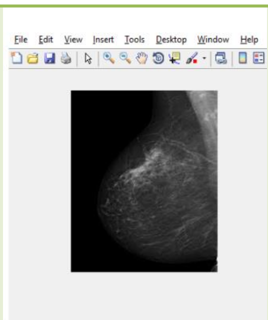
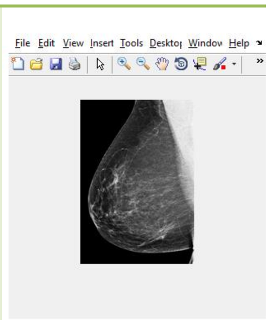
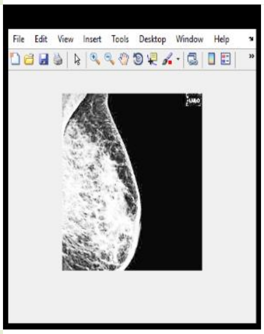
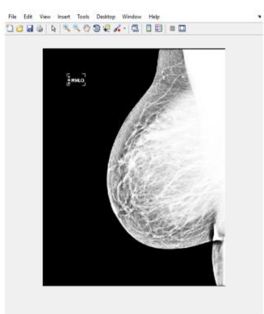
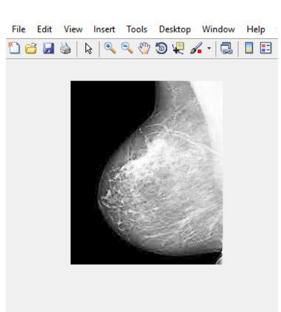
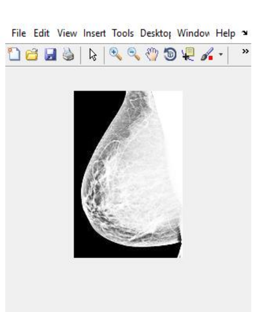
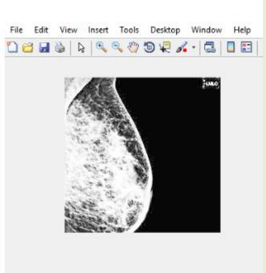
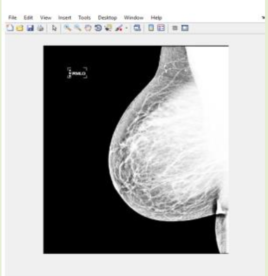
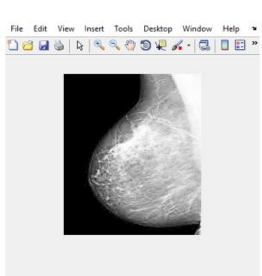
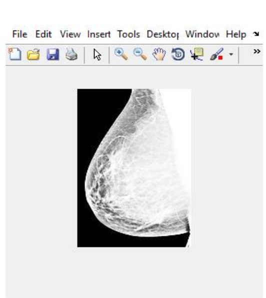
Test image	Type II fuzzy sets	Otsu thresholding	Image histogram
			
			

TABLE 2. APPLYING THE SECOND TYPE OF FUZZY SET METHOD WITH DIFFERENT VALUES OF α. *a)α=0.6, b) α=0.6*

	Original image1	Original image2	Original image3	Original image4
				
α=0.6				
α=0.65				

In this section, digital mammogram images are used to study the effect of the second kind of fuzzy group on image thresholding results. These tests are primarily intended to evaluate the Otsu thresholding method to the second sort of fuzzy group method.The final ends of these methods are presented in Table 1.

The Hamacher t-conorm is used to calculate the new membership function:

$$\mu^{enc}(g)=\frac{\mu^{upper}(g)+\mu^{lower}(g)+(\lambda-2)\cdot\mu^{upper}(g)\cdot\mu^{lower}(g)}{1-(1-\lambda)\cdot\mu^{upper}(g)\cdot\mu^{lower}(g)}$$

The Hamacher t-conorm is used to calculate the new membership function:

$$\mu^{enc}(g)=\frac{\mu^{upper}(g)+\mu^{lower}(g)+(\lambda-2)\cdot\mu^{upper}(g)\cdot\mu^{lower}(g)}{1-(1-\lambda)\cdot\mu^{upper}(g)\cdot\mu^{lower}(g)}$$

and λ=*im_avg*, where *im_avg* is the average of the image. The second type of fuzzy affiliation function's upper and lower ranges are determined using α=0.6. The improved image is the resultant new image. The following computer parameters are used for all experiments: Intel Core i3, 4 GB DDR3 L memory, and Intel HD Graphics 520.

The collection includes more than 80 photos that were gathered by the "ZARMED PRATIKSHA Hospital Groups" LLC and the oncology service of the Samarkand region. The sizes of the used photos are different, the smallest is 138×200 and the largest is 840×1034. Eight mammography images were used in experiments with 80 medical images, and the outcomes are displayed in Tables 1 and 2.

VI. CONCLUSIONN AND FUTURE WORK

In image processing, the problem of image thresholding is challenging. There can never be a perfect algorithm that can process every kind of image. We must therefore seek out new approaches. We now have reliable, knowledge-based tools for developing thresholding techniques because of fuzzy set theory. By including the second type of fuzzy set applications into the fuzzy threshold, the primary objective of our work was to address this issue. To gauge how uncertain a second kind of fuzzy set is, a new ultra-uncertainty metric is presented. The Hamacher t-conorm and fuzzy numbers are used in a new threshold technique based on the second type of fuzzy set that follows. The benchmarking procedures, data sets, and computing requirements are described in depth. Additionally, the comparison results and their reasoning are discussed along with the experimental results attained by using the suggested algorithm on various image kinds. The collection includes more than 80 photos that were gathered by the "ZARMED PRATIKSHA Hospital Groups" LLC and the oncology service of the Samarkand region. The sizes of the used photos are different, the smallest is 138×200 and the largest is 840×1034. Eight mammography images were used in experiments with 80 medical images, and the outcomes are displayed in Tables 1 and 2. The pictures are chosen at random. It should be emphasized that we used the Hamacher t-conorm to find microcalcifications in mammograms in the second type of fuzzy set. The outcomes demonstrate that the algorithm greatly outperforms problematic images. This is brought on by the pathological images' improper lighting, and the segmentation outcomes are enhanced by the suggested enhancement strategy. Since there are several ambiguities in medical images and it is considered that they have fuzzy membership in the first kind of fuzzy group, the second sort of fuzzy set can be used to analyze medical images.

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