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of Food Technologies***



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DRONESC - A TOOL FOR DRONES DESIGN USING GENETIC ALGORITHMS

Author: *Alexandr Vopilov*

Advisor: *Viorica Sudacevschi*

Technical University of Moldova (Moldova)

Abstract. *DronesC aims to develop software that will help people build and configure drones quickly and easily. We aim to apply our expertise to agriculture as well. In this paper, we provide a simulation that demonstrates the impact that drones can have in watering crops on the fields. This project utilizes Unity3D in conjunction with C# NEAT (NeuroEvolution of Augmenting Topologies) technology to successfully simulate the environment from where we can extract the necessary data.*

Keywords: *Drones, Agriculture, water, watering, NEAT technology, genetic algorithms, machine learning, simulation*

I. INTRODUCTION

Agriculture is one of the most crucial industries to keep the world running. Therefore, we believe that it is important to continuously create new technologies to optimize agricultural processes.

We offer the opportunity to learn about genetic algorithms, neuroevolution, agricultural simulation, and integration with drones. We investigate the problem of optimizing Pesticide Spraying via Multi-UAVs Using Genetic Algorithms. Finally, we will create a simulation using the popular game engine Unity3D, using C / C++, C# for programming. Our goal is to simulate a simplified crop creation process for different kinds of crops. For example: wheat, corn, tomato, beet, etc.

The process goes something like this. First, a field is pre-created by sculpting the Terrain and then placing a variety of Assets on it. Next, a drone is placed in the field which then makes a watering flyby of our field in the runtime. Depending on the flight of the drone, we acquire a parameter of how well the field absorbed the liquid which ultimately affects the population of our crops. Using NEAT technology, our drone is able to use this data to evolve and mutate to produce better results.

At the moment, the agricultural industry is going strong. However, times are changing and new technology is developing and we should try and not fall behind. We understand that there might be some concerns in regards to automating different tasks, but just like during the industrial revolution these changes will create new opportunities for growth and prosperity to the agricultural industry.

II. BASIC RESEARCH DIRECTIONS

The most important step in understanding the process is to develop a tool which can be used to allow humans to manipulate the entire process in different ways.

2.1. Unity3D and Simulations

If we look at the information provided in [1, 4, and 9], we understand that a game engine is very well suited to different high-performance applications. These applications do not necessitate very expensive hardware unlike the large-scale physics simulations do. This discrepancy appears even more starkly in applications based on real-time physics.

Unity3D applications use several different types of logic to determine the best speed of the simulation. Since we are dealing with the actual user and the application layer, programmers and students have an actual engine to work with.

With these advantages in mind, we were able to implement our simulation in Unity 3D graphics with a simple algorithm.

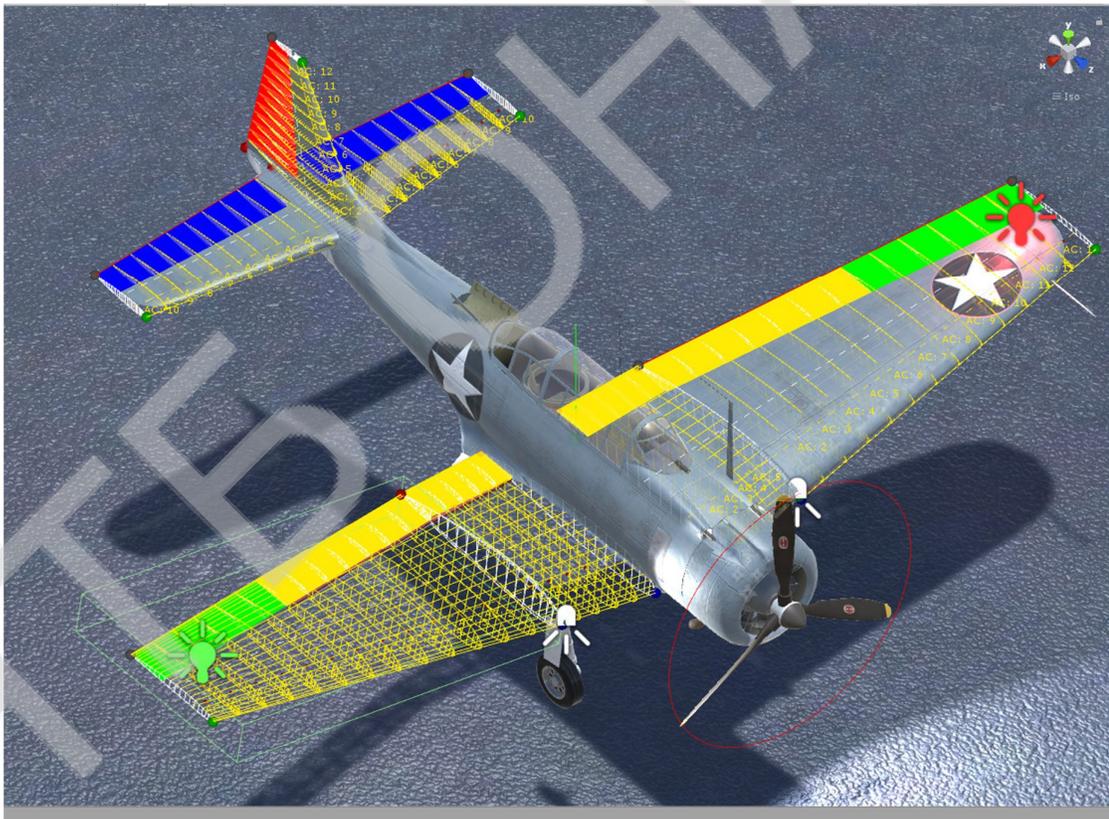


Fig. 1. Simulation of plane in Unity3D

2.2. Genetic Algorithm and Neuroevolution

The author of the work [2] presents an outstanding understanding of the role

and capability of UAVs, and the role of robotic operators in selecting and implementing specific types of tasks. This paper includes some details regarding the role and capability of robotics on a specific level. This article provides a comprehensive introduction and complete overview of the role and capability of robot operators in the production and delivery of agricultural aviation. Furthermore, the paper covers various aspects of robotics operations.

If the NEAT [6] is already training, it might be that they are already building an Artificial Neural Network and they are not yet doing anything to learn of the specific area in which they want to become more proficient. It might also be the case that they are not using the same neural network from the same time, but instead using the same neural network to work with the different populations. To learn about the locations, the pigs might be interested in looking for more information (and then infer whether they are using the same neural network to construct the artificial neural network):

It is known that this is exactly what the AI was used in this study. It was decided to create a neural evolution algorithm for drones.

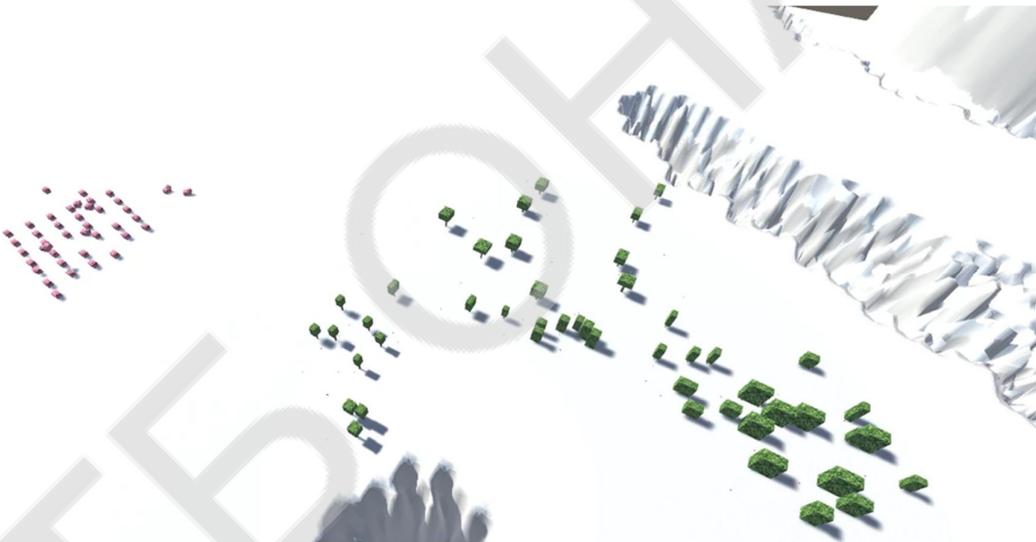


Fig. 2. Population example Unity3D

2.3. Drones and Agriculture

Based on the sources [3, 7] that provide information about drones, about the use of drones, in particular agriculture, we can form certain understanding.

As mentioned earlier, the purpose of the drone is to allow farmers and other operators, to identify potential agricultural and ecological impacts through a variety of techniques. For instance, this technique can be used to map crops for harvesting, agriculture, or land use. At a low cost, it can be used for irrigation, agricultural water harvesting, and food production. Thus, aerial reconnaissance can assist farmers in identifying patterns of agricultural and environmental problems using these techniques.

Farmers are also encouraged to use satellite imagery, which can provide a detailed view and the results. These results can be used to help understand specific agricultural processes and their environment. This drone can also provide specific environmental information, and information about soil and water. The drone also comes with a special camera for monitoring the water consumption of farmers and other operators in order to help monitor changes in soil pH and the water supply of crops.

2.3. Big data and Machine Learning

Based on the sources [7, 8], the researchers used machine learning to find specific species of crop under consideration. They combined this data and published a paper on the data quality that predicted crop yields in the United States. In the paper, the researchers compared the yield with all varieties (ranging from three to fifty trees varieties) in a way that could also be used to generate improved forecasts of crop production.

The results showed improvements in the yield of cultivar seeds to 70 percent while the yield for hybrid varieties had improved at nearly 10 percent. The results are clear now, but what happened to those crop yields in Iowa State? What led the scientists to conclude that genetically engineered wheat varieties could provide better yields from a variety of crops.

Although there are genetic variations in how and where to determine mutations, there are quite a many genetic and biological side effects that are not considered genetic. In some cases, there are different types of alleles. In some cases, mutations are associated with gene-receptors, where genes are associated with genotype — the genetic factors can be changed by a mutation. Genetic studies might also be used to test genetic traits.

III. OBJECT, SUBJECT AND RESEARCH METHODS

We're researching drones used in, the agricultural industry through the connection of optimizations and algorithms. As an example, we study the topic of optimizing crop growth in a field depending on water irrigation. The water is watered by a drone that flies around the field. The essence of the problem is that we do not use simple machine learning algorithms, but a genetic algorithm to do this more efficiently and clearly. We use visualization to make it easier to understand how our programs work. The world is rendered using the Unity3D game engine.

What can we do if it involves a new algorithm, a new approach? Even in a new technology, improvements are limited to itself. For example, we see how our software can be simplified in our applications and will need to be built to be more accurate in our projects. However, a new approach will be needed.

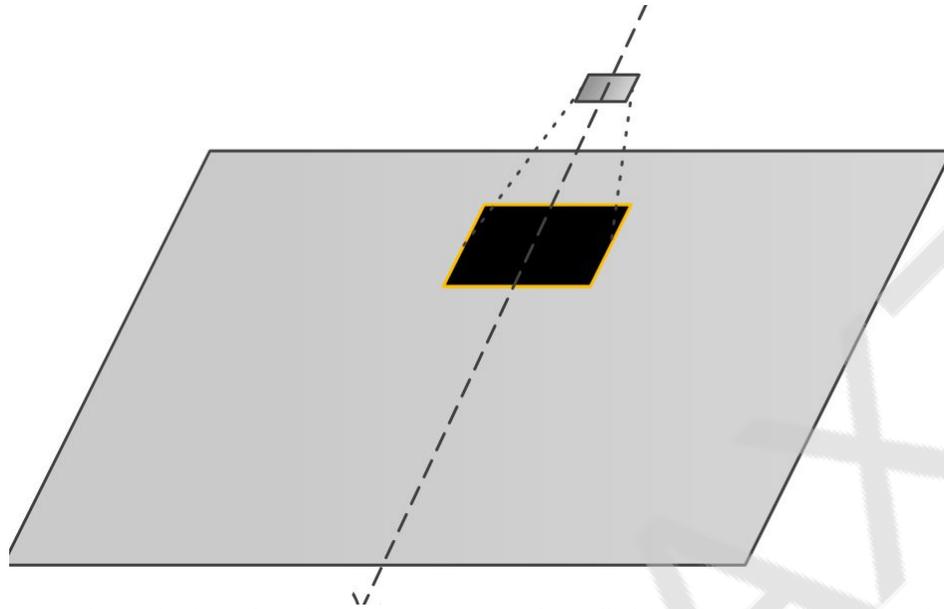


Fig. 3. The mission for drone. Gray area is a field. Black is the spraying area

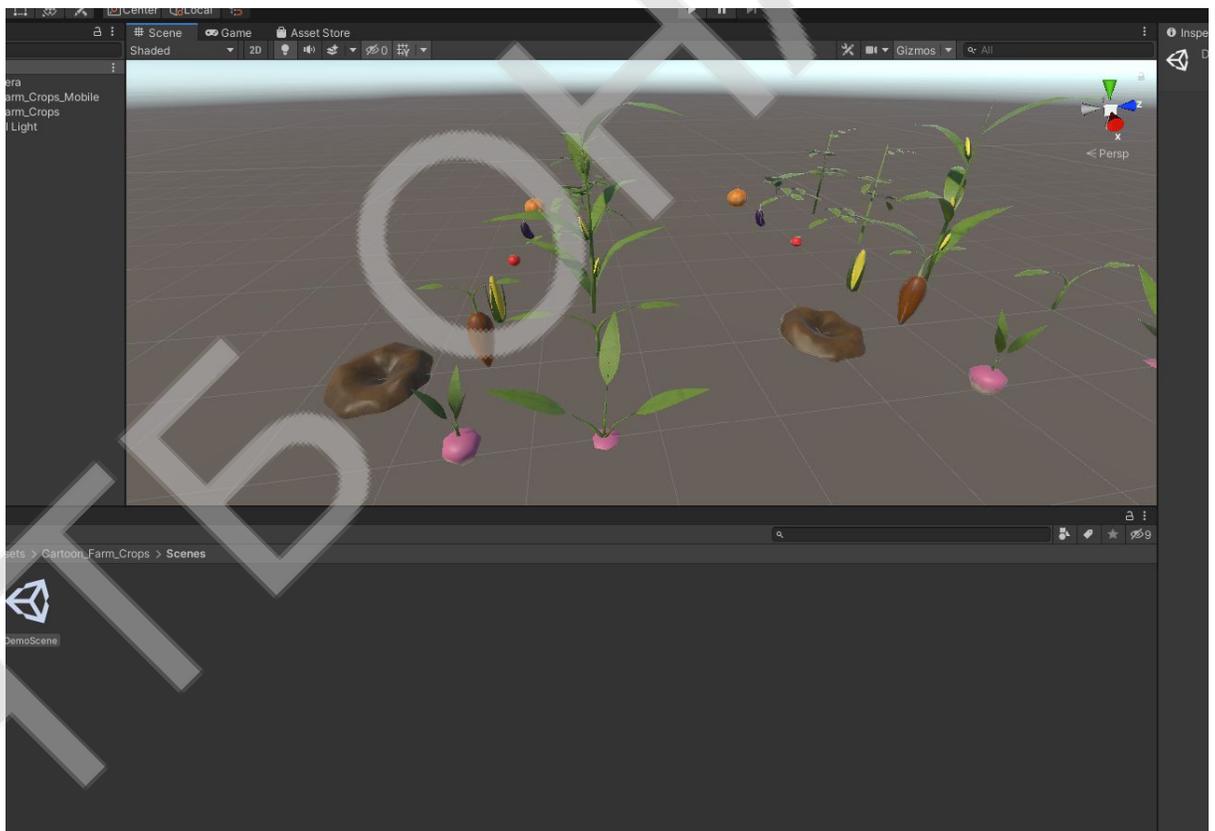


Fig. 4. Planting crops

IV. RESULTS

First, we create a landscape and an environment [10] that shows what this application will be about. Water is added in the form of a river so that plants and crops from the field can consume water and minerals from the soil.

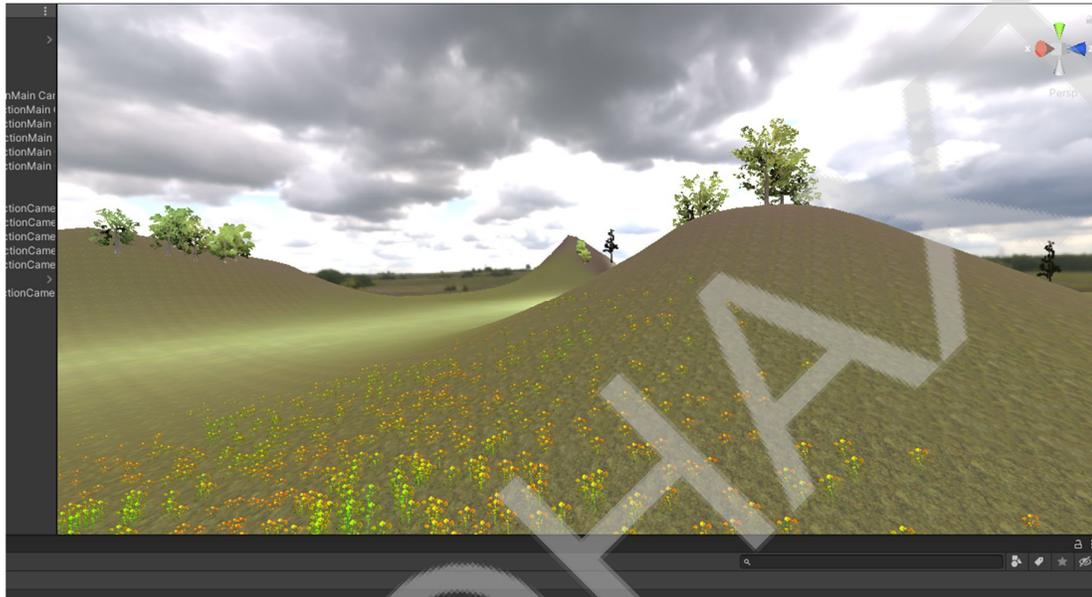


Fig. 5. Environment

As a result, a minimalistic simulation was created with a minimum of parameters for both the environment and the genetic algorithm.

Now a world (a field of cultures) is going to be created from several species. First of all, an earth hole is created so that any crop can be planted in it.



Fig. 6. A field of crops

To create a model of farms and crops, so-called assets from the Unity3D store were used. Also, from there we took textures and a 3D model of the drone.



Fig. 7. Asset store

Each culture contains its own genetic code, which expresses the parameters and development of a particular plant.

Each plant has a life cycle parameter set. During this cycle, the plant must absorb a certain amount of water. The more water it has absorbed, the more resilient the population will be. When a plant decomposes, new plants are formed with different probabilities. Also, empty trenches remain on the field.

Plants have a system of reproduction. It was found that during reproduction, half of the genes are transmitted from the mother and from the father. Next, 2 descendants from the plant are formed, which turned out to be the strongest, but in this situation we made a fairly frequent intersection of genes.



Fig. 8. Genome

So, a population of 10 plants was developed. Each of them began to evolve and mutate. Each plant consumes water, which is sprayed by the drone. Depending on the flight path and the speed of the drone, the water consumption changes. It was noticed that if the drone has a horizontal speed of about 13 m/s, then the spraying is as efficient as possible.

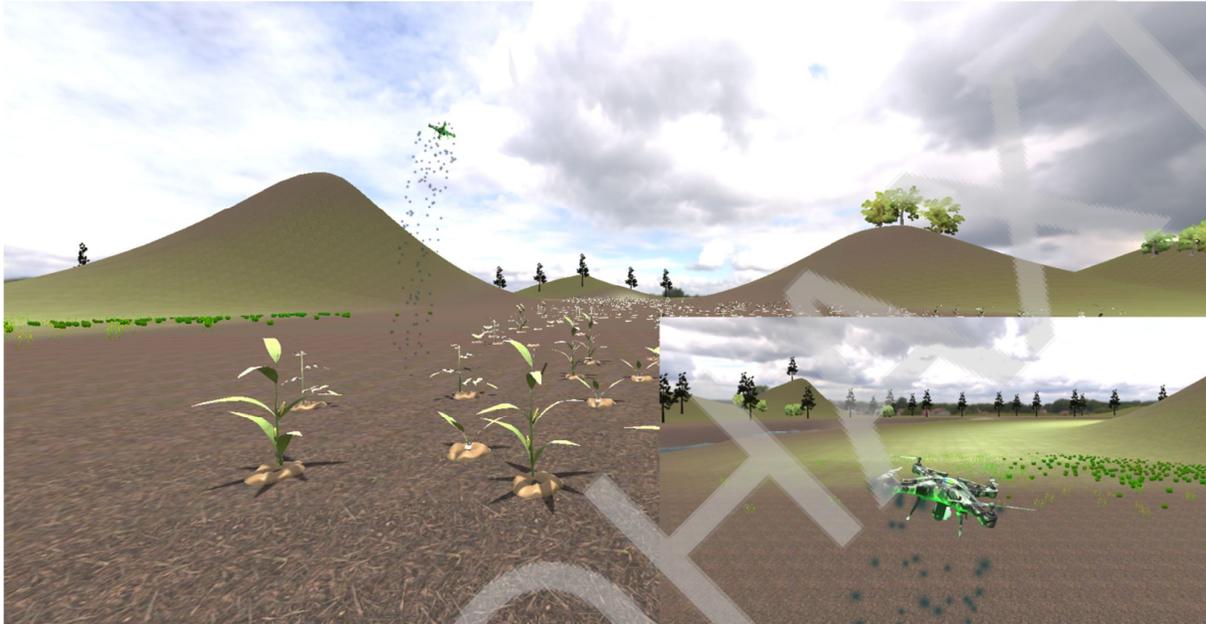


Fig. 9. The simulation

Figure 9 shows that we have a field with beet, corn, and wheat crops, as well as a flying drone that sprays water.

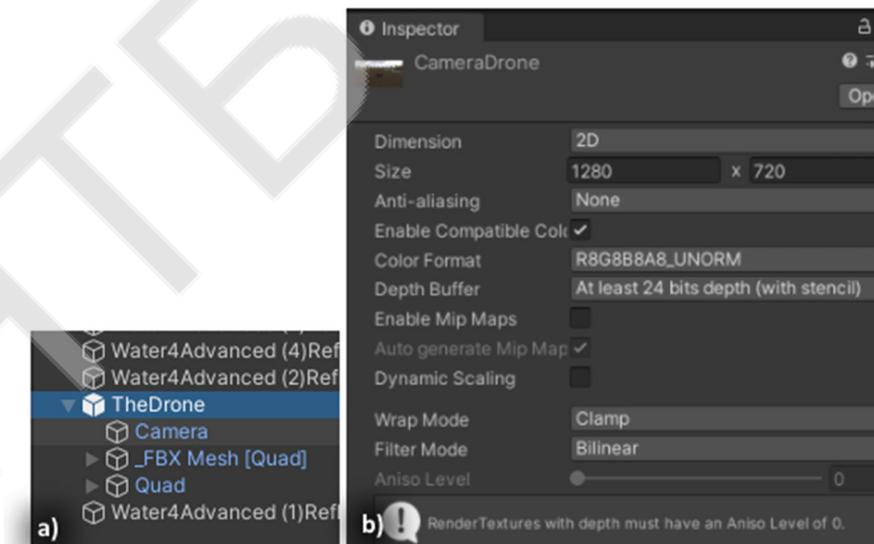


Fig. 10. a) Camera b) Render Texture

A separate camera that would monitor the flight was created (Figure 10). To

display two cameras on the screen, we made the design of the drone camera on a separate screen in the Render Texture component. The main camera is free. That is, you can fly on our field using the keyboard and mouse for a more detailed inspection of the situation.

It is logical that if our algorithm, or rather our populations, have all possible favorable conditions for development, then the situation will be as in Figure 11.

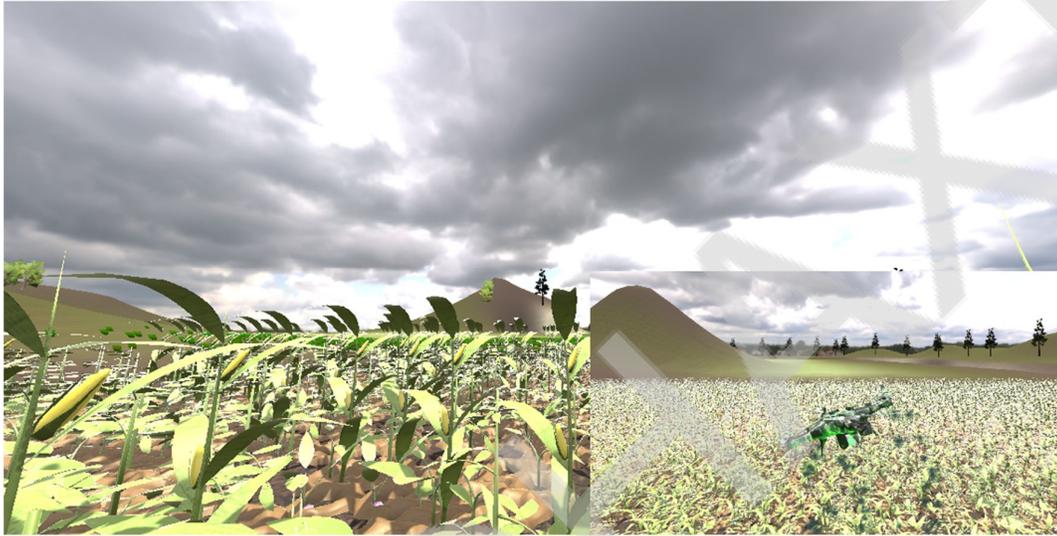


Fig. 11. Ten thousand individuals

To create a drone (Figure 12), the DJI Phantom four drone model was used. The rotation of the propeller was set by the engine power. The equation of flight and the trajectory of the drone were also given by the equations.



Fig. 12. The DJI Phantom Drone

V. CONCLUSIONS

To sum up, we think that the experience of optimizing water spraying with a minimum amount of data from drones was a success. as it proved its dependence on the changing genes of the genetic algorithm that was used.

It is also clear that the algorithm of genetic evolution works slower, and requires more resources. However, such an algorithm is better in terms of results than other algorithms. This was revealed based on the fact that the largest amount of crop was harvested using genetic algorithm rather than when using conventional machine learning from agricultural source articles.

However, the research was conducted on minimal data and the simplest topology of both the agro system, the drone system, and the genetic algorithm. Therefore, we believe that it is mandatory to introduce new criteria and new functionality into the simulation, and then recalculate the data and results.

The entire project can be found on our github page at <https://github.com/Drones-C/ga-agro-unity>

VI. REFERENCES

1. Silantro Flight Simulator (Forum user Oyedoyin1) Oct 30, 2016 <https://forum.unity.com/threads/released-silantro-flight-simulator.522642/>
2. Optimization of Pesticide Spraying Tasks via Multi-UAVs Using Genetic Algorithm (Yanqiu Niu, Moning Zhu, Xiaoxuan Hu, Huawei Ma, Dylan F. Jones) 12 Nov 2017 <https://www.hindawi.com/journals/mpe/2017/7139157/>
3. Drones in agriculture (Laurent Probst, Bertrand Pedersen & Lauriane Dakkak-Arnoux, PwC) January 2018 https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/Drones_vf.pdf
4. A framework and simulator for UAV air traffic integration, control, and communication (Amjed Al-Mousa, Belal H Sababha, Nailah Al-Madi Amro Barghouthi1 and Remah Younisse) October 2019 <https://journals.sagepub.com/doi/pdf/10.1177/1729881419870937>
5. DEVELOPMENT OF FLIGHT SIMULATION EDUCATIONAL GAME (VALENTINA PAUNOVIC, TATJANA GVOZDENOVIC, RADOSLAV STOJIC) 29 September 2016 <https://econference.metropolitan.ac.rs/wp-content/uploads/2016/10/06-Valentina-Paunovic-Tatjana-Gvozdencovic-Radoslav-Stojic-Development-of-flight-simulation-educational-game.pdf>
6. Example of NEAT implementation (Alvin Sartor) 2017 <https://connect.unity.com/p/example-of-neat-implementation>
7. How Big Data Analytics Are Impacting the Agriculture Industry (Kayla Matthews) August 30, 2019 <https://www.vxchnge.com/blog/data-centers-analytics-and-agriculture>
8. Genetic Algorithms in Machine Learning (Jonathan Shapiro) September 20, 2001 https://link.springer.com/chapter/10.1007%2F3-540-44673-7_7
9. STUDENT RESEARCH PROJECT ON PHYSICAL SIMULATIONS IN UNITY3D GAME ENGINE (M. Buszewicz, M. Plechawska-Wojcik) March 6, 2017 <https://library.iated.org/view/BUSZEWICZ2017STU>
10. Terrain (Unity Documentation) <https://docs.unity3d.com/Manual/script-Terrain.html>

OUTPUT OF DATA OF MECHANICAL CONTROL SYSTEMS FOR THERMAL MOVEMENTS OF STEAM PIPELINES OPERATING AT THERMAL POWER PLANTS INTO A DIGITAL APCS SYSTEM

Author: *Abykenova Zarema Aydinovna*

Advisor: *Seytkanov Sabriden Seytkanovich*

Academician K. I. Satpayev Ekibastuz Engineering and Technical Institute
(Republic of Kazakhstan)

Abstract

The conversion of existing mechanical control systems of steam pipeline thermal displacements into a digital control and monitoring system for technological parameters of the tested object, in real time using the APCS software is considered in this scientific paper. A step-by-step algorithm for the practical implementation of signals from sensors of thermal displacements of steam pipelines with analog outputs into the digital system of the automated process control system has been developed. The control system of the thermal displacements of steam pipelines is integrated into the APCS system and operates according to the operating software of the APCS. This topic is relevant in the field of automation and control.

Keywords: sensor, indicators of thermal movements, algorithm, distributed periphery stations, controller, automatic control system for technological processes.

I. Introduction

During the operation of the power unit, the thermal displacements of the steam pipelines can be affected by loads that are not provided for in the design. These loads, first of all, include beyond design movement of equipment, coolant in all operating modes.

To obtain reliable results on operational loads, it is necessary to identify all possible loading factors and develop methods for their determination based on the readings of thermal displacement sensors of steam pipelines.

To measure thermal displacements of steam pipelines, manufacturers produce sensors with analog and digital outputs, as well as ultrasonic sensors.

After connecting the sensors of thermal displacements of steam pipelines to the PTC controller, the system for monitoring the thermal displacements of steam pipelines functions according to the operating software of the PTC.

The introduction of the input of signals of the control system the steam pipelines thermal displacements in the APCS makes it possible to identify all possible loading factors and methods of their determination based on the load indication:

- To identify beyond design thermal displacements of steam pipelines in the “On-line” mode in all operating modes and take into account their real movements.

- Timely identify zones of occurrence of thermal displacements and promptly signal operating personnel about non-design thermal movements of steam pipelines.

The control of thermal displacements of steam pipelines at thermal power plants is carried out mechanically, which does not provide prompt information acquisition in the “On-Line” mode for quality control and monitoring. Steam temperature changes in steam lines cause changes in their linear dimensions, as a result of which compensation stresses arise in steam lines.

Any kind of pinching caused by a malfunction of the supports or by restriction of movement by equipment or building structures located nearby can lead to a sharp increase in the level of compensation stresses and thereby reduce the reliability of the steam pipeline.

A means of observing the thermal displacements of steam pipelines are special indicators (benchmarks), which must be installed on all straight sections of these steam pipelines at a distance of at least 100 mm from the bend or welded joint and at least 200 mm from the edge of the support.

All steam pipelines with an inner diameter of 150 mm and more and a steam temperature of 300 ° C and above are subject to control over thermal displacements [1]

1. Indicators of thermal displacements of steam pipelines (benchmarks). Fig . 1



Fig . 1. Mechanical indicator of thermal displacement of steam lines

Readings from mechanical indicators are taken when the steam pipeline reaches the design parameters. On paper or plates, the points of contact of the leads or the tips of the rods are marked crosswise, corresponding to the operating state of the steam lines. The readings of the plates are transferred to tracing paper. The scale bar measures the projections of the obtained curves on each axis. The measurement results for each indicator are recorded in the forms.

The measured values of displacements are compared with the calculated (design) ones. Then the plates are repainted or new sheets of paper are installed, after

which all three fixed points are applied. Mechanical pointers (indicators) of the thermal displacement of steam pipelines, the existing control of the displacements of steam pipelines at thermal power plants is carried out mechanically, which does not provide prompt receipt of information in the "On-Line" mode.

1.1 Installation of indicators of thermal displacement on the steam line. (Fig . 2)

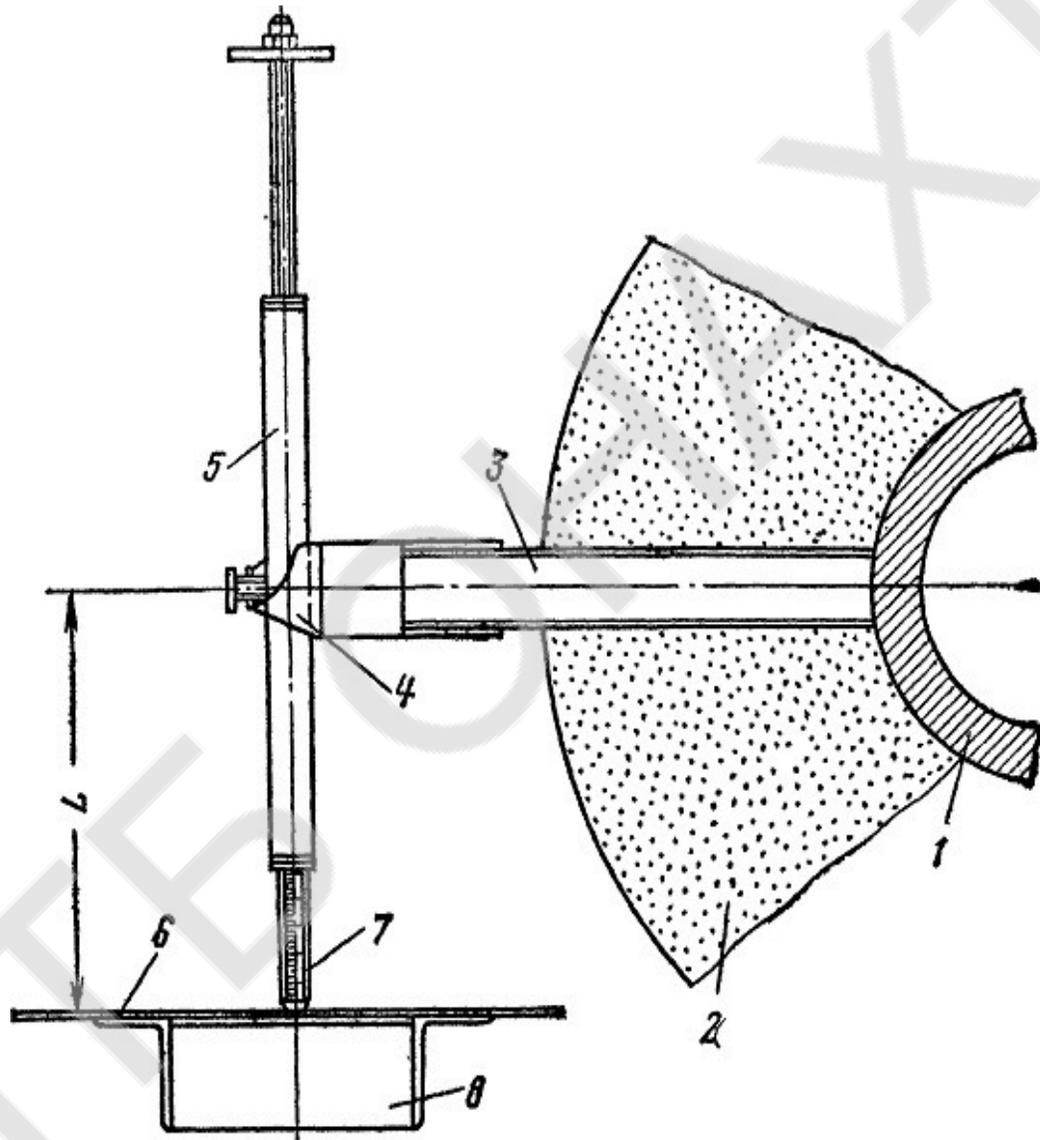


Fig . 2. Installation of thermal displacement sensors on the steam line.

Installation of sensors on the steam line: 1 - steam line; 2 - thermal insulation; 3 - bracket; 4 - indicator housing assembly; 5 - stock; 6 - plate; 7 - rod; 8 - removable head.

The purpose of control over the thermal displacements of steam pipelines is:
- assessment of compliance of actual thermal displacements of steam pipelines with design ones;

- prevention and timely detection of pinching of steam lines;
- assessment of the serviceability of the steam pipe fastening system;
- detection of violations of the operating modes of steam pipelines due to violations of the heating and cooling modes (deformation of the steam pipe axis, hydraulic shocks).

A means of control of the displacements of steam pipelines is a movement indicator that allows you to register and measure the spatial displacements of the steam pipeline relative to fixed structures.

The development of control schemes for thermal displacements with the determination of the installation locations of the indicators is carried out by the design organization when designing steam pipelines. The control over displacements of steam pipelines in operation that have not been organized, these schemes are carried out by the personnel of the TPP and are coordinated with the design or with a specialized commissioning contractor.

Covered by the project the indicator design should provide the ability to register the visible thermal displacements of steam pipelines, i.e. displacements during heating from a cold state to a working one and during cooling. It is allowed to use an indicator to control total thermal displacements, i.e. displacements from the installation state to the working one.

The design should indicate the dimensions of the gaps in the working and cold states of the steam pipeline in the places where the steam pipeline passes through the ceilings, service platforms, building structures, taking into account the thickness of the thermal insulation and thermal displacements of the steam pipelines.

The project should provide the sites for servicing the indicators.

The indicators are installed on straight sections of steam pipelines, preferably near the bends through 2-3 inter-support spans in places with the expected maximum values of thermal displacements and convenient for access and maintenance.

At least three indicators should be provided on the steam pipelines from the boiler to the turbine of block plants, on power plants with cross-links - at least two indicators on the steam pipelines from the boiler to the switching header and from the switching header to the turbine.

In order to detect deformation of the steam pipeline due to temperature irregularities, it is advisable to install two indicators at the ends of the section and one in the middle of the section on horizontal sections longer than 5 m.

It is not recommended to install the indicator near fixed supports of the steam line.

The installation of indicators should be carried out in the following sequence:

- welding the bracket to the steam line before applying thermal insulation;
- installation of rods in the bracket, installation of the corner frame and its welding to fixed structures after applying thermal insulation and cutting off the blocking ties of the supports springs.

In the case when the measurement limits of the indicator exceed the maximum design values of the total displacements of the steam line, it is allowed to install the corner frames of the indicator before cutting off the blocking ties of the support

springs, while controlling the complete displacements of the steam line. At the same time, in order to avoid damage during installation and insulation work, after fixing the position indicators of the steam line axis on the plates (the springs of the supports are interlocked with welded ties), the rods should be removed and reinstalled after all installation and insulation works are completed before the steam pipeline warms up.

The indicator bracket is welded to the steam line at a distance of at least 100 mm from the bend, welded joint and at least 200 mm from the edge of the support. In this case, the indicator rods should be directed along the coordinate axes adopted in the design calculations.

In order for both indicator plates to be in a vertical plane (in this case, the cleanliness of the working surfaces of the plates under operating conditions is ensured), it is recommended to place the bracket welded to the steam line vertically. In cases where this is impossible due to the layout conditions or when installing the indicator on vertical sections of steam pipelines, it is allowed to cut the bracket and weld its head to fix the rods at an angle of 90 °. It should be provided that the distance L1 from the head of the bracket to the surface of the thermal insulation is greater than the length of the indicator rod. This ensures the possibility of replacing the rods in case of damage during operation.

The existing control of the displacement of steam pipelines at thermal power plants is carried out mechanically, which does not provide prompt information acquisition in the "On-Line" mode for quality control and monitoring.

During the operation of the power unit at thermal power plants, the displacement of steam pipelines may be affected by loads that are not provided for in the design. These loads, first of all, include non-design movement of equipment, coolant in all operating modes. To obtain reliable results on operational loads, it is necessary to identify all possible loading factors and develop methods for their determination based on the readings of thermal displacement sensors of steam pipelines.

To measure thermal displacements of steam pipelines, manufacturers produce sensors with analog and digital outputs, as well as ultrasonic sensors. After connecting the sensors of thermal displacements of steam pipelines to the controller, the system for monitoring thermal displacements of steam pipelines operates according to the working software of the PTC (software and hardware complex).

1. A step-by-step algorithm for outputting these signals from thermal displacement sensors of steam pipelines with analog outputs in the APCS:

This scientific paper describes the conversion into a digital system of signals from sensors of thermal displacement of steam pipelines with analog outputs in the process control system.

Further the scientific paper describes and gives the references to the conversion algorithm of existing mechanical systems into digital ones of.

Algorithm for transferring existing mechanical systems for controlling thermal movements of steam pipelines into a digital APCS system:

1.1 Purchase a displacement sensor with a free stem (with no guides, the stem moves freely) with an analog output 4-20Ma from the manufacturer's plant

(Germany, Japan, Russia, etc.) Or order for each steam line individually according to the technical requirement;

Displacement sensor with analog output of the DCTH series (LVDT). (Fig . 3)

The DCTH series displacement sensor is designed for accurate displacement measurements. It has a built-in preamplifier and allows you to receive an analog voltage or current signal at the output.

Versions available: free stem, spring return, guided, high resolution / precision; great resource; stainless steel.

DCTH series with free stem. Free stem sensors have no guides. The stem moves freely.

It is recommended to take the following designation and direction of the axes of the coordinate system (parameters are measured in 3 or three coordinate axes):

X1 - along the main building towards the temporary end;

X2 - at an angle of 90 ° to the axis of the main building;

X3 - vertically [2].

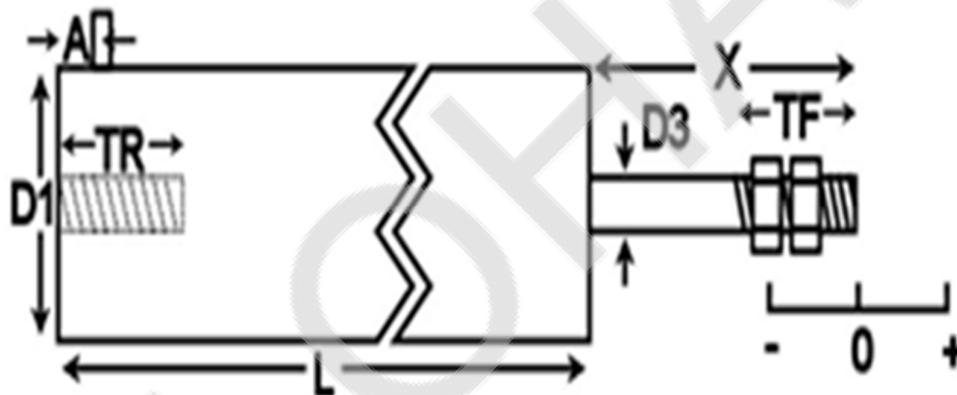


Fig . 3. DCTH Series sensor with Free Stem

1.2 Install the displacement sensor to the steam line, in accordance with the technical requirements, similar to the installation of indicators of thermal displacement on the steam line (see Fig . 3 Installation of indicators of thermal displacement on the steam line).

1.2.1 Connect the ~ 220V power supply to the sensor and the 4-20mA output to the ADC module; (Fig . 5)

Output signals from steam pipe thermal displacement sensors with 4-20mA output analog signals or digital signals can be connected directly to the PLC, sensors with analog output through analog-digital modules, sensors with digital output through digital modules, where signals are processed.

2. Connect the displacement sensor to the analog module, which serves to filter signals and convert the analog signal into digital one. (Fig . 4)

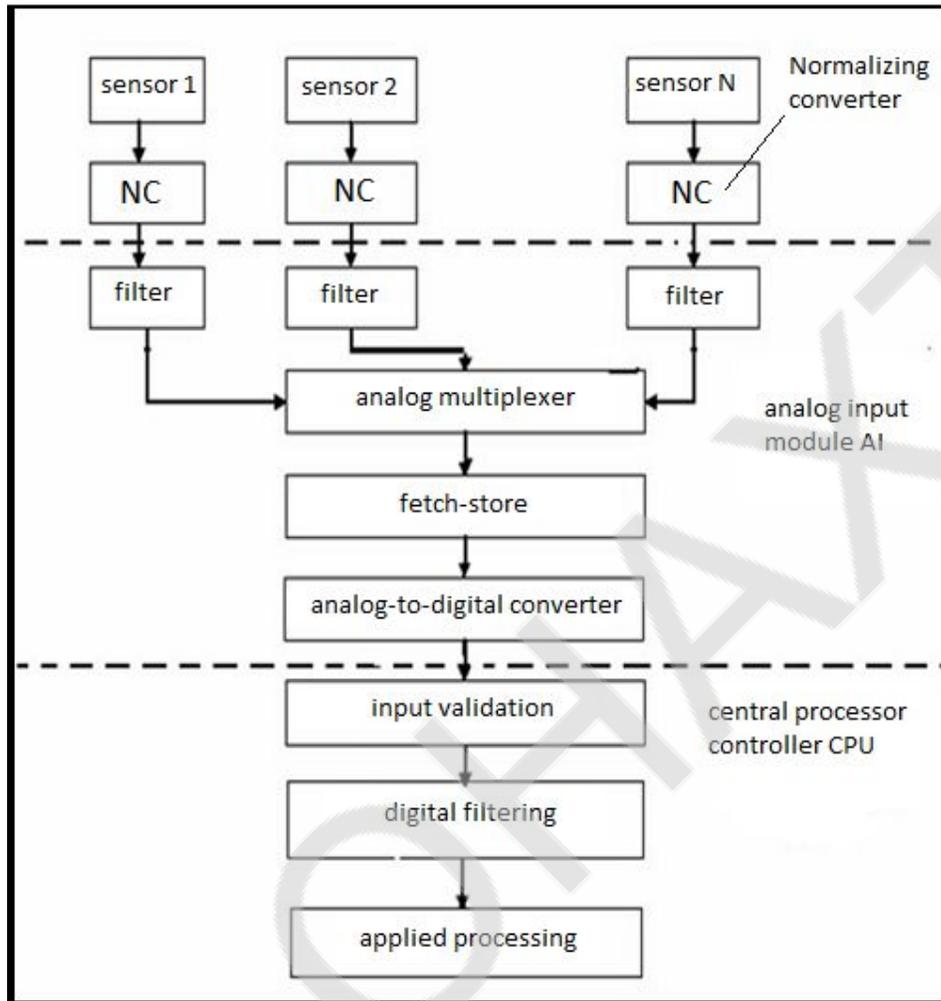


Fig . 4. chart of processing an analog signal when entering the controller

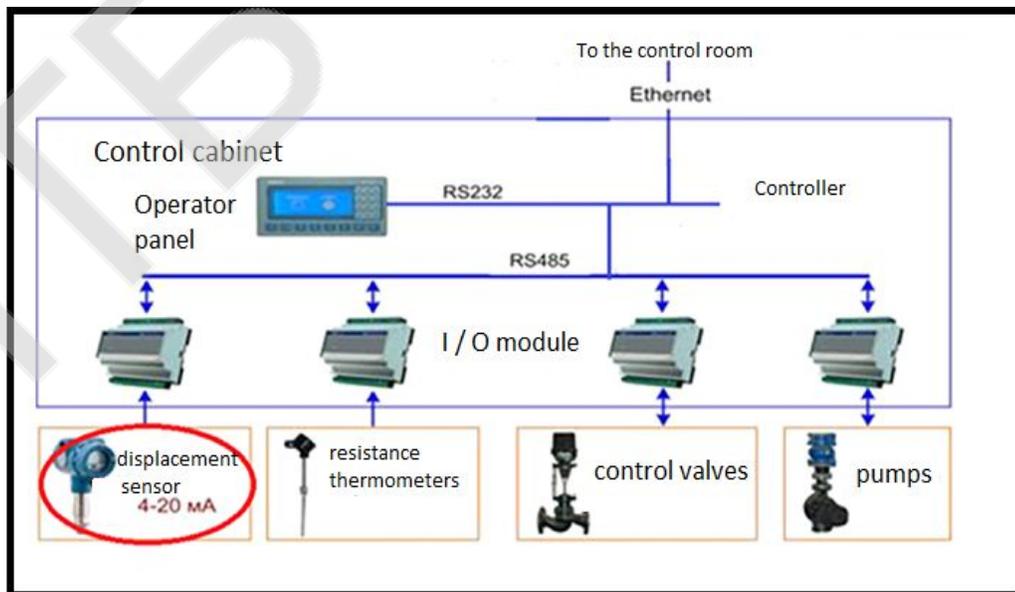


Fig . 5. Connecting analog sensors to the APCS system

3. Use of the station of the distributed periphery for sensors of thermal displacement of steam lines and connection to controllers.

If the sensor is located at a long distance from the controller, then a distributed periphery station is installed close to the displacement sensors;

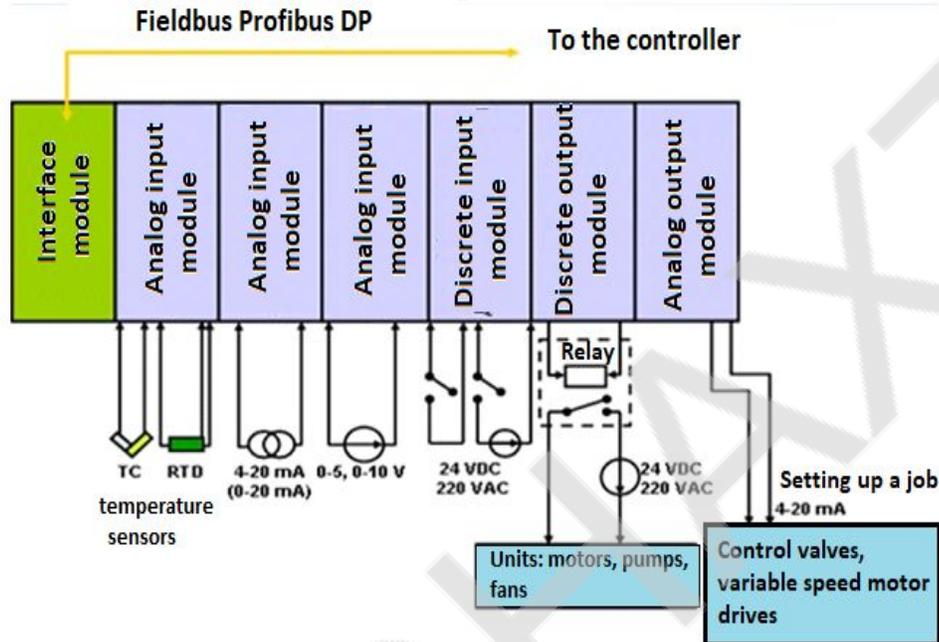


Fig . 6. Input / Output chart using a distributed periphery station

More rational in this situation is the use of distributed periphery stations located in close proximity to the sensors of thermal displacement of steam pipelines. (Fig . 6) These stations contain the necessary input and output modules as well as interface modules for connecting to the PLC via a digital fieldbus (for example, using the Profibus DP protocol, or Modbus RTU).

All signals are digitally transmitted over a single cable with a high level of noise immunity. The so-called intelligent sensors and actuators (which include controllers and other units that convert the signal into digital form and implement data exchange through the field bus) can also be directly connected to the field bus.

5. Loading the analog module to the controller;

Load the analog module to the APCS controller, after completing 8 points of loading the sensor to the module, the controller receives all messages from the sensor. (Fig . 7)

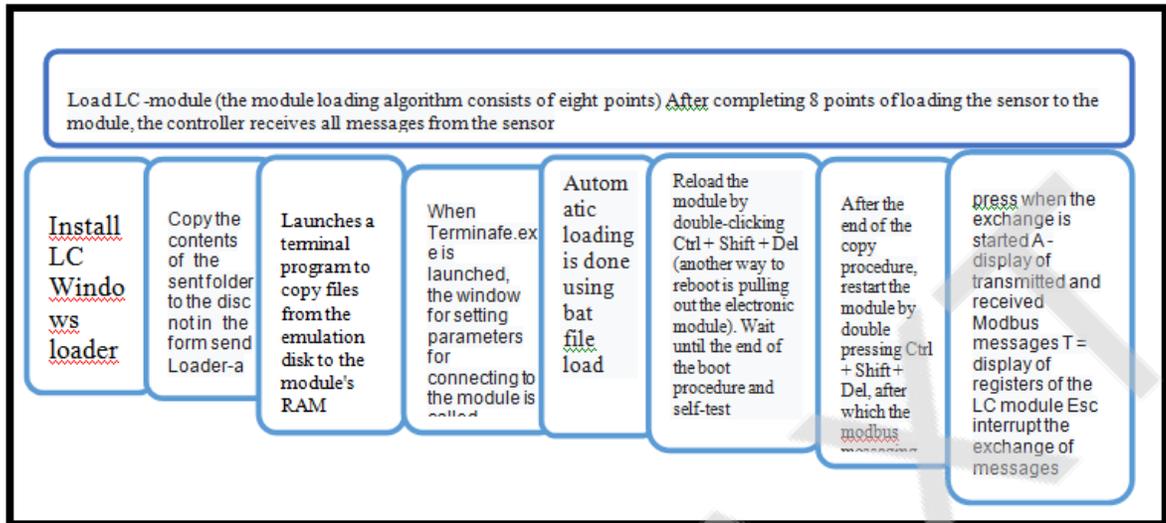


Fig . 7. Loading the analog module to the controller

6. Algorithm for creating a point in the system of global databases of APCS

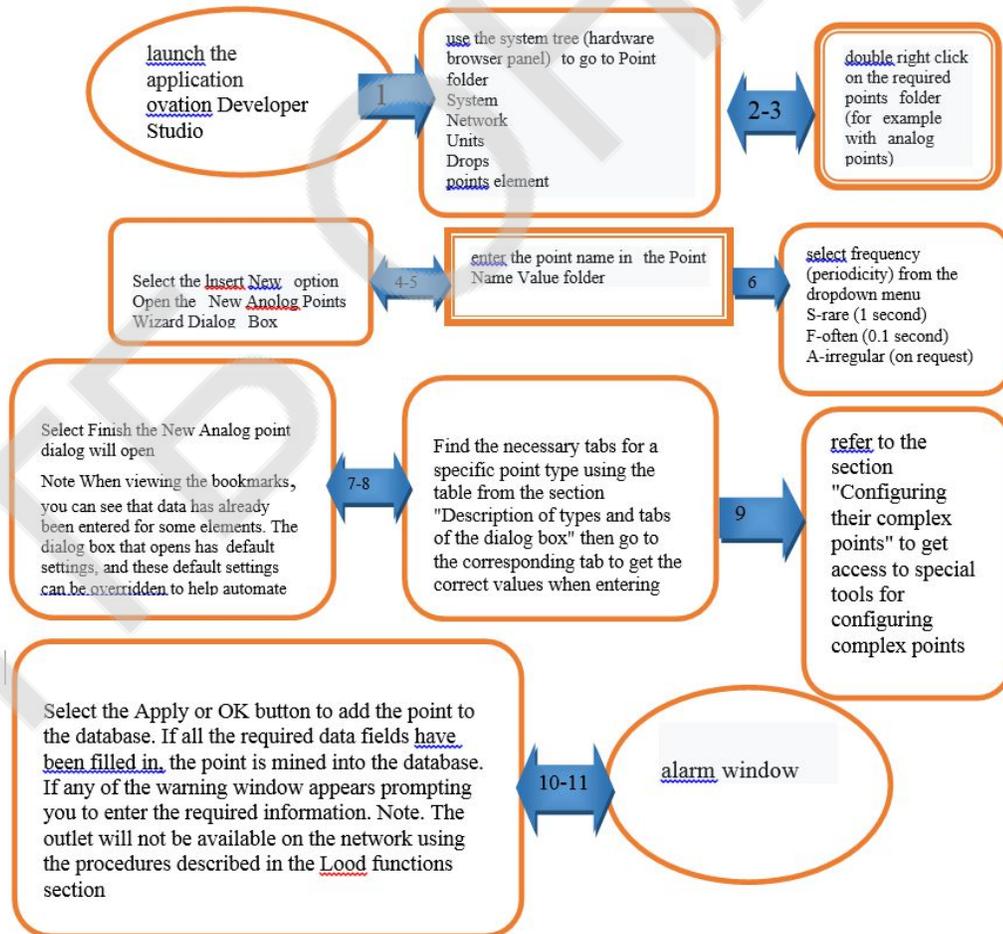


Fig . 8. Creation of a point in the system of global databases of the PTC APCS.

After loading the analog module to the controller, a point is created in the global PTC database. A point is a record in the global database that contains a value (for example, an input or output signal) and other related data.

At the moment, there are 11 types of points in the APCS system. (Fig . 8). Each point type has its own dialog box with separate tabs and fields.

After connecting the sensor to the module, loading the module to the controller and creating a point in the PTC database. The control system of the thermal displacements of steam pipelines is integrated with the APCS system.

The control system of the thermal displacements of steam pipelines operates according to the operating software of the PTC APCS. To identify non-design thermal displacements of steam pipelines in the "On-line" mode in all operating modes and take into account their real displacements; Timely identify zones of occurrence of thermal displacements and promptly signal operating personnel about non-design thermal displacements: Alarm triggering with output: - to light signaling (board); - for warning signaling; - for emergency signaling.

Simultaneously in real time (On-Line) measurement of the current values of the displacements of steam pipelines, accumulates and stores the values of the measured values, and presents the measured value in the form of tables, graphs, including archived changes [3]

V. Conclusion

The research subject of scientific paper is:

- Conversion of a functioning mechanical control system for thermal displacements of steam pipelines into a digital control and monitoring system of technological parameters of the tested object, in real time using the software of the PTC APCS.

According to the results of the study, it can be concluded that an "Algorithm with the output of data from displacement sensors to the PTC of APCS" has been developed.

The control system of the thermal displacements of steam pipelines is integrated into the APCS system and operates according to the operating software of the APCS.

The task of the scientific paper is to output the signals from the sensors of thermal displacement of steam pipelines to the APCS.

The object and subject of study is the connection of sensors of thermal displacement of steam pipelines with analog and digital outputs to the PTC controller of the APCS.

The proposed algorithm will allow adding signals from displacement sensors to the PTC of the APCS.

With a significant territorial length of cable lines from each displacement sensor, it is proposed to use a distributed periphery station to connect the PTC sensors of the APCS.

PTC APCS monitors the control system of thermal displacement of steam pipelines:

- The value of the thermal displacement of the steam pipelines in the specified coordinates.

- Comparison of the values of the displacements of the steam lines with previous measurements.

- Determination of the actual measurement parameters of steam lines - the rate of change and the metal temperature value change at the point of displacement control.

The achieved results of the scientific paper can be recommended for use in the control system of thermal displacements of steam pipelines with the output of data from displacement sensors to the automated process control system PTC "Ovation".

An algorithm for inputting data from the sensors of the control system of the thermal movements of steam pipelines in the automated process control system of the PTC "Ovation" has been developed:

An algorithm for loading (eight items) of an analog module into the Ovation controller has been proposed.

- An algorithm for creating a point in the system, the global database of the APCS PTC "Ovation" with illustrations of dialog boxes, which consists of 11 points, is proposed.

VI. References:

1. RD 34.39.301-87 Guidelines for control of thermal displacements of steam pipelines at thermal power plants, http://www.conatem.ru/tehnologiya_metallov/teplovoe-rasshirenie-metalla.html

2. <http://www.ndt-td.ru/katalog/tenzometricheskoe-oborudovanie/tenzometricheskie-datchiki/datchiki-peremescheniya/induktivnie-datchiki-peremescheniya-lvdt/datchik-peremescheniya-s-analogovim-vihodom-serii-dcth-lvdt.html>

3. Kuznetsov A. PTC "Ovation" modernizes power plants <http://www.energoportal.ru/ptk-ovation-moderniziruet>, <http://www.emersonprocess.com>

EDUCATION CAPSULES PROJECT

Author: *Yurii-Ihor Syrotynskyi*

Advisor: *Vasyl Lytvyn*

Lviv Polytechnic National University (Ukraine)

Abstract: *The modern school faced many important challenges, which are connected to the active spread of the technologies among children, and to the pandemic that led to to online learning. These difficulties made us to ask a question: how to overcome these and other problems? Moreover, with the rapid dissemination of information and the corresponding changes in the educational process, there is a need to apply new forms of learning.*

The are next priority requirements: the ability to reformat educational materials, provide educational information in playing form, develop creative skills and flexibility of thinking, as well as persistence and focusing on results. Innovative educational project "Educational Capsules" fulfills these requirements. The project consists of three developed games: "Chronicle of Ukrainian Victories", "Knights of the Golden Gate" and "Menagerie of King Danylo". They combine a form of school testing with elements of different computer games. Going through different levels, consistent problem solving and the final culmination provide a continuous dynamic process and emotional tension. In this way, the latest information technologies serve to significantly improve and reform the educational process.

Keywords: *informational technologies, educational capsules, computer games, educational reform.*

I. INTRODUCTION

"Educational capsules" is an innovative development project, which can be used in various educational areas. The project satisfies need of modern schooling, which requires additional educational resources that are relevant to the information environment in which children persist. Therefore, the project "Educational capsules" is an important tool for the quality development of modern pedagogy.

II. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of research is issue of educational environment in Ukraine.

Subject of research is educational and pedagogical methods.

III. CONCLUSIONS

The modern world demonstrates extraordinary information saturation and brightness. A lot of children today grow up and are brought up in this environment, and these children used to be in tight relationship with game industry as well. Therefore, the adaptation of characteristic game forms is relevant and appropriate for the creation of a new type of teaching aids. And that is the deal for our games: "Chronicle of Ukrainian Victories", "Knights of the Golden Gate" and "Menagerie of King Danylo". They combine a form of school testing with elements of different types of computer games. Going through different levels, consistent problem solving and the final climax provide a continuous dynamic process and emotional tension. In this form, the necessary information is figuratively visualized, colored emotionally and meaningfully summarized.

The project "Educational capsules" presents two games of historical plan - "Chronicle of Ukrainian victories" and "Knights of the Golden Gate", which are based on real events in Ukrainian history. First one chronologically presents the victorious battles of the Ukrainians from Duche Oleh's march on Constantinople to the long defense of the Donetsk airport. After successfully passing all levels, the Ukrainian Trident shines. In the second game, Ukrainian history is associated with the heroic deeds of the Ukrainian elite, and, when player passes all levels, Golden Gate will be opened. This content not only affirms the heroism of national history, but also emphasizes the historical importance of Ukrainian victories. This is a crucial ideological moment from the standpoint of long-term colonization of Ukrainian lands and the planting of a complex of inferiority.

The third game "Menagerie of King Danylo " is a fantastic quest. You need to find the magical beasts of the young prince Danylo, who got lost in three halls of the castle: the Arsenal, the Library and the Throne Room. During the search, players get acquainted with medieval traditions and culture, as well as important historical events. All this firmly fits the Ukrainian state into the European context.

In this way, the presentation of the material involves emotional and intellectual forms of perception of information. This allows you to teach, educate and develop children at the same time. It is important that such innovative educational tools as "Educational capsules" are understandable for children. They are relevant for various profiles of school subjects and are promising for further use.

DECISION SUPPORT SYSTEM FOR CALCULATING THE OPTIMAL PROVISION OF RESIDENTS OF SMALL TOWNS WITH DRINKING WATER IN EXTREME CASES

Author: *Olexij Zakabula*

Advisor: *Oleksandr Melnykov*

Donbas State Engineering Academy (Ukraine)

Abstract. *This work is devoted to the disclosure of the problem of transporting water to settlements during environmental catastrophes, military operations or unscheduled replacement of the pipeline. The urgency of the work is justified by the frequent lack of water supply to settlements on the demarcation line. A feature of the work is the connection of mathematical formulas that are not used in analog applications. The program was made with the aim of helping people around the world who find themselves in difficult conditions or habitats. The further goal of this program is to promote it to the mass market and its main advantage will be accessibility to everyone and the absence of paid content.*

Keywords: *lack of water, "traveling salesman" problem, distances, formulas, design, map, logistics, path, speed, distance.*

I. INTRODUCTION

The supply of the housing stock with drinking-quality tap water is a strategic task of the state to ensure the life and sanitary and hygienic safety of the population. When selling water supply and sewerage products to the population, it is important not only to solve the problems of profitability of water supply and sewerage enterprises, but also to meet social needs [1-2].

The water supply system available in most cities can be disrupted as a result of man-made disasters or other extreme events, and the task of delivering water to the consumer is carried out using specialized vehicles [3]. In the districts (microdistricts, individual quarters, workers' settlements) of the city, there are temporary points for bottling drinking water from tank trucks into consumer containers [4].

Sources of water for the population are such:

- 1) water is collected before the overlap or is contained in large supplies on the balconies / under the table, in case water is interrupted;
- 2) people go to the store and buy drinking water to use as tap water;
- 3) in winter, people can drain the water from the batteries, which almost leads to an emergency, because there is nothing to heat;
- 4) in the city, in the landing, 6 kilometers from the microdistrict, there is a source, but it is already drying up, there are two taps, mainly those who are in the rural couple of the city take water, 25% -50% of the private sector.

The purpose of the work is to calculate the optimal provision of residents of small towns with drinking water in extreme cases using specialized software of our own design. To achieve this goal, it is necessary to solve the following tasks:

- to consider the existing procedure for providing the population of small towns with drinking water in the event of industrial accidents;
- to study methods and models to determine the optimal route;
- to review existing applications to determine the best route;
- to design an application for calculating the optimal provision of residents of small towns with drinking water in extreme cases;
- to implement software implementation in a visual programming environment.

II. LITERATURE ANALYSIS

Route4Me Route Planner (Fig. 1), unlike conventional maps and navigation systems, gives you the best route when you need to go to multiple locations [5].

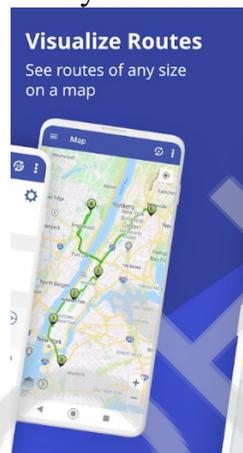


Fig. 1 Route4Me Route Planner

Difference from the task: the lack of accuracy of the set route, also the lack of an interpreter, a purely English interface. ABM Rinkai TMS [6] is a program for automating the transport logistics of an enterprise (Fig. 2). One solution combines: route planning, execution control, customer information, analysis and assessment of the efficiency of using transport resources, including hired cars. Cloud service, provided for rent, does not require installation on the company's servers.

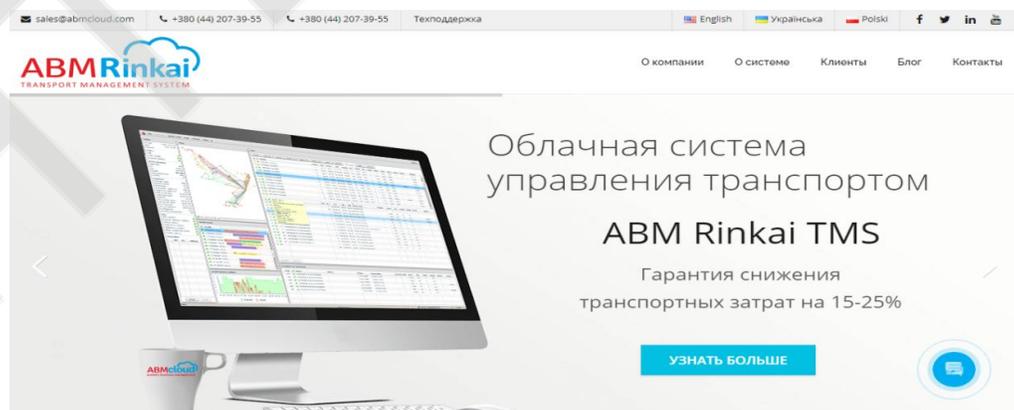


Fig. 2. ABM Rinkai TMS

Difference from our task: access only through the site, long registration and paid content. Only one week trial mode. App obsession - hangs in the background.

"Ant Logistics" [7] is a cloud-based transport management system: automatic route planning, assessment of the profitability of delivery points, GPS control of traffic routes, analytical reporting (Fig. 3).

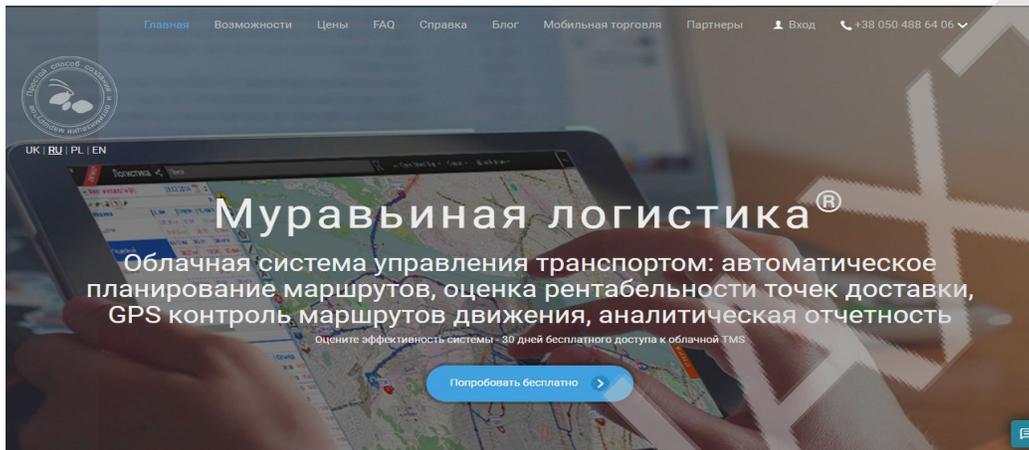


Fig. 3. "Ant Logistics"

Difference from our task: inaccuracy of the method and ways of building the route. Very long registration and filling in information before starting to use the project. Also a paid basis.

Google Maps [8] is set applications built on the basis of free cartographic service and technologies provided by the company Google (Fig. 4). Created in 2005.

Difference from our task: the impossibility of building a straight route, extra points appear when building. Lack, as in other sites / applications, the ability to track the optimal route and the time to complete it.

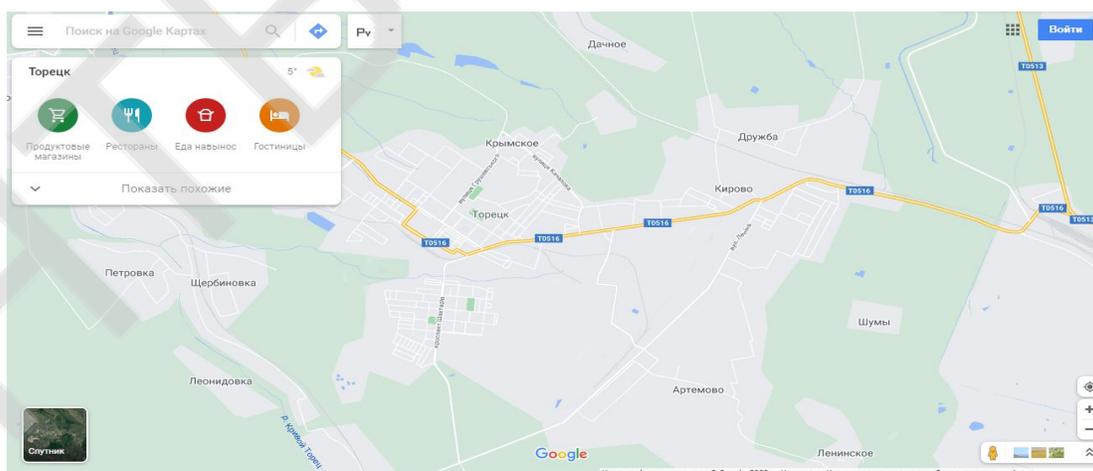


Fig. 4. Google Maps

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Consider the situation in the city of Toretsk. Since it is closest to the collision line, there are frequent signals from the local population about broken water or its absence for a very long time, so I can operate with facts and have access to accurate data that we will need in the course of our work. Link to google map, where the map of the settlement of Toretsk is located [9].

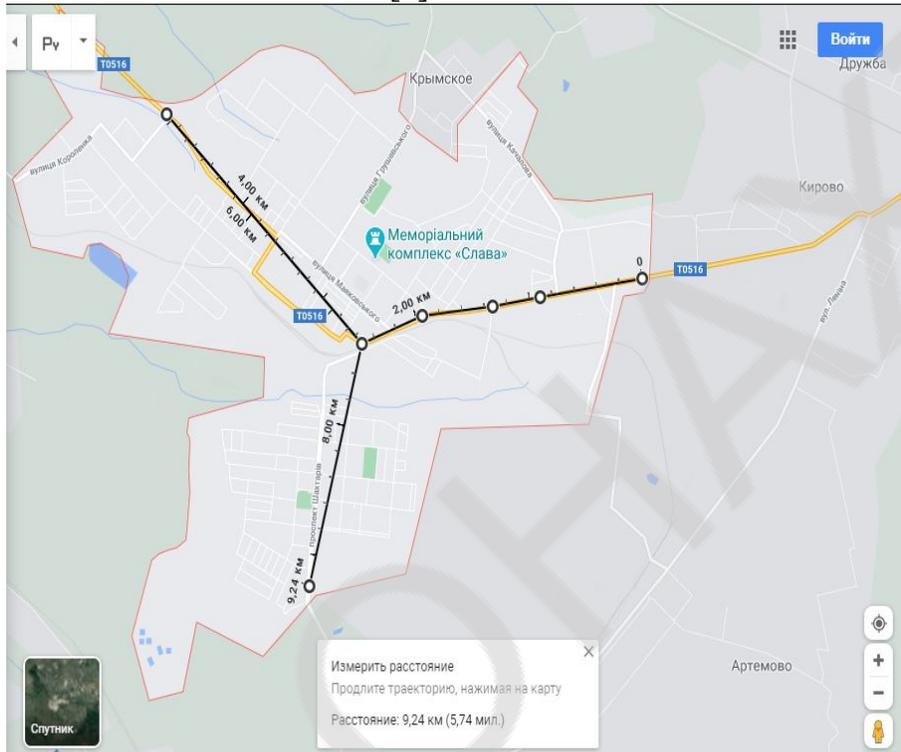


Fig. 5. Map of the city of Toretsk



Fig. 6. An illustrative example of water delivery

In different districts of the city there is a certain amount of population, so the supply is carried out from the starting point, which is taken by "Samanny" and, thus, water is delivered to the next three points to the intersection of the main road: here you will have to choose which point will be the last and which route will be more convenient for the driver himself. But, most likely, the last stop will be "Central Market", because from there the car goes to another settlement – Bakhmut. Where, in fact, it comes from.

The peculiarities of the route are that the entire path goes in straight lines, there is no shortcut or detour.

As for the disadvantages: there is only one car, and this increases the time spent on delivering water to the regions. Also, due to the large difference in the number of people at certain control points, the delivery of water to a certain point is difficult to calculate in the plan at which time it will be.

Benefits. Since the population of this city is accustomed to very frequent water cut-off due to hostilities or the old equipment, in the event of an announcement of a water cut-off, the population knows on what day (most often once a week) and at what time (range changes) the car can arrive ...

Let's check with the data that we have on the population in certain areas. As a calculation example, we take data for the city of Toretsk, Donetsk region, tab. 1, tab. 2.

Table 1. Number of inhabitants, people

No. nn	Microdistrict (name)	Population, people
1	Adobe	3325
2	Microdistrict	9392
3	Center	11495
4	Private sector	3870
5	Central market	3395
6	Zabalka	2901

Table 2. Distance between microdistricts, m

	Adobe	Microdistrict	Private sector	Center	Central market	Zabalka
Adobe	X	1310	900	1860	4800	4640
Microdistrict	1310	X	803	2420	4530	4175
Private sector	900	803	X	295	4050	3520
Center	1860	1390	295	X	1370	546
Central market	4800	4530	4050	1370	X	4920
Zabalka	4640	4175	3520	546	4920	X

It is necessary to solve a number of tasks, for example:

- to determine the optimal route for specialized vehicles;
- to draw up an optimal schedule for the movement of specialized vehicles;
- others.

We assume the following:

- there are N specialized vehicles (tank trucks), $N \geq 1$;
- there is a list of M districts (micro-districts) of the city, indicating the

population S_i in each (total in the city $S_s = \sum_{i=1}^M S_i$ residents);

- there is a table of distances between areas, taking into account the possibility or prohibition of direct passage between each pair of areas;

- the beginning of the path can be from different places: a) all cars leave from one selected point; b) each car can start moving from the point chosen for it;

- it is possible to introduce a limitation on the volume of dispensed water (18 liters per person).

We also assume that all specialized vehicles (tank trucks) are the same (have identical speed characteristics and can carry the same volume of water).

It is necessary to solve the following tasks.

1. Assuming that only one car works, calculate its optimal route (the total length of the path should be minimal). Feature: the starting point of the path (the first of the microdistricts) is indicated by the user.

2. Continuing the previous task, draw up a schedule of movement along the calculated route (time of arrival in each microdistrict), if there is an average service time for one resident and what percentage of the population immediately goes out for water.

3. Calculate the recommended (optimal) number of cars N ($1..N_{\max}$), based on the constraints: a) the minimum and maximum volumes of water per inhabitant; b) allocated fuel limits. Movements between microdistricts are not taken into account here, the total number of residents in the city is taken.

4. Assuming that N cars work, calculate the optimal travel route for each car so that: a) the total length of each path is minimal; b) the total population in the neighborhoods served by each vehicle was approximately the same. (That is, the difference between the microdistricts "covered" by the car and the average S_{sm} / N per car should tend to zero).

5. Continuing the previous task, draw up traffic schedules along the calculated routes (arrival time in each microdistrict), if there is an average service time for one resident.

The classical formulation of the problem of finding the optimal path is called the "traveling salesman problem" (6-8) and looks like this: there are N cities that the traveling salesman must go around with minimal costs; the traveling salesman must visit each of the cities exactly once, that is, he must go around all the cities, while not visiting any city twice; the necessary condition and the only content of the problem is to find the most profitable way.

We can formulate the mathematical formulation of our problem so:

$$F(X) = \sum_{i=1}^M \sum_{j=1}^M C_{ij} X_{ij} \rightarrow \min, \quad (1)$$

where:

M is the number of microdistricts with tank stops for water consumers;

C_{ij} , $i, j = 1..M$ is the “cost matrix”, where C_{ij} is the “transition costs” from the i-th micro-district to the j-th, that is, the distance between these micro-districts;

X_{ij} is transition matrix with components:

$X_{ij} = 1$, if the tank makes a move from the i-th microdistrict to the j-th,

$X_{ij} = 0$, if the tank does not move,

where $i, j = 1..M, i \neq j$.

We have restrictions:

$$\sum_{i=1}^M X_{ij} = 1, j = 1..M, \quad (2)$$

$$\sum_{j=1}^M X_{ij} = 1, i = 1..M, \quad (3)$$

$$U_i - U_j + M \cdot X_{ij} \leq M-1, i, j = 1..M, i \neq j. \quad (4)$$

Condition (2) means that the tank leaves each area only once; condition (3) - enters each region only once; condition (4) ensures that the route containing microdistricts M is closed and does not have closed internal loops.

Since it is possible to drive along one-way streets, the distance between the i-th and j-th microdistricts, on the one hand, and the j-th and i-th, on the other hand, may be different:

$$C_{ik} \neq C_{ji} \quad (5)$$

Thus, we have an asymmetric problem statement. Since the number of microdistricts in the city of Toretsk is 6, to solve the problem, you can use the brute force method, which requires brute force at most $(n-1)!$ options ($5! = 120$).

Next, we design the application and execute its software implementation in the visual programming environment.

IV. RESULTS

Figure 7 provides general information data that we need when making calculations.

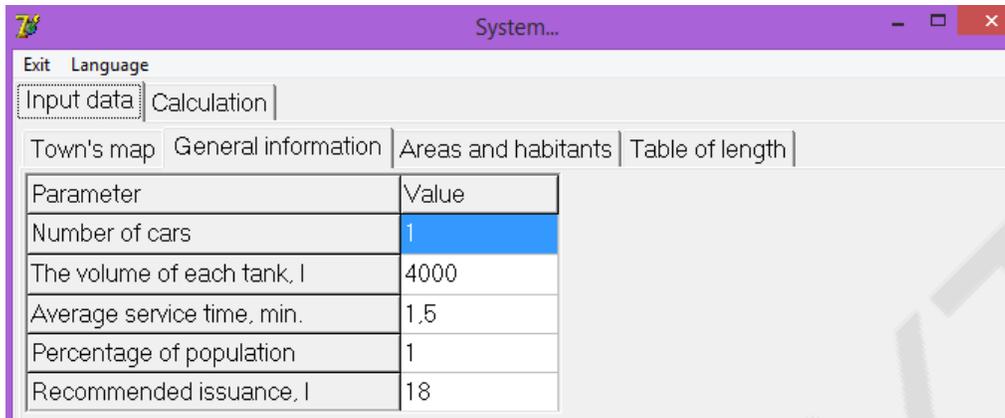


Fig.7. General information

The entered data on the population in the districts, the amount of water in one hand, the total number of people, the total time of service to the population in minutes and hours is shown in Figure 8.

The data in Fig. 9 shows a list of distances between areas.

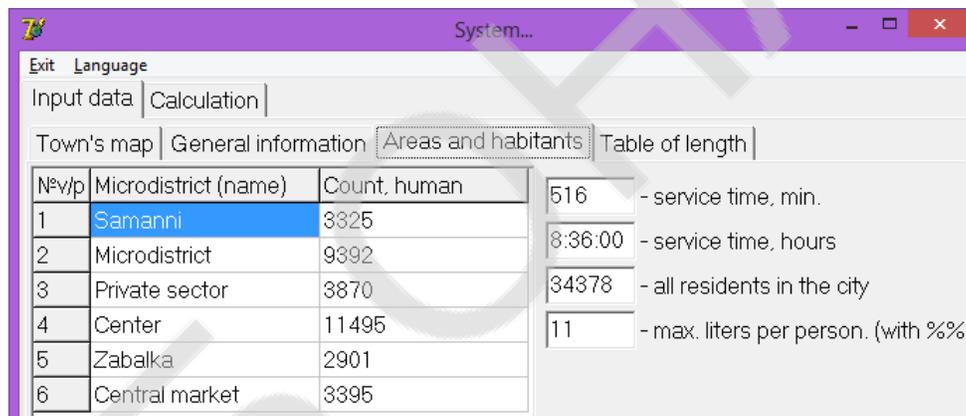


Fig. 8. Data on the number of population in the regions

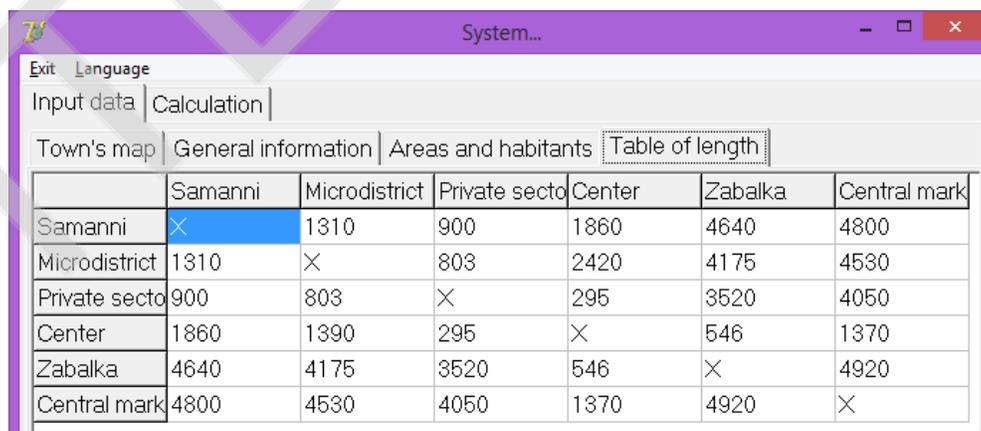


Fig. 9. Distances between areas

Figure 10 shows a map of the city on which the program for calculating the shortest path is made.

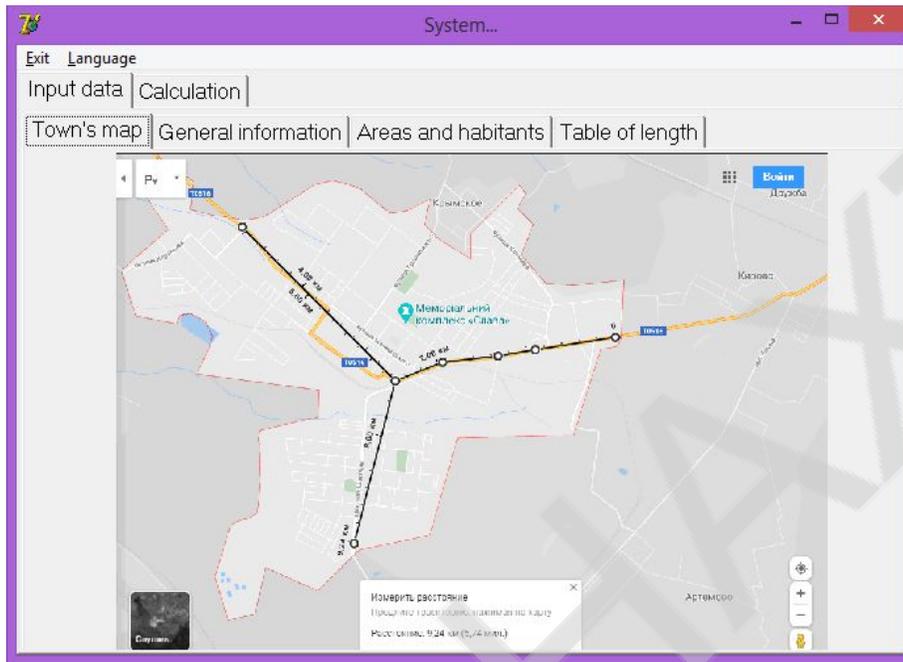


Fig. 10. Map of the studied city

Figure 11 shows the creation of a route from 9:00, taking into account the service time, but this is only taking into account one car.

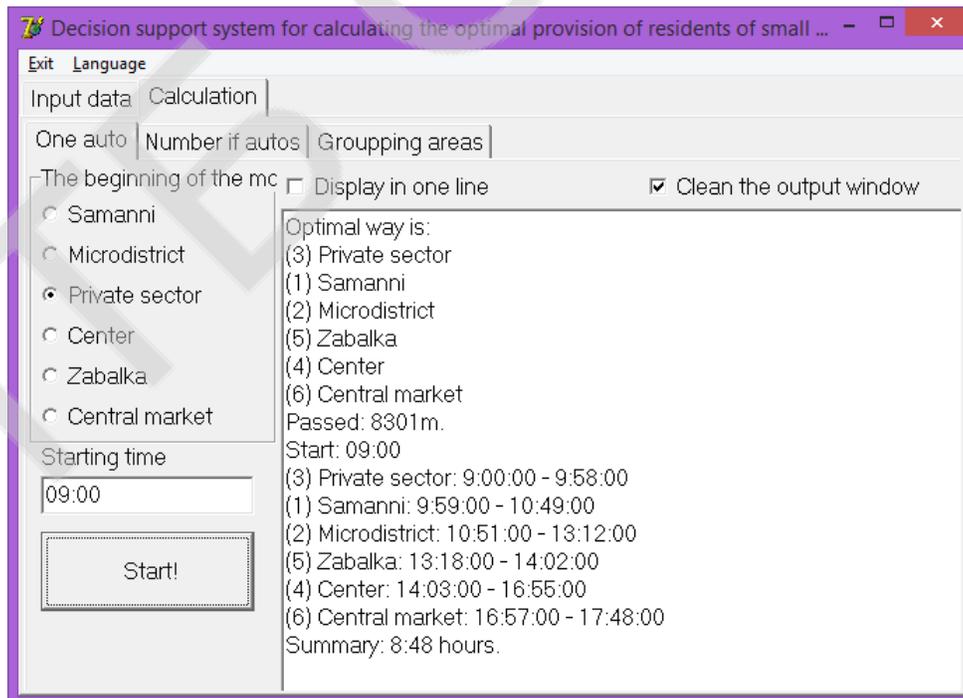


Fig. 11. Working distance traveled by one machine

The process of tasking data on liters of water per one hand, amount of water and time in Figure 12.

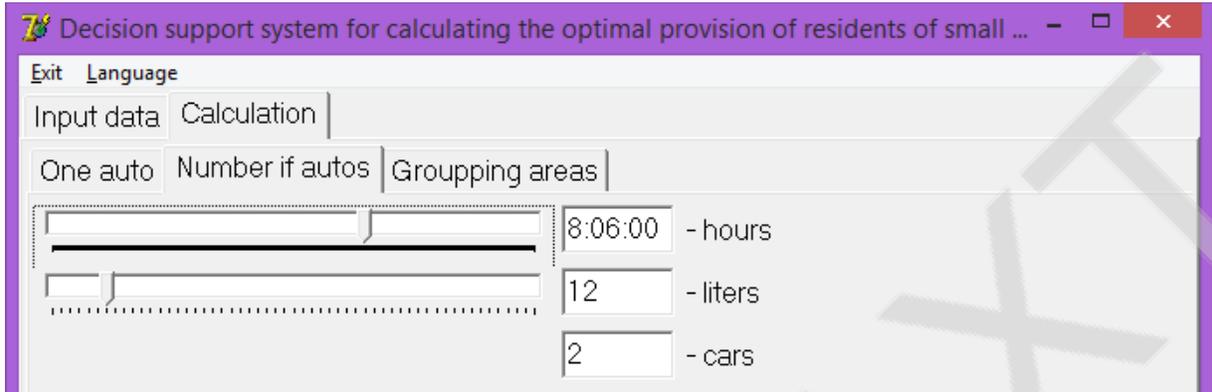


Fig. 12. Setting data on the amount of water and machines

By enumerating, we found out that the maximum possible and required number of cars is six units ($64 = 0$), shown in Figure 13.

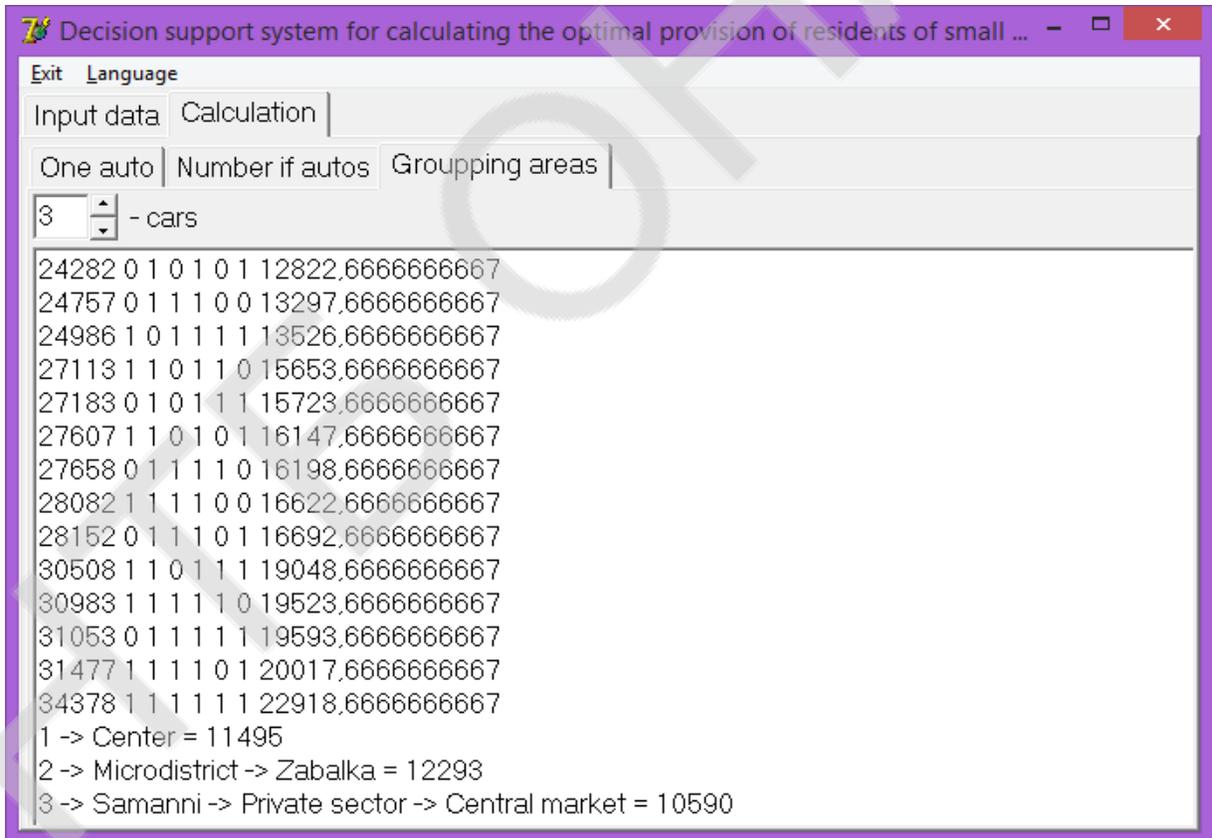


Fig. 13. Required maximum car availability

Figure 14 shows the route directions, the program works as we needed it to.

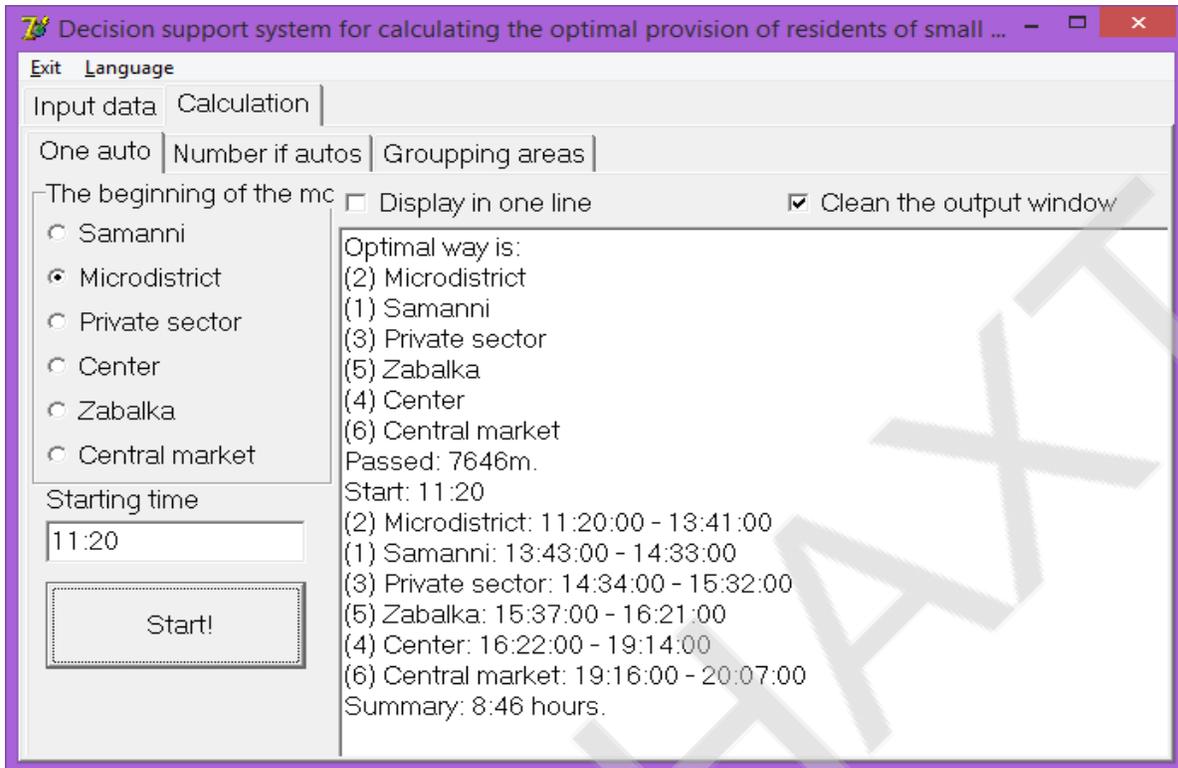


Fig. 14. The process of finding the optimal route

V. CONCLUSIONS

This work is devoted to the creation of an application that will demonstrate the work of algorithms for concise construction of routes by enumerating them and calculating the distance. Also, everything will be recorded from the data that will be entered into the table. The purpose of the work is based on the desire to make life easier for people in the event of man-made disasters or as a result of the destruction / damage of the pipeline as a result of the Operation of the Joint Forces. Indeed, today any enterprise deals with streams of various information that need quick and efficient processing. Therefore, this program facilitates the work of an enterprise that supplies water to settlements. The amount of information depends mainly on the size of the enterprise and the number of districts and cities that will require assistance from the enterprise. Depends on how much will the reserves for an unforeseen event be filled, or how prepared people will be for this, having made their own reserves as in our example – 98-99% of the city of Toretsk is ready for this because of living in such conditions for almost seven years. In this case, the larger the enterprise, the greater the volume and level of complexity of the processed information.

To create such a system, it was required to know the algorithms for constructing a short route according to the "traveling salesman" problem and enumerating the most optimal from all the options, therefore this application should better help enterprises, private companies or city leaders with the development of water and help the cities of Donbass in emergency situations. And since our program

is with extended functionality, it can be applied not only in the above region, but also in any place in our country or on the mainland with a less established infrastructure and work of water supplies.

VI. REFERENCES

1. Svintsov, A.P., Malov., A.N., Masri, G.Kh. (2009). Implementation of plumbing and sewerage products in the segmented market for housing stock. *Water supply and sanitary engineering*, 2, 23-27.
2. Suchchenko, V.N., Grishin, D.K., Tami, Al-Harami. (2010). Water supply of the population as a socially significant benefit. *Bulletin of RUDN. Series: Engineering Research*, 2. 61-66.
3. *Tanks for milk and water carriers ZIL*. http://www.tank-cars.ru/vodovozy_molokovozy
4. *Law of Ukraine "On water, food water supply and water supply" (Vidomosty Verkhovnoy Rada Ukraine (VVRU), 2002, No. 16, article 112)*. <https://zakon.rada.gov.ua/laws/show/2047-19>
5. *Route4Me Route Planner*. <https://play.google.com/store/apps/details?id=com.route4me.routeoptimizer>
6. *ABM Rinkai TMS*. <https://tms.abmcloud.com>
7. *Ant logistics*. <https://ant-logistics.com>
8. *Google Maps*. <https://www.google.com.ua/maps/>
9. *Misto Toretsk. GoogleMaps*. <https://www.google.com.ua/maps/place/Toretsk,+Donetsk+region,+85200>
10. Wentzel, E. S. (2004). *Operations research: tasks, principles, methodology*. M.: High school.
11. Zaychenko, Yu. P. (2000). *Pre-operation*. Kiev: ZAT "Vipol".
12. Zakabula, O. Yu. (2020). The task of providing optimal care for the inhabitants of small places with drinking water in extreme drops. *Science Notes of Young Students*, 6, <https://phm.cuspu.edu.ua/ojs/index.php/SNYS/article/view/1749>
13. Zakabula, O. Yu. (2020). Statement of the problem to calculate the optimal supply of drinking water to residents of small towns in extreme cases. *Innovative technologies: Materials of scientific and technical. conf. students, graduate students, doctoral students and young scientists / for general. ed. Gorinova P.V., Babikova K.O., Melnichuk L.M.* Kyiv: INTL NAU, 114-117.
14. Zakabula, O. Yu. Melnykov, O. Yu. (2020). Modeling the optimal route of a tank truck to provide a small town with drinking water in extreme cases. *Proceedings of the III All-Ukrainian scientific-practical Internet conference of students, graduate students and young scientists on "Modern computer systems and networks in management": a collection of scientific papers / Edited by G.O. Raiko*. Kherson: Publishing house FOP Vyshemirsky V.S., 238-241.

IMAGE CLASSIFICATION OF THE FOOD PRODUCTS

Author: *Oleh Viniarchyk*

Advisor: *Igor Malyk*

Chernivtsi National University (Ukraine)

***Abstract.** In this work was conducted research related to the problem of the image classification for food products. Based on the research we built several applications. The first one is created for collecting datasets and the second one is related to training of the machine learning model. For building the predictive model I was using Transfer learning and EfficientNet. As a programming language, I was using Python and a very powerful framework - Tensorflow*

***Keywords:** image classification, transfer learning, EfficientNet, tensorflow, python, machine learning.*

I. INTRODUCTION

Transfer learning is a modern approach to solving many problems of machine learning. This paper considers the problem - Food products image classification. Using transfer learning and one of the pre-trained models, we are built an image classifier that will classify different food products. For the training, the model classifiers used a dataset built from real videos of products. This fact justifies the relevance of this work because the classification problem is solved on real data, rather than a publicly available and normalized test dataset.

For example, in supermarkets, pre-recognition of goods at the cash register makes it possible to reduce the burden on cashiers and thus reduce the service time of one customer. Optimization of service time of one client is the decision of one of the actual problems of modern retail that does work as a whole actual.

In this paper, we are solving the problem of image classification using a Convolutional Neural Network and datasets created my own for training and testing. At the same time, we implemented a convenient tool for collecting data needed for training and testing ML models. That tool is built as a chatbot using Telegram.

The machine learning model that we implemented, will expect data with labels of the corresponding classes since we are using supervised learning for the training models. The essence of this method is that the data for training must contain the correct class labels for each object in the set. According to these requirements, the developed mechanism for data collection must aggregate them and group them according to classes.

II. LITERATURE ANALYSIS

2.1. Purpose and scope

Designed software products are using to classify a number of food products on the input images. The ability to recognize goods on a photo or video is using in many areas, it helps to improve and automate different processes. Food recognition is

widely used in retail, namely in process automation, time cost optimization, and pricing.

2.2. Problem statement, literature review, approaches to solving

The “Transfer Learning” approach used in this paper is something that, according to researchers, can contribute to the further development of “AGI”. Artificial general intelligence is the hypothetical intelligence of a computer program that has the capacity to understand or learn any intellectual task that a human being can. Andrew Yan-Tak Ng, a well-known researcher, and world-class Data Scientist wrote in one of his works: Next to the Teacher Learning approach, the development of the Transfer Learning approach will be a future success factor in commercial machine learning. Transfer training is a situation when the knowledge gained in solving one problem is used to improve the results and generalize in another problem. Deep learning models have some drawbacks - for very accurate and generalized possibilities, very, very large data sets with class labels are required to train the model. Also, the training itself takes a lot of time and resources. As a solution to this shortcoming, an approach to the use of modern, pre-trained models of deep learning was developed. Today, we have the ability to use modern deep network architectures that have been pre-trained on a large data set and the corresponding weights have been retained. The weights can be imported into the model for later use. There are a number of pre-trained models to solve a variety of machine learning problems. This approach takes place in solving problems related to working with text and voice, classification of images and segmentation of objects in images, and so on.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

We were using the modern approach for solving ML problems called Transfer Learning. Transfer learning is an approach to machine learning that is closely related to deep learning. There is a significant difference between the traditional approach, for building and training machine learning models, and the methodology of transfer learning. The traditional approach is isolated and learning takes place purely on the basis of specific tasks, datasets, and learning individual isolated models on them. Acquired knowledge that can be transferred from one model to another is not stored. During the transfer training, you can use the knowledge (features of objects/weights extracted by ML model) from previously trained models to train new models and solve new problems with a smaller amount of data. Let us now consider the formal definition of Transfer learning, and then use it to understand the different strategies.

Domain D is defined as a tuple of two elements, namely: feature areas and probability distribution - $P(X)$, where X is the data point in the set. Thus we can describe the domain mathematically as $D = \{X, P(X)\}$. The probability distribution $P(X)$, $X = \{x_1, \dots, x_n\}$, $x_i \in X$. Here X_i reflects a specific feature vector. We can define task T as a two-element tuple of the space of labels of classes - γ and objective function - η . The predicate function can also be denoted as $P(\gamma | X)$ from the point of view of probability theory. In this manner the test T can be represented as:

$$T = \{\gamma, P(Y | X)\} = \{\gamma, \eta\}, Y = \{y_1, \dots, y_n\}, y_i \in \gamma.$$

Having domain D_1 corresponding to task T_1 and domain D_2 corresponding to

task $T2$, Transfer Learning allows us to calculate the target conditional probability $P(Y1 | T1)$ in domain $D1$, using the knowledge obtained in training the model in domain $D2$ and task $T2$. In this case, $D1 \neq D2$, and $T1 \neq T2$. When using Transfer Learning in model training, the dataset required for training is usually exponentially smaller than the dataset for which the corresponding model was previously trained.

In this work, I used the architecture "EfficientNet", proposed in 2019 and to this day is one of the most effective models, which achieves the highest accuracy in solving image classification problems. Based on official documentation, "EfficientNet" is a family of ready-made models of various depths and widths. This family includes models: "EfficientNet0", "EfficientNet1", "EfficientNet2", "EfficientNet3", "EfficientNet4", "EfficientNet5", "EfficientNet6", "EfficientNet7". The "EfficientNet0" model is the smallest of all listed, and the size of the input image is 224x224 pixels. Accordingly, the model "EfficientNet7" is the largest and requires the most time and resources for training, the input image size there is 600x600 pixels. A variety of architecture from the EfficientNet family:

Base model	resolution
EfficientNetB0	224
EfficientNetB1	240
EfficientNetB2	260
EfficientNetB3	300
EfficientNetB4	380
EfficientNetB5	456
EfficientNetB6	528
EfficientNetB7	600

Fig. 1. EfficientNet family

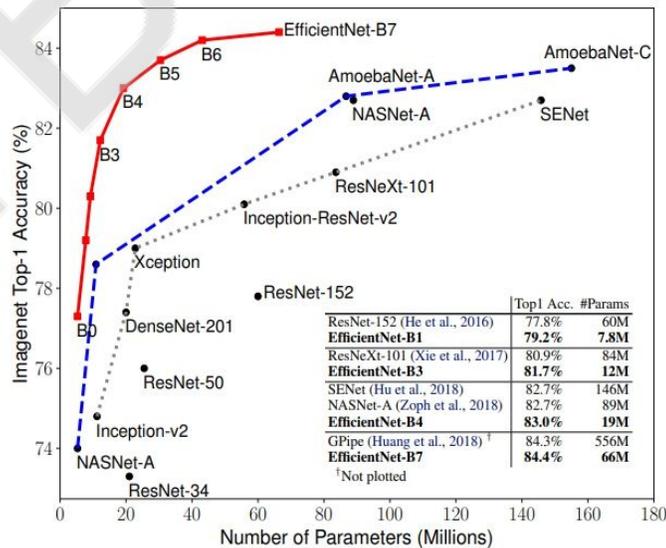


Fig. 2. Modern Pre-trained models

There are also other ready-made architectures of convolutional neural networks for working with images. Compared to other models, EfficientNet is much smaller and shows better results:

Architecturally, the EfficientNet0 model can be divided into the following set of blocks:

Stage i	Operator $\hat{\mathcal{F}}_i$	Resolution $\hat{H}_i \times \hat{W}_i$	#Channels \hat{C}_i	#Layers \hat{L}_i
1	Conv3x3	224×224	32	1
2	MBCConv1, k3x3	112×112	16	1
3	MBCConv6, k3x3	112×112	24	2
4	MBCConv6, k5x5	56×56	40	2
5	MBCConv6, k3x3	28×28	80	3
6	MBCConv6, k5x5	14×14	112	3
7	MBCConv6, k5x5	14×14	192	4
8	MBCConv6, k3x3	7×7	320	1
9	Conv1x1 & Pooling & FC	7×7	1280	1

Fig. 3. Architecture of EfficientNet0

To avoid overfitting of the model, we were using data augmentation for the collected dataset. Overfitting a model is a condition where a statistical model begins to describe the random error in the data rather than the relationships between variables. Image augmentation artificially creates training images through different ways of processing or a combination of multiple processing, such as random rotation, shifts, shear, and flips, etc. Here are examples:



Fig. 4. Image augmentation

IV. RESULTS

The developed product can be divided into two parts:

User interface where user can extend training dataset and actually can try to predict food product name using products images;

Convolutional neural network, trained on its own data set;

We used Telegram platform for building user interface represented as a chatbot. The chatbot is a convenient mechanism that is widely used in various fields. The Chatbot used Python as a programming language and several additional modules to work with the Telegram API and recognize barcodes in the uploaded images. This Chatbot is designed to collect dataset that is needed for training the machine learning model and it is also using for the classification of food products. Using barcode photos and videos of relevant foods, we can easily collect and associate data on the fly with the appropriate class labels - barcode, product name, etc. The classifier model is implemented using a modern approach in in-depth learning, which is called Transfer Learning. There are several options for using Transfer Learning and given the individual requirements and resources, it is important to choose the best option. In the first case, we use a pre-trained model to obtain quality features of objects in training. Using this approach and replacing the last layers of the network, we can re-train and adapt the model to solve the problem of food recognition.

Otherwise, we continue to use most of the weights obtained during the pre-training, and re-train some layers of the network. The second approach requires more resources than the previous one, as it requires more calculations and a much larger set of training data. It is conditionally possible to allocate 4 situations which are possible at use of the Transfer Learning approach:

	Similar dataset	Different dataset
Small dataset	Transfer learning: highest level features + classifier	Transfer learning: lower level features + classifier
Large dataset	Fine-tune*	Fine-tune*

Fig. 5. Transfer learning strategies

In this work, I used part of the existing weights of the pre-trained model and re-trained the twenty final layers of the network. As a result, we implemented a the model that is able to recognize food products on the given images.

The classifier interface is a chatbot built using a modern and convenient messenger platform - Telegram. The user needs to start a chat with the bot, then the bot itself will ask for the desired action and show the appropriate function buttons. Interaction with the developed chatbot is intuitive and takes a few minutes to get acquainted with its capabilities. Here is an example of usage:

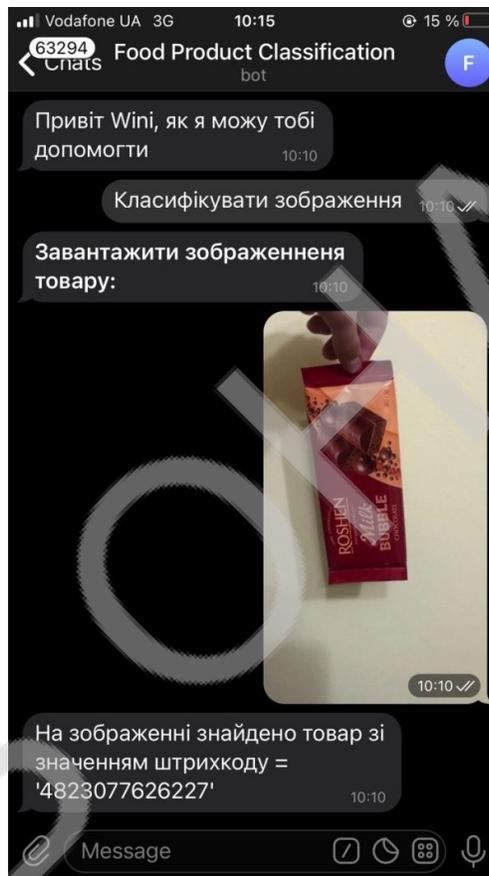


Fig. 6. Developed chat bot example of usage

V. CONCLUSIONS

In this paper, we investigated the problem of image classification using artificial intelligence and appropriate approaches using Python as a programming language. The following approaches were used to build an AI model:

- 1) Deep learning methods and in particular - Transfer Learning
- 2) Pre-trained model EfficientNet0

In general, we developed a software product for solving the problem of image classification for food products. At the same time, we built another application that we found very useful for data collecting, grouping, and association. The chatbot

expects images of the barcodes and videos about each specific product, then it is decomposing and groups all videos using associated barcodes. As a result, we have folders in the file system for each of the upload barcodes. Each folder contains images decomposed from previously uploaded videos, so we can use these already associated images for training and testing AI models. Also, this chatbot can be useful for solving other AI problems.

VI. REFERENCES

1. Keras. (n.d.). Wikipedia. Retrieved October 15, 2020, from <https://uk.wikipedia.org/wiki/Keras>
2. Tam, M., & V. Le, Q. (n.d.). *EfficientNet: Rethinking Model Scaling for Convolutional Neural Networks*. Arxiv. Retrieved September 5, 2020, from <https://arxiv.org/pdf/1905.11946.pdf>
3. *Transfer learning & fine-tuning*. (n.d.). Keras.io. Retrieved October 10, 2020, from https://keras.io/guides/transfer_learning/
4. *Telegram Bot API*. (n.d.). Core.Telegram.Org. Retrieved September 5, 2020, from <https://core.telegram.org/bots/api>
5. Elisha, O. (2020, July 26). *Overcoming overfitting in image classification using data augmentation*. Heartbeat. <https://heartbeat.fritz.ai/overcoming-overfitting-in-image-classification-using-data-augmentation-9858c5cee986?gi=3814d601b63e>

USE OF NEURAL NETWORKS TO MAXIMIZE THE EFFECTIVENESS OF SHOT PUTTERS TRAINING

Author: **Kadatskyi Mykyta**

Advisor: **Oleksandr Melnykov**

Donbass State Engineering Academy (Ukraine)

Abstract: *The main factors influencing the results of shot put are considered. The necessity of using modern methods for solving forecasting problems is substantiated. The method of artificial neural networks with different architecture is proposed to solve the following problems: finding the percentage of correction of the shot put technique, finding the subtype of the technique, the activation function of the sigmoid and the algorithm of reverse propagation of errors for learning networks. A software package has been developed that allows to find the approximate result of pushing the shot using the technique of "glide" and "from the ground". Examples of calculations in the environment Deductor Studio Lite are given.*

Keywords: *shot put, neural network, prediction, reverse search method, physical culture, athletics.*

I. INTRODUCTION

The current level of development of athletics, in particular shot put, sets the task of developing new, more rational means and methods of sports training that

contribute to the rapid and reliable achievement of high sports results. But the force can not be increased indefinitely, and further growth of results is possible not so much by improving the technique of throwing, for which it is advisable to use information technology.

The aim of the work is to find the best indicators for the most effective use of force and speed of the athlete when performing an attempt, using a mathematical model of throwing (pushing technique without prior acceleration of the projectile) and software for calculating a number of elements (angle, initial force, initial speed). Also modeling of the push angle and the ejection angle of the nucleus for maximum results with the technique of pre-acceleration ("jumping" technique). Explore the possibility the use of artificial neural networks in calculating the performance of the athlete-thrower of the nucleus on the available data on age, height, body weight of the athlete, as well as the characteristics of the flight of the nucleus to determine the range of this flight, selection of subtypes of nuclear pushing techniques

II. LITERATURE ANALYSIS

The problem of finding the most effective shot put technique can be solved by artificial neural networks. As a neural network model, it is advisable to choose a two-layer perceptron. Estimation of the predominant number of neurons in the latent layer is performed using the known inequality [7-9].

In physical culture and sports, neural networks are used to analyze and predict the indicators of physical fitness of athletes, as well as the results of sports competitions [1]. For example, for the available data from [2] the prediction problem was formulated: to determine the range of this flight based on the available data on the age, height, body weight of the athlete, as well as the characteristics of the nucleus flight. This problem was solved by the method of artificial neural networks in [3], but it did not take into account a number of important factors.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

There are five tasks, each of which according to the available data on age, height, body weight of the athlete and other characteristics should determine the range of the nucleus, but the list of characteristics in each case will be different.

1. All men with the characteristics "Speed-angle-height" and without division into the used throwing technique (actually a model with [2]) are considered.

2. All men with the characteristics "Speed-angle-height" and without division into the used throwing technique, but with the addition of new parameters of the distance traveled by the core of the acceleration by the athlete.

3. All women are considered without division into the used throwing technique with the characteristics of the distance traveled by the nucleus.

4. Men with the technique of throwing "Glide" with the characteristics of "Speed-angle-height" and the parameters of the distance traveled by the nucleus are considered.

5. Men and women with the technique of throwing "Glide" with the characteristics of the distance traveled by the nucleus are considered.

We will prepare data for each task.

Table 1. Specified tasks

№	Sex	Technique	Speed-angle-height	Length of glide	Foot distance in power position	Length in flight phase	Length of spatial relocation in power position
1	People.	Any	+	-	-	-	-
2	People.	Any	+	+	+	+	+
3	Women.	Any	-	+	+	-	-
4	People.	Glide	+	+	+	-	-
5	Everyone	Glide	-	+	+	-	-

Name	Technique	Sex	Age [years]	Height [m]	Weight [kg]	Length of glide [m]	Foot distance in power position [m]	Distance [m]
Majewski	Glide	m	27	2,04	132	0,91	1,28	21,91
Bartels	Glide	m	31	1,87	135	0,87	1,29	21,37
Mikhnevich	Glide	m	33	2,02	127	0,92	1,17	20,74
Vili	Glide	w	24	1,96	120	0,89	1,19	20,44
Kleinert	Glide	w	33	1,9	90	1	1,03	20,2
Gong	Glide	w	20	1,8	85	0,85	1,23	19,89
Mikhnevich	Glide	w	27	1,8	85	0,88	1,08	19,66
Carter	Glide	w	23	1,75	95	0,99	1,14	18,96
Meiju	Glide	w	29	1,74	80	0,84	1,25	18,76
Gonzalez	Glide	w	31	1,79	75	1,02	1,08	18,74

Fig. 1. Given and prepared data (example of the fifth problem)

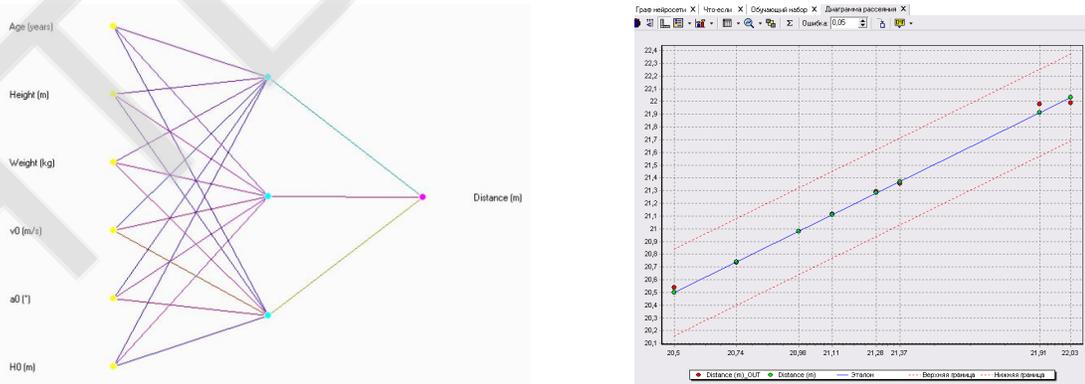


Fig. 2. Graph and scattering diagram of the neural network MLP-6-3-1 (task 1)

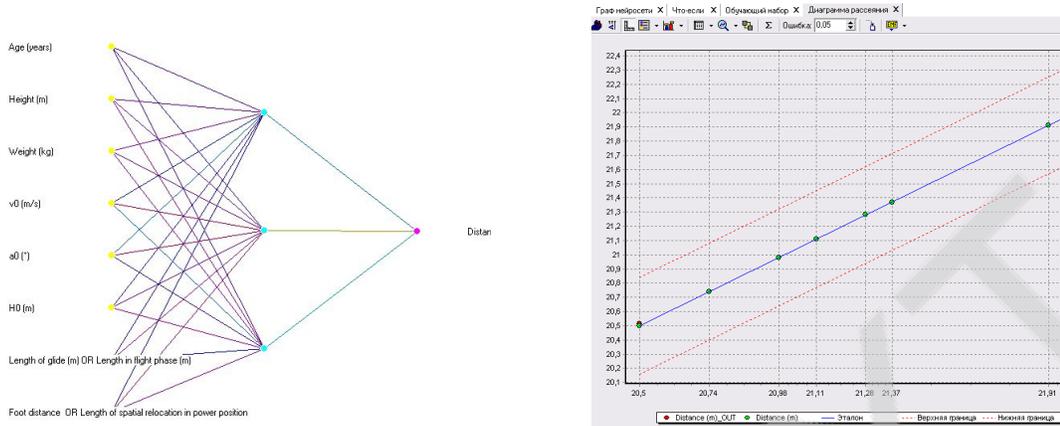


Fig. 3. Graph and scattering diagram of the neural network MLP-8-3-1 (task 2)

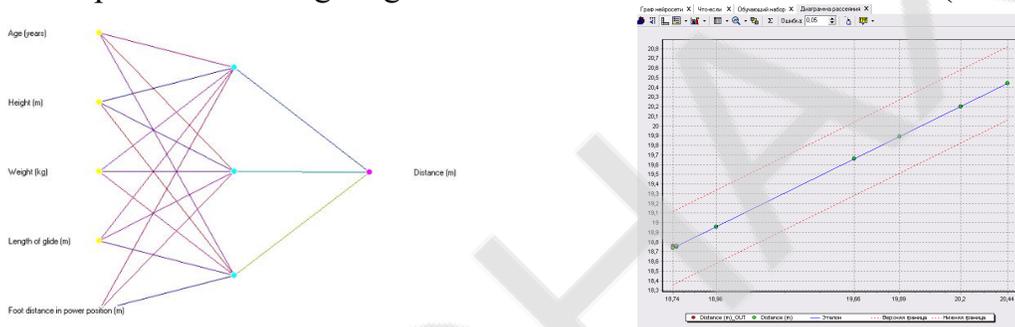


Fig. 4. Graph and scattering diagram of the neural network MLP-5-3-1 (task 3)

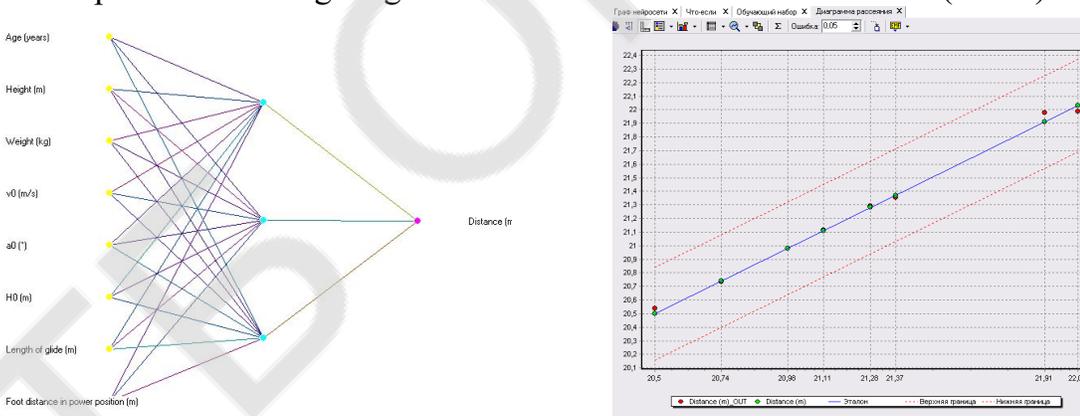


Fig. 5. Graph and scattering diagram of the neural network MLP-8-3-1-Glide (task 4)

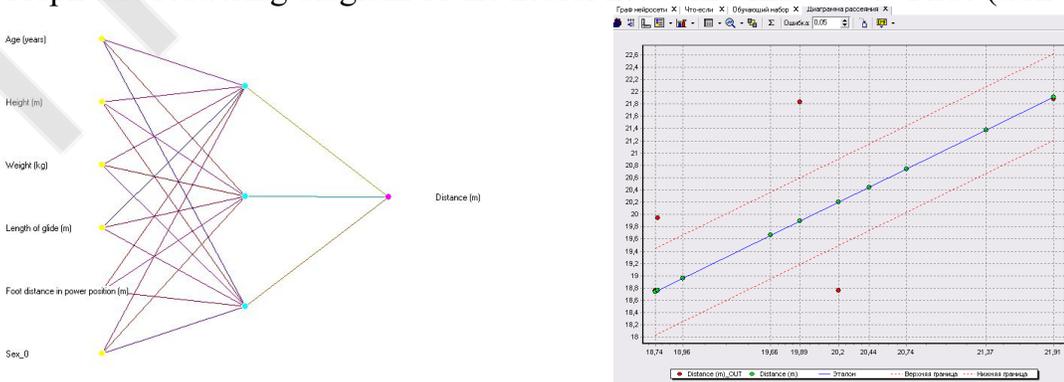


Fig. 6. Graph and scattering diagram of the neural network MLP-6-3-1-Glide (5)

The average accuracy (average errors - deviations) of all calculations are summarized in table 2.

It can be concluded that models that take into account all the characteristics of the thrust of the nucleus (№2 and №3) show slightly higher accuracy of calculations than the model based only on the characteristics "Speed-angle-height" (№1). At the same time, the patterns that determine the throwing distance in men and women are different, as evidenced by the model №5. The significant magnitude of the error in the model №4 is explained by the small number of examples for network learning.

Table 2. Accuracy of each calculation

Problem	Sex	Machinery	Average accuracy [m]	Average accuracy [%]
1	People.	Any	0.004632	0.0216%
2	People.	Any	0.003464	0.0163%
3	Women.	Any	0.003627	0.0192%
4	People.	Glide	0.375513	1.7144%
5	Everyone	Glide	0.6242436	3.3280%

However, this is only an assumption for modeling the shot put, it uses only 8 input data, 3 which can be neglected (article, technique and jump length), but they do not affect the assessment of the qualities of the athlete. The updated system helps to find the relationship between power, explosive, anthropogenic, speed and angular group of indicators of the athlete-thrower.

IV. RESULTS

In the table. 3. the list of the factors influencing result of pushing of a kernel is resulted.

Consider the example of two athletes using the developed software [2]: the first has high performance in strength training and blasting (barbell press 90 kg, squats 120 kg, push 50 kg, chest 60kg at a weight of 90 kg), the angle of departure of the projectile from height 1.8 m will be 30 degrees, the height of the release is 2 m, and the horizontal speed is 2 m / s, the final speed is 7 m / s. This athlete pushes the core to a result of 8.70 m.

Table 3. List of factors

№	Group	Factor	Unit of measurement
1	Height and height of issue	h_0 - height of the core release	m
2		Dr - arm length (scope)	m
3		ZT - the growth of the athlete	m
4	Subversive	LJ - the result of long jumps from a place	m
5		TJ is the result of a triple jump	m
6	Power	LT - result in bench press	kg
7		LS - the result of squats with a barbell on his shoulders	kg
8		VG - the result of taking on the chest	kg
9		TK - push rod	kg
10		WS - weight of the athlete	kg
11	Speed	v_ϕ - the final rate of release of the projectile	m / s
12		v_r - horizontal speed of projectile acceleration	m / s
13	Angular	ω_0 - push angle (from the upper arm)	degree
14		θ_0 - ejection angle (palm angle)	degree

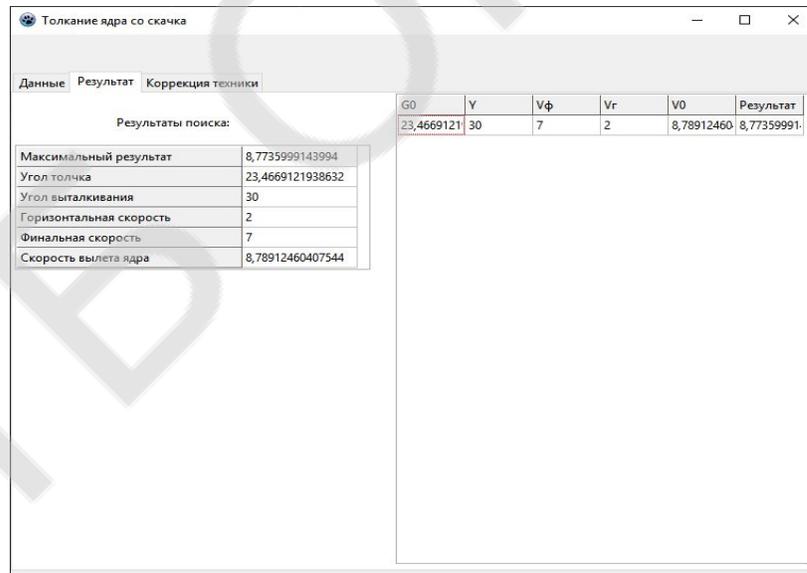


Fig. 7. The result of the first athlete

Consider the second case, let the athlete have average performance in power and explosive training (barbell press 70 kg, squat 100 kg, push 30 kg, chest 50kg at a weight of 70 kg), the angle of departure of the projectile with a height of 1.7 m will be 36 degrees , release height 2.1 m, and horizontal speed 1.5 m / s, final speed 8 m / s. This athlete pushes the core to a result of 10 m 20 cm.

Результаты поиска:		G0	γ	Vφ	Vr	V0	Результат
		30,5337900	36	8	1,5	9,25561493	10,2875963

Максимальный результат	10,2875963872545
Угол толчка	30,5337900443812
Угол выталкивания	36
Горизонтальная скорость	1,5
Финальная скорость	8
Скорость вылета ядра	9,25561493716105

Fig. 8. The result of another athlete

The question arises: why an athlete with less strength training was able to push an athlete with a higher, and anthropogenic data which one is better? This is due to the effective maximum use of the technique of pushing the nucleus. In the example of the first athlete, he hoped for more strength, that his acceleration (horizontal speed) was faster than he was able to translate it into the final, so he pushed the core lower in angle and height. The second athlete had a slightly higher speed than the power, and worse anthropogenic data, but he was technically able to reduce the initial speed, translate it into the final and raise the angle of ejection, which was reflected in the result.

So, we have to answer the question:

1. How effectively the athlete's performance is used to achieve the best result;
2. What indicators for a particular athlete to consider important or less important;
3. To what extent the pushing technique is ahead of the power indicators, or the power technique;
4. How to improve the technique of pushing the nucleus.

Thus, we have 14 input values that belong to 5 classes - groups of dependence, which are divided into physical quantities and action class. The matrix of input values of the neural network will look like:

$$X_1 = \begin{bmatrix} h_0 & dr & ZT & 0 & 0 \\ LJ & TJ & 0 & 0 & 0 \\ LT & LS & VG & TK & WS \\ v_\phi & v_r & 0 & 0 & 0 \\ \omega_0 & \theta_0 & 0 & 0 & 0 \end{bmatrix} \quad (1)$$

The initial factor will be the range of pushing the nucleus.

After the calculations, you can get answers to the following questions:

- how effectively the athlete's performance is used to achieve the best result;
- how to improve the technique of pushing the nucleus;
- what indicators for a particular athlete to consider more or less important;
- to what extent the pushing technique is ahead of the force indicators, or the force indicators are ahead of the technique.

These problems are solved by the first neural network, which finds the percentage of correction of the pushing technique [2].

After 14 factors were found [4] that affect the result of nucleus pushing, namely: core release height, arm length (scope), athlete's height, result in long jumps, result in triple jump, result in bench press, result in squat with barbell on shoulders, result in chest, barbell push, athlete's weight, final projectile release speed, horizontal projectile acceleration speed, push angle (from the upper arm), ejection angle (palm angle). These 14 input values belong to 5 classes - groups of dependencies, which are divided into physical quantities and by action class: height and height of release, subversive, power, speed, angular. The initial factor was the range of the nucleus. The results of calculations are given in [5].

But it is still necessary to determine which throwing technique is more suitable for the athlete according to his physical parameters. We have data on athletes, which can be considered input factors (Fig. 1):

1. The height of the release of the nucleus by different techniques.
2. Athlete's height.
3. Become an athlete.
4. Age of the athlete.
5. Arm length.
6. Leg length.
7. Type of muscle fibers.
8. Shoulder width.
9. Abalakov's test for motor quality - speed.
10. Acceleration length.

Висота випуску	Зріст	Стать	Вік	Довжина рук	Довжина ніг	Тип волокон м'язів	Широта плечей	Тест Абалакова	Довжина розгону	Тип техніки
220	190	2	16	90	70	2	50	27	120	1
184	160	1	18	78	67	2	65	21	134	2
150	150	2	23	87	67	1	56	15	100	2
178	165	1	23	67	56	1	57	23	123	1
196	170	2	21	65	65	2	67	25	130	3
221	166	2	21	58	48	2	47	34	130	1
223	205	1	19	92	70	2	76	22	148	2
152	217	2	25	74	82	2	24	26	142	4
208	186	2	32	92	56	2	51	25	127	4
208	150	2	23	55	85	1	24	35	125	4
197	225	1	26	69	54	2	75	35	139	3
221	225	1	25	108	64	2	40	20	123	2
150	188	1	28	66	80	2	53	27	114	2
192	185	2	25	82	60	1	69	27	143	1
209	187	2	23	54	58	1	21	19	121	1
198	178	1	35	72	78	1	41	23	135	3
171	227	2	15	100	94	2	64	24	134	4
167	160	1	32	100	87	1	65	26	128	4
170	165	2	30	63	63	1	59	15	119	2

Fig. 9. Input data

Each athlete can use a different throwing technique (one of 4 varieties): jump; circular swing (low legs); circular swing (high legs, low shoulders); circular swing (high legs, high shoulders). When using each technique, it gets different results. Thus, we add a new factor - "technique used for throwing" - as a result. We find the best results for each athlete for each of the factors and conduct a classification. Then we enter the data of the new athlete, and the model (Fig. 2) advises which technique is best to use this athlete to get the best results.

By conducting a series of numerical experiments, a was selected neural network architecture with one hidden layer containing three neurons. The results of calculations in the Deductor environment are shown in Fig. 3.

The problem can be solved by the method of artificial neural networks with the architecture of a conventional perceptron with ten input factors, shown in Fig. 10, one hidden and one original ("selected technique"). The use of this model will help to reduce the time of the equipment almost twice, which in turn will help to rationally use the time to train the athlete in his age category.

V. CONCLUSIONS

The scientific novelty of the work lies in the system of modeling and finding the percentage of correction of equipment using a neural network device, with which it is possible to improve the training process of the athlete-thrower, which in turn will improve the result. Also psychologically the athlete will be ready for the best result.

The practical value is that a decision support system has been developed - an application that allows you to simulate the result of pushing the nucleus, and find the percentage of correction of technology.

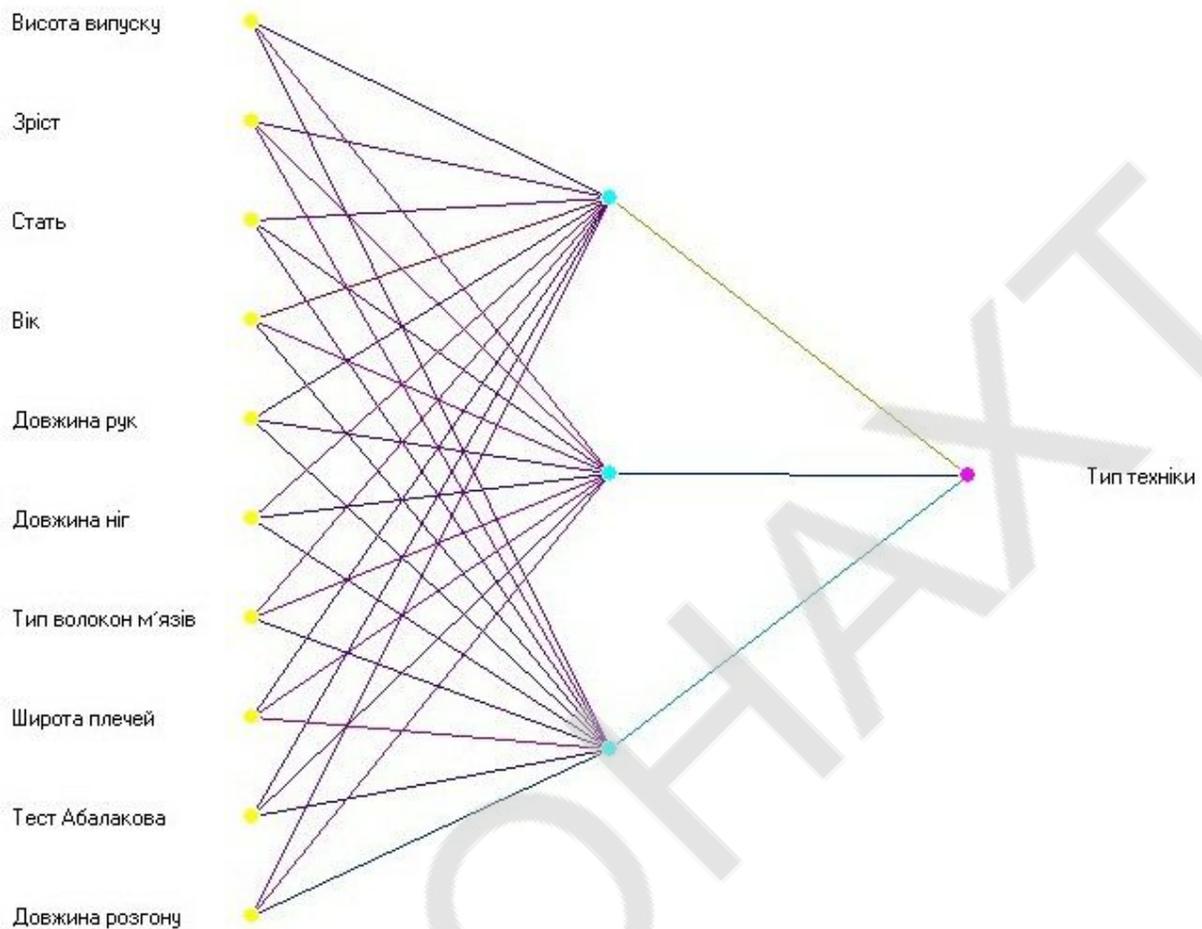


Fig. 10. Scheme of the neural network

Тип техніки	10x2x1	10x3x1
1	1,0265	1,0258
2	1,9963	2
2	1,9993	1,9998
1	1,0007	1,0069
3	2,9988	2,9997
1	1,0194	1,3062
2	1,9987	2
4	3,9783	3,998
4	3,9910	3,9818
4	3,9803	3,9825
3	2,4982	2,9999
2	1,9975	1,9995
2	2,5026	2,001
1	1,0259	1,0122
1	1,0152	1,0027
3	2,9991	3,0007
4	3,9872	3,99
4	3,9929	3,9882
2	1,9995	2,0002

Fig. 11. Comparison of the results of two calculations and available data

The use of artificial neural networks in the calculation of the performance of the athlete-thrower of the nucleus can allow the available data on age, height, body weight of the athlete, as well as the characteristics of the flight of the nucleus to determine the range of this flight. The comparative analysis of several models allowed to formulate certain conclusions about the accuracy of their calculations.

The problem of finding a technique can be solved by the method of artificial neural networks with the architecture of a conventional perceptron with ten input factors, shown in Fig. 10, one hidden and one original ("selected technique"). The use of this model will help to reduce the time of the equipment almost twice, which in turn will help to rationally use the time to train the athlete in his age category.

VI. REFERENCES

1. Tutevich, V.N. (1956). *The theory of sports throwing*. Publisher: Physical Culture and Sports.
2. Melnikov, A.Yu., Kadatsky, N.A. (2019). Development of an information system for an approximate finding of the indicators of an athlete-thrower using mathematical modeling of shot put and the use of neural network technologies. *Bulletin of Donbass State Machine-Building Academy: Collection of Science Practices*, 2 (46), 145-149.
3. Kasyuk, S.T. (2013). The use of neural networks for the analysis and forecasting of data in physical culture and sports. *Scientific and theoretical journal "Scientific notes"*, 12 (106), 72-77.
4. Wilko, Schaa. (2010). Biomechanical Analysis of the Shot Put at the 2009 IAAF World Championships in Athletics. *New Studies in Athletics*, 3-4, 9-21. URL: <https://www.researchgate.net/publication/265661202>.
5. Melnikov, A. Yu. (2019). The use of neural network technologies for an approximate finding of the indicators of an athlete-thrower of the nucleus. *Automation and computer-integrated technologies in virobnstvi and coverage: camp, progress, prospects for development: materials of the All-Ukrainian scientific-practical Internet conference*, 87-89.
6. Kadatsky, M.A. (2020). Setting the task for the development of the indicators of the athlete-metal worker of the nucleus from the consumption of piece neuronal lines with 14 input factors. *Materials of the All-Ukrainian scientific-practical conference for students, postgraduate students and the form of young scientists "Applied technologies"*, 22-24.
7. Kadatsky, M.A. (2020). Calculation of the indicators of an athlete-thrower of the nucleus using an artificial neural network with 14 input factors. *Youth in the world of modern technologies: materials intern. scientific-practical conf.*, Kherson: Publishing house FOP Vyshemirsky VS, 280-283.
8. *Type of fibers*. <http://mir-la.com/303-sostoyanie-myshc-i-rabotosposobnost-legkoatletov.html>
9. *Abalakov's test*. <https://studfile.net/preview/4309968/page:2/>
10. *BaseGroup Labs: official site*. <https://basegroup.ru/community/articles/intro>

IMPLEMENTATION OF IMAGE PROCESSING AND OUTPUT USING DIGITAL FILTERS USING FPGA

Author: **A. A. Mukhanbet**

Advisors : **Y. S. Nurakhov, T. S. Imankulov**

Kazakh National University named after Al-Farabi (Almaty, Kazakhstan)

Abstract. *Digital image processing is an ever-growing industry, including medicine, video surveillance, and more. To improve the performance of image processing systems, image processing algorithms are implemented not programmatically, but hardware. The idea here is to achieve results by processing images at the hardware level faster and more efficiently than software processing. Thus, digital signal processing algorithms and operations were implemented using the Basys 3 FPGA board. FPGA provides the advantage of parallelism, low costs, and low energy consumption. In this article, the advantages of using FPGA for the implementation of image processing algorithms such as median filter, morphological, convolution, smoothing and edge detection, etc.were demonstrated and the results were obtained. The picture is provided .we send it to the FPGA block RAM in .coe format, and then we can check the processing operations performed depending on our choice. Then we output the images to the monitor using VGA. Image types use eight bits to encode the value of each pixel, resulting in shades of gray with a black value of 256 to 0 and a white value of 255.*

Keywords: *FPGA, digital image processing, algorithms, filter, VGA*

Introduction. Digital image processing means processing and displaying images. Image editing-used to change the image. There are three main categories of image processing: image enhancement, Image recovery, and image classification. image enhancement, which allows you to effectively display data for visual interpretation. This helps the user see the image and recognize different segments of the image. An example of this is the processing of shades in an image. This method is very useful to help you distinguish between different objects in an image. Image correction and recovery is another important aspect of image processing. It mainly deals with image correction, which can affect the image due to geometric distortions or noise. It can also eliminate blurring, as a result of which a low-quality image can be updated to an image with high-quality and clear features.

There are many useful image processing applications. It is used as an emotion sensor to guide the robot and recognize goals. It is also used for industrial control and in medical technologies such as X-ray amplification. A very useful application for digital image processing is to look at the color intensity in the image and divide the image into segments based on the results obtained. The biggest performance challenge is the time it takes to process the images captured by the camera. Such applications may be easy to implement on a general-purpose computer, but they are not very time-consuming due to additional memory limitations and other peripherals.

This leads to the study of possible hardware alternatives. Image processing algorithms, which have recently been introduced in hardware, have become the most viable solution for improving the performance of image processing systems. FPGAs are often used as platforms for real-time image processing. An FPGA is a programmable device [1] in which the logical structure can be configured directly by the user. An FPGA consists of an array of unwritten elements that can be programmed or interconnected and have virtually unlimited ways according to the user's description. Reprogrammed and easily updated, the FPGA offers a compromise between the flexibility of universal processors and the speed of ASIC hardware. They allow you to quickly create a prototype of the system and provide a cheaper option for testing system requirements [2]. Placing the functionality of image processing applications on the hardware makes it possible to speed up processing, since there is no need to break down individual instructions into the sampling, decoding, and application cycles that are required on a typical computer processor. In addition, taking into account the speed of the recorded process and the obvious dynamics of the variability of its flow structure, it is necessary to quickly capture at a high frame rate, which creates a large flow of video frames that must be analyzed and processed in real time. An effective solution to this problem is possible by parallel processing of the image stream. The construction of parallel image processing systems can be carried out using SystemOn-Chip technology based on the FPGA architecture.

This paper provides an overview of the implementation of image processing applications in FPGA, focusing on the features inherent in FPGA. The rest of the article describes in detail the processing algorithms and operators. In addition, various filtering algorithms were described, such as accumulation filter, Gauss filter [3], etc. finally, the results obtained by implementing image processing algorithms in FPGA were shown.

Image processing algorithm. Many studies have been conducted in the field of hardware image processing using FPGA. The image processing algorithms considered for hardware implementation include aggregation, image filtering, and edge detection (Sobel, Prewitt, and edge detection). These algorithms are based on image processing. Grinding filters are widely used in many applications, such as object recognition, identification, classification, etc. they are used as pretreatment to eliminate unnecessary particles and noise. We focus on image filtering based on the Gauss filter.

Gauss mask. The Gauss filter is one of the most important and widely used filtering algorithms for image processing [4]. The Gauss filter (G) is defined in equation 1.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \quad (1)$$

where G is a Gaussian mask at a point with coordinates x and y , σ is a parameter that determines the Gaussian standard deviation. If the σ value is greater, then the image smoothing effect is higher.

Accumulation operation. In general, smoothing is obtained by calculating the sum of the products between the input image and a small Gaussian Matrix (3×3). Using a 3×3 mask and a 3×3 input image, you can achieve a 2D convolution image [5].

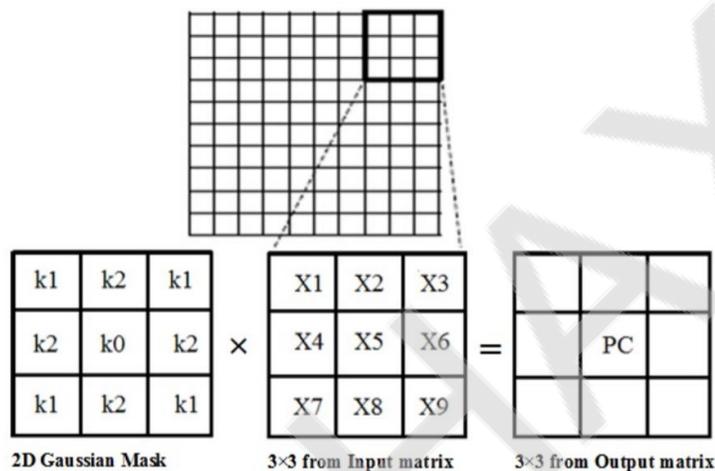


Figure 1. Accumulation operation

In image processing, the core, convolution matrix, or mask is a small matrix. It is used for blurring, sharpening, drawing patterns, defining edges, and more. This is achieved by performing a connection between the core and the image.

If the core is symmetrical, then you need to set the center of the core to the current pixel. The core overlaps with adjacent pixels around the place of origin. Each core element must be multiplied by its overlapping pixel value, and all the resulting values must be added. This resulting amount will be the new value of the current pixel, which currently overlaps the center of the core [6].

Implementation of hardware image filtering

Blocking memory. To upload an image to Verilog, you need to convert it to binary. It is created using python, and it is a format .it's called coe. The converted image is as many lines as the total number of pixels, and each line has 24 bits (8X3). Thus, the 160x115 image will have 18400 lines. Then the block memory module is executed, which has many addresses, such as strings and 24-bit data. So, for an image in 160x115 format, it will have 215 addresses. This memory module, like other modules, can be designed and used in the main module. The module contains input signals such as clock, address, datain, and read-write and dataout commands as outputs. Thus, it can only output one data set at a time, in which case it is one pixel. To summarize, you need several pixels at the same time, which use cores that are used by adding and subtracting values to the address[7-8].

VGA interface. For VGA, a 480p display code with a refresh rate of 60 Hz was written. The refresh rate is how many times the screen is updated per second. With each update, each pixel (480X640) is updated one at a time. To do this, the counter starts with the origin (0,0) and up to (0,799) and so on. They include the invisible area in the images, as well as the reverse path. They are displayed on the screen using hsync and vsync signals. The Hsync signal will be "0" after the counter reaches the end of the right border, where it will start tracking again. After re-searching, the signal will be "1" once, starting the search for the left border and the display area. In addition, for the screen, we only need to start the display from one point and end with the number of pixels connected to it in both directions [7].

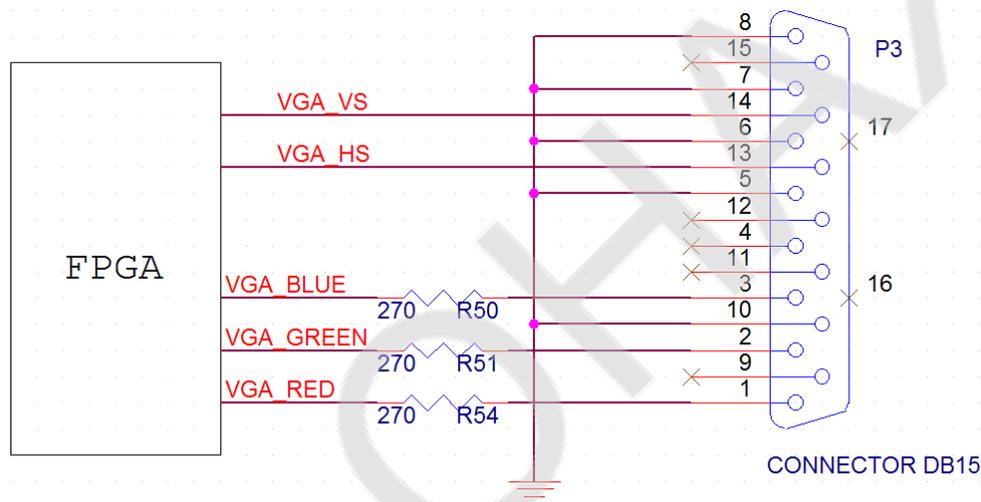


Figure 2. FPGA connection scheme with VGA

You need to convert the image to a list of binary numbers, where each binary number represents the Pixel value of the image. Using a specially designed file, you can perform basic image operations such as increasing/decreasing brightness, RGB2Gray, color inversion, and various color filters. To perform these basic image processing operations, we need to reach one pixel at a time. For example, we can convert a color image to black and white using the operation $R+g+b/3$ [9] for this Pixel. Therefore, we can read one pixel at a time to perform an action and display the result on the screen or save the image to your computer. We can't create any blur or define borders, because we need access to the pixels around this pixel to get the result. To apply blurring, border detection, and other filters, you need to stock up on the image using different cores. So, in the course of work, using python, the image was converted to grayscale and all the necessary pixels [10] to perform kernel operations in a single line, i.e. up, down, right, etc., pixel values were placed around the Pixel. Basically, this is not an effective method, as it uses more memory than a single image in grayscale.

In the course of our work, we will use Basys 3, a first-level FPGA development board developed specifically for the Vivado Design Suite, which is distinguished by the Xilinx Artix-7 FPGA architecture. [11].

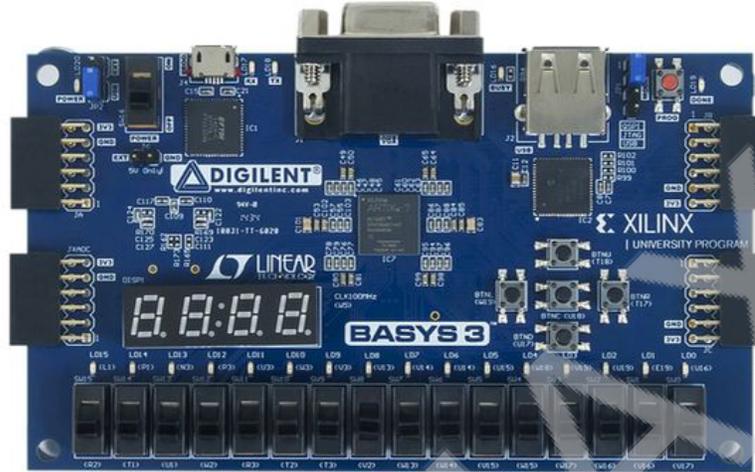


Figure 3. FPGA Basys 3 Xilinx Artix-7 board

We use the Vivado programming environment to create a common FPGA architecture. We will create a circuit using the Clock module and VGA [12] generators.

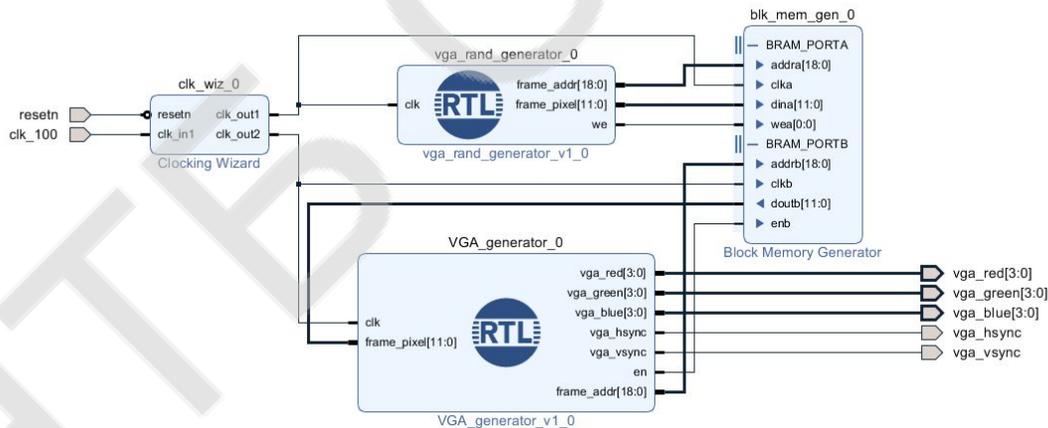


Figure 4. Functional design and circuit of VGA

Since the scope of this work is limited to real-time image processing, this means that the image must be stored in the chip's memory. This paper deals with the upper vhd module, which used a block memory generator to create a single-port ROM with a read width of 8 bits and a read depth of 128x128 pixels. Well .coe files are provided as an image file and must be loaded into the IP kernel generator when

creating ROM [13]. When tracking address bits, pixels are removed from the ROM one after the other. These bytes are then sent to another VHD file, which is responsible for storing these bytes in a separate FIFO along with the processed pixel bytes. After the FIFOs are filled in, the data is displayed on the screen and the program starts again with the ROM address 0.

After creating a VGA circuit, we can implement the synthesis and implementation process and see the simulation result in the following image.

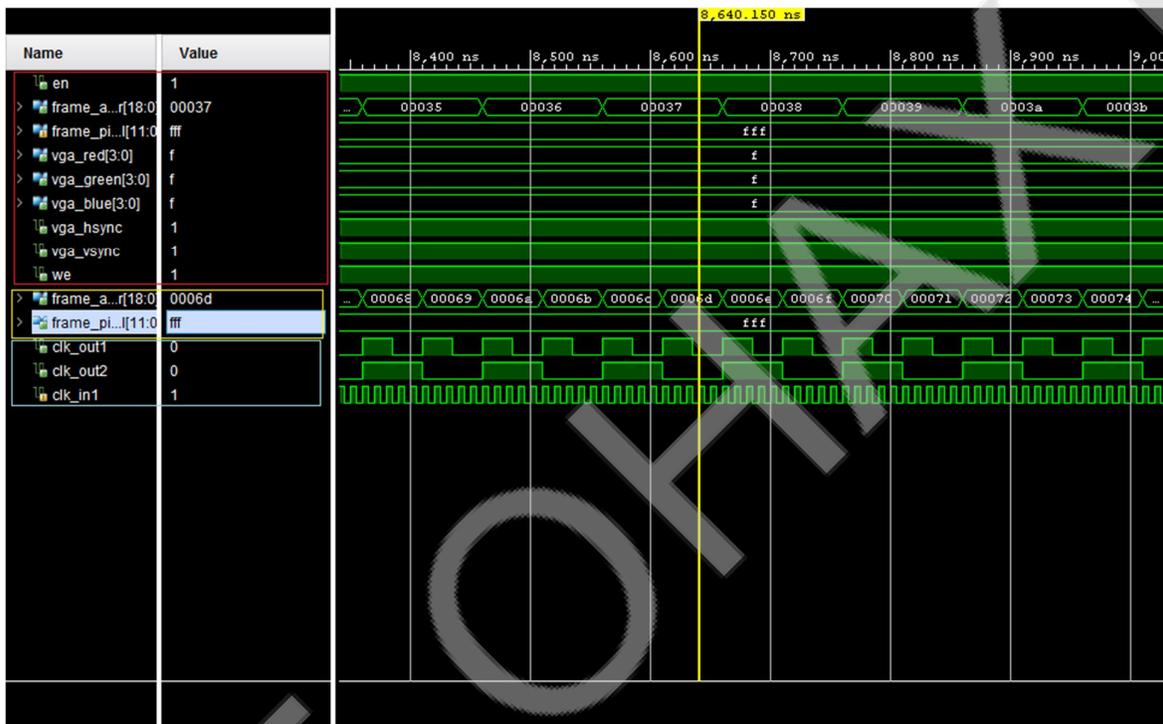


Figure 5. Results of simulation in Vivado

Input signals can be set as binary or hexadecimal values for input contacts or ports, and the result can be seen on the screen in a time diagram similar to the output of a logic analyzer. An example of a time diagram can be seen in Figure 6, which shows the actual output of the image processing code created for the project. A detailed analysis of the simulation results is shown in the figure. The first result of Pixel reproduction occurs at 525ns[14].

The "bad negative failure (WNS)" reported by teams like Report_timing_summary is actually a bad positive failure. If the WNS is positive, then this path will pass. If it is negative, then this path is doomed to failure. According to the results of my work, this indicator was positive. To be precise, it was 6,459 ns. "Total Negative Slack (TNS)" [15] is a (real) negative weak amount in the design. If 0, then the construction corresponds to time. If this is a positive number, then this design has a negative weakness, the design is doomed to failure. It can't be negative. According to the results of my work, it was 0.

Results. As a result, we can see images created using image processing algorithms using VGA. The results are shown in Figure 6. In addition, the time of image processing algorithms on the computer and on the FPGA was calculated. The computer had 0.17708635330200195 seconds, the Basys 3 board had 0.00195 seconds.

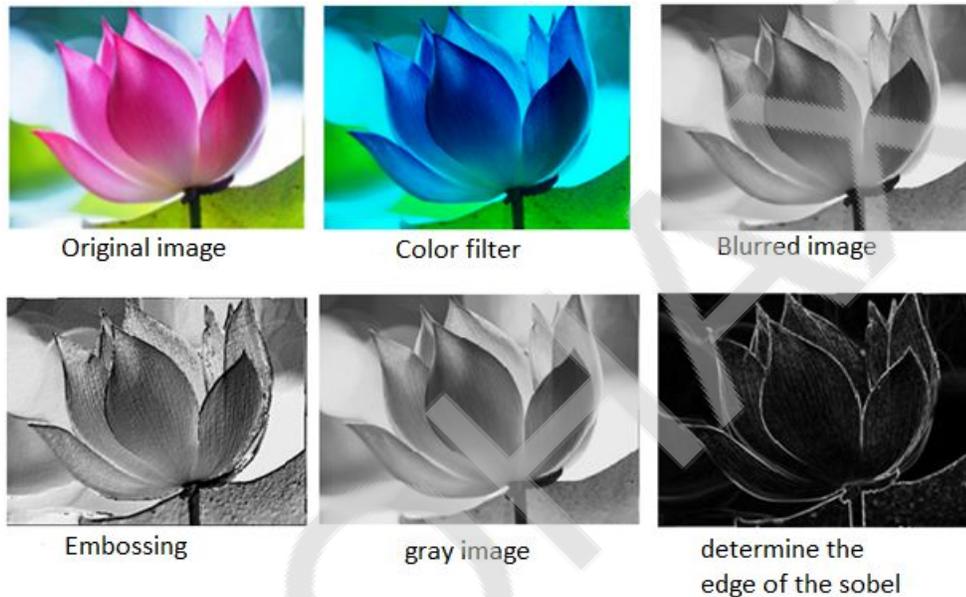


Figure 6. Images obtained as a result of processing

The most commonly used in processing is the edge detection algorithm for creating an image that highlights the edges of the image. First, we use the sobel [15] operator in the direction of x, then in the direction of y, and get the average value of both values to create the final image.

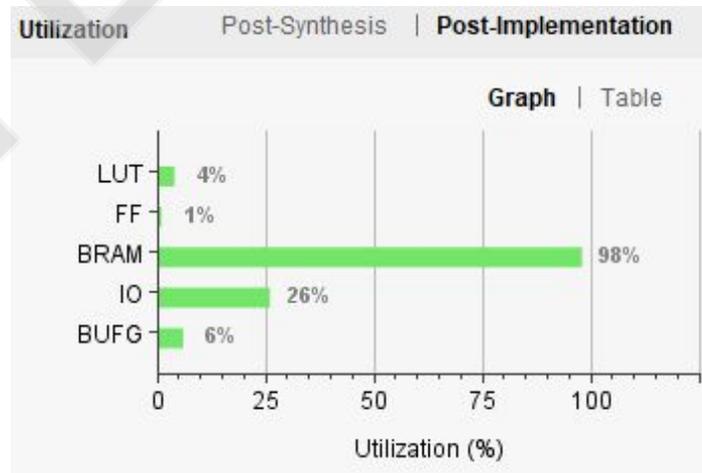


Figure 7. The place of image processing in FPGA memory

This graph shows the size of all the signals used, the amount of memory. In other words, data on resource usage and performance are provided. Since I work in Verilog and Python, the amount of memory is 98%. If we add the C language to it, it means that the size will be larger. The amount of input and output signals was 26%. This is directly related to the blocks used during processing.

Power		Summary On-Chip
Total On-Chip Power:		0.079 W
Junction Temperature:		25,4 °C
Thermal Margin:		59,6 °C (11,8 W)
Effective θ_{JA} :		5,0 °C/W
Power supplied to off-chip devices:		0 W
Confidence level:		Low
Implemented Power Report		

Figure 8. The amount of current and performance spent during image processing on the FPGA Basys 3 board

This is a detailed description of the power used in my work. A current of 0.079 W was spent on everything. The transition temperature was 25.4 C. And the maximum operating temperature was 59.6 C.

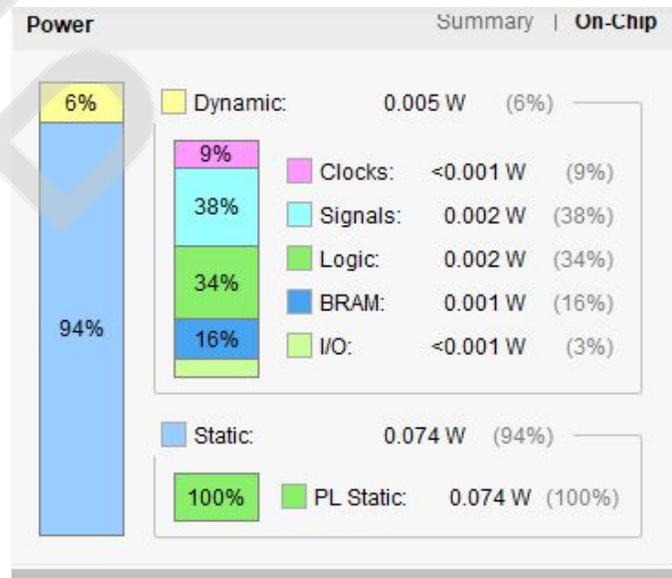


Figure 9. Graphic amount of power and performance spent during image processing on the FPGA Basys 3 panel

This is the amount of current in the chip. And the amount of current spent on time and signals is indicated.

Conclusion. With the help of Basys3 FPGA, image processing algorithms were implemented in Verilog. In this article, image processing operations were performed on the image transmitted by FPGA Basys-3, including operations related to the console. We send the transmitted image in binary form to the FPGA block RAM, and then, depending on the user's choice, perform some special processing applications, and then display it via a VGA display. To convert a given digital image to binary, we use Verilog as a hardware description language and python. Vivado software was used to do this. As a result, the processing time of the image on the computer and FPGA was calculated. And so it was made sure that image processing works quickly on the FPGA. Finally, the amount of memory spent on processing images was calculated. In addition, a current of 0.079 W was spent on processing. The transition temperature was 25.4 C. We can see that this is a very effective value for productivity.

REFERENCES

- [1] Zhou, H.; Machupalli, R.; Mandal, M. Efficient FPGA implementation of automatic nuclei detection in histopathology images. *J. Imaging* 2019.
- [2] Donald G. Bailey, Anoop S. Ambikumar. «Border Handling for 2D Transpose Filter Structures on an FPGA». School of Engineering and Advanced Technology, Massey University, Palmerston North 4442, New Zealand; 2018
- [3] Kevin Morris Cray Goes FPGA. Algorithm Acceleration in the New XD1. *FPGA and Programmable Logic Journal*. April 5, 2005.
- [4] Paulo Garcia, Deepayan Bhowmik, Robert Stewart, Greg Michaelson, Andrew Wallace. «Optimized Memory Allocation and Power Minimization for FPGA-Based Image Processing». Received: 19 November 2018; Accepted: 27 December 2018; Published: 1 January 2019
- [5] Aiman Badawi, Muhammad Bilal. «High-Level Synthesis of Online K-Means Clustering Hardware for a Real-Time Image Processing Pipeline». Received: 29 November 2018; Accepted: 7 March 2019; Published: 14 March 2019.
- [6] Lysakov K. F., Shadrin M. Y. SLSP – Special Processor for Image and Video Processing // *Proceedings of the IEEE International Siberian Conference On CONTROL AND COMMUNICATIONS SIBCON-2007*. Russia, Tomsk, April 20–21, 2007. P. 140–144.
- [7] Haonan Zhou, Raju Machupalli and Mrinal Mandal. «Efficient FPGA Implementation of Automatic Nuclei Detection in Histopathology Images». Received: 30 November 2018; Accepted: 11 January 2019; Published: 17 January 2019

- [8] Fahad Siddiqui, Sam Amiri, Umar Ibrahim Minhas , Tiantai Deng , Roger Woods, Karen Rafferty, Daniel Crookes. «FPGA-Based Processor Acceleration for Image Processing Applications». Received: 27 November 2018; Accepted: 7 January 2019; Published: 13 January 2019.
- [9] Devjataikin A. M., Lysakov K. F., Shadrin M. J. FPGA implementation of sub-pixel images matching algorithm // Proceedings of the Second IASTED International Multi-Conference AUTOMATION, CONTROL, AND APPLICATIONS (ACIT-ACA). Russia, Novosibirsk, June 20–24, 2005. P. 93–97.
- [10] Mohassin .M, Najeeb-Ud-Din Hakim. Review on Image Processing: FPGA Implementation perspective. International Journal of Innovative Research in Computer Science & Technology (IJIRCST), ISSN: 2347-5552, Volume-2, Issue-1, January 2014
- [11] Stefano Di Carlo, Giulio Gambardellay, Marco Indaco, Daniele Rolfof, Gabriele Tiotto, Paolo Prinetto, “An Area-Efficient 2-D Convolution Implementation on FPGA for Space Applications,” Proceedings of the IEEE 6th International Design and Test Workshop (IDT), Vol. 7, Issue 3, 2011.
- [12] Madhuri Gundam, Dimitrios Charalampidis, “Median Filter on FPGAs,” 44th IEEE Southeastern Symposium on System Theory , University of North Florida, Jacksonville, FL March 11-13, 2012.
- [13] Elmoncef Benrhouma, Meddeb Souad, Abdulqadir Alaqeeli, Hamid Amiri, “Study and Design of Median Filter,” SIDOP 2nd Workshop on Signal and Document Processing, 2012.
- [14] R.Arunmozhi, G.Mohan, “Implementation of Digital Image Morphological Algorithm on FPGA using Hardware Description Languages,” International Journal of Computer Applications, Vol. 57, No.5, pp 0975 – 8887, Nov. 2012.
- [15] Runbin Shi , Justin S.J. Wong and Hayden K.-H. So . «High-Throughput Line Buffer Microarchitecture for Arbitrary Sized Streaming Image Processing». Received: 21 January 2019; Accepted: 25 February 2019; Published: 6 March 2019

THE SYSTEM OF PHOTO, VIDEO RECORDING OF THE RAILWAY WAGON WEIGHING PROCESS

Authors: *Karalina Dubitskaya, Katsiaryna Bondar*

Advisor: *Denis Demenkovets*

Belarusian State University of Informatics and Radioelectronics (Belarus)

Abstract. *The problem of wagon weighing process is considered in the paper. Are analyzed the process of railway wagons weighing, the problems of the functioning of the automated system, and a description of the functions of the software. When implementing the weighing procedure, it is important to save the photo/video of the weighing process. Are presented the characteristics and differences of the existing systems. Principles of good weighing-machine are examined. The work describes the types of static and dynamic weights. The main part of the work is devoted to consideration, the system structure, and its structural scheme. The composition of the system and technical characteristics are described.*

Keywords: *scales, weighing process, video recording, automated system.*

I. INTRODUCTION

For proper operation of the rolling stock, traffic organization, and commercial calculations, it is of great importance to take account of the goods carried by rail. It is also important in the transport of hydrocarbons, liquefied automotive and household gases, and plays a significant role in determining their prices.

To ensure such an account, we need a railway weighing-machine with an automated system and the corresponding software. An electromechanical weighing-machine that converts the effect of gravity into an electrical signal is called a tensometric weighing-machine [1].

When implementing the weighing procedure, it is important to fix (photo- or video-) the weighing process with the help of the special equipment. In this precis, the organization of such a system is presented.

II. LITERATURE ANALYSIS

2.1. Overview of the existing systems

The electronic wagon scales are divided into two types: for static weighing and for weighing in motion. When choosing weights, it is important to determine which of the weighing methods is most convenient and optimal for the enterprise.

Wagon scales for static weighing are the most accurate and are the most massive. Static railway scales are intended for weighing in a static position of cars. Scales for dynamic weighing are designed for weighing in the movement of wagons and cisterns.

If there is a need for two scales: dynamic, for weighing and static, to save space and facilities, it is possible to produce two scales in one installation frame. These combined scales have the advantages of both types: they allow you to quickly

weigh the train in motion in the dynamic mode, and if necessary, more accurate results, in static mode.

According to the method of installation, rail scales are divided into two types: foundation and foundationless. Foundation wagon scales are installed on a concrete foundation. The non-foundation scales are installed on the prism of the railway track, then they are filled with crushed stone. Preparatory works are not required, they are installed within one to two working days. The warranty period for the rail scales is 2 years [5].

2.2. Principles of good weighing-machine

Scales wagon must have a certificate of entry in the register of measuring instruments. Having a certificate means a serious approach to production. It gives a guarantee of compliance with the declared technical characteristics.

Weighing wagons should be easy to assemble, installation should not take more than 3 days. The total cost of work with all materials and the performance of the technical conditions can reach the value of the scales themselves and even exceed their cost.

Digital transmission of data. Scales with digital data transmission eliminate interference from some operating equipment and can transmit the signal over long distances.

Scales should be unpretentious in service.

Scales wagons should be able not only to measure the weight but also to determine the longitudinal and transverse displacement of the center of gravity of the wagon, to avoid uneven loading and as a consequence of tipping the car while driving.

Each sensor must have a separate channel. That allows you to diagnose the balance. On low-cost devices, this can not be done, as a rule, unscrupulous manufacturers use the cheapest equipment, where the sensors are combined into a single channel.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

3.1 Structure of the system and the structural scheme

For the organization of weighing of wagons with photo and video recording the following equipment is necessary:

- IP video cameras (Cam 1 and Cam 2);
- Information (LED) board;
- Ethernet Switch;
- weight measuring indicator (weighing device);
- personal computer.

The structural diagram of the system illustrating the interaction of these components is shown in Figure 1.

All components of the system are connected to a personal computer through standard system interfaces and protocols. The names and devices are displayed in Table 1.

Table 1 - Table of interfaces of the system

Device	Communication interface with PC
Video cameras	Ethernet, IP
Informational board	Ethernet, UDP
Weighing device	RS-232

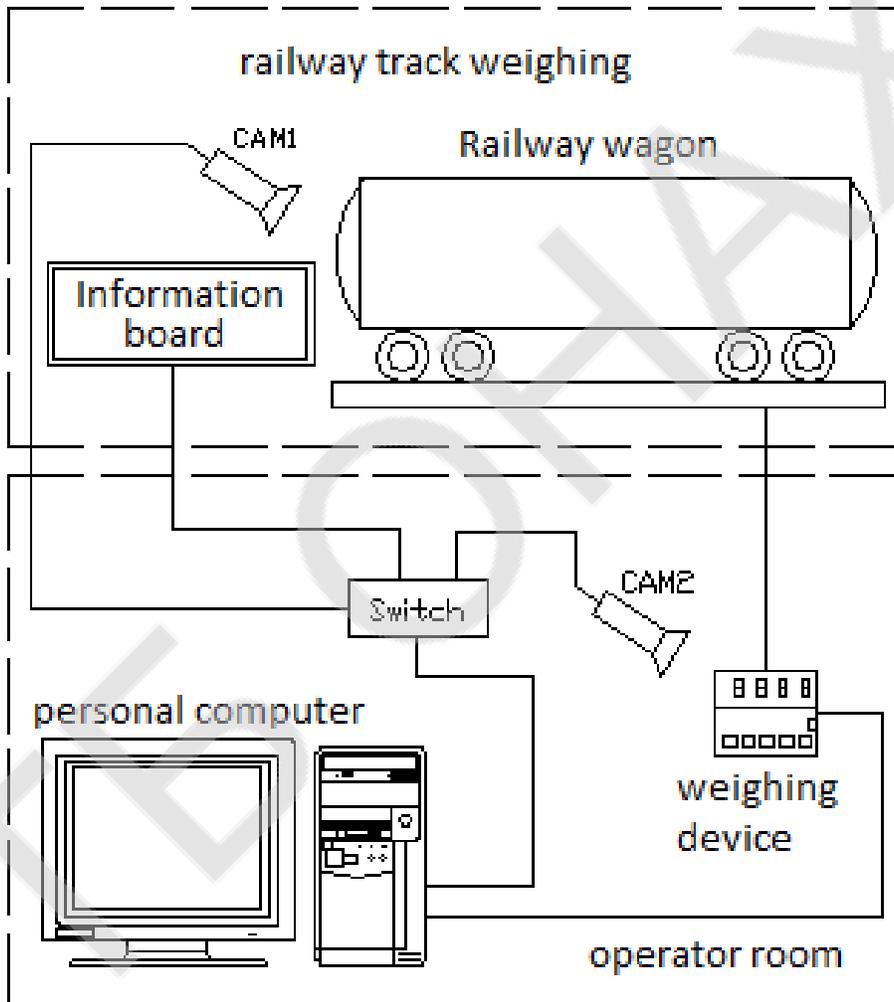


Fig. 1. Block diagram of the system video fixing

The main issues that arise when creating such a system are:

- when installing the car on the measuring platform, the maximum speed limit is not always observed;
- great increase in the time of stabilization of the weight of half-empty wagons with liquid cargo (filling less than 70 percent);

- Impossibility of direct visualization of the process of weighing the car due to significant distance of the operator's room from the weighing platform (more than 400 meters);
- lack of feedback on the information (LED) board, the inability to see what is displayed on it;
- the inability to correctly read the numbers of the wagons, due to the often occurring contamination, different background colors, a large number of other technical records on the wagon, a certain location of the record number of the wagon.

Most of these problems can be solved with the photo and video fixation of not only the weighing process itself but also the entire process of the weighing. For example, recording a video or creating a series of photos.

The problem of determining the number of the wagon can be solved as follows. Since the image of the railway wagon has a known resolution of 1920x1080, it allows us to apply the algorithm of number recognition for certain areas, even when the number field occupies only part of the image.

IV. RESULTS

The developed software not only maintains reports and displays the current weight, but also implements photo and video-recording of the weighing process, allows weighing without the operator's participation.

The software allows recording the weighing process results both in automatic and manual modes. An example of the type of software is shown in Figure 2.

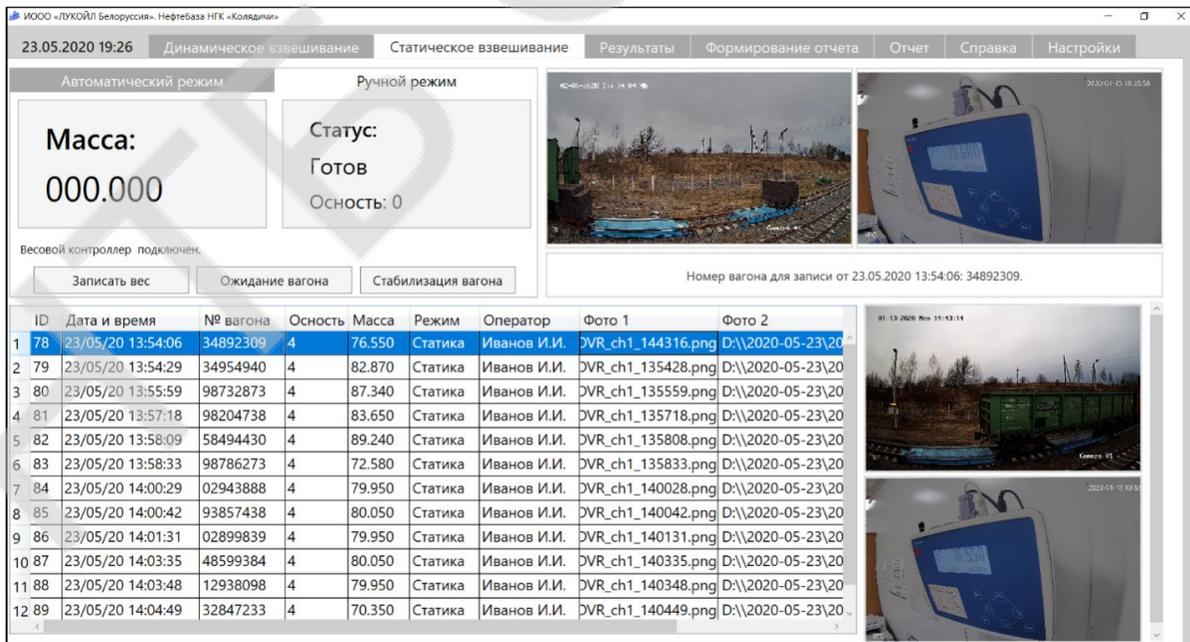


Fig. 2. Software of weighing system

The software has an intuitive interface with a minimum number of control components. It is implemented taking into account the requirements for ease of use [9].

Technical features and capabilities of the software and systems:

- registration of complete information on all weighing of wagons;
- support for work with the data received and stored;
- display and analysis of weighing data in an interactive (real) mode;
- measuring the mass of the empty car (tare) and automatic calculation of the mass of the goods carried;
- creation of an entry (information card) for each weighing with the following information:
 - number of weighing, date and time of weighing, number of the car;
 - mass of the container, gross, net, type of cargo;
 - organization shipper;
 - comparison of the photo image of the load measuring indicator and the car with the information card;
 - generation of specific reports.

Figures 3-4 shows the general view of the installed scales.



Fig. 3. Calibration of scales of a weight-measuring wagon



Fig. 4. General view of the installed railway scales

V. CONCLUSIONS

These rail scales and software proved to be sufficiently reliable and functional. It not only maintains reports and displays the current weight, but also implements photo and video-recording of the weighing process, allows weighing without the operator's participation since all the necessary information for the wagon compiler is displayed on the LED display board.

The capabilities of the developed system and software are not inferior to the best analogs and models in terms of their characteristics and functionality [2-6].

VI. REFERENCES

- The Interstate Council for Standardization, Metrology and Certification of the Commonwealth of Independence States (CIS). (2011). *State system for ensuring the uniformity of measurements. Non-automatic weighing instruments. Part 1. Metrological and technical requirements. Tests* (GOST IOIML R 76-1-2011).
<http://docs.cntd.ru/document/1200096305>
- Nais Volgograd. (2017). *Software for truck and wagon scales from Nais-Volgograd*.
<http://www.etalonves.ru/programs>
- VesTehnoPribor. (2019). *Wagon scales*.
<http://vtpr.by/index.php/katalog-vesov/zheleznodorozhnye-vagonnye-vesy>
- Mettler-Toledo Ltd. (2020). *Highly Accurate Static Weighing*.
https://www.mt.com/int/en/home/products/Transport_and_Logistics_Solutions/rail_scales/static_rail_scale.html
- Sakha-prom. (2020). *Wagon scales: static and dynamic*.
<https://sakha-prom.by/weight/weight-sd.html>
- Technowag Ltd. (2019). *UniScale v1.19 software*.
<https://technowag.com.ua/en/product/programma-uniscale-v1-1/>

INFORMATION AND ANALYTICAL RESOURCE OF THE SCIENTIFIC JOURNAL " PROBLEMS OF INFOCOMMUNICATIONS»

Authors: *Leonid Lazuta*

Supervisor: *Olga Ryabychina*

Belarusian State Academy of Communications (Belarus)

Abstract. *The article is dedicated to the development of an electronic information-analytical resource for the automating evaluation process, selection and publication of articles in the scientific journal "Problems of infocommunications".*

Keywords: *information-analytical resource, scientific journal, web-development, information system.*

INTRODUCTION

Since 2015 the scientific journal "Problems of infocommunications" has been approved by "Belarusian state academy of communications", which is intended for publishing materials of scientific and practical studies of researchers, teaching staff, students, graduate students and postgraduates, as well as specialists working in the field of telecommunications and postal services.

The journal publishes materials, which are related to the following fields of knowledge:

1. Digital Communications
2. Computing Systems and Networks
3. Information Security
4. Communication Technologies
5. Radio Engineering and Electronics
6. Cyberphysical Systems
7. Economics and Management in the Telecommunications Industry
8. Postal Services.

Currently, there is a need for information systems, which allow to automate not only routine operations, but also the process of selecting and reviewing articles in scientific journals. Therefore, the relevance of the development and implementation of information-analytical systems is beyond doubt. The purpose of our work is to develop an information-analytical resource of the scientific journal "Problems of Infocommunications".

OBJECT, SUBJECT, AND METHODS OF RESEARCH

The electronic resource of the scientific journal "Problems of Infocommunications" allows to automate and visualize the process of accepting, reviewing and selecting the articles for further publication in the scientific journal "Problems of Infocommunications".

The information-analytical resource of the scientific journal "Problems of Infocommunications" has been developed to implement the following functions:

- creation and maintenance of a database of articles, authors, and reviewers;

- registration/authorization of authors/reviewers;

Table 1. Users' permissions

Users' permissions	Auth or	Review er	Edit or	Administ rator
General				
Authorization	+	+	+	+
Identity change	+	+	+	+
Logout	+	+	+	+
Account deletion	+	+	+	+
Contacting technical support	+	+	+	+
Communication with developers	-	-	+	+
Reviewer				
Request for the "Reviewer" role	+	-	-	-
Approval of the application for the "Reviewer" role	-	-	-	+
Demoting a user with the "Reviewer" role	-	-	-	+
Viewing users with the "Reviewer" role	-	-	-	+
Assigning a reviewer to an article	-	-	-	+
Article review	-	+	-	+
Article				
Article placement	+	+	+	+
Amending article	+	+	+	+
Deleting an article	+	+	+	+
Viewing my articles	+	+	+	+
Viewing articles on reviews	-	+	+	+
Viewing articles	-	-	+	+
Viewing all articles by publication code	-	-	+	+
Article assessment	-	-	+	+
Approval of an article for publication	-	-	-	+
Refusal to publishing the article	-	-	-	+
Notifications				
Notifications via the internal service	+	+	+	+
Notifications via Telegram	+	+	+	+
Categories and subcategories				
Category adding	-	-	+	+
Subcategory adding	-	-	+	+
Category editing	-	-	+	+
Subcategory editing	-	-	+	+
Category removal	-	-	-	+
Subcategory removal	-	-	-	+

- submission of articles;

- review of articles;
- feedback.

In the project users are divided by roles. The most important role is the "Administrator" role, which has all the functionality and rights inside the system.

The newly registered user is assigned the "Author" role.

The assignment of the "Reviewer" role is carried out by submitting an application in the required section and approving it for the reviewer role by a user with the "Administrator" role. A user with the "Reviewer" role can be approved or demoted by a user with the "Administrator" role only.

The "Editor" and the "Administrator" roles cannot be assigned with the help of the functionality of the resource. There is an individual instruction for assignment, which is carried out via the software support service of the resource.

All users' permissions are shown in table 1.

The user of the resource has the right to change personal data, track sessions and terminate the account activity, through the personal account.

The user is given the option to view the "User Manual".

During authorization, the user gets to the page of the electronic resource presented on Figure 1.

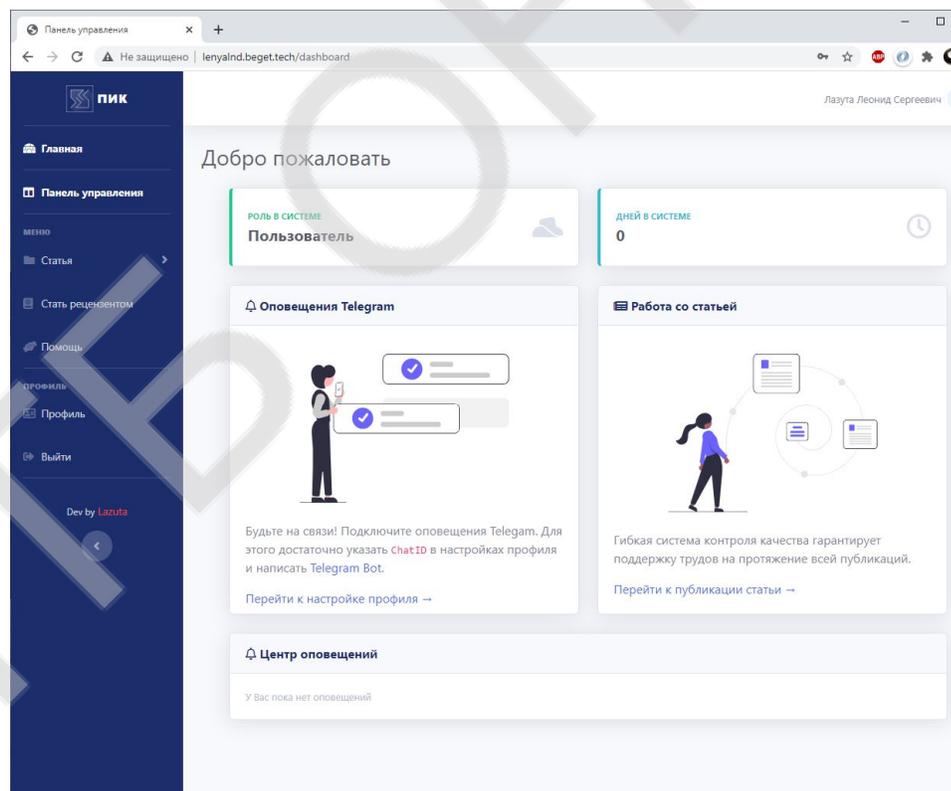


Figure. 1. Control panel

The electronic resource of the scientific journal "Problems of Infocommunications" is designed on the basis of the Laravel 8 Framework. The server part is implemented on PHP and includes the use of the Model-View-

Controller design pattern, internal and external notification systems via Telegram APIs.

The security of personal data is ensured by the encryption of confidential data and the use of the enhanced security protocol https. All the data is stored in MySQL database.

The client part is written in JavaScript, HTML5, CSS using Bootstrap 5 components and is based on Laravel Blade Comments and Laravel Jetstream technologies, which allow to organize a component approach to the design of the visual elements of the project.

The electronic resource of the scientific journal "Problems of Infocommunications" has a Telegram Chat Bot, through which the process of an external notification system is carried out. Telegram Chat Bot is written in Ruby using the Telegram Bot Ruby library.

For the correct work of the electronic resource, the following software requirements are needed:

- server part: Apache 2.4 web-server; PHP 5.6.30; MySQL 5.5.58 DBMS.
- client part: any of the following browsers (latest versions) with the JavaScript interpreter enabled: Mozilla Firefox; Opera; Google Chrome, Safari.

CONCLUSION

Thus, the information-analytical resource of the scientific journal "Problems of Infocommunications" has been developed, which allows you to automate the work of the Academy staff in the process of selecting and publishing articles in the scientific journal, and provides authors with a convenient tool for submitting and reviewing articles.

So far, the electronic resource of the scientific journal "Problems of Infocommunications" has been launched into the stage of pilot operation.

INFORMATION AND COMMUNICATION TECHNOLOGIES AS A MEANS OF ORGANIZING TRAINING OF FUTURE TECHNICAL SPECIALISTS

Authors: *Dmytro Tsarenko, Oleksandra Greenberg*

Advisors: *Volodymyr Umanets, Liudmyla Shevchenko*

Vinnytsia Mikhaïlo Kotsiubynskyi State Pedagogical University, (Ukraine)

Abstract: *We have to determine the theoretical foundations of the use of ICT in the training of future technical professionals. information and communication technologies include a set of methods, tools for finding, storing, processing, presenting and transmitting any kind of information using personal computers and the Internet.*

Learning with the help of ICT The effectiveness of the implementation of ICT tools in the training of future technical specialists, first of all, depends on the material and technical base of HEI, which should include the computer network of the university, local computer networks of faculties and departments, as well as appropriate software.

is one of the most promising means of professionalism of future qualified technical specialists, as it allows future technical specialists to obtain the necessary data, differentiate and separate educational material, comprehensively perceive new information, repeat and consolidate knowledge and achieve self-realization. results.

Computer tests to control and test the knowledge and skills of future technical specialists in the discipline of «Applied Programming» were developed using the program MyTestX.

The main benefits of computer testing are that:

- *the teacher has the opportunity to objectively assess the applicant for higher education, as the control of knowledge is carried out by the program;*
- *every graduate has the opportunity to assess their own knowledge;*
- *the quality of preparation of higher education students for classes increases and their activity and organization during independent processing of material increases;*
- *saves teacher time;*
- *the level of openness of the testing process increases.*

Keywords: *HEI, ICT, Technical profile, Information security, MyTest, Internet*

I. INTRODUCTION

Nowadays, information and communication technologies (ICTs) have become a powerful force in the transformation of social life and innovative development, and the widespread use of computer technologies in education is gradually, but quite confidently, becoming an essential part of the educational process.

The future of higher technical education applicants will depend, first of all, on how well they will be able to use and use information technology in their future professional activities, how well they will be able to accomplish their tasks competently and with new approaches.

Of course, the use of the latest technologies in their work practices will affect their career prospects.

Qualitative training of future specialists in the technical profile in higher education institutions (HEIs) is possible provided ICT is introduced into the educational process. The use of ICT is the norm in the training of technical professionals.

Another important step in the training of future specialists in the technical profile is the control and testing of knowledge and skills, which allows to obtain a certain quantitative assessment of the obtained learning outcomes.

Knowledge control and assessment is an integral structural component of the educational process. Based on the logic of the learning process, it is, on the one hand, the final component of mastering the content block, and on the other, a kind of feedback in the system of educational activity of the individual.

Due to the work of teachers on the credit-modular system, there is a problem of current modular control of knowledge of higher education applicants and their assessment on the ECTS scale. Computer-aided testing is one of the most effective modern tools for measuring the academic achievement of higher education students.

The aim of the study: to explore the theoretical foundations of the use of ICT tools and to develop a means of controlling and testing knowledge to train future technical professionals.

Object of study: professional training of future specialists of technical profile.

Subject of study: the use of information and communication technologies in the preparation of future specialists of the technical profile.

Hypothesis of Study: Increasing the level of knowledge and skills of future specialists in the technical profile is possible through the use of information and communication technologies.

Objectives of the study:

1. To determine the theoretical basis for the use of ICT in the preparation of future specialists in the technical profile;
2. Develop a tool to control the knowledge of future specialists in the technical profile;
3. Experimentally test the effectiveness of the use of ICT in the preparation of future specialists in the technical profile.

Research methods:

- theoretical: analysis of scientific and psychological sources of information, which allowed to generalize and systematize scientists' views on the problem, study, systematization and theoretical analysis of literature and Internet sources;

- empirical: testing, discussions with teachers and higher education applicants, pedagogical experiment to test the validity of the working hypothesis;

- methods of mathematical statistics: at the stage of generalization, processing and interpretation of the results obtained during the experiment and determining their accuracy.

Theoretical basis of the study form the basic philosophical and psychological-pedagogical provisions on the leading role of information and communication technologies in the preparation of future specialists of technical profile.

Scientific novelty and theoretical significance of the study the first is to identify and substantiate the use of ICT tools in the preparation of future

professionals in the technical profile and the method of implementation of ICT tools in the process of training future professionals in the technical profile.

The practical significance of the results obtained the job is to develop a tool to control and test the knowledge and skills of future specialists in the technical profile.

II. LITERATURE AND ANALYSIS

According to the academician of the National Academy of Pedagogical Sciences of Ukraine Gurevich RS the application of ICT in the educational process allows [3]:

- save study time;
- develop important life skills and functional life competencies;
- carry out mutual training between the teacher and the higher education applicant;
- to promote the development of creative thinking;
- Promote better presentation, memorization and learning of educational material through multimedia clarity;
- to destroy stereotypes;
- develop communication skills;
- to train everyone at their level;
- develop cooperation skills;
- make cross-curricular links;
- promote the development of computer technologies;
- to form an active cognitive activity of higher education applicants;
- makes you feel important and important, promotes the self-esteem of teachers and higher education graduates.

A similar approach is found in the scientific works of Bespalov PV, Bykov V. Yu., Zhaldak MI, Kademii Yu.

Professor Robert I.V. proposes to classify ICT tools by way of use in professional activity, namely [5]:

- as a learning tool that enhances the teaching process;
- as a tool for knowledge of the surrounding reality and self-knowledge;
- as a means of developing the personality of the educational recipient;
- as an object of study in the course of mastering computer science;
- as a means of information and methodological support and management of the educational process;
- as a means of communication;
- as a means of automating the processing of experiment results and control;
- as a means of automation of processes of control, correction, results of educational activity, testing and psychodiagnostics;
- as a means of organizing intellectual leisure.

2.1. Information and communication technologies: concepts, nature, types

Modern information technology is one of the most important and sustainable tendencies in the development of the world educational process. In recent years,

computer education and other ICT tools have become increasingly used in most educational disciplines in domestic educational institutions.

Informatization of society significantly influenced the process of knowledge acquisition. ICTs allow us to intensify the educational process, increase the speed of perception, understanding and depth of learning of vast masses of knowledge [1].

Information and communication technologies - a set of methods, tools for searching, storing, processing, presenting and transmitting graphic, text, digital, audio and video data on the basis of personal computers (PCs), computer networks and communications [2].

Today, the term «information and communication technologies» is also used to refer to the integration (convergence) of audiovisual and telephone networks with computer networks, and in educational institutions the term is used as a general covering the field of information systems and technologies for organizational level, software development and computer systems.

Information and communication technologies have become an integral part of the modern world, which determine the further economic and social development of mankind.

The use of ICT in the educational process is not accompanied by the replacement of «paper» media with electronic ones. They make it possible to combine the process of studying, generalizing, securing and controlling the acquisition of higher education material by the applicants. ICTs also allow individualization of the educational process.

The use of computer-based tests (CT) and diagnostic systems will allow the teacher to obtain an objective picture of the level of mastering the material studied by all higher education students in a short time and to correct it in a timely manner. It is possible to choose the level of complexity of the task for a particular higher education applicant. It is important for higher education students that immediately after completing the test (when this information has not yet lost its relevance), it receives an objective result indicating errors, which is not possible, for example, in an oral poll [7].

2.2. Analysis of international experience in the preparation of technical profile specialists

The most advanced national training systems for future technical professionals (including information security (IT) professionals) have been established in the USA, Germany, the United Kingdom, France and Austria, which is determined not only by their economies' needs, the development of information infrastructure and, accordingly, the information security system. geopolitical and military factors.

In Germany, HEI can independently establish compulsory (normative) subjects for study. For example, the general normative disciplines in the field of IB include: «Introduction to programming», «Fundamentals of physics and mathematics», «Theoretical informatics», «Analysis and numerical methods», «Software development», «Databases and control systems», «Information Security», «Data Structures and Algorithms». Regulatory specialties

include: Information Security Management, Electronic Keys, Mobile Security, Applied Cryptography, and more.

At the same time, higher education students can study different disciplines of their choice. As a rule, at the end of studies, the higher education student chooses one of the optional areas that contains several specialized courses (Computer Hacking, Internet Information Protection, etc.) that will determine his specialization.

As a result of an analysis of the specialties of HEI, it was determined that in the UK, training of future specialists in the field of IB is carried out in the following areas:

- computer security;
- legislation in the field of information systems;
- investigation of computer incidents;
- information technology security;
- security of computer networks;
- information security management.

But the most common and sought-after area of interest is the investigation of computer incidents.

The main disciplines of professional direction include: «Fundamentals of Computer Incident Investigation», «Computer Network Protection», «Information Systems Protection», «Programming Technologies», «Information and Communication Systems Security», «Information Security Management», «Legal and regulatory support for information security», «Computer hacking» and others.

A distinctive feature of the UK from other countries is that only in this country are higher education majors able to earn a master's degree in information technology.

Among the methods used in the educational process should be distinguished method «reverse». For example, in one of Scotland's universities, higher education graduates are taught to «hack computers».

The «Computer Hacking» course is one of the main stages in the training of future IT professionals. It is created on the basis of systematization and generalization of work of modern hackers. Higher education providers are exploring banking network penetration techniques and techniques for deciphering complex codes and more.

According to an analysis of HEI educational programs, in France, the training of future IS professionals is largely based on the study of information systems audit, network security and cryptography.

In general, the training of future specialists in IB is carried out in such areas as:

- information security management;
- audit information systems;
- security of information systems;
- network security;
- cryptography, etc.

The main disciplines of professional direction include: «Information Security Management», «Programming Technologies», «Fundamentals of cryptography», «Cryptographic protection of information», «Protection of information and

communication systems», «Protection of computer networks», «Databases», Audit Systems, etc.

A distinctive feature of France from other countries is that in this country applicants for higher education have the opportunity to get a thorough mathematical education, which is an integral part of the study of cryptography and computer security.

The most well-known HEI, which prepares future specialists in the technical profile in Austria, is the Vienna Technical University (Access mode: <https://albioneducation.com/ua/vienna-university-of-technology-tu-wien-avstriya/>). It is one of the three most prestigious universities in Austria, cooperates with the best technical HEIs in the world, and most importantly - provides a quality educational base, on the basis of which has grown "not one generation of famous entrepreneurs and reputable scientists.

As a result of the analysis of educational and vocational programs of HEI, it was determined that the Technical University of Vienna offers future specialists of technical profile training in such specialties as:

- informatics;
- economic informatics;
- technical informatics;
- medical informatics;
- media informatics;
- software engineering;
- systems engineering;
- information management.

The main disciplines of professional direction include: «Software development», «Databases», «Applied programming», «Data structures and algorithms» and others.

Unlike most Austrian universities, the Vienna University of Technology pays great attention to practical training. Higher education applicants are trained in industrial enterprises, participate in scientific development, work with orders of existing enterprises.

Higher education in Austria is different from higher education in other countries of the world, because in this country there are no summaries, daily lectures, seminars and tests. Higher education students study most of the material individually, and classes take only 2-3 days a week. Studying technical majors is combined with internships at technology companies, and one of the semesters is required to be outsourced to an international internship program for higher education applicants. This means that in addition to Austria, you can see life in another country and gain more experience.

The most well-known university that train future technical specialists in Poland are: Warsaw Polytechnic University (Access mode: <https://www.pw.edu.pl/engpw>), Wrocław Polytechnic University (Access mode: <http://pwr.edu.pl/en/>), Tadeusz Kosciuszko Polytechnic University of Krakow (Access mode: <https://www.pk.edu.pl/index.php?lang=en>) and the Lublin Polytechnic University (Access mode: <http://www.pollub.pl/>).

In general, the training of future specialists in the technical profile in these HEIs is carried out in the following areas:

- information security;
- robotics;
- computer control systems;
- information systems in automation;
- engineering;
- electronics;
- telecommunications, etc.

The main disciplines of professional direction include: «Fundamentals of Physics and Mathematics», «Information Systems Protection», «Information Security Management», «Databases and Systems» and others.

The main emphasis in the preparation of future specialists of technical profile is on:

- creativity that changes the trajectory of the future;
- professionalism and hard skills.

A special feature of the training in Poland is cooperation with HEI of the leading countries of the world, such as: USA, Canada, China, Japan, Austria, Germany, Great Britain, Australia, France, Italy, Denmark, etc.

In the United States, great attention is also paid to the training of future IS professionals. The most popular and popular training programs in this country are those related to computer incident investigations, information security, computer security, and computer network security.

A distinctive feature of US education is the «flexibility» of the educational process, focused on the success of each higher education student in the formation of professional competence, accessibility to higher education, in particular. This «flexibility» consists in the formation of a personal curriculum, that is, a schedule of study of disciplines taking into account personal intellectual abilities, available experience, professional inclinations and preferences. At the same time, the number of regulatory disciplines in leading HEI is much smaller than the educational disciplines of the choice of higher education applicants, which allows each individual to plan his or her own system of training and professional development and lifelong learning more effectively. In addition, HEI implements a scheme of individual mentoring (Student Mentor) - assistance assigned to the applicant for higher education contact person in the planning and correction of the organization of training on an individual trajectory, taking into account the results of career guidance and wishes of the applicant of higher education in the distribution of their physical load own comfort during training.

In addition, the US recommends an online e-learning system for prospective IS specialists during bachelor's and master's degree programs, as well as postgraduate education.

The major disciplines taught to future IS professionals include: «Architecture and Security Models», «Data Security», «IT Operations Security», «Operating Systems Security», «Computer Security», «Network Security», «Network Security Management», «Cryptography», «Physical Information Security», «Information Security Risk Management», «Business Continuity» and «Disaster Recovery» «Information Security Audit», «IT Law and Ethics», «Cyber Law and Privacy privacy in the age of numbers of these technologies »[9].

For clarity, we present all the data in the Annex A, Table 1.2.

Therefore, as a result of the analysis of international experience, we can say that the training of future specialists in the technical profile (including specialists in IS) in Ukraine is carried out on the basis of generally accepted standards.

1.1 Design and implementation of ICT tools in the preparation of technical profiles

Explanation of theoretical principles of teaching technical disciplines by means of ICT is reduced to actual directions, which play a significant place in the development of educational process of applicants for higher education of technical specialties [10, p. 29].

By integrating ICTs into the educational process, depending on their technical capabilities, the higher education acquirer has access to a variety of broader information, which encourages his or her independent work. As evidenced by pedagogical practice, proper organization of independent work helps to activate the learning process [11, p. 45]. Moreover, independence in gaining more knowledge in practical classes using ICT hardware and software intensifies the formation of psychological, theoretical and practical readiness of higher education applicants for self-education, self-improvement. It is clear that the ability to self-education is an integral part of quality professional training of a specialist [12, p. 27].

The quality of training of future specialists in the technical profile, according to Professor Spivakovsky O.V., directly depends on the quality of education provided to him, and the quality of education - on the relevance of content and adequacy of pedagogical technologies. In the context of accumulating a large amount of information, it is natural to change the education system from “lifelong education” to understanding the need and possibility of “lifelong education”. Informatization of education is aimed at finding the forms and content of the educational process, the introduction of computer-based teaching methods, which gives the opportunity to solve problems of higher education in the light of world requirements, to organize educational and cognitive activity of students and to form in the future professionals the experience of independent search for knowledge and their application in new conditions, to gain experience of creative activity [13, p. 76].

Information security specialists must possess certain general and professional qualities [14, p. 4]. The quality data are shown in Annex A, Table 1.3.

Effective implementation of ICT tools in the educational process is not possible without an adequate material and technical base. The HEI logistics base includes the university's computer network, local computer networks of faculties and departments. Laboratory and practical classes in the disciplines that involve the use of information technology are conducted in computer classes, usually equipped with modern computers. Most of the HEIs that provide technical profile training report free access to the Internet. For lecture classes, the department creates multimedia classrooms using a multimedia projector and a multimedia presentation board (usually created at MS Power Point), which helps higher educators to better perceive learning material, as it provides a visual and conducive to compelling material, charts, tables, etc. are also facilitated. Presentations can also be created not only to be displayed on a large screen for a student group in an auditorium, but they can

also be used for individual viewing on a computer and can be used both for teaching with the direct participation of the teacher and without his participation (for example, while performing the required amount of independent work provided by the curriculum of the discipline) [12, p. 28].

Also, appropriate software is required for effective implementation of the ICT education process, namely [12, p. 29]:

- operating systems and their administration tools;
- integrated software development environments;
- database management systems;
- CASE-software design tools;
- CAD-systems;
- computer graphics software products;
- office software;
- packages of mathematical and statistical applications;
- WEB technologies and etc.

ICT tools enable higher education providers to access unconventional sources of information - e-textbooks, teaching websites, cloud technologies, web services, etc., all of which make it possible to increase the effectiveness of cognitive self-development and provide new opportunities for creative growth of higher education applicants which contribute to the enrichment of the educational process with an emotional-visual form of cognition. However, it should be remembered that in teaching subjects using ICT tools, it is the teacher who manages the process and determines the duration of the use of technical means [12, p. 29].

III. DESIGN OF A COMPLEX OF ELECTRONIC EDUCATIONAL RESOURCES OF TRAINING IN PREPARATION OF TECHNICAL PROFESSIONALS

3.1 General requirements for complexes of electronic educational resources of training

The process of formation of the future qualified specialist of technical profile is based on the fact that a lot of information needs to be processed by the higher education qualifier, so the question of introducing electronic educational resources into the educational process arises.

The Electronic Educational Resource (EER) is a logically complete block of educational and methodological support necessary for the effective organization of educational and educational process, in part concerning its provision of quality educational and methodological materials [15].

The purpose of creating an EER is to modernize education, to substantially fill the educational space, to ensure equal access of the educational process participants to quality educational and teaching materials regardless of their place of residence and the form of training created on the basis of information and communication technologies [16].

According to the regulations on the procedure for granting the electronic educational resource the status of VSPU publication [17], the main types of EER include: electronic document, electronic publication, electronic analogue of printed edition, electronic didactic demonstration materials, information system, computer test, electronic dictionary, electronic reference book, e-tutorial, e-textbook, electronic methodological materials, electronic resources depository, electronic laboratory workshop, electronic library of digital objects and a distance learning course. A detailed description of each species is given in Annex B, Table 2.1.

Functionally, the EER is divided into [17]:

- educational and methodological EER (curricula, work programs of disciplines, developed in accordance with the curricula);
- methodological EER (guidelines, methodical manuals, guidelines for the study of a separate course and guidance on project work, thematic plans);
- EER training (online textbooks and tutorials);
- Auxiliary EERs (collections of documents and materials, directories, indexes of scientific and educational literature, scientific publications of teachers, conference materials, electronic directories, dictionaries, encyclopedias);
- EER for knowledge quality control (testing programs, test banks and coursework, and other EERs that provide for quality control of knowledge).

According to the order of the Ministry of Education and Science of Ukraine [15], the main requirements for EER are:

- functionality;
- safety;
- reliability of functioning;
- user-friendly;
- cross-platforming;
- compliance with the principles of implementation of the principles of the state policy of digital development;
- compliance with the laws of Ukraine on copyright protection;
- Compliance with International Standards (Experience API, etc.).

To summarize, we can conclude that ESDs help to systematically submit teaching materials and make them more accessible to higher education applicant.

3.2 Creating computer tests to train technical profile professionals

The introduction of ICTs into the learning process facilitates their penetration into the control process as an important and integral element of the learning process. The use of ICT also contributes to changing goals, content of training, including control, which causes the emergence of new methods, tools and organizational forms of learning and control. This, in turn, led to the transition of standard (blank) testing to computer testing [18].

The term «test» comes from the English word «test» and translates as a test or test. The test is a standard form task, the performance of which helps to identify certain knowledge, skills, abilities of higher education applicants and is determined by the following characteristics [19]:

- relative simplicity of procedures and equipment, direct fixation of results;
- the ability to use both individually and for the group;
- ease of processing;
- brevity.

Today, there is no institution of higher education that, to one degree or another, does not apply test methods to determine the level of knowledge of the applicant for higher education. For this purpose, special software containing a module for computer testing is used [20].

Computer Testing is an automated test based on specialized computer programs. It is used in conducting current, boundary and final control of knowledge of higher education applicants, in checking residual knowledge and in passing exam grades in relevant disciplines [21].

There are several types of computer testing, namely:

- entrance testing from a discipline;
- ongoing testing in the discipline;
- control module testing in the discipline;
- control module testing in the discipline;
- state testing certification testing.

Incoming and current computer tests are conducted during scheduled classes and are supervised by a teacher, and computer based computer tests are conducted outside scheduled scheduled training classes [22].

Computer testing is carried out in the form of an independent dialogue of the higher education student from the PC, in the presence of the teacher, with the possibility of saving the test results.

Computer-based testing is one of the most optimal means of control, which satisfies the requirements of objectivity of the obtained assessment, quality of the control process and has a positive impact on the motivation, interest of higher education applicants in the learning process as a whole [23].

The use of computer-based testing is an effective and up-to-date method of knowledge testing, which saves teacher time, arouses the interest of higher education applicants, encourages them to study the material qualitatively, and allows for an objective assessment. In addition, the quality of preparation of higher education students for the classes increases and their activity and organization during the independent processing of the material increases [24].

And:

- the teacher has the opportunity to objectively evaluate the applicant for higher education, since knowledge control is carried out by the program;
- every higher education student has the opportunity to evaluate their own knowledge;
- higher education students do not have the opportunity to use the supporting literature when answering because there is limited time for passing tests.

Compared to traditional testing, computer testing has several advantages that allow it [18]:

- use more sophisticated methods and algorithms to control and evaluate the knowledge of higher education applicants;

- use your computer's multimedia capabilities in test tasks;
- reduce the costs of organizing and conducting testing;
- reduce the time of testing a large amount of training material in a large group of respondents;
- get objective estimates with the exclusion of the human factor;
- increase the openness of the testing process.

The main component of any testing system is test tasks. The test task is a clear and clear task for the subject area, which requires a uniquely conditioned answer or a certain algorithm of actions, which together with the answer expresses the conformity (inconsistency) of knowledge, skills, skills tested by the selected criteria.

Computer tests to monitor and test the knowledge of future technical profile professionals in the Applied Programming discipline were developed by MyTestX.

MyTestX is a system of programs (Student Testing Program, Test Editor, and Results Log) for creating and conducting computer-based testing, collection and analysis of results, and grading on a test scale.

The system consists of three main modules, namely:

- MyTestEditor (test editor) - used to create the test (Annex B, Fig. 2.1);
- MyTestStudent (testing module) - used directly during testing (Annex B, Fig. 2.2);
- MyTestServer (test log) - can only be used when connected to a LAN, it generates a test result log.

MyTestX software supports four testing modes, namely: training, penalty, free and monopoly.

In training mode, the test taker displays his error messages, may be explained to the task.

In the penalty mode, points are deducted for incorrect answers, you can skip tasks (points are not added or removed).

In free mode, the test subject can answer questions in any sequence, go (return) to any question on their own.

In monopoly mode, the program window occupies the entire screen and cannot be minimized.

MyTestX works with such types of tasks as (Annex B, Fig. 2.3):

- 1) single choice;
- 2) multiple choice;
- 3) establishing a sequence;
- 4) establishing a compliance;
- 5) indication of the truth or falsity of statements;
- 6) choosing a place in the image;
- 7) enter the number manually;
- 8) enter text manually;
- 9) permutation of letters.

In our case, we used only the first 5 types of test tasks.

A single choice involves choosing one correct answer from several proposed. An example of a task with a single choice is shown in Annex B, Figure 2.4.

Multiple choice involves choosing one or more correct answers from several proposed (Annex B, Fig. 2.5).

Establishing a sequence involves arranging the list of statements in the correct sequence. To do this, for each answer, select its sequence number from the drop-down list. Drop-down lists are similar to menus. In the minimized state, this list displays only the currently selected option, other available options are hidden until the mouse button is clicked. An example of a compliance task is shown in Annex B, Figure 2.6.

Matching involves selecting the number of the appropriate option from all proposed (Annex B, Fig. 2.7). That is, two columns are given - for each variant from the first column it is necessary to specify the corresponding variant from the second column.

Indicating the truth or falsity of the statements involves selecting the statement "Yes" or "No" from the list for all proposed options.

An example of a problem to indicate the truth or falsity of statements is shown in Annex B, Figure 2.8.

To reduce the possibility of writing off, a random order of questions and answer options will be used.

A 100-point system will be used to assess the level of knowledge.

In total, the computer test developed by us contains 200 test tasks on various topics, but only 50 test tasks out of 200 at random will be used for the final control and testing of knowledge and skills of future technical specialists.

3.3 Methods of computer tests

The most important task of daily pedagogical work is the need to control and test the knowledge of higher education students. The most common forms of control and testing of higher education students' knowledge are written and oral surveys. But these forms have drawbacks.

For example, when conducting an oral interview, a large number of applicants for higher education do not participate in educational activities, in addition, a large amount of time is spent on oral interviews. And in the process of writing, a lot of time is spent on checking the work.

That is why the best means of control and testing of knowledge and skills of higher education, today, is computer testing, which meets all the requirements for the objectivity of the assessment and the quality of the control process [24].

The main requirements for computer tests are given in Annex C, Table 2.2 [26].

Computer-based testing systems enable a higher education student to assess the level of their knowledge and skills, and the teacher - to systematize and simplify the process of assessing the quality of knowledge and skills of higher education students.

Also, computer testing of higher education seekers allows you to quickly and efficiently:

- daily control and testing of knowledge and skills of higher education students in each class;
- control and testing of knowledge and skills of higher education students in the test (final) lesson;

- examination testing, etc.

In general, in pedagogy, computer testing performs three main functions that are interrelated, namely [27]:

- diagnostic;
- educational;
- disciplinary.

The diagnostic function is to identify the level of knowledge, skills, abilities of the applicant for higher education. This feature is basic in testing.

The educational function of testing is to motivate the applicant to intensify work on the assimilation of educational material. To strengthen the educational function, additional measures can be used to stimulate students of higher education, such as providing the teacher with an indicative list of questions for self-preparation, the presence of test questions and advice in the test, joint analysis of test results.

The educational function is manifested in the periodicity and inevitability of test control, which in turn helps to organize and direct the activities of higher education, identify and eliminate gaps in knowledge and form a desire to develop their abilities.

Computer testing is considered to be one of the fairest methods of monitoring and testing the knowledge and skills of higher education students, as it puts all higher education students on an equal footing, both in the process of control and evaluation, virtually eliminating teacher subjectivity.

In the process of studying the technical profile of the discipline "Applied Programming" by future specialists, we developed and used computer tests to control and test their knowledge and skills.

To begin with a higher education student, you need to run the appropriate CT scan in MyTestX. Then, a window will appear with information about the name of the test, the number of questions and evaluation criteria (Annex C, Fig. 2.9).

Next, you need to run the command "Test" - "Start" and enter the name and surname of the applicant. Then a window with the task will appear on the screen (Annex C, Fig. 2.10). you need to choose the correct answer and click "Next" to go to the next task.

After passing the test, a window with a score is displayed (Annex C, Fig. 2.11). In which two diagrams are shown, one with statistics of questions, the second - points.

The green color on the chart indicates the number of correct answers and points, and the red color indicates the number of incorrect answers and the number of points not scored, due to errors.

V. CONCLUSIONS

In general, we present the results of theoretical and empirical research.

1. We have identified the theoretical foundations of the use of ICT in the training of future technical professionals. As a result of studying scientific sources on this topic, we can conclude that information and communication technologies include a set of methods, tools for finding, storing, processing, presenting and transmitting any kind of information using personal computers and the Internet.

Learning with the help of ICT is one of the most promising means of professionalism of future qualified technical specialists, as it allows future technical specialists to obtain the necessary data, differentiate and separate educational material, comprehensively perceive new information, repeat and consolidate knowledge and achieve self-realization. results. But the biggest advantage of using ICT in the educational process is that teachers and graduates can access the necessary knowledge anywhere, anytime.

As a result of the analysis of international experience in training future technical specialists, in particular such leading countries of the world as the USA, Great Britain, France, Germany, Austria and Poland, it was determined that these countries pay great attention to training technical specialists (including information security specialists). , due to the rapid development of informatization of society, as well as threats to information and national security of the country.

In addition, we can state that the training of future technical specialists (including IS specialists) in Ukraine is carried out on the basis of generally accepted international standards.

The effectiveness of the implementation of ICT tools in the training of future technical specialists, first of all, depends on the material and technical base of HEI, which should include the computer network of the university, local computer networks of faculties and departments, as well as appropriate software.

2. We have also developed a tool to control the knowledge of future technical specialists. To begin with, we considered the general requirements for complexes of e-learning resources, the main types of EER and identified the main requirements for the creation of EER, namely: functionality, security, reliability and ease of use.

The main advantage of EER is that they help to make learning material more accessible to higher education students.

Computer tests to control and test the knowledge and skills of future technical specialists in the discipline of «Applied Programming» were developed using the program MyTestX.

The main benefits of computer testing are that:

- the teacher has the opportunity to objectively assess the applicant for higher education, as the control of knowledge is carried out by the program;
- every graduate has the opportunity to assess their own knowledge;
- the quality of preparation of higher education students for classes increases and their activity and organization during independent processing of material increases;
- saves teacher time;
- the level of openness of the testing process increases.

In total, the computer test contains 200 test tasks, but only 50 test tasks out of 200 will be used to control the knowledge of future technicians.

3. During the experimental test we conducted a pedagogical experiment, which was conducted in four stages, namely: ascertaining, training, control and comparative. At the first stage, we conducted an input control of the level of knowledge and skills of higher education students of both groups. Later in the training phase, we introduced new teaching aids for EG, namely ICT tools. During the control phase, we conducted a final assessment of the level of knowledge and skills of higher education students in both groups. In the process of the

comparative stage we performed a comparative analysis of the level of knowledge and skills in the control and experimental group.

In total, 33 people took part in the experiment, forming a control group (16 people) and an experimental group (17 people). In the control group, the method of monitoring the knowledge of higher education students did not change, and in the experimental group, ICT tools were used.

Comparing the results of the level of knowledge and skills of higher education before and after the experiment, we can conclude that the number of higher education with high and sufficient levels of knowledge increased by 11.7%, and the number of higher education with low and satisfactory levels of knowledge, on the contrary, decreased by 11.6% and 17.5%, respectively. Which in turn indicates that the level of knowledge and skills of future technical specialists increases with the use of information and communication technologies.

Therefore, we have proved the effectiveness of ICT in the training of future technical professionals. We can say that the results of our study give reason to believe that the initial methodology is correct, the goal is achieved, the tasks are solved, the hypothesis is proven.

VI. REFERENCES

1. UNESCO World Report on Communication and Information, 1999-2000 - Moscow - 2000. - 168 p.
2. Zhaldak M.I. Pedagogical potential of distance learning / Zhaldak M.I. // Materials of the scientific-methodical seminar "Information technologies in the educational process". - Odessa: WWI. - 2009. - P. 6-8.
3. Gurevich R.S. Information and communication technologies in the professional education of future professionals / Gurevich R.S., Kademiya M. Y., Kozyar M.M.; for order. Corresponding Member NAPS of Ukraine Gurevych RS - Lviv: SPOLOM Publishing House, - 2012. - 502 p.
4. Shvachich G.G. Modern information and communication technologies: Textbook / Shvachich G.G., Tolstoy V.V., Petrechuk L.M., Ivashchenko Y. S., Gulyaeva O.A., Sobolenko O.V. - Dnipro: NMetAU, 2017. - 230 p.
5. Robert I.V. Information technology in science and education / Robert I.V., Samoilenko P.I. - M. - 1998. - 178 p.
6. Tarnavska T.V. The essence of information technology in education / Tarnavska T.V. // Bulletin of the Chernihiv National Pedagogical University. Pedagogical sciences. - Chernihiv, 2013. - Issue 108 (1). - P. 150-155.
7. Tikhonova V.P. Discover education - an objective paradigm of the XXI century / Tikhonova V.P. - M. : MESI. - 2000. - 288 p.
8. European credit transfer system ECTS [Electronic resource]. - Access mode: http://academy.gov.ua/ects/inf/1_3.html
9. Chvanova M.S. Training in the field of information security / Chvanova M.S. // Bulletin of TNU, 2012. - № 8. - P. 126-133.
10. Kasyanchuk N.V. ICT as a means of organizing training in teaching disciplines for future specialists of technical profile / Kasyanchuk N.V., Umanets V.O. // Actual problems of modern science and research: collection. Science. etc. - Vip. 10 (13) / editor: R.S. Gurevich (chairman) [etc.]; Vinnytsia State Pedagogical University named after Mykhailo Kotsyubynsky. - Vinnytsia: LLC firm "Planer", 2018. - 280 p.
11. Bespalov P.V. Computer competence in the context of personality-oriented learning / Bespalov P.V. // Pedagogy. - 2003. - №4. Pp. 45-50.

12. Kasyanchuk N.V. Use of ICT in teaching disciplines of professional orientation for future specialists of technical profile / Kasyanchuk N.V., Umanets V.O. // Actual problems of modern science and scientific research: collection. Science. etc. - Vip. 11 (14) / editor: R.S. Gurevich (chairman) [etc.]; Vinnytsia State Pedagogical University named after Mykhailo Kotsyubynsky. - Vinnytsia: LLC firm "Planer", 2019. - 298 p.

13. Zhaldak M.I. System of teacher training for the use of information and communication technologies in the educational process / Zhaldak M.I. // Informatics and information technologies in educational institutions. - 2011. - № 4-5. - P. 76-82.

14. Buryachok V.L. Problematic issues and current tasks of training specialists in cyber security in the field of knowledge «Information Technology» / Buryachok V.L., Parkhomey I.R., Stepanov M.M., Tolubko V.B. // Bulletin. «Modern information protection», 2016. - №2. - P. 4-9.

15. Order of the Ministry of Education and Science, Youth and Sports of Ukraine dated 01.10.2012 №1060 On approval of the regulations on electronic educational resources [Electronic resource]. - Access mode: <https://zakon.rada.gov.ua/laws/show/z1695-12>

16. Fedasyuk D. Formation of a system of requirements for electronic educational resources of higher education institution for the purpose of their certification / Fedasyuk D., Gots N., Mykyychuk M. // Bulletin of the National University "Lviv Polytechnic" Series: Informatization of higher education institution. - Lviv: Lviv Polytechnic Publishing House, 2016. - № 853. - P. 47-58.

17. Regulations on the procedure for granting the electronic educational resource the status of VNTU publication from 04.04. 2016 [Electronic resource]. - Access mode: <https://vntu.edu.ua/images/2016/vid.pdf>

18. Petritsyn I. Computer testing - one of the forms of diagnosis and verification of learning success / Petritsyn I., Petritsyn O. // Youth and Market. - 2011. - №11 (82). - P. 107-112.

19. Maiboroda L.A. Methodology of application of information and communication technologies in the activity of a teacher of professional training (on the example of professions in the field of communication): methodical recommendations / Maiboroda L.A. - K. : FOP Polishchuk O.V., 2012. - 104 s

20. Gladka L.I. The only approach to the formation of the structure of test tasks for knowledge control / Gladka L.I., Zhiryakova I.A. // East European Journal of Advanced Technologies. Volume 1. - 2011. - №2 (49).

21. Bospalko V.P. Tools for diagnosing the quality of students' knowledge / Bospalko V.P. // School technologies. - 2006. - №2. - P. 118 - 128.

22. Shakhina I.Y. Organization of quality control of students' knowledge using electronic testing / Shakhina I.Y., Ilyina O.I. // Physical and mathematical education: scientific journal. - 2016. - Issue 4 (10). - P. 152-157.

23. Sergienko V.P. Computer technologies in testing: a textbook / Sergienko V.P., Malezhik M.P., Sitkar T.V. - Lutsk: SPD Gadyak Zhanna Vladimirovna, printing house «Volynpolygraph», 2012. - 290 s.

24. Kasyanchuk N.V. Control of knowledge of future technical specialists by means of information and communication technologies / Kasyanchuk N.V., Umanets V.O. // Theory and practice of smart learning in vocational education: materials of the All-Ukrainian web-conference «Theory and practice of smart learning in vocational education», Vinnytsia, May 22, 2019 / VSPU. M. Kotsyubynsky; editor-in-chief: R.S. Gurevich [and others]. - Vinnytsia, 2019. - 279 p.

25. Avanesov B.S. Composition of test tasks. Textbook for university teachers, school teachers, graduate students and ped. universities. 3rd ed., Corrected. and ext. / Avanesov V.S. - M. : Centralized testing, 2002. - 240 p.

26. Mayorov A.N. Theory and practice of creating tests for the education system / Mayorov A.N. - M. : "Intellect Center", 2001. - 296 p.

27. Pedagogical testing [Electronic resource]. - Access mode: <https://uk.wikipedia.org/wiki>

28. Nikolay G.Y. Methodology and technology of scientific and pedagogical research / Nikolay G.Y. - Sumy: SDPU. A.S. Makarenko, 1999. - 106 p.

29. Panasenko E.A. Experiment in the system of methods of scientific research in the historical and pedagogical thought of the Soviet era / Panasenko E.A. // *Origins of pedagogical skill*. - Poltava, 2011. - P. 209-215.

30. Vlasenko O.M. Specifics of teaching a special course "Methods of pedagogical experiment" / Vlasenko O.M. // *Professional pedagogical education: formation and development of pedagogical knowledge: a monograph* / ed. prof. O.A. Dubesenyuk. - Zhytomyr: ZhSU Publishing House. I. Franko, 2014. - P. 380-396.

31. Criteria for assessing the knowledge and skills of students of Vinnytsia State Pedagogical University named after Mykhailo Kotsyubynsky dated October 24, 2012 [Electronic resource]. - Access mode: <https://vspu.edu.ua/content/img/education/graph/p2.pdf>

32. The procedure for assessing the knowledge, skills and abilities of applicants for higher education at Vinnytsia National Technical University from 28. 09. 2015 [Electronic resource]. - Access mode: <http://inomzn.vntu.edu.ua/wp-content/uploads/2017/06/9E.pdf>

33. Kasyanchuk N.V. The use of ICT in teaching disciplines for future professionals in information security / Kasyanchuk N.V. // *Innovative learning technologies in the era of civilizational change: materials of the International scientific-practical Internet conference "Innovative learning technologies in the era of civilizational changes "*, Vinnytsia, October 30-31, 2018 / VSPU named after M. Kotsyubynsky; editor-in-chief: R.S. Gurevich [and others]. - Vinnytsia, 2018. - 279 p.

34. Seidametova Z.S. Methodical system of level training of future software engineers in the specialty "Informatics": dissertation abstract. Dr. Ped. Sciences: 13.00.02 / Seydametova Z.S. - K. : NPU them. MP Dragomanova, 2007. - 40 p.

35. Semerikov S.O. Fundamentalization of teaching computer science in higher education: Monograph / Science. ed. E. Zhaldak. - Kryvyi Rih: Mineral; K. : NPU. M.P. Dragomanova, 2009. - P. 55-56.

36. Kademiya M. Y. Information and communication technologies of education: educational and methodical manual - Part 1 / Kademiya M. Y., Kizim S.S. - Vinnytsia: FOP Tarnashynsky O.V., 2017. - 303 p.

37. Bulakh I.E. We create a quality test: a textbook / Bulakh I.E. - K. : Master Class, 2006. - 160 p.

38. Bulakh I.E. Theory and methods of computer testing of learning success: the dissertation of Dr. ped. Sciences: 13.00.01 / Bulakh I.E - Kyiv National Taras Shevchenko University, 1995. - 430 p.

39. Umanets V.O. Innovative technologies in higher education / Umanets V.O., Gurevich R.S., Kademiya M. Y. // *Modern information technologies and innovative teaching methods in training: methodology, theory, experience, problems: coll. Science. pr.* - Kyiv - Vinnytsia, 2018. - Issue 51. - P. 11-15.

40. Gurevich R.S. Problems of preparation of future teachers of technologies in pedagogical universities: monograph / Gurevich R.S., Kademiya M.Y., Shevchenko L.S. - Vinnytsia: Vinnytsia State Pedagogical University named after Mykhailo Kotsyubynsky. - 2011. - 168 p.

41. Shevchenko L.S. Application of innovative pedagogical methods by future teachers of technology / Shevchenko L.S. // *Modern information technologies and innovative teaching methods in training: methodology, theory, experience, problems: collection. Science. pp. ; redcol. : I.A. Zyazyun (chairman) and others.* - Kyiv-Vinnytsia: LLC "Planer", 2013. - [issue. 29]. - P. 497-502.

42. Gurevych R.S. Interactive teaching aids in higher educational institutions: textbook / Gurevych R.S., Kademiya M.Y., Shevchenko L.S. - Vinnytsia: LLC "Planer", 2013. - 309 p.

43. Gurevich R.S. Information and communication technologies in the professional education of future professionals / Gurevich R.S., Kademiya M.Y., Kozyar M.M.; for order. Corresponding Member NAPS of Ukraine Gurevych RS - Lviv: SPOLOM Publishing House, - 2012. - 502 p.

44. Kademiya M.Y. Information and communication technologies in the educational process: Textbook / Kademiya M.Y., Shakhina I.Y. - Vinnytsia, LLC "Planer". - 2011. - 220 p.
45. Gurevich R.S. Modern information technologies and their use: a manual // Gurevich RS, Kademiya M.Y., Shestopalyuk O.V., Kobysya A.P., Kobysya V.M. - Vinnytsia: VDPU, 2006. - 131 p.
46. Gurevych R.S. Information and telecommunication technologies in the educational process and scientific research: a textbook / Gurevych R.S., Kademiya M.Y. - Kyiv: "Education of Ukraine", 2006. - 320 p.
47. Kasyanchuk N.V. Analysis of international experience in the training of future specialists in information security / Kasyanchuk N.V., Umanets V.O. // Open educational environment of a modern university: a scientific journal. - 2019. Issue 7. - P. 110-118.
48. Measurement of educational achievements of schoolchildren and students: humanistic, methodological, methodical, technological aspects: I International scientific-methodical conference. Abstracts. - Kharkiv: OVS, 2003. - 112 p.
49. Samoilenko N. Pedagogical requirements for the test system of self-control / N. Samoilenko // Head teacher. - 2005. - -21 20-21. - P. 55.
50. Alekseychuk I.S. About the technology of creating a testing system / Alekseychuk I.S. // New learning technologies: scientific and methodical collection. - K.: HMЦБД, 2000. - С. 43-92.
51. Voytovyk S.V. Modern approaches to the creation of electronic educational and methodical complexes in secondary schools and universities / Voytovyk S.V., Kovtonyuk M.M. // Actual problems of mathematics, physics and technological education. - № 8. - Vinnytsia, 2011. - P.44-48.
52. Lyulchak S.Y. Project activity of students as a priority direction of formation of key competencies // Coll. Science. etc. - Issue 52 / editor. - Kyiv-Vinnytsia: LLC firm "Planer", 2018. - Art. 341-343.

DEVELOPMENT OF A RECOMMENDATION SYSTEM

Author: *Valeryia Runets*

Advisor: *Vadzim Sakovich*

Belarusian State University (Belarus)

Abstract. *The existing algorithms for developing recommendation systems were studied, the shortcomings in various approaches were examined, and a solution was proposed.*

Keywords: *recommendation systems, search, object, metrics, matrix factorization.*

I. INTRODUCTION

In today's rapidly developing world, where there is a wide variety of different types of products, goods, services, the value of recommendation systems is growing. It is impossible to underestimate the role of recommendation systems in the life of a modern person. Every day, a large number of people are busy searching the Internet for certain goods and services. Recently, recommendation systems have been used to improve the search on various Internet resources.

The purpose of recommendation systems is to inform the user about an object that may interest him. Recommendation systems have significantly improved user interaction with Internet resources. They are also an excellent tool for businesses, helping to successfully promote and develop their product, service or web service.

Nowadays, it is quite easy for the user to find the object of interest, the search is greatly simplified, since the user is not forced to spend most of the time on the Internet in order to find the product or service that he needs. Now you can download the second part of the book you like in just a few clicks, order an additional service when purchasing a product, or watch a movie with your favorite actor. And all this is available thanks to recommendation services.

The development of recommendation services is not limited to using a small number of algorithms. Nowadays, neural networks are often used for development, and algorithms are being improved very quickly. However, there is still no universal method for predicting a person's liking.

II. LITERATURE ANALYSIS

2.1. Definition of recommendation systems

Recommendation systems are programs that tell the user which entities (movies, music, books, news, websites, products) will be of interest to him and how much he will like them. The work of the recommendation system is to select objects based on his personal preferences and tastes. Each user receives his personal recommendation based on various types of information about the user [1]. These predictions can be based both on information received from the user earlier and saved in his profile, and on the basis of information about other users. The process of work of the

recommendation system is clearly shown in Fig. 1.



Fig. 1. The process of the recommendation system

Recommendation systems provide a personalized approach to each user.

Recommendation systems are used on websites with different content. For example, recommendations for films, books, music, goods, various promotions. Each of these cases has its own approaches and solutions. Let's take a look at the differences between some of the recommendation services:

1. Recommendations for films: in this example, it is logical for the user to recommend new films that may be of interest to him;
2. Promotions recommendations: in this case, it makes sense for the user to offer the most profitable promotions on products that might be of interest to him.

The two main strategies for creating recommendation systems are content methods and methods of collaborative filtering, the principle and differences in their work are presented in Fig. 2. A combination of the two strategies is often used.

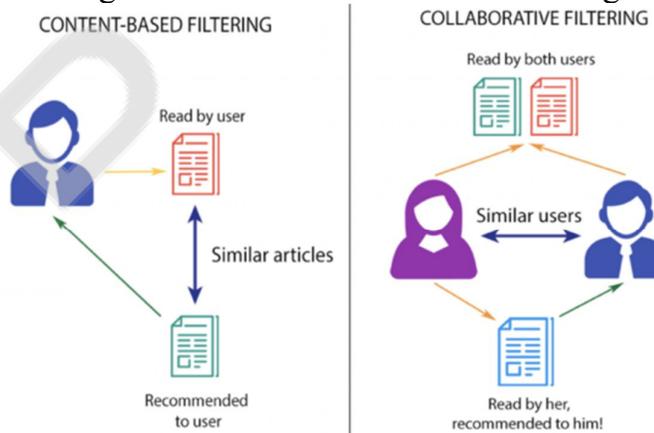


Fig. 2. Recommended systems operation strategies

Recommendation services are used in various fields. They can be seen in such sections as: "Similar books", "They also buy with this", "You may be interested" and others. There are even specialized websites dedicated to recommending certain products. Some directories work on a recommendation basis.

The main question in developing a recommendation system is "What is a similar object?"

Different approaches can be used to solve this problem:

- similar objects are objects that are similar in their characteristics (content-oriented methods);
- similar items are items that are often used together ("customers who bought i also bought j ");
- similar objects are recommendations to the user who liked the given object;
- similar objects are simply guidelines in which the given object acts as a context.

Recommendation systems are a good business solution these days. High-quality recommendations reduce the time users need to search for products and services, and significantly increase the likelihood of getting into the field of view of other objects that may be of interest to him. This can increase the number of sales of even not the best-selling products. The result is increased user satisfaction with web services. As a result, the user will visit this web service more often, and the chance that he will return increases. In addition, the user interacts with those products that he would not have paid attention to if it were not for the recommendation service, which leads to an increase in consumption and an increase in profits. In addition, newsletters, personalized advertisements and push notifications encourage users to come back, increase the frequency of visits by repeat users, and reduce customer churn [3].

Depending on the purpose and place of use, recommendation systems can be both the basis of a web resource and an auxiliary service that allows you to attract customers, increase the percentage of sales, or simplify site navigation for users.

If we take recommendation systems in online business, they usually have two goals:

1. Inform the user about an interesting product;
2. Encourage him to make a purchase (by mailing, making a personal offer, etc.).

2.2. Approaches to the development of recommendation systems

The essence of content-oriented techniques is to map the user to objects based on the products they have purchased or the pages they viewed.

In content-oriented methods, a profile with information about them is required for each user and object. The user profile should contain the characteristics of the products that he likes. This data can be obtained in various ways:

- polling the user or filling out a questionnaire to get information about his favorite properties of the product;
- analysis of user actions and, as a consequence, obtaining characteristics of objects that he likes.

The profile of objects is filled in when adding an object to the database. Characteristics can be different, depending on the category of the object [2].

Content-oriented methods involve searching for similarities between products

by objective characteristics: color, size, genre, etc. The more characteristics, the more accurately the object is described, however, it should be understood that some characteristics may not say anything about the user's preferences. These characteristics can be:

- color of the book cover;
- the year the film was released.

Most recommendation systems based on content-oriented methods offer the same type of recommendation when viewing a product.

Collaborative filtering uses information about the activity of all users on the network:

- visiting certain websites;
- reviews about objects;
- assessment of objects.

In this case, the subjective properties of objects are taken into account, which are difficult to obtain without statistics of certain activity from the user. The advantage of this filtering is that it does not matter what types of objects you are working with, but implicit characteristics can be taken into account that would be difficult to take into account when using object-oriented methods.

In the process, recommendation systems collect data about users using a combination of explicit and implicit methods.

Implicit data collection can be such actions as:

- tracking and storing data on user behavior online;
- tracking the contents of the user's computer;
- tracking objects that the user views on the network.

Examples of explicit data collection:

- selection of the most preferable of the two objects;
- use of a differentiable scale for evaluating objects;
- placing a group of objects in descending or increasing order of the user's interest in the object;
- compiling a list of objects that characterize a specific user.

Recommendation systems compute a list of recommendations for a specific user by comparing information received from all users of the system. Since the user can find objects with the help of the recommendation system that could not be found by the search engine, the recommendation systems are a good alternative. However, it is interesting that often search engines are used by recommendation [2].

There are also two different approaches to collaborative filtering:

1. Filtering based on user similarity. In this approach, the system, according to certain algorithms and criteria, finds a user with similar preferences and offers a set of objects that were interesting to him;

2. Filtering based on the similarity of objects. In this approach, the system searches for objects that are liked by the same user group, such objects are considered similar and are offered to users who liked objects from this group.

The principle of operation and the differences between these approaches are clearly shown in Fig. 3.

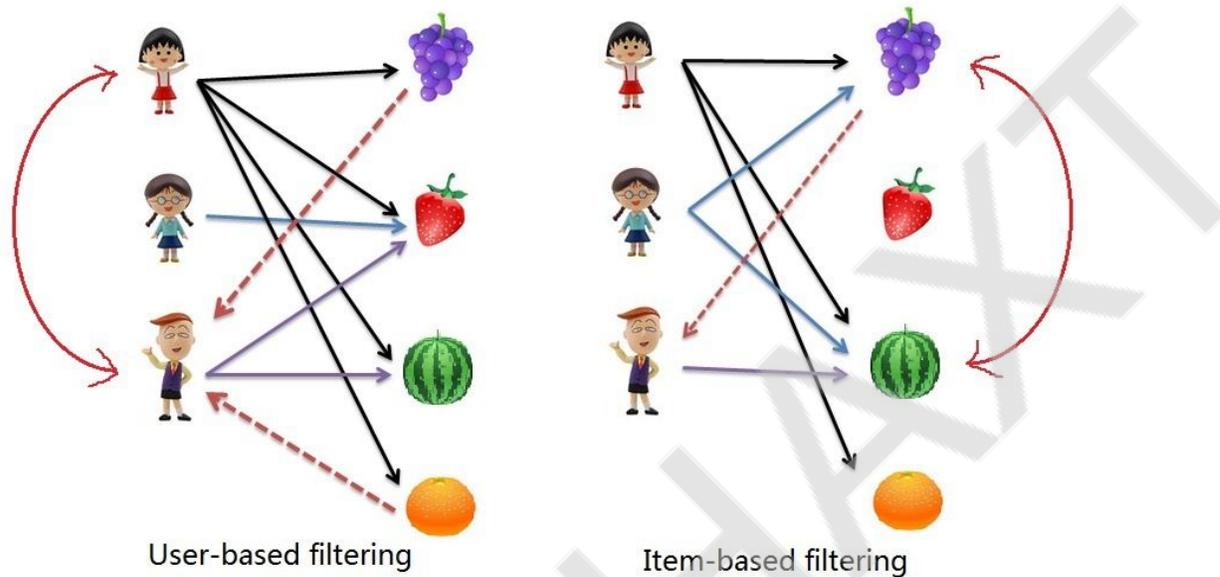


Fig. 3. Collaborative filtering approaches

Advantages of filtering based on similarity of objects over filtering based on similarity of users:

- When the dimension of the problem is large, i.e. when there are a lot of users, the problem of finding the nearest neighbor becomes difficult to compute. Computational complexity is reduced from $O(N^2 * n)$ to $O(n^2 * N)$ when using filtering based on object similarity.

- Filtering based on user similarity usually results in a sparse matrix; there are a lot of goods, but there are few estimates. On the one hand, this helps to optimize the calculation - we work only with those elements that intersect. But on the other hand, the list of recommended products is very small.

- Estimating the proximity of goods is usually much more accurate than estimating the proximity of users. Consequently, the error in calculating the correlation of goods there is significantly less. This is a direct consequence of the fact that there are usually many more users than products.

- Product descriptions are much more consistent than user descriptions because they are user preferences can change over time [6].

2.3. Algorithms

The goal of content-oriented techniques is to find similarities. Similarities can be looked for in two ways:

- between the object and the user;
- between two objects.

Various methods can be used to find similarities between entities. Next, 2 methods will be considered:

1. Cosine similarity. In this method, the coefficient of similarity between two objects is calculated using the formula (1).

$$\text{cosine}(x, y) = \frac{\sum_{i=1}^n x_i y_i}{\sqrt{\sum_{i=1}^n x_i^2} \sqrt{\sum_{i=1}^n y_i^2}} \quad (1)$$

where x, y are comparison objects, and xi, yi are characteristics of these objects. This method is useful for data with high-dimensional features. This method will find similar objects to those that the user liked, and these objects will be recommended to him.

1. Jaccard similarity (also called intersection over union).

Used to find a property between two objects. Calculated by the formula (2).

$$J(X, Y) = \frac{|X \cap Y|}{|X \cup Y|} \quad (2)$$

However, Jaccard's similarity only applies when the characteristics have binary values. If the characteristics are a rating, a score, or other properties that take more than 2 values, then the Jaccard similarity is not applicable.

The collaborative filtering approach is to find users who are similar to a given person, in order to offer him those objects that will potentially be of interest to him. Compared to the content-oriented approach, objects and users have no properties or attributes. All calculations are performed on the basis of a utility matrix, an example of which is presented in Table 1.1.

Table 1. Utility matrix

	HP1	HP2	HP3	TW	SW1	SW2	SW3
A	4			5	1		
B	5	5	4				
C				2	4	5	
D		3					3

The column lists the users and the row lists the objects. Matrix elements are ratings that users have assigned to certain objects. There are 2 methods that can be used for collaborative filtering.

Let's look at a memory-based implementation. In this method, recommendations are composed using a utility matrix function. This function returns the estimated score for the current user.

First, the average rating is calculated, which is formed for user i on the basis of all objects that he has ever rated, according to formula (3).

$$\bar{y}_i = \frac{1}{|I_i|} \sum_{j \in I_i} y_{ij} \quad (3)$$

Using this, we estimate the rating of object k for user i as shown in Fig. 4.

$$\hat{y}_{ik} = \bar{y}_i + \frac{1}{\sum_{a \in U_k} |w_{ia}|} \sum_{a \in U_k} w_{ia} (y_{ak} - \bar{y}_a)$$

Similarity between users a and i

a's rating of k - a's average ratings

All users that have rated k

Fig. 4. Calculating the estimated value of an object for a specific user

The similarity between users a and i can be calculated using the methods described above, for example, cosine similarity, Jaccard similarity, Pearson's correlation coefficient, or any other. Thus, it is very easy to obtain results as long as the data does not become too sparse, in which case performance is degraded.

For the model-driven approach, matrix factorization is most commonly used. In this case, we create user and item views from the utility matrix. The principle of matrix factorization is shown in Fig. 5.

$$\begin{bmatrix} 5 & 1 & 4 & 5 & 1 \\ & 5 & 2 & 1 & 4 \\ 1 & 4 & 1 & 1 & 2 \\ 4 & 1 & 5 & 5 & 4 \\ 5 & 3 & 3 & & 4 \\ 1 & 5 & 1 & 1 & 1 \\ 5 & 1 & 5 & 5 & 4 \end{bmatrix} \approx \begin{bmatrix} u_{11} & u_{12} & \dots & u_{1K} \\ u_{21} & u_{22} & \dots & u_{2K} \\ u_{31} & u_{32} & \dots & u_{3K} \\ u_{41} & u_{42} & \dots & u_{4K} \\ u_{51} & u_{52} & \dots & u_{5K} \\ u_{61} & u_{62} & \dots & u_{6K} \\ u_{71} & u_{72} & \dots & u_{7K} \end{bmatrix} \times \begin{bmatrix} v_{11} & v_{21} & v_{31} & v_{41} & v_{61} \\ v_{12} & v_{22} & v_{32} & v_{42} & v_{62} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ v_{1K} & v_{2K} & v_{3K} & v_{4K} & v_{6K} \end{bmatrix} \approx \begin{bmatrix} 0.2 & 3.4 \\ 3.6 & 1.0 \\ 2.6 & 0.6 \\ 0.9 & 3.7 \\ 2.0 & 3.4 \\ 2.9 & 0.5 \\ 0.8 & 3.9 \end{bmatrix} \times \begin{bmatrix} 0.0 & 1.5 & 0.1 & 0.0 & 0.7 \\ 1.3 & 0.0 & 1.2 & 1.4 & 0.7 \end{bmatrix}$$

Fig. 5. Matrix factorization

Thus, our utility matrix decomposes into matrices U and V, where U represents users and V represents objects in low-dimensional space. To do this, you can use various methods such as SVD (Singular Value Decomposition), PCA (Principal Component Analysis) or others.

Further, the estimated rating is calculated by the formula (4), where i is the user, and j is the object for which it is necessary to calculate the rating.

$$y_{ij} = u_i v_j \quad (4)$$

where u_i, v_i are matrix elements that we got as a result of matrix factorization.

After calculations, you can recommend the properties with the highest predicted rating. This method helps to reduce the dimension of the problem, so it is convenient to use this approach with large amounts of data with high sparsity. But it is worth noting one of the disadvantages of this method - we do not know what the elements of the resulting matrices mean.

If you look at the algorithm in a different way, then the essence of matrix factorization is to create a set of factors that unite all users into some specific clusters. The number of characteristics is directly proportional to the found relationships. Each characteristic has its own meaning, since there is a certain number of users whose interests include it, and such users can be combined into one group or cluster [5].

In practice, more than one approach is almost always used; they are often combined. The two main goals of combining models are to increase forecast accuracy and avoid various problems associated with small user groups. The main disadvantages are the laborious implementation and poor interpretability of the algorithm.

Examples of such combination strategies:

- switching - application of different algorithms for different products and users;
- stacking - predictions of individual models are the inputs of another classifier, which learns to correctly weigh intermediate estimates;
- mixing - calculating recommendations for different algorithms and combining them into a common table;
- weighting - the predicted score is calculated based on several characteristics.

Thus, each algorithm has its own advantages and disadvantages, you can get the maximum benefit by combining them [8].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The main problem with recommendation systems is that they recommend objects that the user has already bought earlier. To solve this problem, you need to choose the right metrics for optimization.

All quality metrics can be roughly divided into 3 categories:

- Prediction Accuracy - assessment of the predicted rating accuracy (applied in case of scale ratings);
- Decision support - assessment of the relevance of recommendations (works only with binary data);
- Rank Accuracy - an assessment of the ranking quality of the issued recommendations, ie. how correct the order of the recommended objects is when the list is sorted.

Metrics are used to assess the accuracy of a method. For this, the projected estimates are compared directly with the actual estimate given by the user [4].

Consider the metrics that assess the accuracy of the predicted rating. Typical statistical metrics are mean absolute error (MAE), root mean square error (RMSE), and correlation. The most popular is the MAE metric. MAE is calculated using formula (5) and RMSE is calculated using formula (6).

$$MAE = \frac{1}{N} \sum |predicted - actual| \quad (5)$$

$$RMSE = \sqrt{\frac{1}{N} \sum (predicted - actual)^2} \quad (6)$$

Recommendations forecast - inversely proportional to the values of the MAE and RMSE metrics, the more accurate the method used to forecast recommendations. These metrics come in handy when recommendations are based on predicting rating

or number of transactions. Metrics can be used to assess the quality of the recommendation system [3].

Decision Support class metrics work with binary data (0 and 1, yes and no). If ratings are initially plotted on a continuous scale in a task, they can be converted to a binary format, but in this case the results will be less accurate.

The popular metrics in this class are Precision and Recall. These metrics are necessary so that users can choose the most similar from the available set of objects. The calculation of these metrics is performed using formulas (7) and (8).

$$\text{recommender system precision: } P = \frac{\text{\# of our recommendations that are relevant}}{\text{\# of items we recommended}} \quad (7)$$

$$\text{recommender system recall: } r = \frac{\text{\# of our recommendations that are relevant}}{\text{\# of all the possible relevant items}} \quad (8)$$

As a rule, the recommended objects are displayed in a sorted list of several positions (first the best, then in descending order of priority). Rank Accuracy metrics are used to measure the correctness of the order in which recommendations are displayed.

Thus, evaluating metrics are needed to improve the recommendation system, to understand how close the forecast is to real data, which helps to correct future forecasts [4].

But, in addition to the accuracy of the prediction, we may be interested in other things:

- coverage - the share of products that is present in the list of recommendations;
- personalization - how much the recommendations are personalized for each individual user;
- diversity - variety of objects in the list of recommendations.

These characteristics are also important in assessing the quality of the recommendations received.

IV. RESULTS

4.1. Application architecture and operation

The purpose of the developed recommendation system is to recommend the user of films that he might like. The architecture of this application is built on 2 entities:

- user;
- film.

Each user has the opportunity to add information about the films they have watched: leave a review, rate. Thus, the characteristics of the films viewed are not binary (i.e., they can take on more than two values). In this application, the user assigns a score from 1 to 10.

Collaborative filtering is used to find any recommendations.

In the developed application, data about users, movies and views is stored in a MySQL database, the data is retrieved using the JDBC standard.

The algorithm for providing the calculation of recommended grades is developed in the Java language. A user with information about his views is fed to him, at the output we get a list of films with a predicted rating.

4.2. Algorithm operation

Having information about the films viewed by users, a matrix is compiled, presented in table 2.

Table 2. Assessment matrix

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
User 1	5	4	5			
User 2	4		5			
User 3		3	5		4	
User 4				3	4	
User 5			4	2	4	
User 6	3					5

In this matrix, the column contains the users, and the row contains the movies. The corresponding mark is indicated at the intersection of the i-th user with the j-th film.

Further, groups are formed, called clusters, where similar users are united. This grouping is done by calculating the average difference between user ratings. Those who have such a difference in the range from 0 to 2.5 are considered similar users.

The user's rating for an object will be predicted as the average cluster rating for this object according to formula (9), and the user is recommended films with the highest conjectural ratings.

$$\hat{r}_{ui} = \frac{1}{|F(u)|} \sum_{v \in F(u)} r_{vi} \quad (9)$$

where r_{ui} is the rating of user u for film i , and $F(u)$ is the cluster distribution function.

The system recommends films with an estimated rating > 5 . The list of films is sorted in descending order of estimated ratings and presented to the user.

This method has the problem of recommending films to new users. Since nothing is known about the user, if the user has less than 3 watched movies, the system offers to rate popular movies at each login, hoping that the user has watched them.

Another problem is that recently added movies are not recommended to anyone. In this system, the problem is solved by the fact that each user is recommended a group of films, one of which is a film that has never been watched. Such a movie is selected at random.

4.3. User part

The user part is developed in Java using the Swing library. The interface is represented by a windowed application, which clearly shows the difference between the real user assessment and the predicted by the algorithm.

Let's take a look at how the application works:

Step 1 (shown in Fig. 6). You must enter the id of the user for whom you want to create a list of recommendations.

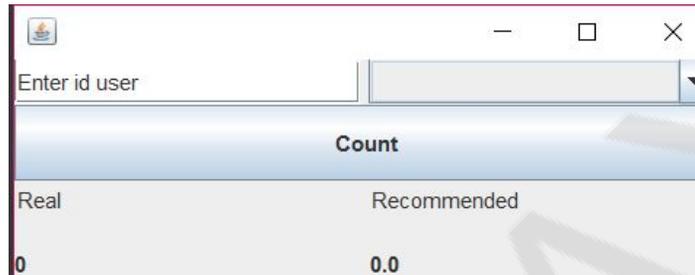


Fig. 6. The first step of the application

Step 2 (shown in Fig. 7). After entering id, the drop-down list displays the movies that this user has already watched and rated. You must select a movie for which the predicted score will be calculated.

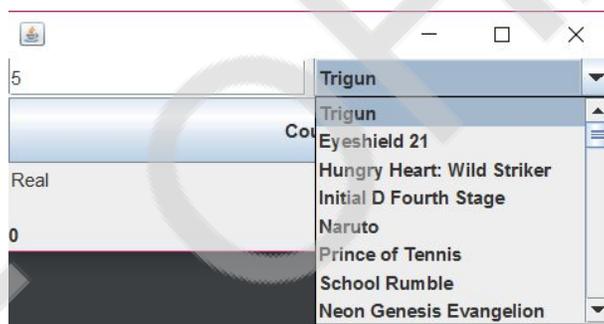


Fig. 7. The second step of the application

Step 3 (shown in Fig. 8). When you press the Count button, the selected user is input to the algorithm. The resulting list of recommendations contains the selected movie and its predicted score. And as a result of the application's work, the screen displays the user's real assessment and the predicted one.

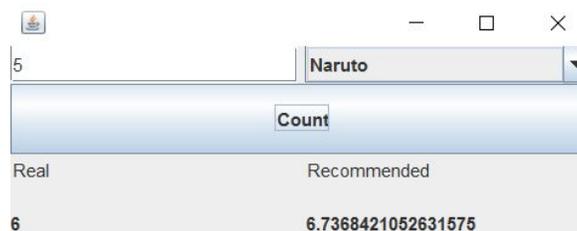


Fig. 8. The third step of the application

4.3. Results

The result of the application is a list of movies recommended to this user. Only those films are recommended with an estimated score of > 5 (otherwise the film will

not be of interest to the user). The list is displayed in descending order of the estimated estimate.

To assess the work of the developed algorithm, data on the real assessments of some users from the site kinopoisk.ru were taken. They are presented in table 3.

Table 3. User ratings

Film\User	Mistry <u>girl</u>	zenitos_rostov	alexokarev1 701
«Once upon a time in hollywood»	8	8	10
«Joker»	7	9	10
«Factory»	5	9	8
«Butterfly Effect»	9	8	10
«La-La Land»	7	6	3

For this test, we took users who, under certain conditions, according to the developed algorithm, will be included in one cluster.

The predicted score was calculated for the first user for each of the films. The test was carried out as follows: for the user Mistry_girl_, the data was entered as if one of the films had not been watched, and the score was predicted from it. The predicted and real estimates for the above user are presented in table 4.

Table 4. Algorithm results

Rating type/Film	«Once upon a time in hollywood»	«Joker»	«Factory»	«Butterfly Effect»	«La-La Land»
Predicted	8.0	9.5	8.5	8.0	4.5
Real	8	7	5	9	7

Let's estimate the RMSE (Root Mean Square Error) by the formula (10)

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (real(i) - predicted(i))^2} \quad (10)$$

For this sample, an RMSE of 5.5 was obtained. For comparison, Netflix's own algorithm in 2006 predicted user ratings with quality 0.9514 on the RMSE metric. Now this recommendation system is the most technologically advanced in the world and is a combination of 27 recommendation algorithms.

In fact, this value can be interpreted as the distance between two points on the plane, i.e. we get a rather large deviation from the real result.

Since this result turned out to be far from correct, the sample was expanded by 3 times. As a result of the work of the developed algorithm, based on the provided data, RMSE = 1.997 was obtained. This result shows that with an increase in the number of users, the algorithm works more correctly. However, this cannot be considered a regularity, since it is impossible to predict what will happen when the sample is increased by 5, 10, 100 times.

At the next stage of the study, a sample was taken with the number of users = 1000 and the number of films = 11876, and as a result, an RMSE = 1.22 was obtained, which indicates rather accurate predicted estimates during the operation of this algorithm. However, it must be said that this metric shows the average value of the overall work of the algorithm. In some situations, the algorithm does not work correctly and requires further improvements.

Thus, during the operation of the application according to the developed algorithm, some problems were identified: a rather high complexity of this algorithm and some inaccuracies in individual situations.

The results obtained can be saved and used in the future for evaluating metrics. Optimization of this algorithm will lead to a decrease in operating time and an increase in the accuracy of the results.

V. CONCLUSIONS

During the implementation of this project, the following results were obtained:

- requirements for recommendation systems were identified;
- studied and analyzed the main algorithms for the development of recommendation systems;
- developed and implemented an algorithm for solving the problem;
- Possible problems and ways to solve them were identified.

As a result of the work carried out, an algorithm was built that works with small data and gives a result. This system can be optimized to handle large input data correctly. It is necessary to improve the quality of the provided recommendations through the use of assessment metrics.

The constructed algorithm is the basis for further optimization and study of this problem.

VI. REFERENCES

1. Avkhadeev, BR Development of a recommendation system based on data from the profile of the social network "VKontakte" / BR Avkhadeev, LI Voronova, EP Okhapkina // CyberLeninka [Electronic resource]. - 2014. - Access mode: <https://cyberleninka.ru/article/n/razrabotka-rekomendatelnoy-sistemy-na-osnove-dannyh-iz-profilya-sotsialnoy-seti-vkontakte>. - Date of access: 08.11.2019.
2. Botov, DS Development of a recommendation system for music service based on methods of content and collaborative filtering / DS Botov, NV Menshikova, IV Portnov // Information technologies and systems: tr. Sixth Int. scientific. Conf., Bannoe, March 1-5, 2017 / Feder. issled. Center "Informatics and Management" Ros. acad. Sciences, Chelyab. state un-t; otv. ed. : Yu. S. Popkov, A. V. Melnikov. - Chelyabinsk, 2017. -- 37 p.
3. Karaush, AS Recommendation systems in public libraries / AS Karaush // Bibliosphere. - 2009. - No. 1. - 41 p.
4. Klemenkov, P. A. Building a real-time news recommendation service using a NoSQL DBMS / P. A. Klemenkov // Informatics and its applications. - 2013. - T. 7, No. 3. - 14 p.
5. Kvyatkovskaya, I. Yu. Information and recommendation system adapted to the cloud-based advertising service / I. Yu. Kvyatkovskaya, PN Savchenko // Vestn. Astrakh. state tech. un-that. Ser. : Management, vychisl. technology and informatics. - 2015. - No. 2. - 88 p.
6. Nefedov, Yu. V. Recommendation systems of Internet services: design and development

stages / Yu. V. Nefedov, IA Galperina // Scientific and technical. inform. Ser. 2, Inform. processes and systems. - 2018. - No. 10. - 29 p.

7. Taratukhina, Yu. V. General principles of designing a recommendatory web service for modeling the individual educational trajectory of students / Yu. V. Taratukhina, MS Markaryan // Open and distance learning. Education [Electronic resource]. - 2016. - No. 2. - 77 p. - Access mode: http://journals.tsu.ru/ou/&journal_page=archive&id=1413&article_id=28949. - Date of access: 01.12.2019.

8. Tregubov, AS Development of methods for adapting user interfaces for USSD services / AS Tregubov // Electronic journals of the Notabene publishing house [Electronic resource]. - 2016. - Access mode: http://e-notabene.ru/kp/article_19497.html. - Date of access: 29.11.2019.

GUITAR TUNER FOR ANDROID OS

Author: *Andrii Andriichuk*

Advisor: *Vasyl Lazoryk*

Yuri Fedkovych National University (Ukraine)

Abstract. *The software product was created according to the research. The main function of the program is to process the digital signal and display the corresponding data on the screen of the device, which enables the user to tune the strings on the guitar.*

Keywords: *fast Fourier transformation; sound signal processing; guitar tuner, guitar metronome.*

I. INTRODUCTION

The software product includes a wide range of functionality that will be useful to large users. The main functionality of the program is the analysis of the sound flow, then its processing using the algorithm "Fast Fourier Transform". As a result, the device screen displays the frequency in Hertz, which corresponds to the sound stream, the number and display of strings in the guitar, which is responsible for the frequency and distance between frequency streams and the frequency of the required strings, converted into musical tones.

The program also implements an additional module to display the main guitar chords. The user can view them in various combinations with a specially created graphic element and listen to the sound with the speakers.

Another equally important module is the guitar metronome. A metronome is a device or program that plays sounds at a set speed and is created to help musicians at the right tempo. While playing any musical instrument, it is very easy to lose your sense of rhythm or apply something at the wrong speed. The user, if he arranges money on a guitar or other musical instrument, can set the tempo when it is convenient to play a particular melody. The metronome created in the program programs the rhythm, imitating the game of a real drum beat. Most modern musical works are created on the basis of 4 main acad. Each chord corresponds to a note on the bass guitar. The then module allows you to assign responses to the sounds of the

bass guitar on each of the 4 bars of the melody for quality company.

II. LITERATURE ANALYSIS

The software product is intended for use in the field of music art. Music is one of the key and oldest forms of human art. Regardless of culture, nationality or age, all people have more or less come into contact with music. A huge number of people create new compositions, teach this art to others, or just enjoy this kind of creative activity.

In the process of human development, the art of music has been very active. It was a key part of the culture and folklore of many peoples of the world. It manifested itself in singing and playing musical instruments, which also developed and improved very quickly.

It's no secret that the most popular musical instrument is the guitar. This instrument belongs to the class of stringed instruments, which originate before the beginning of our era. This software product is developed for users who own the game on this tool or are just beginning their journey in learning the basics of the game. The program was developed taking into account the functional needs of musicians.

Each of the 3 main modules will be useful to users. Each time, before playing the guitar, the musician tunes the strings. The Tuner module can help him with this, which will quickly display all the necessary information about the audio stream. Guitar chords are the basis for any musical pattern. The Chords module will allow you to view and listen to all the main chords. Each of your music has its own rhythm, which is followed by a musician during the game. The Metronome module will allow you to adjust the rhythm in the form of a drum beat for any song. Also, if desired, the user can assign a bass guitar part to each of the 4 musical beats of the melody. Accompaniment in this form can best reflect the musical pattern of any song.

The developed software product has all chances to enjoy wide popularity among users. The program has a wide range of functionality that is not inferior to the capabilities of programs with similar purposes.

2.1. Purpose and scope

The developed software product is intended for devices on the Android operating system. The program is designed for a custom audience that is engaged in or studying guitar playing. Three main modules can significantly help musicians.

With the main module "Guitar Tuner" you can tune the guitar, the visual representation displays the current string that is tuned, the frequency in Hertz, which corresponds to the sound flow and the distance to the desired note in half bars.

The "Chords" module will allow you to view the main chords on the guitar, including the location of the fingers on the fingerboard and their order. The user can optionally view different interpretations of chords. If you click on the "play" button, the program alternately plays all the sounds of the chord.

The Metronome module plays the rhythm in the form of a drum beat with the game speed set by the user. This module allows musicians to clearly define and improve the tempo of any composition. It is also possible to add a bass guitar part,

which is superimposed on the drum accompaniment, which improves the quality of the accompaniment.

2.2. Problem statement, literature review, approaches to solving

The problem of sound flow analysis and processing using the "Fast Fourier Transform" algorithm is one of the most common tasks in digital signal processing.

This algorithm is widely used in all devices, one way or another associated with audio signals.

Similar problems have been studied by such authors as М.О. Рибальченко, О.П. Egorov, VB Zvorykin, OV Osharovska, SS Ustinov, OF Мазуркевич, Н.О. Patlaenko.

In particular, OP Egorov proposed a method of continuous wavelet transform signal analysis using Fourier transform and to use such an approach to solve such problems. After applying the algorithm, it is possible to draw a graph of the frequency spectrum, which will display the frequencies at which the amplitude of the spectrum is maximum. From this study we can conclude that the frequency spectrum graphs for stationary and non-stationary signal do not differ. The Fourier transform by its nature cannot distinguish a stationary signal from a non-stationary one.

In turn, OV Osharovskaya describes that mathematical models of signals are used for analytical description of signals and processes of their transformation. Signals are considered as functions given in physical coordinates, ie as points and vectors in the functional space - the signal space, which allows you to give a set of signals geometric meaning and clarity. The simplest is the interpretation of signals as elements of a normalized linear metric space. The elements of such a space are called vectors, and a linear combination of independent vectors is called the basis of such a space. One of the most used bases is complex exponential functions (or orthogonal harmonic functions). The decomposition of signals on this basis is called the Fourier series decomposition.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The main algorithm in the software product being developed is "Fast Fourier Transform". Fourier transform - a transformation that compares the functions of a real variable. This operation is performed every time the human ear perceives different sounds. In the human brain, the sound is automatically calculated and converted, which is represented as a spectrum of successive values of the volume level of tones of different pitches, and is perceived in the form in which all people are accustomed to perceive.

This algorithm is used in various fields of science, such as number theory, physics, signal processing, combinatorics, probability theory, cryptography, statistics, optics, acoustics and others. Extensive possibilities of its application are based on a number of useful features which have received the name "properties of Fourier transform":

- This property is known as Parseval's theorem and says that the transformation of a function is a linear operator, which with the corresponding normalization is

unitary.

- The transformation is reversible, ie the inverse result has almost the same form as in the direct application of the algorithm.
- Sinusoidal base expressions are their own differentiated functions. This means that such a representation changes linear equations with a constant coefficient into ordinary algebraic ones.
- According to the convolution theorem, this algorithm converts a complex operation into ordinary multiplication.
- Discrete Fourier transform can be calculated quickly using the Fast Fourier transform algorithm.

IV. RESULTS

To solve the problem of audio stream analysis and frequency search in Hertz, the "Fast Fourier Transform" algorithm in the Kotlin programming language was used.

The user interacts with the product through the software product on the Android operating system, through the interaction with the visual elements of the program. The program consists of 3 main modules: "Guitar Tuner", "Chords" and "Metronome".

The developed product displays the results in the form of animated visual components, which are customized to meet the design requirements of mobile applications. In the "Guitar Tuner" module, the data is displayed as a numerical representation of the sound frequency in Hertz, the current string and the distance to the desired sound. In the "Chords" module, the original data is presented in the form of depicted guitar chords and their sound representation. In the Metronome module, the original data is presented in the form of a drum beat together with a bass guitar, which is played at a user-specified tempo.

V. CONCLUSIONS

In this work, we conducted a study of the problem of sound flow analysis. The result of this study is a software product for the Android operating system, and a detailed report on the work done.

We used the following Fast Fourier Transform algorithm to design the software. The program was created by Android Studio from Google using the programming language Kotlin and XML.

In general, we have developed a software product for solving tasks of analysis and further processing of the sound signal and frequency calculation in Hertz. The developed software product can be used for tuning or playing the guitar. All major modules have been created to help people involved in the art of music.

There are 3 key modules in the software product:

- "Tuner" - a module that reads the audio stream from the system microphone, analyzes it and displays the corresponding results on the screen to the user. The data is converted using the Fast Fourier Transform algorithm and returns the frequency of

the audio stream. In turn, the module analyzes the frequency and displays information about the current music note and frequency in Hertz.

- "Chords" - a module that allows the user to view all the main guitar chords. You can also listen to chords if you wish.

- "Metronome" - a module that plays the drum bit at a user-specified speed. This functionality allows musicians to play melodies rhythmically and clearly. Functionality for overlaying a bass guitar part on each of the 4 rhythm bars has also been implemented. That is, in addition to the drum accompaniment, another melody will be played.

The testing was performed in several stages. Both individual modules and the program as a whole were tested. Manual tests were created with the help of the Junit frame work and automatic tests with the help of Android Espresso. All stages of testing were passed successfully and the program showed excellent results. The application works at a high level along with programs with similar functionality.

The software product has a number of advantages, such as the speed of input data due to multi-threaded processes, unique functional solutions and design.

According to the results of the study, theses were submitted on student scientific conference of Chernivtsi National University, as well as a report on PICT-2019.

VI. REFERENCES

1. [Leiva A. Kotlin for Android developers: a tutorial. New York: The New York Times Press p., 2017. 191 p.](#)

2. [1. Zhemerov D., Isakova S. Kotlin programming language in action: a textbook. Moscow: DMK Press, 2018. 402 p.](#)

3. [Bondarenko VG The unfading glory of the newest Cossacks: the history of the Ukrainian Free Cossacks in Zaporozhye \(1917-1920\). Zaporozhye, 2017. 113 p.](#)

1. [Analysis of frequency and volume in Android. Scribd: website. URL: <https://ru.scribd.com/document/215288056/Analyze-the-Frequency-and-Strength-of-Sound-in-Android> \(access date: 17.10.2019\).](#)

2. [Frequency analysis in Android. Wayback Machine: website. URL: \[http://netscale.cse.nd.edu/twiki/pub/Main/Projects/Analyze_the_frequency_and_strength_of_sound_in_Android.pdf\]\(http://netscale.cse.nd.edu/twiki/pub/Main/Projects/Analyze_the_frequency_and_strength_of_sound_in_Android.pdf\) \(accessed: 15.11.2019\).](#)

3. [Fast Fourier transform. Sodium Media: website. URL: <https://en.sodiummedia.com/4189987-fourier-transform-fast-fourier-transform-discrete-fourier-transform>](#)

[\(appeal date: 11/16/2019\).](#)

4. [Frequency determination using Fast Fourier Transform. Bjorg: website. URL: <http://blog.bjornroche.com/2012/07/frequency-detection-using-fft-aka-pitch.html> \(access date: 26.12.2019\).](#)

5. [Frequencies for uniform scale. Physics of music-notes: web-site. URL: <https://pages.mtu.edu/~suits/notefreqs.html> \(access date: 15.01.2020\).](#)

6. [Guitar tuner with microphone online. Acousterr: website. URL: <https://www.acousterr.com/guitartuner> \(access date: 10.02.2020\).](#)

7. [How to get the frequency of the audio stream. StackOverflow: website. URL: <https://stackoverflow.com/questions/11844914/get-the-frequency-of-an-audio-file-in-every>](#)

[1-4-seconds-in-android \(access date: 03.03.2020\).](#)

8. [How to record sound in Android with better quality and reduced noise. StackOverflow: website. URL:](#)

<https://stackoverflow.com/questions/22282353/how-to-record-sound-in-android-with-better-quality-and-reduce-noise>

[\(appeal date: 15.03.2020\).](#)

9. [Noise absorption in Android when recording microphone sound. Twigs Tech Tips: website. URL:](#)

<https://twigstechtips.blogspot.com/2013/07/android-enable-noise-cancellation-in.html?m=1>

[\(appeal date: 25.03.2020\).](#)

YOUNG'S PROBLEM AND ITS APPLICATION

Author: ***Kulesh Oleksandr***

Advisor: ***Rusnak Mykola***

Yuriy Fedkovych Chernivtsi National University (Ukraine)

Abstract. Today, millions of computers, phones, tablets, and other home appliances work with mobile networks around the world. The problem of providing a large number of devices with high-quality, fast, stable and inexpensive communication is almost at the forefront. An important role in solving this problem is played by the task of optimal, in a certain sense, placement of transceiver stations - nodes of the mobile network.

Keywords: Young's Problem; placement of circles; covering the flat surface with circles; minimum radius; minimum amount of circles.

I. INTRODUCTION

A circle is a part of a plane that lies inside a circle. In other words, this is the locus of points on the plane, the distance from which to a given point, called the center of the circle, does not exceed a given non-negative number R - called the radius of this circle. If the radius is zero, then the circle degenerates into point [1]. A point set is a finite set of points in a plane with fixed coordinates. Coverage circle - a circle of minimum radius, which includes all points of the population.

Jung's Problem is to construct a covering circle for a given point set. By construction we mean the indication of the coordinates of the center of the circle and its radius (diameter).

In this work an attempt is made to adapt a well-known method of constructing a spanning circle of a point set on a plane of minimal diameter to solve such problems [2]. An algorithm was built, a program was developed and the results of its work were tested. Based on them, new tasks could be solved, which have important practical applications.

The developed software product, as a result of the tests showed its full efficiency. The product meets all functional requirements, interface requirements.

The software was implemented using WebStorm 2019.3.1 on HTML, CSS and JavaScript.

II. LITERATURE ANALYSIS

2.1. Problem statement №1

A point set is defined on the plane, the elements of which are set by mobile consumers who need a signal of at least a certain level. Anywhere in the plane, you can install a repeater signal of any power network (range). There is a law of attenuation of the repeater signal depending on the distance to it, and the price of the repeater, depending on its power. It is necessary to choose a repeater of the lowest cost (power), which would provide each consumer with a signal of the desired level and indicate its location.

2.2. Problem statement №2

If we consider **the problem №2** from a practical point of view, then placing one global signal transmitter is expensive, energy-intensive, and the radiation will be too strong in the area closest to it. Therefore, of course, we can consider another problem - covering the point set on the plane with a minimum number of circles with given radii, or covering the point set on the plane with a given number of circles with minimum radii. In terms of the problem №1, this means minimizing the number of repeaters of a given power to provide each signal consumer with at least a certain level, or choose the power of the repeater for this.

2.3. Where to begin

From [2], p. 122-130, we can summarize that from all the specified points by the enumeration method, you can select three points, the circle standing on which will also include all other points, and the radius will be minimal. They can be divided into three types, of which the further development of algorithms will follow:

- **acute-angled**, all angles are less than 90 degrees, - all three points will belong to a circle;
- **obtuse**, one angle is more than 90 degrees, - two sharp peaks will lie on the circle, and the large side between them will be the diameter;
- **right-angled** triangles can be attributed to the second type, since the point at the vertex of the right angle will lie on the circumscribing circle, and its hypotenuse will be the diameter.

Thus, in the first case, the coordinates of the center of the circle can be found from the coordinates of these points by the formulas (1) and (2)

$$x_0 = -\frac{1}{2} \frac{y_A(x_B^2 + y_B^2 - x_C^2 - y_C^2) + y_B(x_C^2 + y_C^2 - x_A^2 - y_A^2) + y_C(x_A^2 + y_A^2 - x_B^2 - y_B^2)}{x_A(y_B - y_C) + x_B(y_C - y_A) + x_C(y_A - y_B)}$$

$$y_0 = \frac{1}{2} \frac{x_A(x_B^2 + y_B^2 - x_C^2 - y_C^2) + x_B(x_C^2 + y_C^2 - x_A^2 - y_A^2) + x_C(x_A^2 + y_A^2 - x_B^2 - y_B^2)}{x_A(y_B - y_C) + x_B(y_C - y_A) + x_C(y_A - y_B)} \quad [3]$$

In the second and third cases, the third point is not needed to calculate the radius and center of the circle. Formulas for calculating the coordinates of the

midpoint of a segment on the plane (3) and (4)

$$x_c = \frac{x_a+x_b}{2} \quad y_c = \frac{y_a+y_b}{2} \quad [4]$$

The number of all combinations of three points for the set $n - C_n^3 = n*(n-1)*(n-2)/3$, the number of combinations of two points, to find the largest radius – $C_n^2 = n*(n-1)/2$. Therefore in order to save computational resources and time, it is better to start sorting out all combinations of two points.

III. METHODS OF RESEARCH

Before working methods and algorithms, we need to check the number of points in total. If their number is two or more, the methods of finding and constructing will work, in the case of one, the global circle will be this point, and the circle with a fixed radius will fall into it.

3.1. Method for solving the problem №1

We will find the largest distance, draw a circle on it and check if all the points belong to it. If yes, the task of building a global circle is solved - the center lies in the middle of this segment and the radius is equal to half of it.

Otherwise, we will need to iterate over $n-2$ points to find the third and build a circle on them according to formulas (1) and (2), the first two points were left from an attempt to construct a circle by two points, since the largest segment will always be included in final triangle.

It follows from this that the solution to the main Young's problem can be found in a minimum of $n * (n-1) / 2$ iterations and a maximum in $n *(n-1)/2 + (n-2)$.

3.2. Method for solving the problem №2

The fixed / given radius imposes an additional condition that makes it necessary to find a method for placing the minimum number of circles to describe all points - this is the problem of covering a set [5].

Predetermined radius creates two possible situations: the radius is equal to or greater than the global, which we found in the past method, and a radius less than the global.

In the first case, after comparing the radii, we will place the center of the circle with a fixed radius in the same place as the center of the global one.

In the second, we must place them so that the rules of the greedy algorithm [6] are fulfilled: at each step we will place one circle that covers the maximum number of not yet covered points until their number is equal to zero.

Since the possible positions of the placement of centers on a flat surface are infinite, we will start from the same methods for finding a circle by two and three points. The time to find all circles is approximately equal to $\sum_{i=1}^m \left(\frac{n_i(n_i-1)}{2} + n_i - 2 \right)$, where n_i is the number of points not yet covered at each step, m is the number of all steps.

3.3. Software product that implements algorithms

Now our task is to bring the methods to life by writing algorithms that will execute them.

To visually demonstrate the performance of the algorithms, we decided to write in JavaScript and upload it as a website with a convenient interface to the online platform GitHub: https://6mahdapihka9.github.io/Coverage_Task_v2/.

First of all, we will write the software modules that we will operate on. The "Dot" class will have two coordinates, the coverage property and information about the circle that dot was covered by.

```
class Dot{
  constructor(_x, _y) {
    if (_x !== undefined && _y !== undefined) {
      this.x = _x;
      this.y = _y;
    } else {
      this.x = 0;
      this.y = 0;
    }
    this.covered = false;
    this.coveredBy = undefined;
  }
}
```

The class "Dist" includes two dots, and the already calculated value of the distance.

```
class Dist {
  constructor(_v, _d1, _d2) {
    this.value = _v;
    this.dot1 = _d1;
    this.dot2 = _d2;
  }
}
```

The class "Circle" has coordinates and the value of the number of covered points, so later determine which circle with a fixed radius to build.

```
class Circle {
  constructor(_x, _y) {
    this.x = _x;
    this.y = _y;
    this.dotsCovered = 0;
  }
}
```

Create array d with all dots in it.

We start the method of building a global circle with a double nested loop, which will go through all possible distances and find the largest:

```
let m = 0, n = 0, max = 0;
let newDist;
for (let i = 0; i < d.length-1; i++){
  for (let j = i+1; j < d.length; j++) {
```

```

lenX = Math.abs(d[i].x - d[j].x);
lenY = Math.abs(d[i].y - d[j].y);
newDist = new Dist( Math.sqrt(Math.pow(lenX, 2) + Math.pow(lenY,2)) , d[i],
d[j]);

if (max < dist[k].value) {
    max = dist[k].value;
    m = i;
    n = j;
}
}
}

```

m and n – numbers of points in the array, the distance between which is the greatest.

Next step – build a circle by two points and check if all the points fall into it:

```

tempX = (d[m].x + d[n].x)/2;
tempY = (d[m].y + d[n].y)/2;
tempR = Math.sqrt(Math.pow(d[m].x - tempX, 2) + Math.pow(d[m].y - tempY, 2));
enoughOne = true;
for (let i = 0; i < d.length; i++)
    if ((Math.pow(d[i].x-tempX, 2) + Math.pow(d[i].y-tempY, 2)) >
Math.round(tempR*tempR) + 0.0001) {
        enoughOne = false;
        break;
    }
Cx = tempX;
Cy = tempY;
R = tempR;

```

If during the check some points are not included, select the third anchor point with index l and draw a circle around them.

```

Cx = -(d[n].y * (d[m].x * d[m].x + d[m].y * d[m].y - d[l].x * d[l].x - d[l].y * d[l].y) + d[m].y *
(d[l].x * d[l].x + d[l].y * d[l].y - d[n].x * d[n].x - d[n].y * d[n].y) + d[l].y * (d[n].x * d[n].x +
d[n].y * d[n].y - d[m].x * d[m].x - d[m].y * d[m].y)) / (2 * (d[n].x * (d[m].y - d[l].y) + d[m].x *
(d[l].y - d[n].y) + d[l].x * (d[n].y - d[m].y)));
Cy = (d[n].x * (d[m].x * d[m].x + d[m].y * d[m].y - d[l].x * d[l].x - d[l].y * d[l].y) + d[m].x *
(d[l].x * d[l].x + d[l].y * d[l].y - d[n].x * d[n].x - d[n].y * d[n].y) + d[l].x * (d[n].x * d[n].x +
d[n].y * d[n].y - d[m].x * d[m].x - d[m].y * d[m].y)) / (2 * (d[n].x * (d[m].y - d[l].y) + d[m].x *
(d[l].y - d[n].y) + d[l].x * (d[n].y - d[m].y)));
R = Math.sqrt(Math.pow(d[n].x - Cx, 2) + Math.pow(d[n].y - Cy, 2));

```

To construct circles of a fixed radius, the same algorithms were used with an additional counter of covered points to select the optimal circle at each iteration.

We will not consider the rest of the program details of the interface type and information input / output functions in this work, since we are not talking about them.

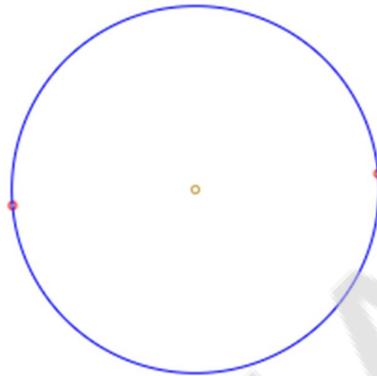
IV. RESULTS

The developed software has the following structure:

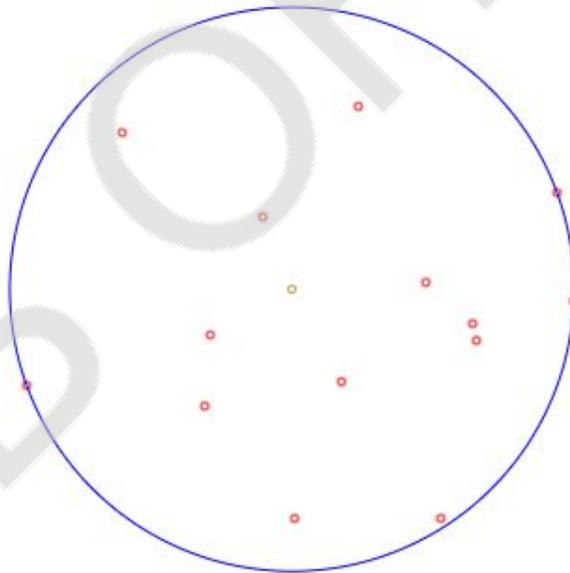
- classes Dot (point), Dist (segment), Circle (circle), which are the main objects with which the algorithms work;
- modules that process user actions;

- algorithms that find and build optimal circles;
- auxiliary modules (implement functions for convenient work with arrays and others).

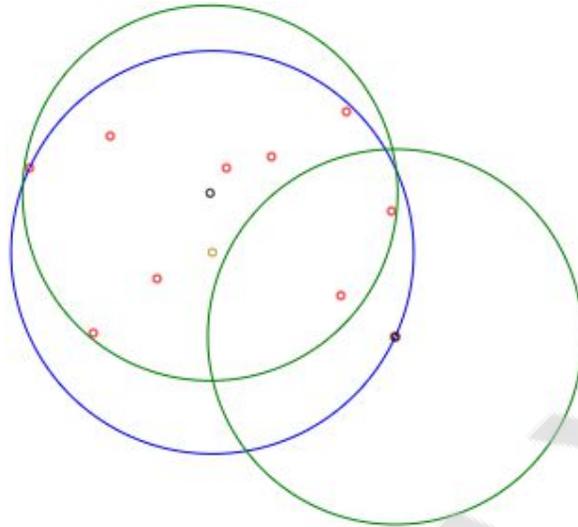
4.1. Software product testing



Img. 1. Test of two dots:
red dots – should be covered, brown – the center of the circle, blue – the global circle



Img. 2. Test of more dots



Img. 3. Test two algorithms at once:
green – circles of minimum radius

V. CONCLUSIONS

In the course of work on the practical part, software was developed to solve problems on covering a flat surface with circle of optimal radius and circles of fixed radius.

We used the following algorithms to design the software:

1. Algorithm for constructing a general range (3.1);
2. Algorithm for constructing circles with a given radius (3.2).

Thus, as a result of the conducted researches algorithms and their program realization for the decision of Jung's problem on the plane with various criteria of optimality are developed. The user has all the necessary information to design new and set up existing mobile networks.

Also in the developed product are realized:

- input of coordinates;
- saving coordinates;
- adding / deleting an image;
- cancellation of actions;
- delete everything;
- input of radius
- construction of a circle and / or circles;
- scaling;
- moving the image;
- output / hiding statistics;
- saving statistics.

The software product is developed in the programming language HTML, CSS, JavaScript. The product allows you to enter coordinates, both manually, on the canvas, and from a file, enter the radius with which the circles will cover the plane,

create and work with files containing coordinates and information about the circles that cover them. It is also possible to add images to the canvas, for the convenience of coordinate points, scaling, moving the image, displaying statistics on the screen.

Checking the operation of the software product was carried out by testing different sequences of actions. No errors were detected during testing. The program works correctly.

The developed software product meets the requirements and has demonstrated its efficiency.

Regarding the prospect of continuing research, we note the need to solve such problems on surfaces with a given relief (maps), taking into account the presence of obstacles of natural and artificial nature. Separately highlight the spread of research on three-dimensional space - the task is to construct a sphere of minimum diameter, which covers a given set.

VI. REFERENCES

1. [Круг](https://ru.wikipedia.org/wiki/%D0%9A%D1%80%D1%83%D0%B3) (28 December 2020). In Wikipedia
<https://ru.wikipedia.org/wiki/%D0%9A%D1%80%D1%83%D0%B3>
2. Rademacher G., Teplitz O. (1962). [Числа и фигуры. Опыты математического мышления \(10th ed.\)](http://ilib.mccme.ru/djvu/bib-mat-kr/num-fig.htm)
<http://ilib.mccme.ru/djvu/bib-mat-kr/num-fig.htm>
3. [Описанная окружность](https://ru.wikipedia.org/wiki/%D0%9E%D0%BF%D0%B8%D1%81%D0%B0%D0%BD%D0%BD%D0%B0%D1%8F_%D0%BE%D0%BA%D1%80%D1%83%D0%B6%D0%BD%D0%BE%D1%81%D1%82%D1%8C) (23 June 2020). In Wikipedia
https://ru.wikipedia.org/wiki/%D0%9E%D0%BF%D0%B8%D1%81%D0%B0%D0%BD%D0%BD%D0%B0%D1%8F_%D0%BE%D0%BA%D1%80%D1%83%D0%B6%D0%BD%D0%BE%D1%81%D1%82%D1%8C
4. [Середина отрезка](https://ru.wikipedia.org/wiki/%D0%A1%D0%B5%D1%80%D0%B5%D0%B4%D0%B8%D0%BD%D0%B0_%D0%BE%D1%82%D1%80%D0%B5%D0%B7%D0%BA%D0%B0) (16 October 2020). In Wikipedia
https://ru.wikipedia.org/wiki/%D0%A1%D0%B5%D1%80%D0%B5%D0%B4%D0%B8%D0%BD%D0%B0_%D0%BE%D1%82%D1%80%D0%B5%D0%B7%D0%BA%D0%B0
5. [Задача о покрытии множества](https://ru.wikipedia.org/wiki/%D0%97%D0%B0%D0%B4%D0%B0%D1%87%D0%B0_%D0%BE_%D0%BF%D0%BE%D0%BA%D1%80%D1%8B%D1%82%D0%B8%D0%B8_%D0%BC%D0%BD%D0%BE%D0%B6%D0%B5%D1%81%D1%82%D0%B2%D0%B0) (17 October 2020). In Wikipedia
https://ru.wikipedia.org/wiki/%D0%97%D0%B0%D0%B4%D0%B0%D1%87%D0%B0_%D0%BE_%D0%BF%D0%BE%D0%BA%D1%80%D1%8B%D1%82%D0%B8%D0%B8_%D0%BC%D0%BD%D0%BE%D0%B6%D0%B5%D1%81%D1%82%D0%B2%D0%B0
6. [Жадный алгоритм](https://ru.wikipedia.org/wiki/%D0%96%D0%B0%D0%B4%D0%BD%D1%8B%D0%B9_%D0%B0%D0%BB%D0%B3%D0%BE%D1%80%D0%B8%D1%82%D0%BC) (30 December 2020). In Wikipedia
https://ru.wikipedia.org/wiki/%D0%96%D0%B0%D0%B4%D0%BD%D1%8B%D0%B9_%D0%B0%D0%BB%D0%B3%D0%BE%D1%80%D0%B8%D1%82%D0%BC

ANALYSIS OF MIXTURES AT LASER SURFACING USING COMPUTER VISION

Author: *Mykhailo Kovalevskiy*

Advisors: *Dmitriy Kritskiy, Olha Pohudina*

National Aerospace University Kharkiv Aviation Institute (Ukraine)

Abstract. *A method of contour recognition is considered, which includes several stages of processing the original image. Some methods of contour recognition are highlighted and their characteristic features are described. A certain sequence of applying the stages of processing the input image is proposed. Examples of output data after applying image processing and the results of their analysis are given. The comparison of the quality of contour recognition for each type of powder is carried out, the error of the analysis is calculated, and the corresponding conclusions are drawn.*

Keywords: *computer vision, OpenCV, laser surfacing, Freeman chain code, Gaussian filter, threshold transformation.*

I. INTRODUCTION

Using of computer vision-based systems for the analysis of mixtures, powders, etc. already applied. In the presented work, it is proposed to use the OpenCV library to create software that allows analyzing the powder during laser surfacing in order to calculate the required operating modes of the machine.

The field of computer vision is quite popular now. Interest in it arose at the dawn of attempts to create artificial intelligence [4]. Currently, the number of new solutions and relevant applications for computer vision and artificial intelligence in general continues to grow.

With an increase in the number of proposed methods and algorithms for recognizing contours within an image, it becomes unclear the choice of any specific method for certain needs, since each separately taken method is good for some specific narrow range of tasks.

There are many approaches to the selection of boundaries, but almost everything can be divided into two categories [5]: methods based on finding maximums and methods based on finding zeros. Methods in the first category isolate boundaries by calculating the “edge strength”, represented as an expression of the image gradient, and then finding the local maximum of the edge strength using the assumed direction of the boundary, usually perpendicular to the gradient vector. Methods of the second category look for the intersections of the abscissa with the second derivative expression, which are usually the zeros of the Laplacian or the zeros of a nonlinear differential equation. As a preprocessing step, image smoothing is almost always applied to edge selection. As a rule, a Gaussian filter is used for these purposes [5].

Although many of the known boundary extraction techniques are based on the computation of the gradient of an image, they differ in the types of filters used to

compute gradients in different directions.

The complexity of this problem is significant heterogeneity of the contour boundaries on the powder granules.

II. LITERATURE ANALYSIS

Significant restrictions on the scope of contour analysis are imposed by problems associated with contour selection in images, namely:

- due to the same brightness with the background, the object may not have a clear boundary, or may be noisy with interference, which leads to impossibility to recognize the contour;
- overlapping of objects or their grouping leads to the fact that the contour is recognized incorrectly and does not correspond to the boundary of the object.

However, the transition to considering only the contours of objects allows to go from the image space to the space of the contours, which significantly reduces the complexity of algorithms and calculations.

Thus, we can conclude that the contour analysis has a rather weak immunity to interference, and any intersection or only partial visibility of the object leads either to the impossibility of detection or to false positives. However, the simplicity and speed of the contour analysis make it possible to apply this approach quite successfully (with a clearly defined object against a contrasting background and no interference).

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The **object** of the article is the process of finding the contours of objects in the images of mixtures used in laser surfacing. The **subject** of the article is the methods of computer vision in the processing of graphic information in images obtained from a microscope. The **aim** is to improve the quality of laser surfacing by detecting granules of small, medium and large powder in the material to be used. **Objectives:** to analyze the characteristics of images of the material obtained under a microscope; consider methods to eliminate the noise of the original image; get a binary image with a binarization threshold that will allow you to detect the maximum number of objects; develop an algorithm that allows you to get at least 80% of the granules in the image and estimate their size. The used **methods** are: Gaussian filtering method, threshold transformation method for obtaining a binary image, contour detection method using approximation by horizontal, vertical and diagonal segments.

IV. RESULTS

4.1. Step-by-step image processing

Since it is known that a contour is a kind of boundary of an object that separates it from the background (other objects), in order to select it, as a rule, several stages are necessary.

The first step is to blur the image. This operation is performed for reasons of more precise detection of the boundaries, since the step between the color gradations

will be higher than in the original image. There are quite a lot filters that provide smoothing (Gaussian filter, median filter, etc.).

But how to get the contours directly? Of course, Canny's edge detector is remembered first, and then any other methods of obtaining a binary image can be cited. For example, threshold transformation and detection of an object by color.

In all these cases, we get a binary image that explicitly sets the boundaries of the object to us. This collection of pixels that make up the boundary of the object is the object contour.

To operate on the resulting contour, it must be somehow represented (encoded). For example, indicate the vertices of the line segments that make up the contour. Another well-known way of encoding a contour is Freeman's chain code.

Chain codes are used to represent a boundary as a sequence of straight line segments of a certain length and direction. This representation is based on a 4- or 8-connected grid. The length of each segment is determined by the resolution of the grid, and the directions are given by the selected code (to represent all directions in a 4-connected grid, 2 bits are enough, and for an 8-connected grid of the chain code, 3 bits are required).

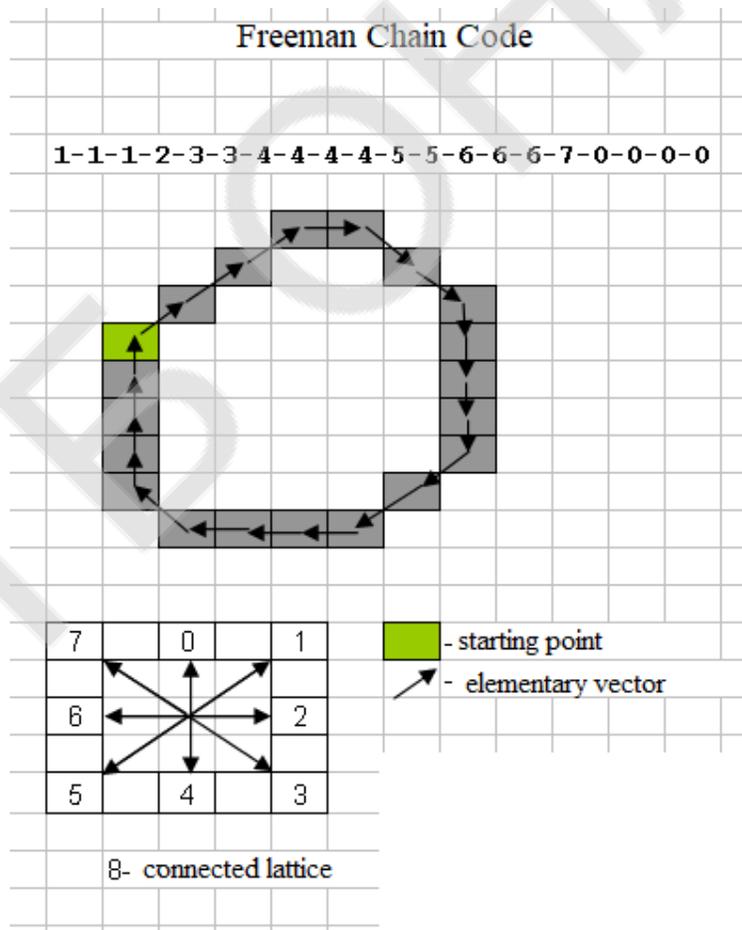


Fig. 1. Freeman chain code

Thus, the algorithm of actions for object recognition is as follows:

1. pre-processing of the image (smoothing, filtering noise, increasing the contrast);
2. binarization of the image;
3. objects contours detection;
4. filtration of contours (along the perimeter, area, etc.);
5. enumeration and display of found contours.

4.2. Description of the created software product

To solve the problem, namely to find and analyze powder granules on the image, a software product was developed using the OpenCV computer vision library.

The input to the software product is an image of the powder that must be analyzed. Powder, in turn, can be classified into 3 categories: small (Fig. 2), medium (Fig. 3) and large (Fig. 4).

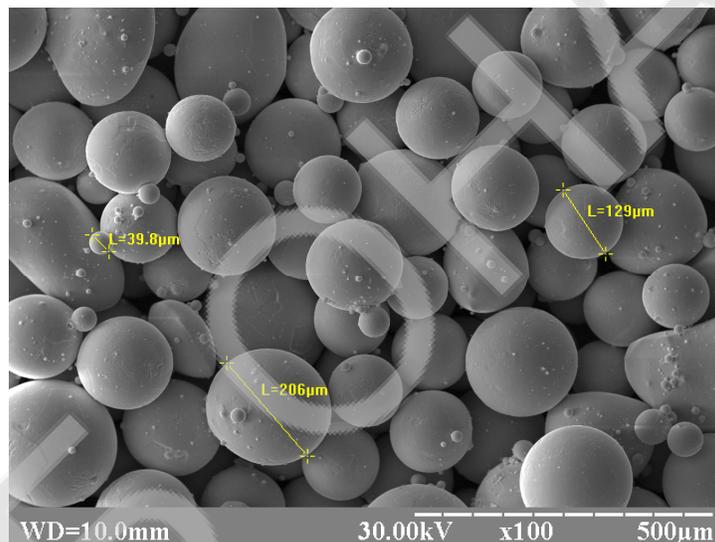


Fig. 2. Small powder

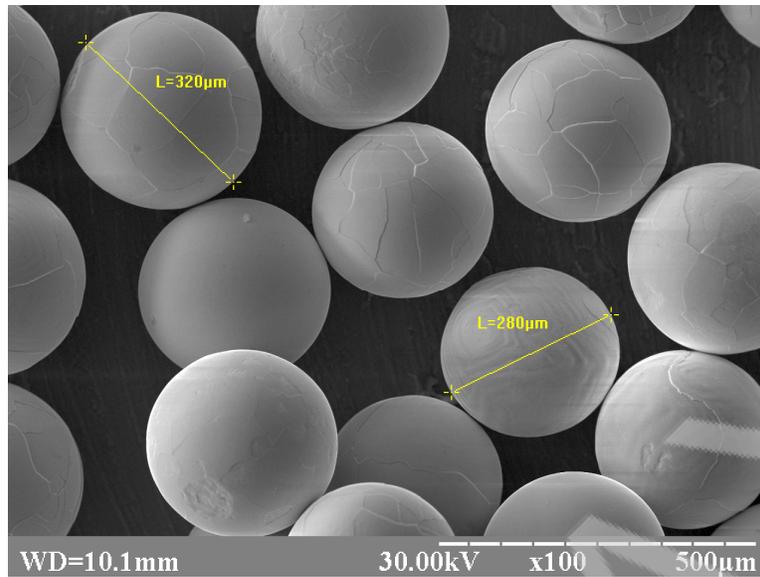


Fig. 3. Medium powder

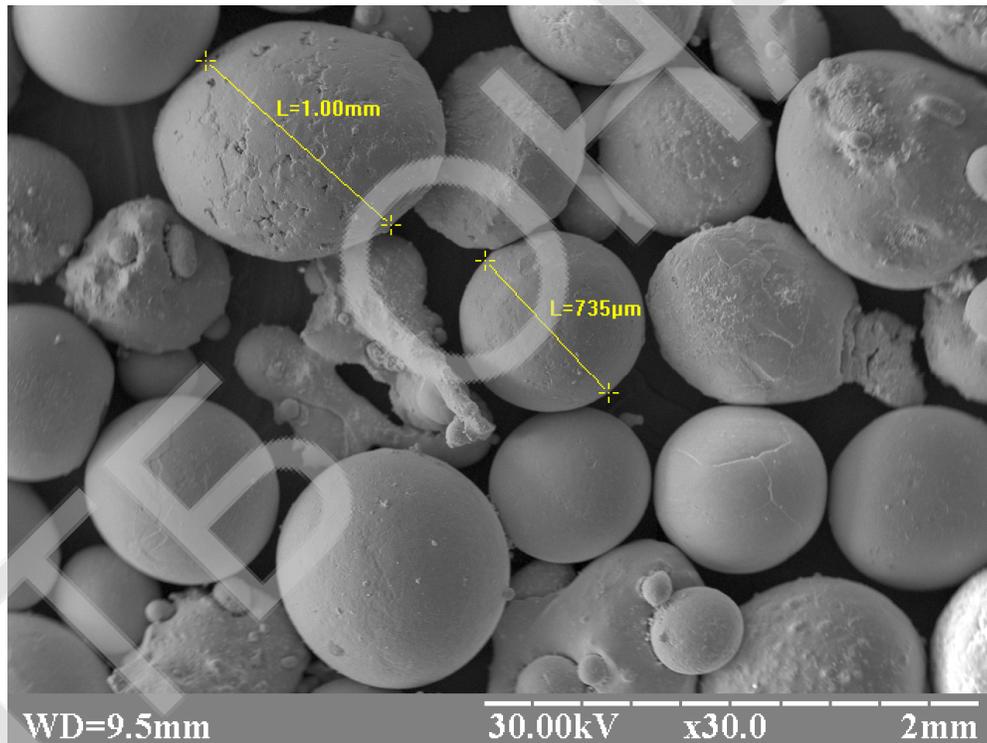


Fig. 4. Large powder

After the image has been submitted to the input, the program processes it according to the above described algorithm and analyzes it. As a result, two windows open:

- 1) window with the input image and the contours found on it (Fig. 5);
- 2) window with analysis results (Fig. 6).

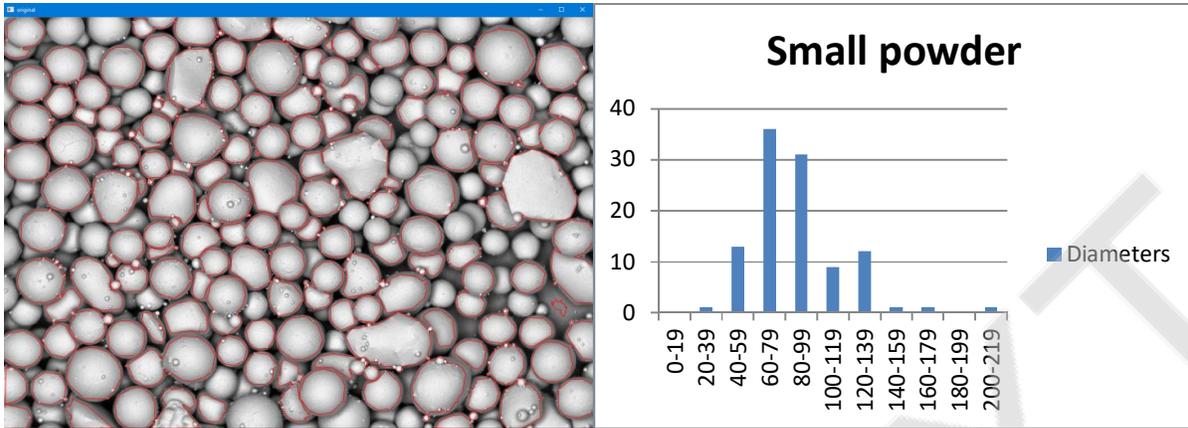


Fig. 5. Found contours for small powder and diameter distribution

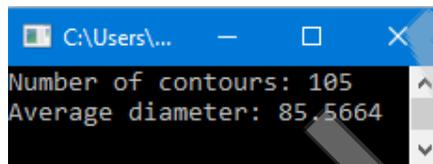


Fig. 6. Analysis results for small powder

As you can see from Figures 5-6, the program recognized the powder granules, calculated their number and the average diameter of one granule. Despite the blur and thresholding there are still some noise and darkening on the images, so the recognition algorithm has some error. This error depends not only on the quality of the image received at the input, but also on the quality of the powder, since on some granules the program was able to recognize the internal contours of the granule.

For example, when analyzing small powder, it was possible to recognize 105 granules, while the actual value is 175. Thus, the analysis error for small powder is:

$$\varepsilon_s = \frac{|175 - 105|}{175} = \frac{70}{175} = 0,4 = 40\%.$$

The medium powder is analyzed in the same way. The analysis results are shown in Figures 7-8.

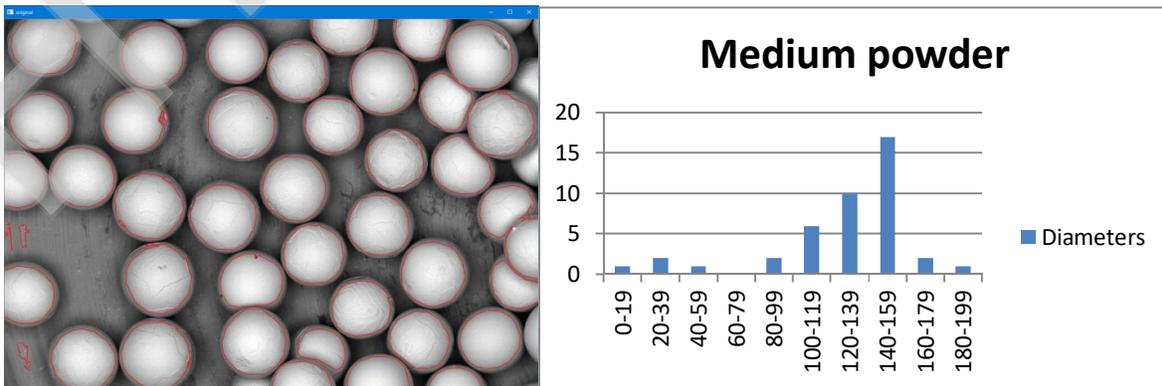


Fig. 7. Found contours for medium powder and diameter distribution

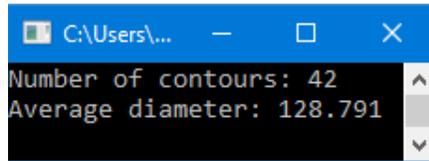


Fig. 8. Analysis results for medium powder

Analysis error for medium powder:

$$\varepsilon_m = \frac{|40 - 42|}{40} = \frac{2}{40} = 0,05 = 5\%.$$

Now let's also analyze the large powder. The analysis results are shown in Figures 9-10.

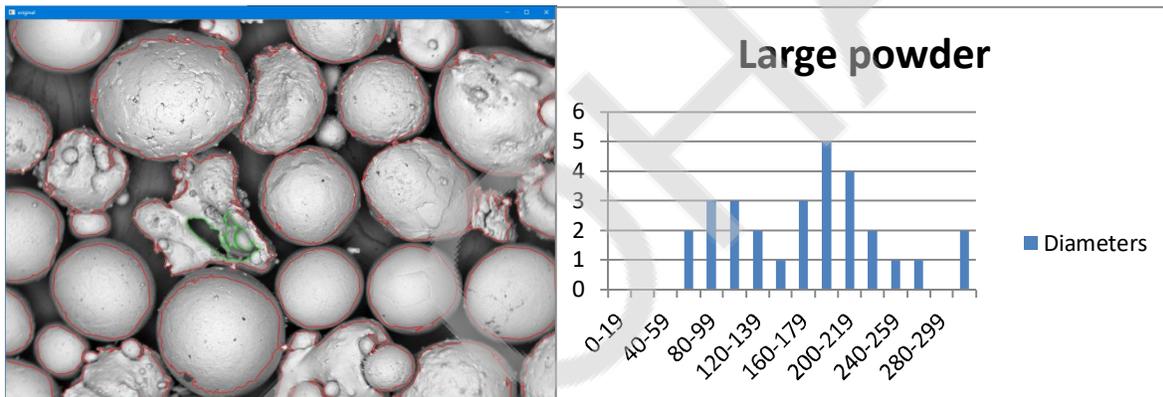


Fig. 9. Found contours for large powder and diameter distribution: red color – external contours, green color – internal contours

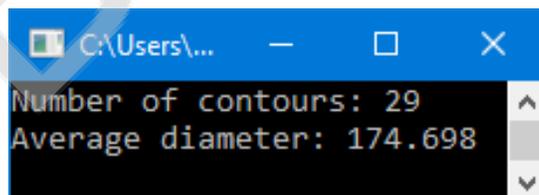


Fig. 10. Analysis results for large powder

Analysis error for large powder:

$$\varepsilon_l = \frac{|31 - 29|}{31} = \frac{2}{31} \approx 0,06 = 6\%$$

So the average error of the algorithm:

$$\varepsilon = \frac{\varepsilon_s + \varepsilon_m + \varepsilon_l}{3} = \frac{40 + 5 + 6}{3} = \frac{51}{3} = 17\%.$$

V. CONCLUSIONS

A step-by-step method for recognizing contours in an image using computer vision is proposed for analyzing powders and mixtures during laser surfacing, where the working conditions are quite difficult due to the presence of hardly distinguishable gray gradations in the images and strong heterogeneity of the boundaries of recognized objects. A similar approach is used to recognize phase and grain contours in steel microstructure images. We also analyzed the results of a software product built on the basis of the proposed object recognition approach. The comparison of the quality of contour recognition is carried out for each type of powder: small, medium and large. The analysis error was calculated, which average value is 17%.

Thus, the proposed solution showed quite good results for medium and large powder, where the error was 5% and 6%, respectively. However, it still needs further improvement when analyzing large powder.

VI. REFERENCES

1. [Gonzalez, R. C., Woods, R. E. \(2008\) Digital image processing, Prentice Hall, 977 p.](#)
2. [Vanyukova, D. I., Popov, S. S., Sokolov, P. A. \(2014\) Combining a digital cartographic image of the area with a radar image. In the book: Materials of the XVI Conference of Young Scientists "Navigation and Traffic Management", Sankt-Peterburg Publ. pp. 1-6.](#)
3. [Klyuev, A. V., Stolbov, V. Yu., Sharybin, S. I. \(2016\) Visualization of complex grain structures of metals and alloys in identifying their parameters. Nauchnaya vizualizatsiya – Scientific visualization., vol.8, no.3, pp. 95-101.](#)
4. [Klestov, R. A., Stolbov, V. Y. \(2017\) Complex recognizing contours method for an image based on computer vision technology. GraphiCon, Perm, PNRPU Publ., pp. 208-211.](#)
5. [Shih, F. \(2010\) Image processing and pattern recognition: fundamentals and techniques., 537 p., IEEE.](#)
6. [Krytskiy, D.M., Pohudina, O.K. \(2019\) Automatic creation of g-code for laser surfacing equipment. XXIV mizhnarodnyy konhres dvyhunobudivnykiv. Tezy dopovidey. Kharkiv. Nats. aerokosmichnyy un-t «Khark. aviats. in-t», p. 104.](#)
7. [Morunov, I. V., Krylova, S. E., Oplesnin, S. P. \(2017\) Principle of gas-shielded laser cladding of corrosion-resistant steels. XVIII mezhdunarodnaya nauchno-tekhnicheskaya Ural'skaya shkola-seminar metallovedov-molodykh uchenykh. Ekaterinburg, 18, pp. 27-31.](#)
8. [Ermolaev, A. S., Ivanov, A. M., Vasilenko, S. A., Babikov, V. S., Mubarakshin, R. M., Kondrashov, E. V. \(2016\) Primenenie lazernykh tekhnologiy dlya izgotovleniya i remonta detaley i uzlov gazoturbinnnykh dvigateley. Aviatsionnye materialy i tekhnologii, 1\(40\), pp. 37-43.](#)
9. [Liu, R., Wang, Z., Sparks, T., Liou, F., Newkirk, J. \(2017\) Aerospace applications of laser additive manufacturing. Laser additive manufacturing. Woodhead Publishing, \(pp. 351- 371.\) doi:10.1016/b978-0-08-100433-3.00013-0](#)

RESEARCH OF THE LOGO! MICROCONTROLLER PROGRAMMING SYSTEM

Author: *Idrisov Marat Rinatovich*

Advisor: *Seytkanov Sabriden Seytkanovich*
Academician K. I. Satpayev Ekibastuz Engineering
and Technical Institute (Republic of Kazakhstan)

Abstract

In this scientific paper the programming system of the microcontroller LOGO! is considered. To design a switching program written in a programming language, a programming system is used. A programming system is software designed for the development of an ACS (automatic control system) and written in a specific programming language, which is developed by manufacturers of controllers and microcontrollers (or firms specializing in creating software for automation systems). Programming of controllers and microcontrollers recorded in IEC 61131-3 languages is carried out using specialized software. Microcontroller LOGO! (logical Siemens controller) is programmed using FBD (function block language) or LAD (relay ladder language) using the LOGO! Soft Comfort. In the research part of the scientific project, the microcontroller LOGO! Programming system is considered.

The LOGO Soft Comfort program is used for programming microcontrollers LOGO! via a PC (personal computer). The program allows you to create a microcontroller switching program (in the programming language of the international standard IEC 61131-3), in the form of a diagram (diagram) of functional blocks (FBD - Function Block Diagram) or in the form of a relay-contactor circuit (LAD - Ladder diagram). The functionality of the circuit program can be tested on a personal computer in emulation mode, which does not require a connection to the LOGO! Microcontroller. In the research part of the scientific work, the switching program Automatic control system for internal lighting is considered.

The program allows you to create a microcontroller switching program (in the programming language of the international standard IEC 61131-3), in the form of a diagram (diagram) of functional blocks (FBD - Function Block Diagram) or in the form of a relay-contactor circuit (LAD - Ladder diagram). The functionality of the circuit program can be tested on a personal computer in emulation mode, which does not require a connection to the LOGO! microcontroller. In the research part of the scientific work, the switching program Automatic control system for internal lighting is considered.

Introduction

A feature of the modern development of production is the emergence and massive use of qualitatively new technical means that reduce human participation in the production process. At the same time, these funds allow increasing the intensity of the production process, reducing costs and expenses, as well as almost completely eliminating errors caused by the so-called human factor.

Modern industrial automation systems allow solving a wide range of tasks, which can be divided into several groups with their own characteristics:

- Automation of control of technological processes (ACS TP);
- Interaction of the system by the dispatcher (operator);
- Automated control and measurements (monitoring);
- Security;
- Remote control, measurement, signaling (telemechanics tasks).

To solve the problems listed above, high-level universal programming languages and a team of professional programmers were initially used. However, practice has shown extremely low efficiency of such development. It turned out that the development of the system should be carried out not by programmers, but by specialists of the subject area that needs automation, i.e. technologists, as well as system integrators who carry out complex implementation of the system.

The emergence of the IEC 61131 - 3 standard for programming languages for controllers in 1993 was a big step towards the creation of open automation systems and provided a reduction in development costs, shorter lines, improved implementation of automation algorithms and the possibility of detailed study of programming languages suitable for any controller. IEC 61131-3 established the standards for five programming languages intended for professionals in a variety of non-programming professions.

At present, custom programs are naturally ousted from the industrial automation market by means of programming controllers in the languages of the IEC 61131-3 standard.

Programming of controllers and microcontrollers in the IEC 61131-3 languages described above is carried out using specialized software, which is developed by manufacturers of controllers and microcontrollers specializing in design of software for automation systems [1].

Микроконтроллер LOGO! позиционирует данное устройство как «интеллектуальное реле», позволяющее строить несложные системы автоматизации. Ниже на рис.1 приведен микроконтроллер LOGO! .

Fields of application of LOGO! microcontroller

Siemens LOGO! includes the logic modules LOGO! , digital input / output modules DM8 / DM16, analog input / output modules AM2 / AM2 AQ, CM communication modules, silent switching modules for 3-phase AC circuits LOGO !, LOGO! power supplies, accessories and LOGO! Soft Comfort software. For more demanding applications, there are modifications of the LOGO! modules.

The LOGO! microcontroller is designed to solve the simplest problems of automatic control; software implementation of control algorithms and flexible adaptation of the equipment to the requirements of the tasks being solved, allow using logic modules in all sectors of industrial production.

LOGO! microcontroller positions this device as a "smart relay" that allows you to build simple automation systems. Fig. 1 below shows the LOGO! microcontroller.

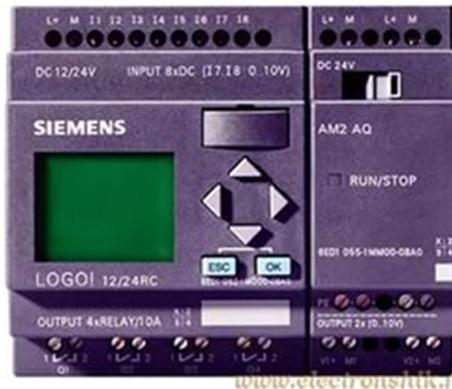


Fig. 1 . LOGO! microcontroller

As examples of such systems can be garage doors, staircase lighting, traffic light control, and simpler systems that include several actuators and controls (buttons and switches). Fig. 2 below shows the LOGO! with additional module [2].



Fig. 2. LOGO! microcontroller with additional module.

Programming the LOGO! microcontroller

The LOGO! Soft Comfort is designed for programming the LOGO! microcontroller using a PC (personal computer). The program allows you to develop a switching program in the language of the international standard IEC 61133-3, in the form of a function block diagram FBD (Function Block Diagram) or in the form of a relay-contactor circuit LAD (Ladder diagram). The introduction of the IEC 61133-3 controller programming language standard in 1993 was a major step towards open automation systems and reduced development costs.

The standard was originally called IEC 1131-3 and was published in 1993. But in 1997 IEC switched to a new notation system and the number "6" was added to the name of the standard.

IEC - International Electrotechnical Commission - a world organization that has been developing international standards in the field of electrical engineering, electronics, telecommunications and information technology since 1906; in 1975 the working committee 65A for the development of a PLC (programmable logic controller), which in 1993 adopted an international standard IEC - 1311 (currently IEC 61133-3), the third part of which deals with languages for PLCs. It includes five languages.

FBD (Function Block Diagram) - Function Block Diagram Language is a graphical, functional programming language that uses analogy with digital diagrams. A program in this language is a collection of functional blocks connected by lines. FBD languages are chosen by specialists in automatic control systems (ACS) and circuitry.

LAD (Ladder diagram) relay program language is a graphical language, the program in which is an analogue of a relay-contactor circuit. The LAD language is chosen by specialists with experience in relay logic.

SFC is a language of sequential functional diagrams, (is a graphical language in which a program is described as a sequence of steps united by transitions. This language is convenient when you need to describe a sequence of relay operations spaced out in time and check the conditions that arise for their execution).

ST - structured text language, (is a high level text language (BASIC, Pascal).

IT- the language of system commands.

Programmers tend to choose IL (similar to assembler language) or ST (similar to high level language).

LOGO! Soft Comfort in IEC 61133-3 or FBD (Function Block Diagram) programming language is designed to program the LOGO! microcontroller.

LAD (Ladder diagram) are graphical programming languages.

Development of switching programs for logic modules LOGO! can be performed using the LOGO! Soft Comfort. LOGO! Soft Comfort runs on Windows 95/98 NT 4.0 / ME / 2000 / XP, Linux, MAC OSX operating systems.

It can be used in client / server applications and provides maximum convenience for developing, debugging, documenting and archiving LOGO! (and also in an interactive mode).

Program development and debugging can be performed automatically without communication between the computer and LOGO! as well as in the interactive mode. In the latter case, the connection between the computer and the logic module is established using the PC-LOGO! **connecting cable**.

The finished program can be loaded into the memory of the logic module via the LC cable (PS-232 interface). Below is an example of a commutation program in FBD (Function Block Diagram) language.

LOGO! Soft Comfort

- develop programs for logic modules LOGO! Soft Comfort
- develop, debug, document and archive LOGO! Soft Comfort programs in both automatic and interactive mode.

- use LAD (Ladder diagram), FBD (Function Block Diagram) languages for program development.
- Configure the parameters of modules and used functions.
- Carry out a quick view of all or some parts of the program.
- Use symbolic addressing for inputs, outputs and functions. Introduce for all variables and functions.
- Simulate the work of the LOGO! on the computer. Load the finished program into the logical module or read the program from the memory of the logical module.
- Display the connection of all variables and functions in the modulation mode of the program or during the program in the logical module.

LOGO! Microcontroller programming system.

A **programming system** is software designed for the development of an ACS (automated control system) and written in a specific programming language, which is developed by manufacturers of controllers and microcontrollers. Microcontroller LOGO! programmable in FBD (Function Block Language) or LAD (Ladder Language) using the LOGO! Soft Comfort.

To develop and debug programs, the LOGO! Soft Comfort is designed. This software package allows you to graphically enter and edit the program, as well as debug the program in the logic module emulation mode. The finished program can be loaded into the memory of the logic module via a special cable or written to the memory module via a special device LOGO !.

LOGO! Soft Comfort provides a well-designed operating environment in which it is convenient to display and change the circuit program. Using the function panel, you can call connections, basic and special functions and simply drag them into the program, move them, and combine them in any order. In emulation mode, you can check and debug the created program. It is possible to add your comments not only to the inputs and outputs, but also to the function blocks.

LOGO! Soft Comfort runs on Windows 95/98 / NT 4.0 / ME / 2000 / XP, Linux and MAC OS X operating systems. It can be used in server applications and provides maximum convenience for developing, debugging, documenting and archiving LOGO! .

Programming of LOGO! modules can be performed from the keyboard using the built-in display. The programming process is reduced to the serial connection of the built-in function blocks and setting the settings (on / off delays, counter values, etc.). All these operations are performed using the built-in menu system. The finished program can be copied to the memory module [3].

Development of the switching program for an automatic interior lighting control system.

LOGO! Soft Comfort allows you to design a switching program. In the scientific paper, the switching program of the automatic control system for interior lighting is considered.

The automatic control wiring diagram of indoor lighting and its description. (Fig. 3)

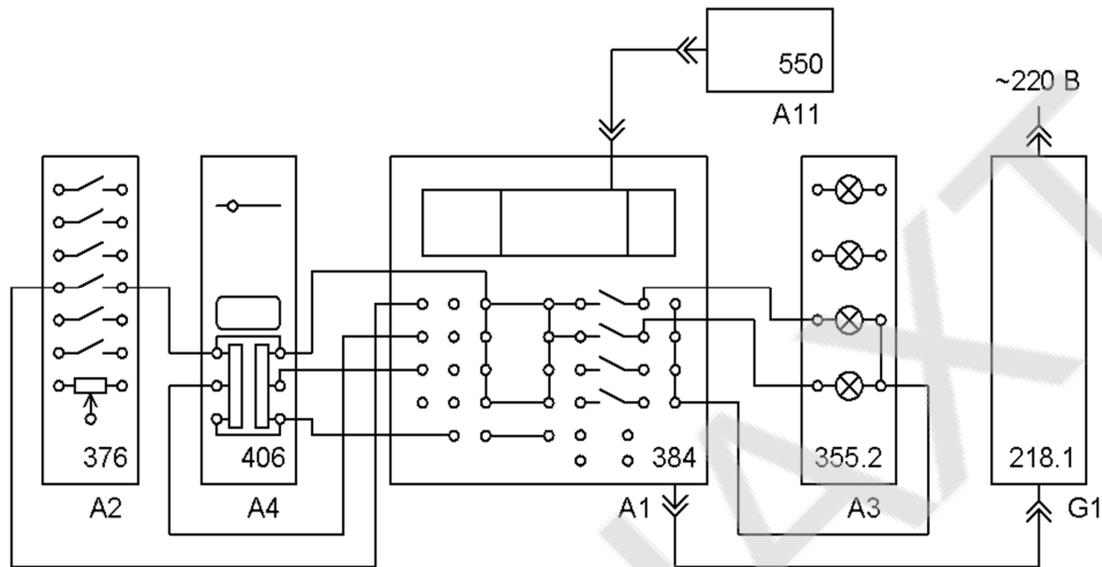


Fig. 3. Basic electrical diagram.

The single-phase power supply G1 is designed to safely supply the A1 programmable controller unit.

Computer A11 is connected with a cable to the connector on the front panel of the controller and is intended for downloading and debugging the switching program. The locking button of the A2 control station is designed to turn on (turn off) the system.

The block of optical switches A4 simulates an illuminated room with a moving object (person).

The lamps in block A3 simulate lighting lamps.

Algorithm of the internal lighting control system

- 1) The system is switched on (off) by a locking button.
- 2) When the object crosses the beam of the optical switch, the zone illumination is turned on. When the object crosses the beam of the next optical switch, the illumination of the zone is stopped and the illumination of the next zone is turned on.

The switching program of the automatic interior lighting control system is designed in the language of the international standard IEC 61113-3, in the form of a diagram of functional blocks FBD (Function Block Diagram).

After designing the switching program for the automatic interior lighting control, the LOGO! Soft Comfort will take the form shown in the figure.

FBD diagram of the interior lighting control system.

FBD diagram of the interior lighting control system. (Fig. 4)

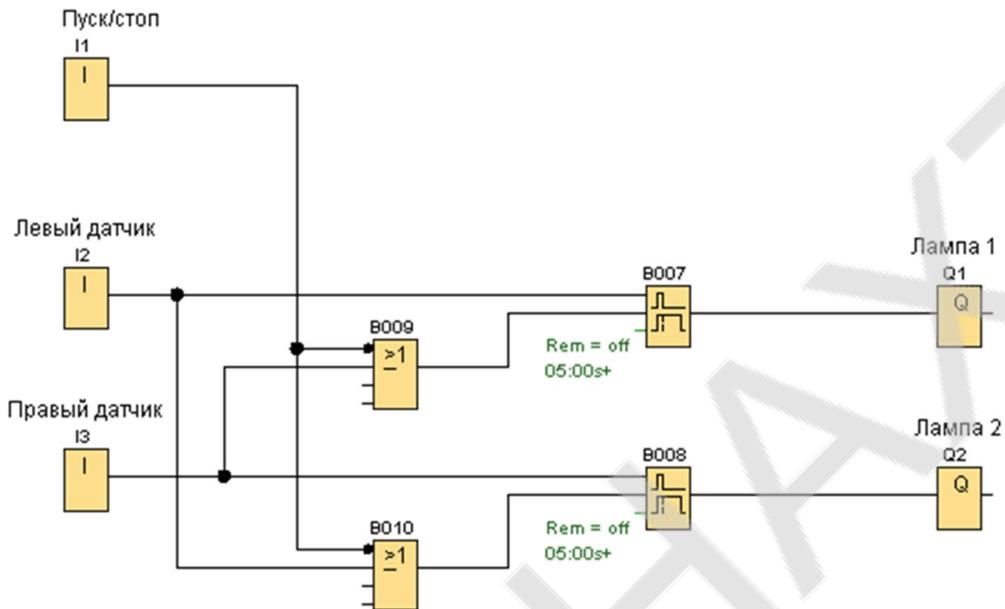


Fig. 4. FBD diagram of the interior lighting control system.

The functions listed in the table are used in the switching program. (Table

1)

Table 1

	I1 – input (Co list). Controls system on / off (0 - off, 1 - on). I2, I3 – sensor signal inputs 1 (left sensor of block A4) and 2 (right sensor A4). The signal is 1 when the sensor is triggered.
	B009, B010 – OR function (list GF).
	B007, B008 – off delay (list SF). The top input is the relay start (the relay output is set to 1 and remains in this state after the input pulse transitions from 1 to 0 for the set delay of 5 s), the second input from the top is reset (the output is immediately set to 0).
	Q1, Q2 – programmable controller outputs (Co list). The lighting lamps of zones 1 and 2 of the sensors are controlled, respectively.

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Q1, Q2 – programmable controller outputs (Co list). The lighting lamps of zones 1 and 2 of the sensors are controlled, respectively.

The point near the input of the function denotes the inversion of this signal (logical NOT operation).

Description of the switching program

- when the system is off (the signal at input I1 is 0) through the inverting inputs the OR function (B009, B010) to the reset inputs of the delay functions (B007, B008) 1 is applied. The outputs of the delay functions and the controller outputs are in state 0 (off).

- when the system is turned on (1 is at input I1), the signal is removed from the reset inputs of the delay functions (B007, B008).

- in the absence of signals from optical switches (0 is at inputs I2, I).

- outputs of off-delay functions and controller outputs are off.

- when a signal from one of the optical switches (1 at input I2 or I3) appears 1 at the input and output of the corresponding off-delay functions (B007 or B008). The controller output contacts (Q1 or Q2) close the power supply circuit of the "zone" lighting lamp of the corresponding optical switch. At the same time, a signal is given to reset the off delay of another lamp (second from top input B007 or B008).

- when the optical switch is turned off (the "object" has left its area of action), the lamp continues to burn for the set delay of blocks B007 and B008 (5 s), or instantly turns off when the optical switch of another channel is triggered [4].

References

1. Demenkov N.P. MVTU - programming languages between controllers, MVTU named after N.E. Bauman, 2004.
2. Michel J. Programmable controllers and microcontrollers: architecture and application. - M.: Mechanical Engineering, 1986.
3. Parr E. Programmable controllers: a guide for an engineer. - M.: BINOM. Knowledge laboratory, 2007, - 516 p. ISBN 978-5-94774-340-1.
4. Krasnogortsev I.L., Senigov P.N. Automation based on a programmable controller. Basic Experiment Guide. APK.001 RBE (929) - Chelyabinsk: IPC "Educational Technique", 2007. 118 p.
5. Petrov I.V. Programmable controllers. Standard languages and techniques of applied design. Ed. Prof. V.P.Dyakonov. - M.: SOLON-Press, 2004. - 256 p. ISBN 5-89003-079-4.
6. Minaev I. G. Programmable logic controllers. A practical guide for a novice engineer. /AND. G. Minaev, V. V. Samoilenko - Stavropol: AGRUS, 2009. - 100 p. ISBN 978-5-956-0609-1.
7. Minaev I. G. Programmable logic controllers in automated control systems / I. G. Minaev, V. M. Sharapov, V. V. Samoilenko, D. G. Ushkur. 2nd ed., Rev. and additional - Stavropol: AGRUS, 2010. -- 128 p. ISBN 978-5-9596-0670-1
8. Prangivshili I.V., Ambartsumyan A.A. The basis of programming of automated control systems by complex technological processes, M. energoatom - published, 1994.

IT SOLUTION REGARDING TO THE IMPLEMENTATION OF THE EU GDPR

Authors: *Aurelian Gore, Ivan Postu*

Advisor: *Rodica Bulai*

Technical University of Moldova (Moldova)

Abstract. *The main objective of the developed software is to implement the principles of the GDPR, the methodology for evaluating the impact of data protection, assessing the severity of the compromise of personal data within an organization and to keep track of personal data processing activities that are performed by responsible employees. The app also includes the possibility to manage the organization, the employee data and to process requests for personal data of those to whom the data belong.*

The functionality of managing an organization is creating it, modifying it by updating its information, deleting it, adding new departments, as well as editing the information about the departments. It is possible to evaluate the organization compliance with GDPR and to analyze statistically the results of the last evaluations.

The management of the departments of the organization includes creating it, changing its information, adding the head of the department, adding employees, displaying them in a list form and deleting it.

The basic functionality of managing the employees of the departments are adding them into respective departments, modifying, deleting their data and adding documents referring to the employee (especially necessary for that who is responsible for processing personal data to prove that he has the legal right to perform the given action). The decision if the employee can be responsible for personal data is made by answering a set of questions.

Keywords: *GDPR, confidentiality, personal data, impact evaluation, privacy, compliance, audit, protection, regulation, accountability.*

I. INTRODUCTION

By May 25, 2018, many of us woke up with dozens of emails in our inboxes from companies, politely asking us if we still wanted them to hold our personal data. The reason for this email campaign is the General Data Protection Regulation (GDPR).

The GDPR is considered the biggest change in the last two decades brought by the European Union legislation referring to data protection and having a global impact.

The strictness of the regulations and the colossal fines that were maximized in the media alarmed both EU and foreign companies. The created situation has become a gold mine for law firms and legal consultants, IT, offering GDPR consulting services at colossal sums.

Therefore, small companies found themselves in the situation of implementing the GDPR on their own, informing themselves on the requirements of the regulation found online, having too small budgets to use specialized consulting services and assuming the risks of deficiencies in compliance with the GDPR.

A law project transposed the EU GDPR to the Republic of Moldova and additions to Law 133 [12] were created based on the protection of personal data. Certain requirements of the regulation have been proposed, but have not yet been adopted.

However, some organizations tend to implement the requirements of the regulation, in particular those that are subsidiaries of European organizations or that collect and process data from European citizens.

II. ANALYSIS OF THE GENERAL REGULATION ON DATA PROTECTION IN A NATIONAL AND INTERNATIONAL CONTEXT

2.1. Evolution and current state of implementation of the GDPR

Data protection is a fundamental right within the European Union, as set out in Article 8 of the Charter of Fundamental Rights of the European Union and Article 16 (1) of the Treaty on the Functioning of the European Union (TFEU).

Until 25 May 2018, the main legal instrument for data protection in the European Union was Directive 95/46 / EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and the free movement of such data. [1]

The provisions of Directive 95/46 / EC have been transposed into the legislation of the Republic of Moldova by Law no. 133 of 08 July 2011 [12] for the protection of individuals with regard to the processing of personal data and on the free movement of such data. [2]

Fast rhythm of technological evolution has led to a colossal increase in the volume of data collected, used, transmitted and processed, which was not foreseen in 1995 when the directive was adopted, the internet being at an early stage and the major players in processing large volumes of data had not yet appeared on the scene (Google was founded in 1998, [3] and Facebook in 2004 [4]).

Increasingly, users have begun to make their personal information public, which has created new challenges in ensuring the protection of personal data.

According to a study conducted by Javelin Strategy & Research, in 2016 a maximum share of online fraud involving identity theft had been reached [5]. Their growth trend was maintained in 2017 with 16.7 million victims. [6]

One of the most publicized and major breaches of personal data security is the Cambridge Analytica scandal, which has affected approximately 87 million users worldwide. In the European Union were affected users from all 28 Member States about 2.7 million Facebook accounts. The largest exploitation took place in Great Britain with 1,079 million and Germany with over 309,815 accounts. In Romania, 112,421 users were affected. [7]

In this digital environment, the need of modernization EU rules on the protection of personal data has become vital. Thus, in 2016 the European Commission adopted REGULATION no. 679 of 27 April 2016 on the protection of individuals with regard to the processing of personal data and on the free movement of such data and repealing Directive 95/46 / EC (General Data Protection Regulation), - GDPR - effective from 25 May 2018. [1]

In the Republic of Moldova, the supervisory authority is - the National Center for Personal Data Protection, based in Chisinau - <https://datepersonale.md/>. [8]

GDPR is legislation with a global impact. Its provisions are applied to all organizations (operators or persons empowered by the operator) operating in the territory of European Union countries. Even if the company's registered office is abroad or is fully established abroad, as long as the company processes personal data collected or processed in the EU, of individuals located in the EU, it must comply with the provisions of the regulation. [1]

According to a study by Hiscox among micro, small and medium-sized enterprises (SMEs) in the UK, more than a third of SME managers (39%) do not know who is affected by GDPR, while 1 of 10 respondents do not believe that the GDPR offers consumers new rights. The study showed that many SMEs still do not comply with the provisions of the GDPR. Also 96% of small business owners do not know what the maximum fine for violating the GDPR is. [9]

2.2. Current approaches in implementing and complying with GDPR

Given the global impact of GDPR provisions, the complexity of compliance processes, but also the complex specifics of some businesses, the provision of consulting services and the development of information systems to provide support in the implementation and compliance with the provisions of the regulation came naturally. .

Analyzing the GDPR market, the implementation and compliance solutions can be divided into several broad categories:

1. **Consulting services** provided by law firms, legal advisers, IT consultants specializing in GDPR - this option being necessary especially for large companies, corporations whose complexity of personal data processing actions are high and the automation of this process is weighty.

2. **GDPR kits** - templates with standardized documentation specific to GDPR (registers, procedures, forms, contracts), created by lawyers, in word and excel format that can be adapted to the specifics of organizations.

3. Various **software solutions**, which vary by the technologies used and by the way of approaching GDPR compliance, as well as by the purpose but also of the service delivered:

- Software products that provide the actual protection of personal data and / or infrastructures where they are processed (threat detection and prevention software, access management, application security, network security, DLP solutions, Endpoint Protection, etc...);

- Solutions that allow the identification of personal data, using machine learning and artificial intelligence technologies, with their subsequent labeling;
- Software that automates the process of implementing the requirements of the regulation but also the compliance flows, such as records of personal data processing operations, management of access requests from data subjects, notification of security breaches, creation of specific GDPR documentation, automation of the process of obtaining and recording the consents obtained from data subjects, data protection impact assessment, etc..

The list of software solutions presented is not exhaustive as technology evolves, which facilitates the creation of new horizons for automation of GDPR requirements but also creates new challenges in the process of personal data protection.

Analysis of software solutions

Further will be presented a brief analysis of several software tools that offer its customers the automation of GDPR requirements. This analysis aims to understand the strengths and weaknesses of these software, in order to create our own tool for automating the requirements of GDPR.

Ecomply.io - is an GDPR compliance solution created by a German company, which provides a step-by-step guide to the activities needed to be followed, making it easier to manage the data protection and compliance process. Ecomply covers the following areas:

- Governance and data protection objectives (art. 5. GDPR)
- Evidence of processing activities
- Requests for access from data subjects
- Supplier management
- Designation of the Data Protection Officer (DPO)
- Incident Management [10]



Fig. 2.1 Ecomply.io interface [10]

GDPR 365 - is a GDPR compliance solution created by a Dutch company, such as Ecomply.io, which facilitates the implementation of GDPR requirements, it

offers a series of templates as well as the possibility to export compliance reports, processing registers, etc. GDPR365 covers the following issues:

- Governance;
- Record of processing activities - Mapping of activities;
- Management of access requests from data subjects;
- Supplier management;
- Data transfer;
- Designation of the Data Protection Officer (DPO);
- Data Protection Impact Assessment (DPIA);
- Information of data subjects (templates);
- Employee training;
- Incident Management. [11]

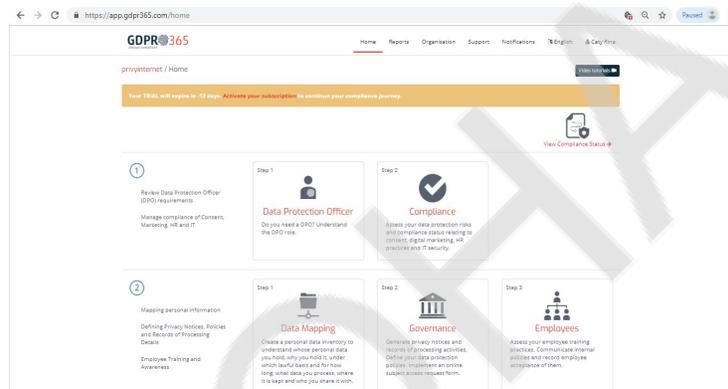


Fig. 2.2 GDPR 365 interface [11]

From all the range of solutions analyzed, including software products that were not presented above. GDPR 365 combines a wide range of GDPR compliance features into a dedicated product.

2.3. Difficulties in defining a unitary framework for implementing GDPR

Implementing and complying with the provisions of the GDPR can be difficult for any organization regardless of size or area of activity, each leading its own battle in the war of conformity.

The challenges of implementing GDPR differ from organization to organization, due to the heterogeneity of personal data processing, IT systems processing, storage, etc., internal operational processes, organizational structure, number of employees who have access to personal data, the company's area of activity, etc.

Although the need for a system that will facilitate the difficult implementation process came naturally, the creation of such a magic wand is virtually impossible for large companies, as the complexity of the challenges requires a consultation of lawyers and IT consultants specializing in GDPR, and the heterogeneous nature but also the large volume of constraints that may arise, makes it impossible to transpose the implementation process on the architecture of a single implementation system.

However, the landscape described above is at the opposite pole in the case of small companies, so the possibility of creating a system that will facilitate the implementation of GDPR takes shape.

III. IMPLEMENTATION MODEL OF THE EU GDPR

3.1. Key requirements of the EU GDPR

The EU General Data Protection Regulation is a set of rules on how companies should process the personal data of data subjects. The GDPR establishes the responsibilities of organizations to ensure the confidentiality and protection of personal data, gives data subjects certain rights and assigns regulators to demand liability demonstrations or even to impose fines in cases where an organization does not comply with the requirements of the GDPR:

- 1) Legal, fair and transparent processing
- 2) Limitation of purpose, data and storage
- 3) The rights of the data subject
- 4) Consent
- 5) Personal data breaches
- 6) Privacy by design
- 7) Data protection impact assessment
- 8) Data transfers
- 9) Responsible for data protection
- 10) Awareness and training

It is important to understand these requirements and their implications for the company and to implement them in the company context.

3.2. EU GDPR implementation

As it is implemented, it is important to understand whether the established plan is going in the right direction. The key GDPR implementation steps that the project must include are:

- 1) *Preparation of the GDPR project.*
- 2) *Defining the policy on personal data and other higher level documents.*
- 3) *Creating an inventory of processing activities.*
- 4) *Defining an approach for managing the rights of the data subject.*
- 5) *Implementation of a Data Protection Impact Assessment (EIPD).*
- 6) *Secure transfer of personal data.*
- 7) *Modification of third party contracts.*
- 8) *Ensuring the security of personal and sensitive data.*
- 9) *Defining data breach management.*

3.3. Data Protection Impact Assessment (DPIA) methodology according to the EU GDPR

EU GDPR implementation model Article 35 of the EU GDPR provides a specific analytical tool for assessing the impact of GDPR in depth, gradually.

In terms of methodology, Article 35.7 of the Regulation provides for the minimum elements to be assessed, which are described below in five steps:

Step 1 is essentially a detailed list of data processing, including the data it uses, the details of the operators and processors, the legal basis or retention periods applied to the data.

Step 2 identifies the legal and risk management controls that are currently being implemented. This phase involves the current and existing set of measures from a legal, technical, physical and organizational point of view.

Step 3 lists the sources of risk for data processing. This raises the question: "Will my business suffer from this new data processing and, if so, where and when will it suffer?" This phase focuses on possible intrusions of confidentiality and an assessment of corporate risks, damage to reputation or financial costs. It takes imagination, especially to browse a fair amount of sources of risk against the company.

Step 4 refers to the analysis and listing of potential negative events and threats to data processing. Its distinction from step 3 is that it will focus on the personal data of the data subjects and on the potential impact of the new processing on these data. If the events are internal or external, human or non-human (technical), this phase is relevant in terms of technological developments. New technologies may not have a clear introduction of privacy-friendly protection measures and thus expose people to threats such as hacking, phishing and spam. Its purpose is to determine what kind of threats your processing may be exposed to.

Finally, **step 5** takes the form of a report and summarizes the analysis, current controls, business risks and threats to personal data. The report sets out the organization's options for addressing each identified risk, threat and defect. Indicate whether each option would eliminate, reduce or accept the risk as it stands. The report will be recorded, kept and presented to the main managers of the organization. These managers can thus decide whether actions have been taken or should be taken and follow up on such actions.

Such an evaluation provides a powerful opportunity to review documents, prepare for project implementation, build or adapt policies, update technical issues, and strengthen controls. In short, the EIPD empowers staff to make changes and raise awareness of the protection of personal data within the company.

Demonstrating compliance with data protection authorities is what must be considered and must be kept on record. In the case of an audit, these records may be submitted. In addition, the company's customers and data subjects will have the guarantee of data protection and reputation.

3.4. Methodology for assessing the severity of the compromise of personal data (ASCPD) according to the EU GDPR

Methodology for assessing the severity of personal data breaches, in line with

the views of the Article 29 Working Party "Guidelines on the notification of personal data breaches under Regulation 2016/679" and "Recommendations for a methodology for assessing the severity of personal data breaches" issued by the European Union Agency for Network and Information Security (ENISA), is also based on the assessment of the severity of data breaches in organizations in different fields of activity and is intended to provide a simple and comprehensive model for assessing data breaches .

The methodology is based on an objective approach, while trying to remain flexible enough to be adopted by various companies. Depending on different requirements, the scoring of some categories can be adjusted to produce the most appropriate results.

In order to assess the general severity of the data breach and to obtain a result that will be easy to interpret, the following formula is proposed:

$$SC = CPD \times UI + CC, \text{ where}$$

SC means Severity of compromise,

CPD means **Context of data processing (possible values 1,2 or 3),**

UI means **Ease of identification, (possible values 1 or 2),**

CC means **Violation circumstances (possible values 1 or 2).**

After obtaining the exact value of the severity of the compromise (SC), you can consult the table below to check the impact on affected data subjects, the possible consequences for data subjects and the company's notification obligations in case of data breach.

Table 1. Assessment of the severity level of data compromise

SC value	Impact on affected data subjects	Possible consequences for data subjects	Obligation to notify
SC is less or equal than 3	Little probability to lead to a risk	Individuals will either not be affected, or they may encounter some inconveniences, which they will overcome without any problem (time spent reintroducing information, upset, irritations, etc.).	Data breach should only be recorded in a register
SC = 4	There may be a risk	People may experience significant inconveniences, which they may be able to overcome despite some difficulties (additional costs, refusal of access to commercial services, fear, lack of understanding, stress, minor physical ailments, etc.).	Data breaches should be reported to the supervisory authority.
SC is equal or greater than 5	More probability to lead to risk	People may experience significant, or even irreversible, consequences that may prove difficult or impossible to overcome (embezzlement, blacklisting by banks, property damage, job loss, subpoena, worsening health, financial distress, such as be substantial debts or incapacity for work, long-term psychological or physical illness, death, etc.).	Data breaches should be reported to the supervisory authority as well as to the data subjects affected.

Although the notification obligations required by the EU GDPR may seem

quite simple, in practice, many infringement scenarios are unclear and require careful case-by-case assessment. The methodology provides a common approach to ensuring accountability and compliance with the EU GDPR provisions on data compromise notification and allows operators to have a clear approach when assessing the seriousness of personal data breaches. The correct assessment of a data breach is essential in the light of the new sanctions that will be applied by the supervisory authorities, as failure to report the data breach, as necessary, can lead to administrative fines of up to EUR 10,000,000 or, in the case of an undertaking, up to 2% of total annual global turnover in the preceding financial year.

Finally, even if the EU GDPR only requires operators to notify data breaches, if processors become aware of a data breach, they must notify the controller without undue delay in order to allow the controller to comply with its notification obligations.

IV. IT SOLUTION REGARDING THE IMPLEMENTATION OF GDPR

The main objective of the information system design is to provide the necessary support in the implementation of the provisions of the GDPR, to a small organization, by:

1. Detailed analysis of the provisions of the GDPR
2. Defining functional and data requirements for key processes:
 - Designation Responsible for data protection
 - Processing register
 - Data protection impact assessment
 - Evidence of requests from data subjects
 - Register of incidents of personal data breach
3. Modeling of modules and flows using UML language and stimulus-response sequences
4. Formalization of functional and non-functional requirements of the system

4.1. Building the system

Implementations of the system were made with much accuracy to maintain all the functionality in a simple interface. The desktop application is cross-platform to maintain the availability for all users. On the other hand the server (web application) with the desktop app and with the Database system the break apart to maintain the security and integrity of data.

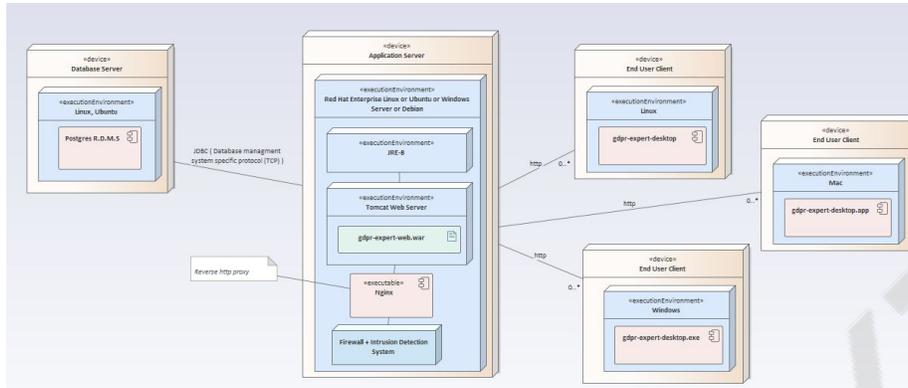


Fig. 4.1 Deployment diagram

In the deployment diagram (Fig. 4.1) is represented the basic scenario in which applications are placed on real environments, the process of interaction - through http between the desktop application on the frontend that can be placed on multiple workstations and running web application on the server using the tomcat container servlet and JVM. The diagram also shows the server for RDMS - PostgreSQL with which the web application interacts.

The following diagram represents the management of the data processing activities, which includes creating of a new data processing activity, visualizing them, updating and changing their information. For every such activity can be implemented an assessment of data protection impact and / or a severity compromising evaluation. All actions, which can be made to data processing activities, are shown in figure 4.2.

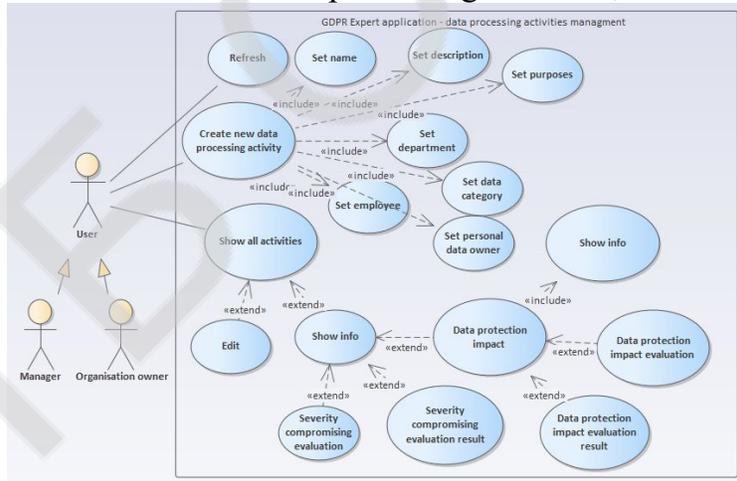


Fig. 4.2 Data processing activity

4.2. The technologies used to create the system

For implementing the GDPR solution was used React + Electron (for desktop app), Java Spring Framework and Gradle (for web app) and postgresQL with Docker for RDMS (Relational Database Management System).

```

async fetchQuestions(): Promise<void> {
  const response = await getDataResponsibleQuestions()

```

```
if (!this._isMounted) return

if (!UnsuccessResponseData.isUnsuccessResponseData(response)) {
  const data = response as Array<GetDataResponsibleQuestionsResponse>
  this.setState({ isLoading: false, questions: data, questionId: data[0].id })
} else {
  const err = response as UnsuccessResponseData
  if (err.isSessionExpired) {
    this.props.clearAuthDataActionCreator()
  }
}
}
```

In this piece of code is a request to the server to get the list of questions and answers that will be displayed on the UI. Depending on the chosen answer, it is determined whether the person can be responsible for personal data or not.

Also, in the following piece of code was written the logic part of determining the responsible person for personal data.

```
@RequestMapping(value = "", method = RequestMethod.POST)
public ResponseEntity<?> evaluateOrganisation(@AuthenticationPrincipal AuthUserEntity
user,
    @RequestBody GDPREvaluationQuestionsResultDto dto) {
  Validator validator = Validation.buildDefaultValidatorFactory().getValidator();
  List<String> errorMessages = validator.validate(dto).stream().map(a
a.getMessage()).collect(Collectors.toList());
  if (errorMessages.size() > 0) {
    return ResponseEntity.status(HttpStatus.BAD_REQUEST).body(errorMessages);
  }
  gdPREvaluationService.saveEvaluationResult(dto.getOrganisationId(),
dto.getPercentages());
  return ResponseEntity.status(HttpStatus.CREATED).build();
}
```

Following the assessment of the organization's compliance with GDPR, an HTTP request to the server is sent, which validates it, extracts the data and keeps the result in the database.

4.3. GDPR Expert system functionalities

After the registration of the user and creating the organizations, the list of all companies appears. In the figure 4.3 are shown a list of companies and the user can make modifications on the organizations, create others, or access the site menu to view all the possibilities.

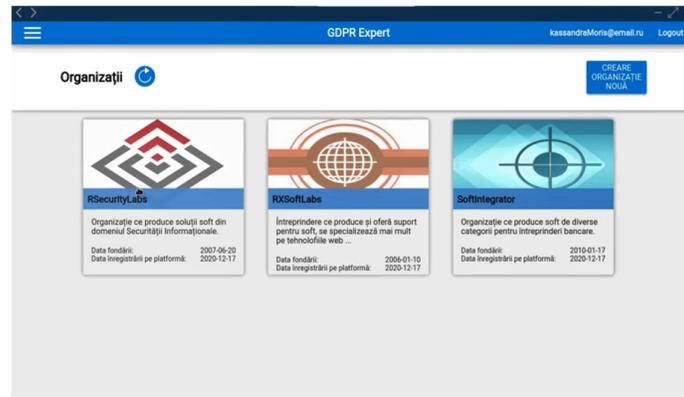


Fig. 4.3 List of organizations

Accessing an existing company in the organization list, it displays all the information about it, showing some functionality, like viewing departments, assessing the conformity with GDPR and viewing previous data processing activities (figure 4.4).

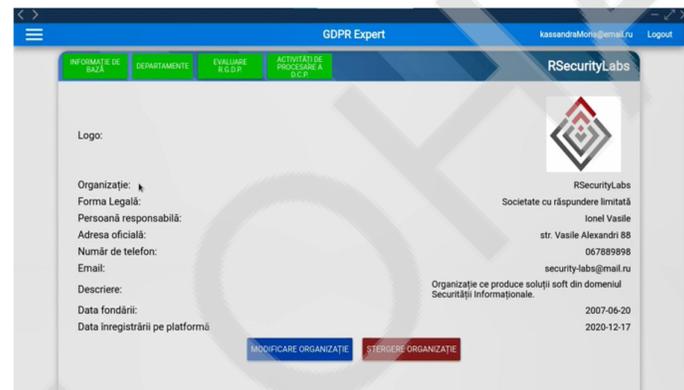


Fig. 4.4 Company information

The interface of adding a department to an organization, of adding an employee to a department and adding documents to an existing employee are shown in figure 4.5 a, b and c.

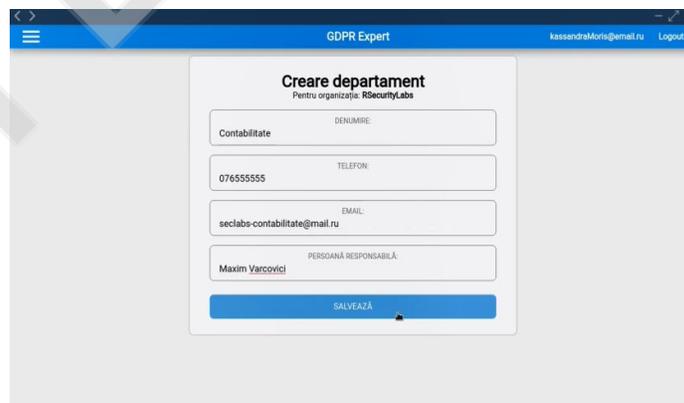


Fig. 4.5. a - Adding a new department

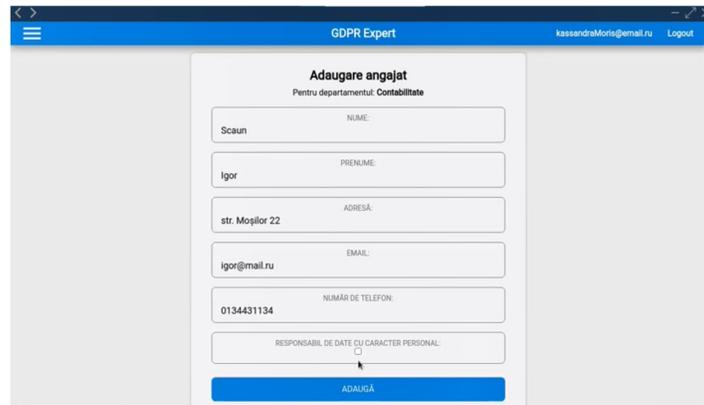


Fig. 4.5. b - Adding a new employee

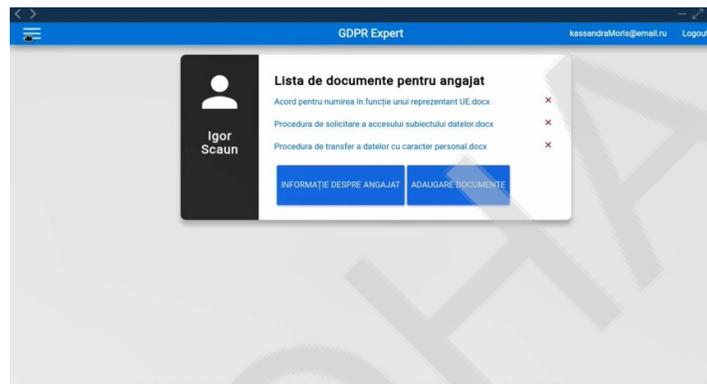


Fig. 4.5. c - Adding personal documents to the existing employee

4.4. Assessment of compliance with the GDPR

It is very important that the system provides a way to assess compliance with EU GDPR requirements. Following the analysis of the main requirements imposed by the Regulation, those essential compartments that can demonstrate an organization's compliance with the GDPR have been established, which are presented below. 1. Principles related to the processing of personal data 2. The rights of data subjects during processing and access to their information 3. Data transfers to third parties 4. Private information 5. Data leaks 6. Data protection impact assessment The review of the EU GDPR conformity assessment questionnaire and the visualization of the current results, as well as the comparison with the previous evaluations are presented in figure 4.6 a, b, c, d and e.

GDPR Expert Organizații q@mail.ru Logout

Evaluarea conformităților cu G.D.P.R. pentru organizația "DevSecOps"

REZULTATUL ULTIMII EVALUĂRI REALIZARE EVALUĂRI

Chestionar:
Pentru evaluarea obiectivă este nevoie de răspuns la setul propus de întrebări.

1) Este documentată fiecare activitate de procesare pe baza legală? („Organizația ar trebui să păstreze un jurnal al fiecărei activități de prelucrare a datelor cu caracter personal la care se angajează, precum și să păstreze un temei juridic corespunzător. Activitatea de prelucrare are temeiul juridic valid numai dacă se aplică unul sau mai multe dintre următoarele: (a) persoana vizată furnizează, cu consimțământ, date valide; (b) prelucrarea lor este necesară pentru încheierea sau modificarea unui contract; (c) prelucrarea este necesară pentru a se conforma unei obligații legale la care este supus operatorul; (d) prelucrarea este necesară pentru a proteja interesele vitale a persoanei vizate sau ale altei persoane, stipulându-se o cauză ce nu încalcă prevederile legii; (e) prelucrarea este necesară pentru îndeplinirea unei sarcini desfășurate în interes public sau în exercitarea autorității statale legitime; (f) prelucrarea este necesară în scopul intereselor legitime urmărite de operatorul cu date personale sau persoane terțe, în măsura în care acesta nu încalcă drepturile și libertățile fundamentale ale persoanei vizate, în special în cazul în care persoana vizată este un copil” - articolul 6, alineatul 1, UE RGPD)

Da

2) Este documentat scopul fiecărei activități de procesare? (Fiecare activitate de prelucrare al datelor cu caracter personal ar trebui să fie documentată. „Prelucrarea datelor cu caracter personal” este orice operațiune sau serie de operațiuni care se efectuează asupra datelor cu caracter personal prin mijloace automatizate sau neautomatizate, cum ar fi colectarea, înregistrarea, organizarea, stocarea, păstrarea, restabilirea, adaptarea ori modificarea, extragerea, consultarea, utilizarea, dezvăluirea prin transmitere, diseminare sau în orice alt mod, alăturarea ori combinarea, blocarea, ștergerea sau distrugerea (conform legii 133/2011 a Republicii Moldova). " - Articolul 4, alineatul 2, UE RGPD)

Da

3) Vor fi prelucrate datele cu caracter personal într-un alt scop decât cel prevăzut în momentul colectării? (Departamentele din cadrul organizației ar trebui să consulte responsabilul de protecția datelor, consilierul juridic sau orice altă persoană relevantă înainte de prelucrarea datelor cu caracter personal pentru un

Fig. 4.6. a - GDPR conformity assessment questionnaire

proporționale cu riscurile implicate în activitatea de prelucrare? („Ținând seama de natura, domeniul de aplicare, contextul și scopurile prelucrării, precum și riscurile diferitelor probabilități și gravități pentru drepturile și libertățile persoanelor fizice, operatorul pune în aplicare măsuri tehnice și organizatorice adecvate pentru a asigura și a putea să demonstreze că prelucrarea se efectuează în conformitate cu prezentul regulament. Măsurile respective vor fi revizuite și actualizate acolo unde este necesar. - Articolul 24 (1) RGPD din UE)

Da

29) Este evaluată confidențialitatea la etapele de început ale dezvoltării oricărei activități de prelucrare?

Da

30) Sunt implementate măsuri precum minimizarea datelor și pseudonimizarea în toate unitățile organizatorice aplicabile? („Ținând cont de stadiul tehnic, de costul implementării și de natura, domeniul de aplicare, contextul și scopurile prelucrării, precum și riscurile de probabilitate și severitate diferite pentru drepturile și libertățile persoanelor fizice pe care le prezintă prelucrarea, operatorul trebuie, atât în momentul stabilirii mijloacelor de prelucrare, cât și în momentul prelucrării în sine, să pună în aplicare măsuri tehnice și organizatorice adecvate, precum pseudonimizarea, care sunt concepute pentru a pune în aplicare principiile de protecție a datelor, precum minimizarea datelor, în o manieră eficientă și să integreze garanțiile necesare în prelucrare pentru a îndeplini cerințele prezentului regulament și a proteja drepturile persoanelor vizate. - Articolul 25 (1) RGPD al UE)

Da

31) S-au finalizat evaluările impactului asupra protecției datelor (EIPD) pentru activități de prelucrare care implică categorii speciale de informații, luare automată de decizii sau profilare?

Da

32) Sunt EIPD finalizate înainte de implementarea noulor tehnologii, procese sau proiecte?

Da

SALVEAZĂ

Fig. 4.6. b - GDPR conformity assessment questionnaire GDPR (ending)

GDPR Expert Organizații q@mail.ru Logout

Evaluarea conformităților cu G.D.P.R. pentru organizația "DevSecOps"

REZULTATUL ULTIMII EVALUĂRI REALIZARE EVALUĂRI

✓
Success
Procesul de evaluare G.D.P.R. a avut loc cu succes.
OK

Fig. 4.6. c – Assessment of compliance with the GDPR



Fig. 4.6. d – The result of the last GDPR conformity assessment

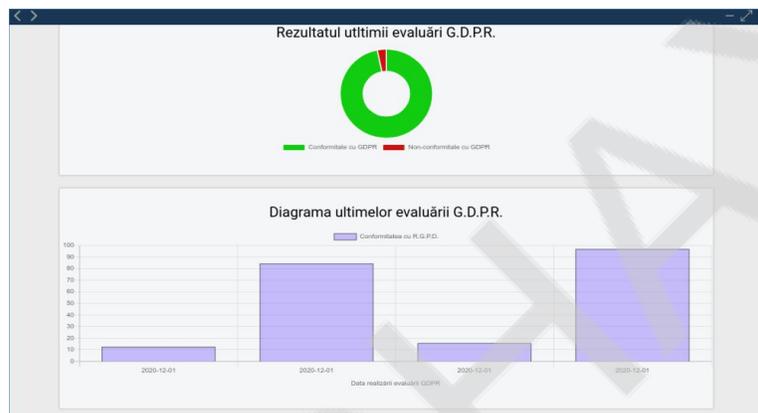


Fig. 4.6. e – Comparison with previous GDPR conformity assessments

V. CONCLUSIONS

The harmonization of the legislation in the field of personal data protection with the legislation of the European Union will be a progressive step in order to obtain the recognition of the Republic of Moldova as a state that ensures an adequate level of protection of personal data. This achievement will increase the credibility of the Republic of Moldova in the eyes of the financial institutions of the European Union, will create optimal conditions for attracting investments and for developing sustainable economic relations.

In this project we tried to conceptually design a solution that will facilitate the implementation of the General Regulation on Data Protection and to materialize the given concept in a software solution.

The analysis of the provisions of the General Regulation of Data Protection competing on the market facilitated the creation of a system that comes to automate and facilitate the process of implementation and monitoring of GDPR compliance.

The system seeks to cover the essential aspects of a small to medium-sized organization in the process of compliance.

Since the purpose proposed in this project is to create a universal solution that can be used by small companies regardless of their field of activity. The complete automation of the implementation process is not feasible at the moment, being necessary the manual adjustment of the provided documentation templates. Full automation would only be possible if the system was created for a certain field of

activity.

The system automates a series of processes and facilitates the implementation of the provisions within small and medium-sized organizations regardless of their field of activity, reducing much of the costs in case of using consulting services at law firms and / or IT consultants.

VI. REFERENCES

1. Jurnalul Oficial al Uniunii Europene. REGULAMENTUL nr. 679 din 27 aprilie 2016 privind protecția persoanelor fizice în ceea ce privește prelucrarea datelor cu caracter personal și privind libera circulație a acestor date și de abrogare a Directivei 95/46/CE (Regulamentul general privind protecția datelor), [cited 10.09.2020]. Available: <https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=celex%3A32016R0679>
2. Sorina-Elena ANGHELUȚĂ. 2015 *Protecția datelor cu caracter personal în contextul angajării*. Internet Documentation, [cited 10.09.2020]. Available: <https://www.juridice.ro/401834/protectia-datelor-cu-caracter-personal-in-contextul-angajarii.html>
3. *From the garage to the Googleplex*, [cited 17.09.2020]. Available: <https://about.google/our-story/>
4. Facebook – Company info, [cited 10.09.2020]. Available: <https://newsroom.fb.com/company-info/>
5. Al Pascual, Kyle Marchini, Sarah Miller. 2017 *Identity Fraud: Securing the Connected Life*. Internet Documentation, [cited 20.09.2020]. Available: – <https://www.javelinstrategy.com/coverage-area/2017-identity-fraud>
6. Al Pascual, Kyle Marchini, Sarah Miller. 2018 *Identity Fraud: Fraud Enters a New Era of Complexity*. Internet Documentation, [cited 21.09.2020]. Available: <https://www.javelinstrategy.com/coverage-area/2018-identity-fraud-fraud-enters-new-era-complexity>
7. Catherine Stupp | EURACTIV.com. *Cambridge Analytica harvested 2.7 million Facebook users' data in the EU*. Documentație Internet, [cited 10.09.2020]. Available: <https://www.euractiv.com/section/data-protection/news/cambridge-analytica-harvested-2-7-million-facebook-users-data-in-the-eu/>
8. Centrul Național pentru Protecția Datelor cu Caracter Personal, [cited 03.10.2020]. Available: <https://datepersonale.md/>
9. *GDPR still a mystery to SMEs: the risks of non-compliance*, january 2019, [cited 07.10.2020]. Available: <https://www.hiscox.co.uk/business-blog/gdpr-still-mystery-smes-risks-non-compliance/>
10. Ecomply.io, Internet Documentation, [cited 13. 09.2020]. Available: <https://ecomply.io/>
11. GDPR 365, [cited 21.09.2020]. Available: <https://www.gdpr365.com/software-features/>
12. Legea nr. 133 din 8 iulie 2011 privind protecția datelor cu caracter personal.

STUDY OF METHODS OF SETTING THE AUTOMATIC CONTROL SYSTEM OF INDUSTRIAL CONTROL SYSTEMS

Author: *Timakov Gennady Sergeevich*

Advisor: *Seytkanov Sabriden Seytkanovich*

Academician K. I. Satpayev Ekibastuz Engineering and Technical Institute (Republic of Kazakhstan)

Abstract

In this scientific paper the methods of tuning the automatic control system of industrial control systems are considered. Methods for determining the optimal tuning parameters of the controllers are considered: a formula method for determining the controller tuning; adjusting the controller by nomograms; experimental method for determining the setting; automatic adjustment system of the controller based on PTC APCS. This topic is relevant in the field of automation and control.

The settings of the regulators should be chosen so that the specified stability margin is provided in the closed-loop automatic control system (ACS), while the selected control quality indicator should be no worse than the required one. In the practice of commissioning, approximate formulas are widely used to determine the optimal tuning parameters for controllers.

Since in the theory of automatic control the stability margin can be assessed in different ways, and various indicators of the quality of regulation are used, several methods are used in engineering calculations to determine the optimal tuning parameters of the regulators. Formula method for determining the setting of the regulator, setting the regulator according to nomograms, experimental method for determining the setting of the controller [1].

The experimental method for determining the setting of the ACS allows, by the type of the transient process in the system, to determine such a direction of change in the parameters of the dynamic adjustment of the regulator, which will provide the desired change in the nature of the transient process. The advantage of which is the absence of the need to determine the absolute values of the controller settings.

Methods of tuning the automatic regulation system of industrial control facilities are considered below

Keywords: *Formula method, P-controller, PI-controller, PID-controller, transient, PTC, tuning, system, automatic control.*

Formula method to determine controller settings

In the practice of commissioning, approximate formulas are widely used to determine the optimal tuning parameters for regulators. The method is used for fast, approximate estimation of the values of the regulator settings for three types of optimal typical control processes. The method is applicable both for static controlled

system with self-regulation (Table 2), and for controlled system without self-regulation. (Table 3).

Table 2 - Formula-based method for determining controller settings for static controlled system without self-regulation.

Regulator	Typical regulatory process		
	Aperiodic	With 20% overshoot	J_{\min}
I	$K_p = \frac{1}{4.5K_{oy}\tau}$	$K_p = \frac{1}{1.7K_{oy}\tau}$	$K_p = \frac{1}{1.7K_{oy}\tau}$
P	$K_p = \frac{0.3}{K_{oy}\tau/T}$	$K_p = \frac{0.7}{K_{oy}\tau/T}$	$K_p = \frac{0.9}{K_{oy}\tau/T}$
PI	$K_p = \frac{0.6}{K_{oy}\tau/T}$ $T_e = 0.6T$	$K_p = \frac{0.7}{K_{oy}\tau/T}$ $T_e = 0.7T$	$K_p = \frac{1}{K_{oy}\tau/T}$ $T_e = T$
PID	$K_p = \frac{0.95}{K_{oy}\tau/T}$ $T_e = 2.4\tau$ $T_a = 0.4\tau$	$K_p = \frac{1.2}{K_{oy}\tau/T}$ $T_e = 2\tau$ $T_a = 0.4\tau$	$K_p = \frac{1.4}{K_{oy}\tau/T}$ $T_e = 1.3\tau$ $T_a = 0.5\tau$

DYNAMIC CHARACTERISTICS OF THE REGULATED OBJECT

(determination of controller settings by calculation method) Fig . 9

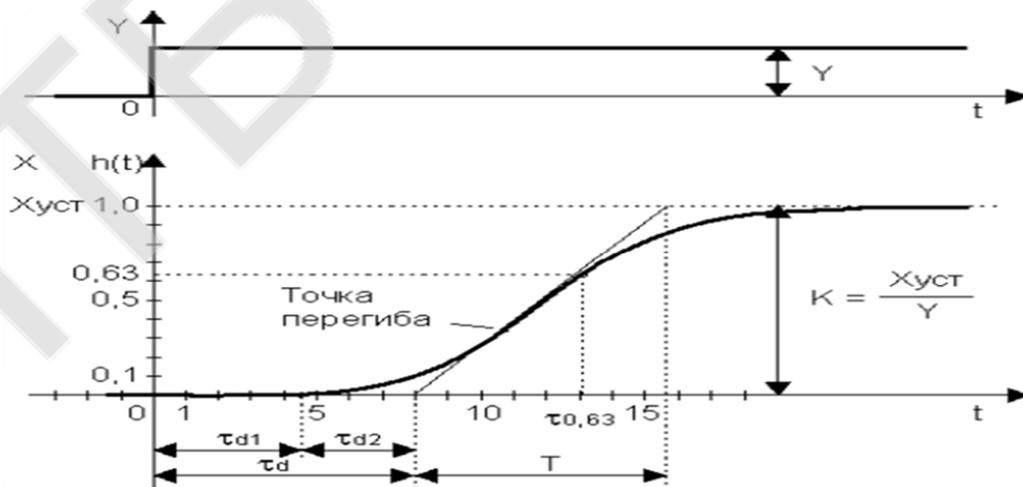


Fig . 9. Transient response of controlled system with self-regulation

The dynamic characteristic of the controlled system (acceleration characteristic, acceleration curve) is a graph of the change in the controlled value over time as a result of an abrupt disturbance applied to the system. Of greatest practical interest is the study of dynamic properties under disturbances from the regulatory action. Dynamic characteristics determine the nature of the change in time of each output parameter with a change in each input value.

Dynamic characteristics are expressed in the form of differential and integral equations where T , τ , C_{oe} - time constant, delay and gain of the system. In these formulas it is assumed that a regulator with dependent settings is being tuned, the transfer function of which has the form:

$$W_p(p) = K_p \left(1 + \frac{1}{T_u p} + T_d p \right),$$

where K_p - controller gain
 T_u - controller integration constant;
 T_d - differentiation constant.

Table 3 . Formula-based method for determining controller settings of the controlled system without self-regulation

regulator	Typical regulatory process		
	Aperiodic	With 20% overshoot	$\min \int_0^{\infty} \varepsilon^2 dt$
P	$K_p = \frac{0.4}{\tau/T}$	$K_p = \frac{0.7}{\tau/T}$	-
PI	$K_p = \frac{0.4}{\tau/T}$ $T_{\dot{\varepsilon}} = 6T$	$K_p = \frac{0.4}{\tau/T}$ $T_{\dot{\varepsilon}} = 3T$	$K_p = \frac{1}{\tau/T}$ $T_{\dot{\varepsilon}} = 4T$
PID	$K_p = \frac{0.6}{\tau/T}$ $T_{\dot{\varepsilon}} = 5\tau$ $T_{\ddot{\varepsilon}} = 0.2\tau$	$K_p = \frac{1.1}{\tau/T}$ $T_{\dot{\varepsilon}} = 2\tau$ $T_{\ddot{\varepsilon}} = 0.4\tau$	$K_p = \frac{1.4}{\tau/T}$ $T_{\dot{\varepsilon}} = 1.6\tau$ $T_{\ddot{\varepsilon}} = 0.5\tau$

Optimal adjustment of controllers according to nomograms

In contrast to the formula method, the calculation method using nomograms allows you to more accurately determine the controller settings, since takes into account the presence of a nonlinear relationship between the settings of the regulator and the value of the ratio τ / T .

There are nomograms for calculating the settings of PI and PID controllers for systems of the first and second orders with delay [1].

The nomogram for the PI controller settings is shown in Fig . 10.

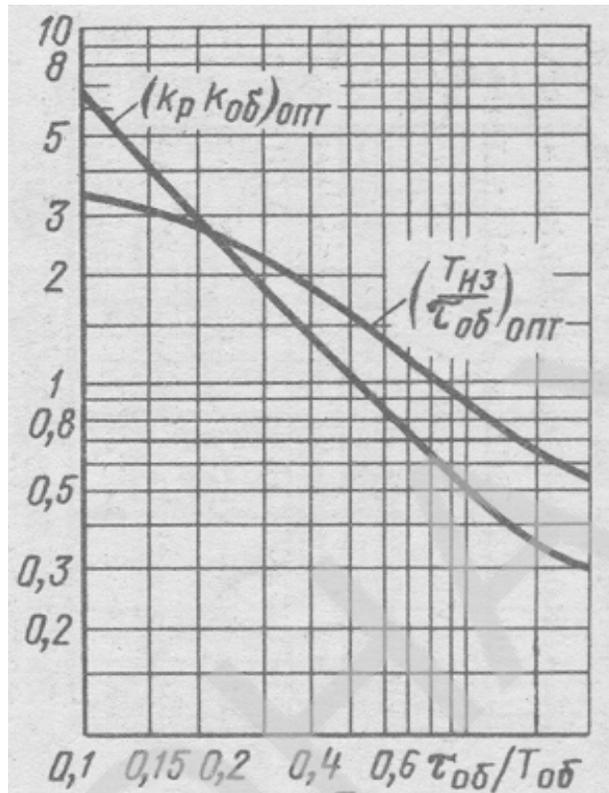


Fig . 10. Adjustment of the controller by nomograms.

Let us suppose that the controlled system is described by a first-order link with delay, and the optimal control process is a process with 20% overshoot. It should be borne in mind that modern electronic and microprocessor controllers implement PI and PID control laws with dependent settings, and pneumatic controllers - with independent settings of the form

$$W_p(p) = K_p \left(1 + \frac{1}{T_u p} + T_o p \right).$$

The differential component of industrial regulators is usually implemented in the form $\frac{K_{p\delta} T_f p}{T_f p + 1} \rightarrow T_o p$,

where $K_{p\delta}$ – regulator gain for the differential component (selectable in the range 1 - 10);

T_f – filter time constant.

These parameters are determined from the relation $K_{pd}T_f = T_\delta$.

The higher the interference level in the output signal of the object, the less it is recommended to take the value of K_{pd} . This will help to reduce the value of the mean square error of regulation [2].

Experimental methods of controller adjustment procedure Undamped oscillation method

In the operating system, the integral and differential components of the controller are turned off ($T_i = \infty$, $T_d = 0$), i.e. the system is translated into the P-law of regulation. By successively increasing K_p with a simultaneous supply of a small step-like signal, the targets are achieved in the system for sustained oscillations with a period of K_{kp} . This corresponds to bringing the system to the boundary of oscillatory stability.

When this mode of operation occurs, the values of the critical gain of the controller K_{kp} and the period of critical oscillations in the system T_{kp} are fixed. When critical fluctuations appear, not a single variable of the system should reach the limitation level. The K_{kp} and T_{kp} values are used to calculate the controller settings:

P-regulator: $K_p = 0.55 K_{kp}$;

PI-regulator: $K_p = 0.45 K_{kp}$; $T_u = T_{kp}/1.2$;

PID-regulator: $K_p = 0.6 K_{kp}$; $T_u = T_{kp}/2$; $T_\delta = T_{kp}/8$.

The controller settings can be calculated using the critical frequency of the actual control system ω_{kp} . Considering that the natural frequency ω_{kp} of the controlled system coincides with the critical oscillation frequency of a closed-loop system with a P-controller, the values of K_{kp} and T_{kp} can be determined from the amplitude and period of critical oscillations of the controlled system itself.

When a closed system is brought to the boundary of oscillatory stability, the amplitude of oscillations can exceed the permissible value, which in turn will lead to an emergency at the facility or to the release of defective products. Therefore, not all industrial facility control systems can be brought into critical operation.

Damped oscillation method

The use of this method allows you to tune controllers without bringing the system to critical operating modes. Just as in the previous method, for a closed-loop system with a P-controller, by successively increasing K_p , a transient process of working out a rectangular pulse is achieved by a reference signal or a disturbance with a damping decrement $D = 1/4$.

Next, the period of these oscillations T_κ and the values of the integration and differentiation constants T and T_d are determined

for PI-regulator: $T_u = T_\kappa/6$;

for PID regulator: $T_u = T_\kappa/6$; $T_\delta = T_\kappa/1.5$.

After setting the calculated values of T_u and T_d on the controller, it is necessary to experimentally clarify the value of K_p to obtain the damping decrement $D = 1/4$. For this purpose, an additional adjustment of K_p is performed for the selected regulation law, which usually leads to a decrease in K_p by 20 ÷ 30%. A similar tuning method is used in adaptive regulators of the American firm Foxboro.

Most industrial control systems are considered to be of good quality if their damping decrement D is equal to 1/4 or 1/5.

Currently, a new method of tuning closed-loop control systems has been developed, based on the supply of trial sinusoidal oscillations to the input of the regulator. By the amplitude and phase of the oscillations of the output signal of the control object, the PI-controller settings are calculated based on the condition of ensuring the specified oscillation index M and the maximum ratio K_p/T_u .

Experimental methods of controller setting

For a significant number of industrial control systems, there are no sufficiently accurate mathematical models that describe their static and dynamic characteristics. At the same time, it is very expensive and laborious to carry out experiments to measure these characteristics.

The experimental method of adjusting the regulators does not require knowledge of the mathematical model of the system. However, it is assumed that the system is installed and can be put into operation, and it is also possible to change the settings of the regulator. Thus, some experiments can be carried out to analyze the effect of changing the settings on the dynamics of the system. Ultimately, it is guaranteed that good settings are obtained for a given control system.

Setting the regulator includes three sequential stages:

- at the first stage, the minimum value of K_p and an overestimated value of T_u (for example, $T_u \approx T_b$) are set at the RU; this ensures the deliberately stable operation of the ACS, an aperiodic component is observed in the transient process;

- at the second stage, at constant T_u gradually increases K_p , achieving the appearance of an oscillatory component in the aperiodic transient process; at this stage, there is no need to strive for the realization of specific values of the degree of damping, but weak damping of oscillations in the transient process should be avoided;

- at the third stage, the aperiodic component of the paths of a gradual decrease in T_u is eliminated at a constant value of K_p , obtained at the second stage. A sign of the elimination of the aperiodic component in the transient process can be considered the approximate equality of the second and third vibration amplitudes. If, with decreasing T_u , in addition to the disappearance of the aperiodic component, a decrease in the damping of the oscillatory component occurs, then this will be a sign that the optimal value of T_u has already been passed. The T_u found at this stage is the optimal T_u opt. Fig . 11 Setting ACS by the type of transition.

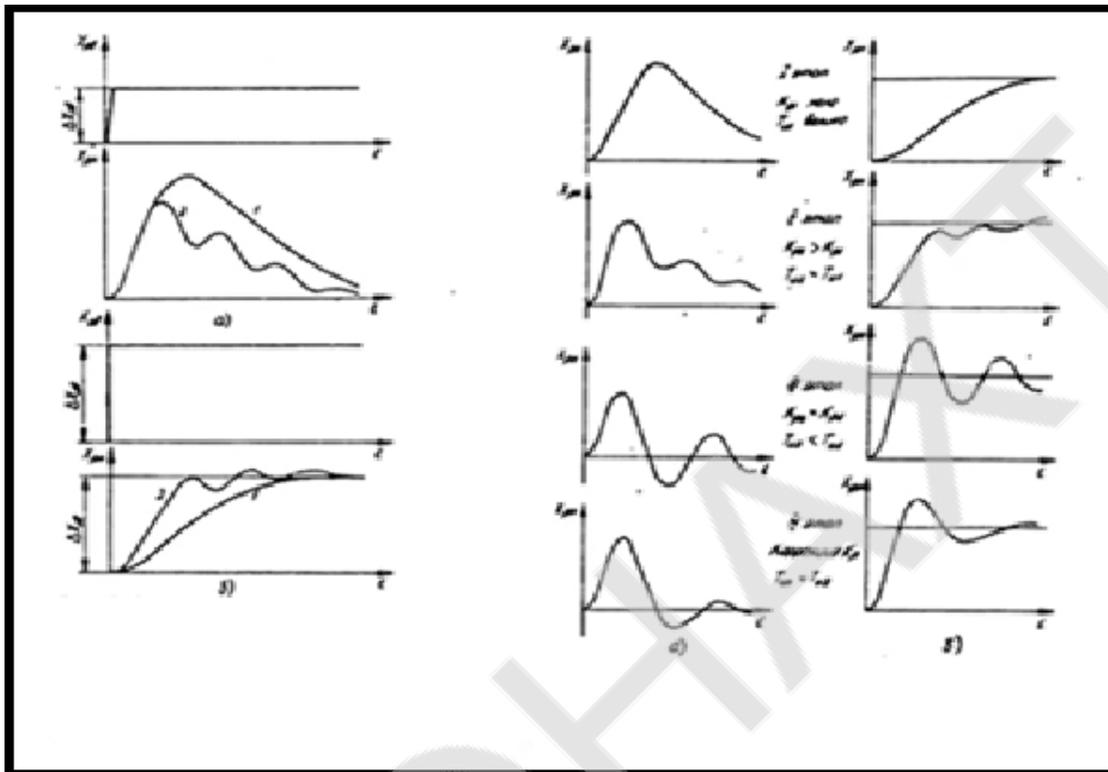


Fig . 11. Setting ACS by the type of transition.

Automatic setting system based on PTC APCS

In recent years, there has been a significant increase in interest in the issues of adjusting the regulators of industrial automatic control systems (ACS). This is associated with higher material and temporary costs, which arise both as a result of the operation of systems that do not work in optimal modes, and as a result of the inappropriateness of the maintenance of frequent re-heading. In this case, the setting is carried out, as a rule, manually and not in the best way, which also leads to substantial economic losses.

The main task of automatic control systems is to stabilize the process parameters at a given level when exposed to external disturbances acting on the control system.

A natural trend in the development of commercial PID controllers is the development of methods that reduce the cost of human labor for their installation, tuning and maintenance. Despite the fact that many of the methods of automatic tuning and adaptation of PID controllers used today were developed back in the 60s, in industrial controllers the adaptive technique began to be used only in the mid-80s. This is due to the technical complexity of implementing adaptive algorithms on an element base, which existed before the advent of microcontrollers.

The advent of digital programmed control made it possible to create and introduce into production controller automatic adjustments of the technological process control system. Many process systems require sophisticated controls to ensure optimal process flow. The practical use of pre-emptive concepts is one of the hallmarks of technological advances in management. The use of pre-emptive technology and the input of the model into the control algorithm creates an additional advantage - stability. This means that changes in the dynamic characteristics of the control system, which inevitably arise during long-term operation, practically do not affect the quality.

Fully automatic tuning can be initiated when a predetermined condition occurs, for example, when the load changes, when external influences change, when the control error changes, or continuously in time. Automatic tuning, initiated without human intervention, is called adaptation.

The technology of anticipatory action, the basis of which is the input of the model of the controlled system into the control algorithm.

PTC - APCS applies the concept of pre-emptive action. Its use eliminates overshooting of the automatic control system and significantly reduces the time of process regulation. The use of pre-emptive technology and the input of the model into the control algorithm create an additional advantage - stability. This means that changes in the dynamic characteristics of the control system, which inevitably arise during long-term operation, practically do not affect the quality of regulation.

In the future, the scientific work is explained by description and implementation with links to accompanying drawings, in which:

The PTC Automatic Tuning System can be initiated when a predetermined condition occurs, when the load changes.

An example of the automatic adjustment of the PTC of the APCS can be the fragment of the mnemonic diagram of the steam temperature controller behind the PRS GPP shown in the figure. (Fig . 12.)

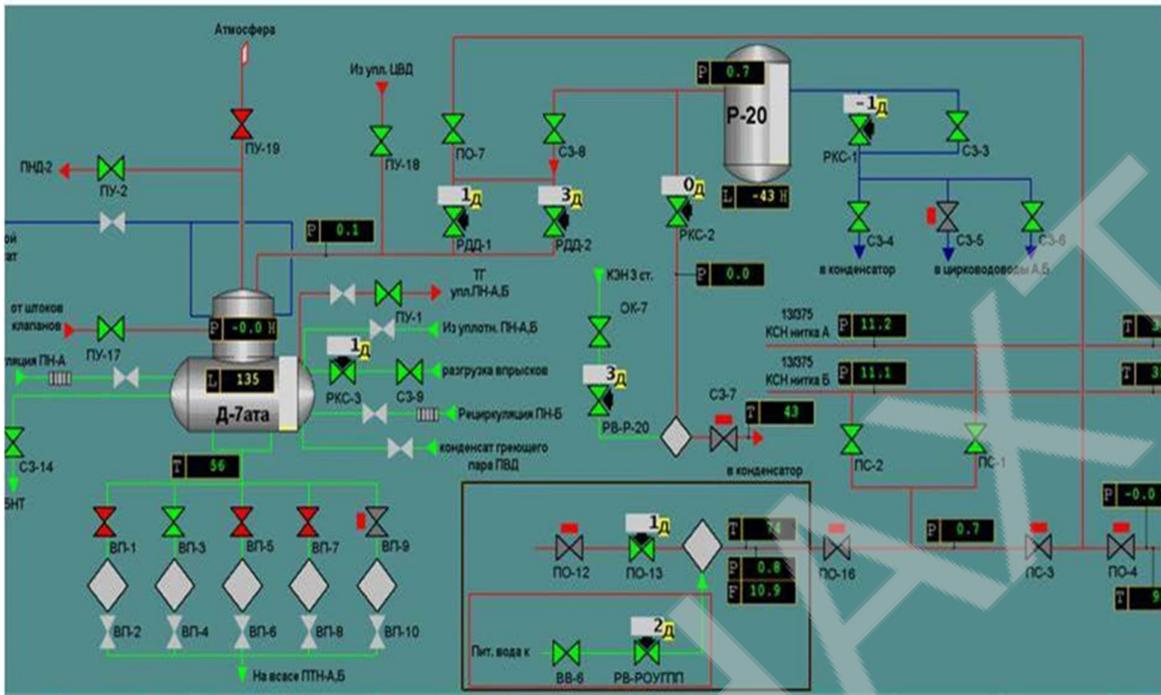


Fig . 12. fragment of the mnemonic diagram of the steam temperature controller behind the ROU GPP.

In Fig . 12 a fragment of the mnemonic diagram of the steam temperature controller behind the RCU HR (reduction cooling unit for hot reheat), steam coming from the secondary superheated steam collector, through the RCU HR (PO-13) are shown. It supplies steam to the auxiliary collector (KSN).

Temperature controller RV-RCU-HR maintains the steam temperature behind the RCU HR. The concept of anticipatory action, the principle of operation is to introduce the model of the controlled system into the control algorithm.

The red line and the square denote the technology of anticipatory action, the basis of which is the introduction of the model of the controlled system into the control algorithm. (Fig . 13)

All types of automatic adjustment use three fundamentally important stages: identification (determination of the dynamic characteristics of the regulation); calculation of controller parameters; setting. Often, the final stage includes a tuning stage (final tuning optimization). Optimization of the tuning is necessary due to the fact that the methods for calculating the parameters of the controller according to the formulas are simplified, do not take into account the nonlinearities of the system, in particular, the always present nonlinearity of the "constraint" type, identification of the parameters of the system is performed with some error. It is important to emphasize that despite the presence of "automatic" tuning, the controller may not provide the required quality of regulation for reasons that do not depend on the quality of the algorithms embedded in it.

For example, the control system may be poorly designed (dependent control loops, long delay, high system order); the system can be non-linear; the sensors may be located in the wrong place and have poor contact with the system, the level of interference in the measurement channel may be unacceptably high; the resolution of the sensor may not be high enough; the source of the input influence on the object may have too much inertia or hysteresis; there may also be errors in the installation of the system, poor grounding, broken conductors, etc.

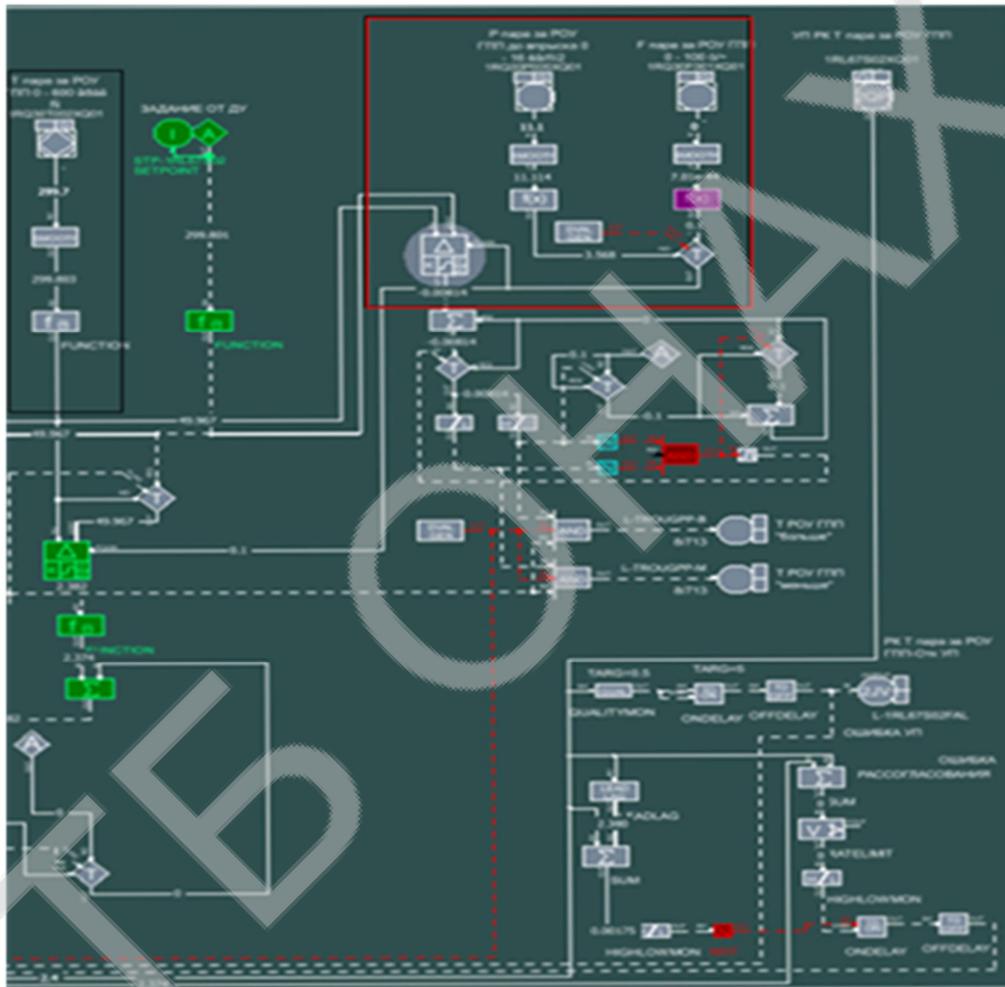


Fig . 13. Scheme of automatic adjustment of the steam temperature controller behind the RCU HR, with the technology of anticipatory action

Therefore, before starting the automatic adjustment, you must make sure that the listed problems are not present. For example, if, due to wear on a mechanical system, a hysteresis is not foreseen by the design appears and therefore the system is in oscillation mode, adjusting the controller may not give the desired result until the cause of the problem is eliminated.

The main stage of automatic adjustment and adaptation is the identification of the system model, it is performed in an automatic mode.

Fig . 14 shows the general structure of the system with automatic adjustment [3].

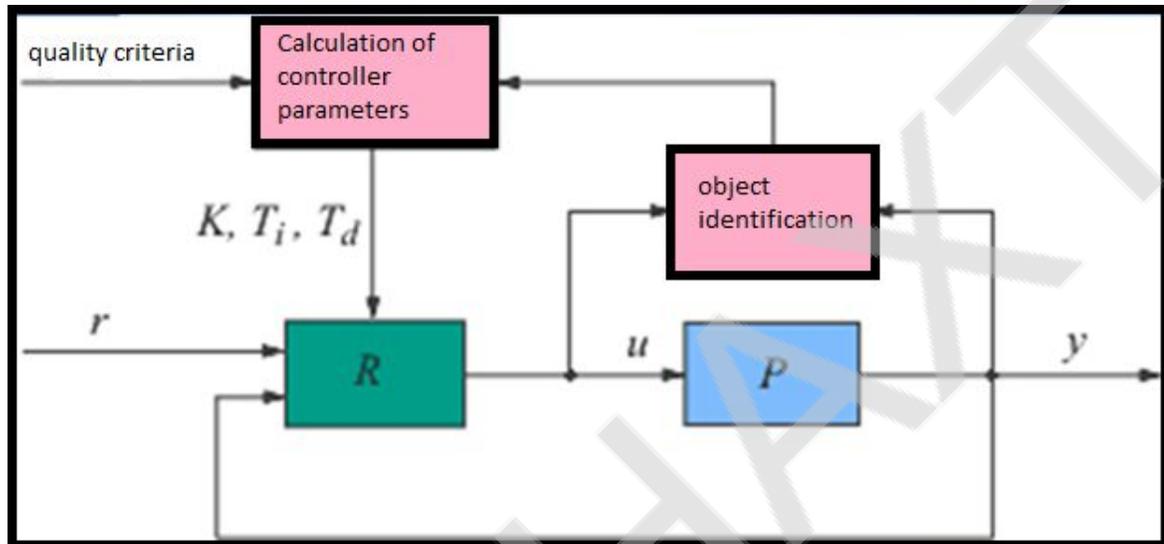


Fig . 14. General system structure with automatic adjustment.

VI. References

1. Rotach V.Ya Calculation of the tuning of real PID controllers: Teploenergotika. 1993, p. 31
 2. Balakirev, V.S., Experimental Determination of the Dynamic Characteristics of Control Objects, Moscow: Energiya, 1967.
 3. Neiman A.D. On the issue of an experimental method for setting up automatic control systems. "Heat Power Engineering", 1968
 4. Alexandrov A.G. Optimal and adaptive systems. - M .: Higher school, 1989.
 5. Shubladze A.M., Gulyaev S.V., Shubladze A.A. Optimal self-tuning general industrial regulators // Devices and systems. Management, control, diagnostics. 2002. No. 10. c. 30-33.
 6. Shubladze A.M., Gulyaev S.V., Shubladze A.A. Adaptive auto-tuning PID controllers // Industrial ACS and controllers. 2003. No. 6.
 7. Shubladze A.M., Kuznetsov S.I. Automatically tuned industrial PI and PID controllers // Automation in industry. 2007. No. 2.
 8. Fomin V.N., Fradkov A.L., Yakubovich V.A. Adaptive control of dynamic systems. - M .: Nauka, 1981.
- Periodicals:
1. S.A.Ivashkevich, G.F.Garansky Instructions on setting up systems for automatic regulation of thermal energy of heat points, 2012.-10 p.

HALL ELEMENTS STUDY WITH MICROPROCESSOR SYSTEM

Author: *Gergana Mironova*

Advisors: *Goran Goranov, Anatolii Aleksandrov*
Technical University of Gabrovo (Bulgaria)

Abstract. *Silicon semiconductor sensors are widely used in practice. Different species are known, classified according to many parameters. For measuring magnetic field are used Hall elements, magnetoresistors, magnetodiodes, magnetotransistors, magnetothyristors, magnetic sensitive integral circuits and etc. However, the remaining challenge is study of their parameters and exploring their capabilities and fields of application. This article purpose study of Hall sensors - HG302C GaAs and HW300B InSb. An electronic system was developed, based on Atmega 128 microcontroller for study the sensor parameters. Measurements were made and the results are compared and analyzed. The results are presented in tables and graphical form.*

Keywords: *Hall element, microprocessor system, magnetic field, magnetic sensitive elements*

I. INTRODUCTION

In the process of design, it is of great importance understanding and assimilation of how the magnetic sensitive semiconductors work. It leads to further opportunities for synthesis of more complex modules and systems.

Electronics develops in every moment because of new integrated technologies. In many areas of industry, like automation, measuring technics, meteorology, mechanical engineering, chemical and automotive industry and so on, are used electronic magnetic sensors.

Laboratory developments and a number of studies are known in literature, but they require device and hardware resource to measure parameters of Hall sensor [8,4,11]. Most often are needed high sensitive ampeters, operating in range of mA, and even in μA . This article proposes the development of model for studying the parameters of Hall sensors, without any external measurement equipment. Approach and study of these electronic elements are repeatedly performed since the creation of the Hall sensor [2, 5].

II. LITERATURE ANALYSIS

Microprocessors and digital technology are increasingly used for signal processing from analog output sensors.[6, 7].

A specific feature in the development is using of operational amplifier AD824 with an input voltage shift of 0.1-1mV. This makes the measurements more accurate. This type of operational amplifiers find applications in photodiode preamps, battery powered devices, controls and protection for power supplies, medical equipment, sensor networks and more. [1, 3, 10]

The developed laboratory measuring system is based on Atmel [9] microcontroller, shown in Fig.1 and has the following parameters:

- Setting and measuring the current through Hall sensor – I_h between 0,1 and 12 mA
- Measure U_h voltage
- All the values are displayed

Due to the fact that the required current of the tested sensor can be from 1 to 12mA, is used different range by switching the resistor in the range from – 1k, 10k or 100k Ohms. The measuring system has an output for connection with personal computer. So, the obtained results can be processed by extra developed software.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

A. Setting module

Main block diagram of the schematic of the measurement system is shown in fig.2. On figure 3 is shown the method of setting the current through selectable resistor 1-10-100k Ohms. Operational amplifier is powered by 13.5V from external power supply. Respectively, at the output of the operational amplifier the voltage changes of 0 to 12V with shift of 256. This is because of the used digital potentiometers of Microchip - type MCP42010, which are controlled by a serial interface and powered by 5 volts. At the middle terminal of the digital potentiometer, the voltage changes from 0 to 5 with shift of 256. The gain of the operational amplifiers is set with feedbacks. It is calculated by the formula $A = 1 + R4 / R3$. The values of the resistors are, respectively, $R4 = 10K$ and $R3 = 6.8K$. The value received for the gain is 2.47, which at a maximum of 5 volts to the non-inverting input of the operational amplifier, will give 12.35 volts maximum output signal.



Fig. 1. View of the measurement module - design and implementation

The digital potentiometers are two in a hull, with a value 10K. The set current of the Hall Sensor is limited by the maximum output current of the amplifier, which is 20mA.

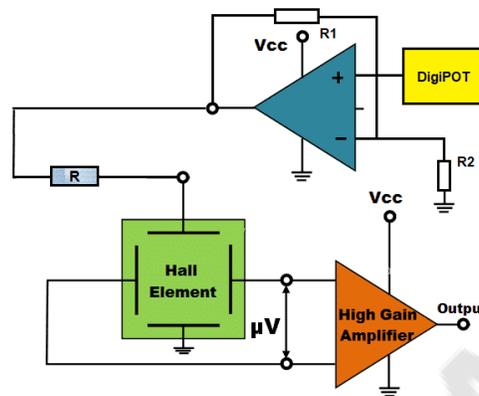


Fig. 2. The block schematic of analog system

Current through the Hall sensor is measured indirectly, i.e. it's measured the voltage drop on the resistor, and the microcontroller calculates the current. Used resistors are pre-measured and their values are set in the software.

B. Measuring module

The measuring module is shown in Figures 4 and 5. Implemented accordingly to measure the current through the sensor. Realized for measuring the current through the sensor, so the resulting voltage is supplied respectively to the inputs of the microcontroller ADC3 for recording the current through the sensor and ADC5 respectively for output voltage from the sensor.

Two differential amplifiers are provided to measure the difference between the two sensor outputs with a range up to 50mV and a measurement shift of 0.1mV - Figure 5. Depending on the polarity of the received voltage, one or the other amplifier operates. This is the way the direction of the magnetic field is recognized. The gain is 100, which at 50 mV potential output difference, will give 5 volts at the ADC input.

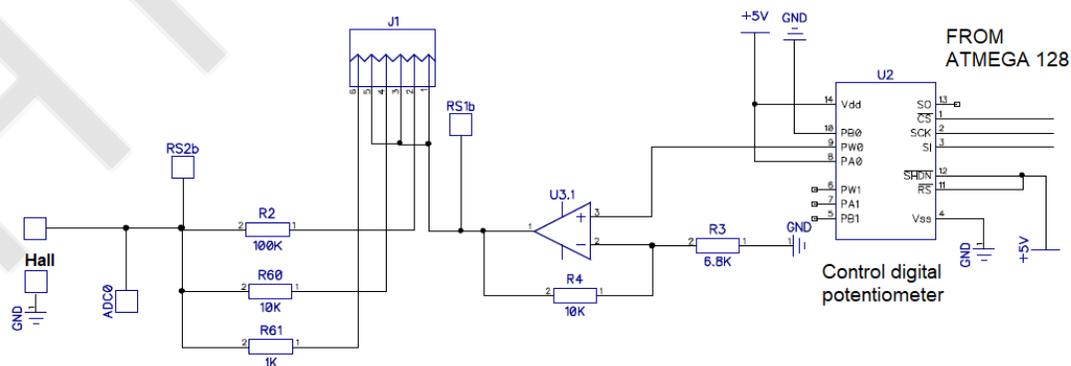


Fig. 3 Setting Ih.

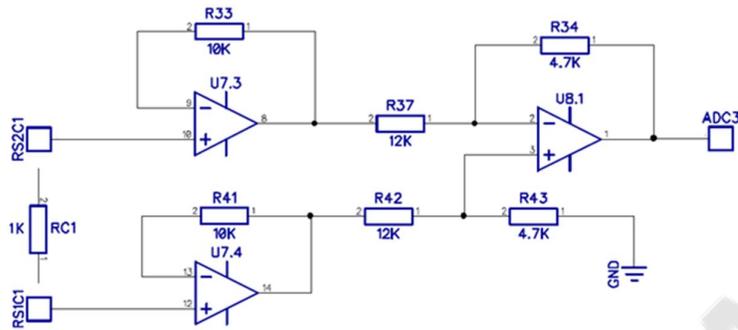


Fig. 4. Measuring I_h .

Working with the laboratory stand is performed by a rotary encoder and a button for recording the setpoints. Exemplary dimensions are shown in Figure 5.

The developed program for the microcontroller performs the following algorithm:

1. Initialization of all ports (inputs, outputs)
2. ADC initialization
3. LCD display initialization
4. Record in digital potentiometers fixed values.

C. Programming cycle

1. Checking encoder status. When the state changes, a value is assigned to an internal variable. Depending on the direction of rotating, the variable decreases or increases. If the encoder button is pressed, a second variable is changed.
2. Depending on the state of the internal variables is running a cycle, which execute operations, related with calculations and displaying parameters on the screen.

There are 2 main screens. The program starts with choosing a resistor to measure the current through Hall sensor – screen 0. This is necessary for correct calculations, and the resistor is set in advance manually with a switch. On screen 1 is set the current and accordingly is measured I_h .

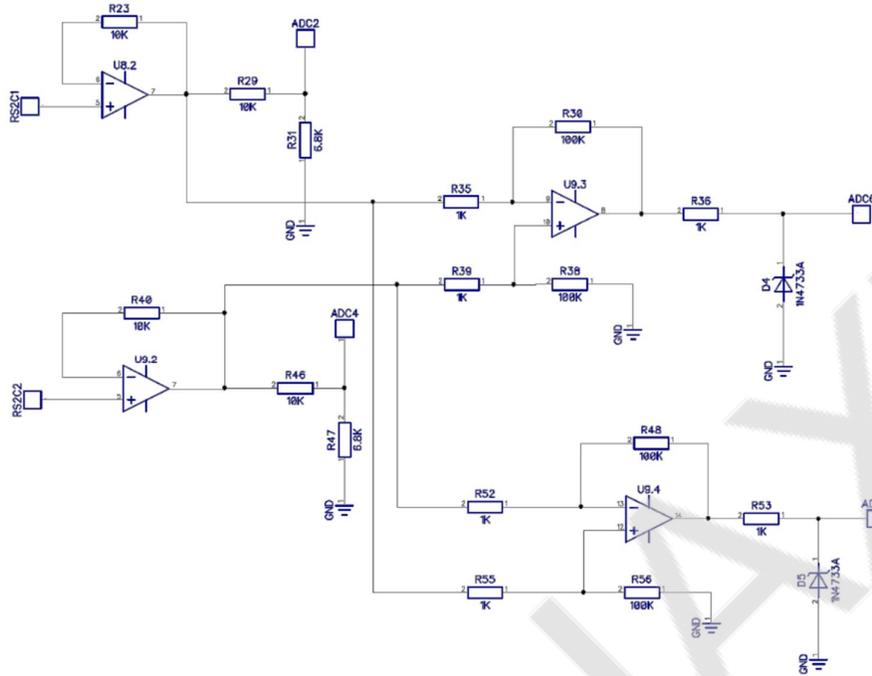


Fig. 5. Measuring U_h

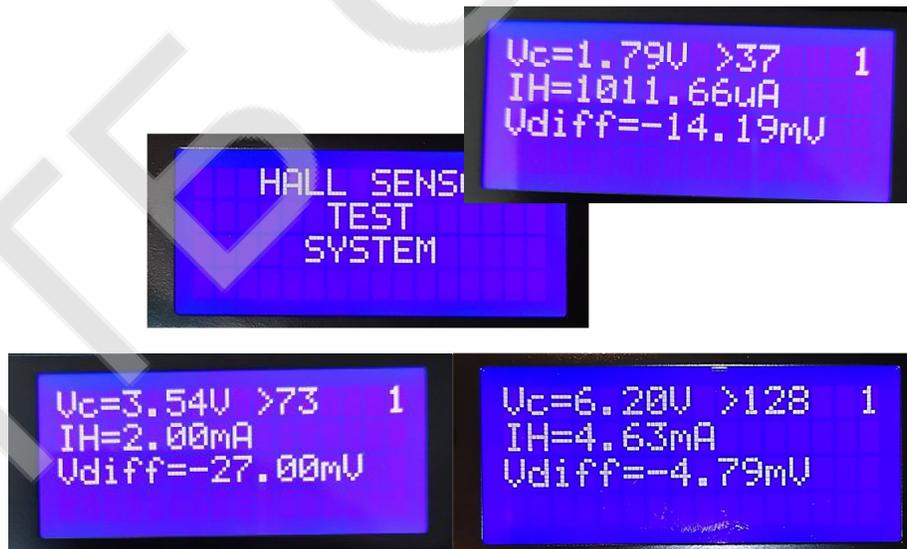


Fig. 6.Options for measuring

IV. RESULTS

The tested sensors are type HG302C GaAs and HW300B InAs. All the results are automatically processed and are presented in a table. For the purpose was used two-pole electromagnet with a maximum current of 4A at 20 volts power supply. (Figure 7).

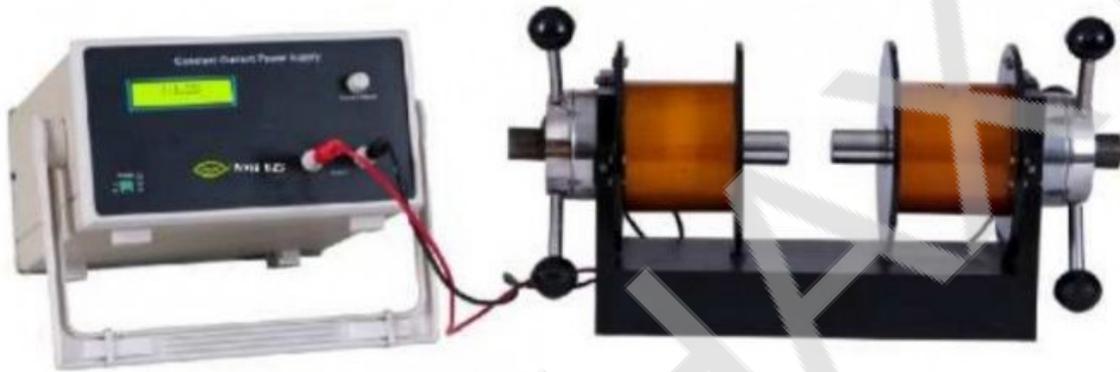


Fig. 7. The electromagnet system

TABLE I. Sensor output voltage, at different magnetic induction

A. Sensor HG 302A

I_h, mA	B, mT	10	20	30	40	50	60	70	80	90
1	U _h , mV	-3.9	-5.5	-6.9	-8.4	-9.8	-11.5	12.7	-14.2	-15.6
	2	U _h , mV	-4.3	-7.3	-10.2	-13	-16	-18.8	-21.5	-24.4
4	U _h , mV	-7.6	-13.2	-19.1	-24.7	-29.7	-33.6	-36.5	-38.5	-40

B. Sensor HW 300B

I_h, mA	B, mT	10	20	30	40	50	60	70	80	90
1	U _h , mV	19	34.7	40.8	43.6	45.2	46.1	46.8	47.3	47.5
	2	U _h , mV	33.3	43.3	46.1	49.8	52.2	55.5	58	62.4
4	U _h , mV	43.5	47.4	51.2	55.3	59.1	63.8	67.4	71.9	75.6

At operating current 0.1mA, the offset $U_0 = 0.12\text{mV}$ and at a value above 0.5mA, $U_0 = -2.6\text{mV}$.

V. CONCLUSIONS

A specialized module has been developed for study of magnetosensitive elements, which dramatically reduces operating time and helps in the proper analysis of the Hall sensor. Next step in developing is connecting the module to a computer and working on software for further automatic processing and analyzing of the results. The tested sensor is HG302C GaAs and HW300B InAs. The obtained results confirm the possibility of using the sensor in low intensity magnetic fields. Sensor sensitivity increases with increasing operating current. At current value $I_h = 2\text{mA}$ and greater, for $B = 50\text{mT}$, the output voltage is between 50 and 70 mV.

VI. REFERENCES

1. [James M. Fiore, Semiconductor Devices: Theory and Application, pp. 407, August 2019, ISBN-13: 978-1796543537](#)
2. [Emil Manolov, Tanya Vasileva, Marin Hristov, Semiconductor Elements, pp. 295, 2007, ISBN 9789549315790](#)
3. [Alexandrov, A. Semiconductor Elements and Integrated Circuits. Gabrovo, ECS-PRESS, 2012.](#)
4. [Alexandrov, A., I. Belovski, Study of Peltier Thermoelectric Module - Yearbook of Prof. Dr. As. Zlatar "XLIII \(1\), 2014, 73 - 76. ISSN 1312-1359](#)
5. [Nelly Georgieva, A. Georgiev, Semiconductor Elements and Integrated Circuits. , Aquaprint Ltd., Varna 2016 , ISBN 978-619-7168-05-1](#)
6. [Rankovska, V. Microprocessor cores for complex programmable logic arrays. Proceedings of the Unitech'11 International Scientific Conference - Volume I, Gabrovo: Vasil Aprilov University Publishing House, 2011, pp. I-186 – I-191](#)
7. [Rankovska, V., S. Rankovski. Multi-functional Demo Module for Microprocessor Development Systems for Educational Purposes. Proc. XXVII International Scientific Conference Electronics - ET2018, September 13 - 15, 2018, Sozopol, Bulgaria, 2018, pp. 55-58. ISBN: 978-1-5386-6691-3](#)
8. [N. Draganov, G. Goranov, and A. Alexandrov. Galvanometric device for contactless DC measurement. Proceedings - UNITECH 08, Volume 1 pp. 142-146, 21-22 November. 2008. ISSN 1313-230X](#)
9. [Atmel, ATmega128 datasheet, Rev. 2467X-AVR-06/11](#)
10. [R. Arnaudov, I. Dochev, and Art. Manev, Analog Circuit Technology, Publishing House of TU-Sofia, 2010.](#)
11. [Georgiev D., Goranov G.. \(2013\), Sensor with Hall effect with parallel output, Journal of Technical University-Sofia, Plovdiv Branch, Bulgaria "Fundamentals Science and Applications" vol.19, pp. 69-72, ISSN 1310- 8271](#)

**RESEARCHING THE SYSTEM FOR VULNERABILITY TO MITM
ATTACKS BY CREATING FAKE AP**

Authors: *Ulyana Karpenko, Igor Chebanenko*

Advisor: *Sergey Krivenko*

Mariupol State University (Ukraine)

Abstract. In the course of the work, security problems of the local wireless wi-fi network were identified, as well as the role of the human factor in the security of wireless connections. One of the ways to implement the Man-in-the-Middle attack by creating a Fake AP has been investigated.

Keywords: *MITM, Fake AP, SSL, WPA, SSID, access point, Kali Linux, aircrack-ng, fluxion.*

I. INTRODUCTION

The term session hijacking is thrown around frequently and encompasses a variety of different attacks. In general, any attack that involves the exploitation of a session between devices is session hijacking. When we refer to a session, we are talking about a connection between devices in which there is state. That is, there is an established dialogue in which a connection has been formally set up, the connection is maintained, and a defined process must be used to terminate the connection. [1]

Despite the fact that MITM has been attacking for many years, it is still relevant due to the fact that it is based on software vulnerabilities of access points or clients, as well as on the features of the ubiquitous 802.11 standard, or rather, on the features of its authentication protocol. Although the standard specifies how a user joins an access point, the way in which that access point is selected is not specified, and there is no mention that it should be authenticated or if it is trusted by default. The solution to this problem was left to the discretion of the operating system hardware and software vendors.

Over time, the number of ways to implement MITM attacks has increased. For example, the attack on sites with the HTTP protocol has been improved to attacks on sites with HTTPS by spoofing certificates and bypassing HSTS. The Rogue AP creation attack evolved into Evil Twin. And even despite the protection against certificate spoofing by browsers, such attacks are still effective, because this protection can be bypassed.

Public networks are most susceptible to MITM attacks. People with no doubts connect to networks that have no password protection, while an attacker can simply sit down and deploy a Fake AP without bothering to force a client to disconnect from the original network. Despite the fact that target OSs have been updated hundreds of times since the advent of MITM attacks and systems have become more secure, this attack is alive and poses a threat to users. And there is no reason to expect that the standard will be corrected or added in the near future.

II. LITERATURE ANALYSIS

2.1. General information

To understand the principle of a middleman attack, you must first understand how the Internet itself works. Main points of interaction: clients, routers, servers. The most common client-server communication protocol is Hypertext Transfer Protocol (HTTP). Browsing the internet with a browser, email, instant messaging are all done over HTTP. When you enter the address of a web page in your browser's address bar, the client (you) sends a request to display the web page to the server. The packet (HTTP GET request) is transmitted through several routers to the server. The server then responds with a web page that is sent to the client and displayed on its monitor. HTTP messages must be transmitted in a secure manner to ensure confidentiality and anonymity. [2]

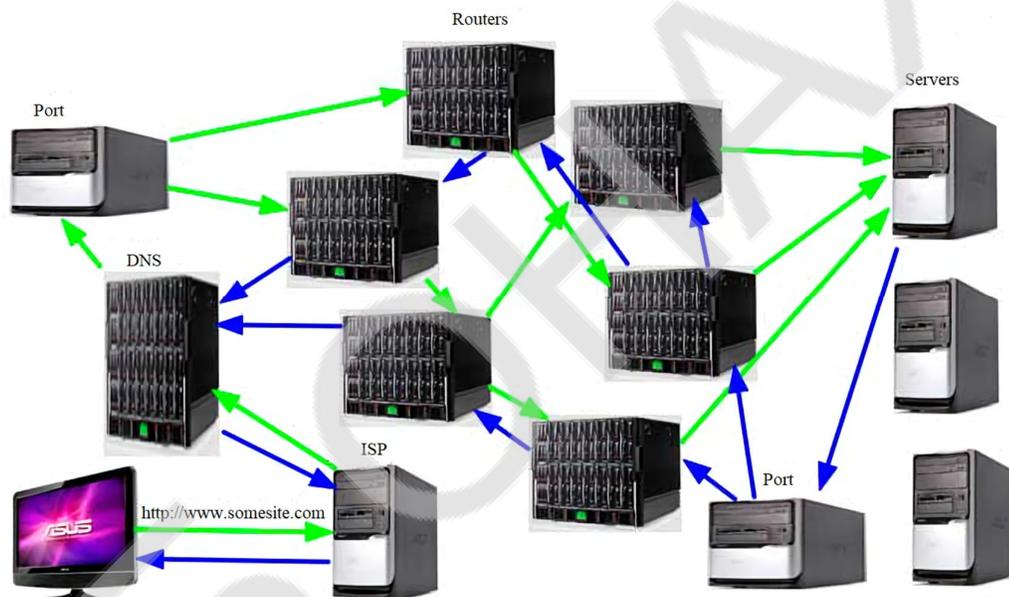


Fig. 5. Client-server communication.

A secure communication protocol must have each of the following properties:

Privacy - Only the intended recipient can read the message.

Authenticity - the identity of the interacting parties has been proven.

Integrity - Confirmation that the message has not been modified in transit.

If any of these rules are not followed, the entire protocol is compromised.

To prevent attacks that exploit APR imperfections, a secure version of the HTTP protocol was created. Transport Layer Security (TLS) and its predecessor, Secure Socket Layer (SSL), are cryptographic protocols that ensure the security of data transmission over a network. Therefore, the secure protocol will be called HTTPS. [2]

Over time, MITM attacks were carried out, finding new ways of implementation, depending on the attacked objects (sites, local networks) and

equipment. The overall goal of this type of attack is one - monitoring and modifying outgoing traffic.

2.2. ARP vulnerability attacks

Address Resolution Protocol (ARP) poisoning is an attack that involves sending spoofed ARP messages over a local area network. It's also known as ARP spoofing, ARP poison routing and ARP cache poisoning.

These attacks attempt to divert traffic from its originally intended host to an attacker instead. ARP poisoning does this by associating the attacker's Media Access Control (MAC) address with the IP address of the target. It only works against networks that use ARP.

ARP poisoning is a type of man-in-the-middle attack that can be used to stop network traffic, change it, or intercept it. The technique is often used to initiate further offensives, such as session hijacking or denial-of-service.

The ARP is a protocol that associates a given IP address with the link layer address of the relevant physical machine. Since IPv4 is still the most commonly used internet protocol, ARP generally bridges the gap between 32-bit IPv4 addresses and 48-bit MAC addresses. It works in both directions.

The relationship between a given MAC address and its IP address is kept in a table known as the ARP cache. When a packet heading towards a host on a LAN gets to the gateway, the gateway uses ARP to associate the MAC or physical host address with its correlating IP address.

The host then searches through its ARP cache. If it locates the corresponding address, the address is used to convert the format and packet length. If the right address isn't found, ARP will send out a request packet that asks other machines on the local network if they know the correct address. If a machine replies with the address, the ARP cache is updated with it in case there are any future requests from the same source.[3]

2.3. Attacks based on mDNS vulnerabilities

Protecting your environment is a complex and critical task. At every turn, it seems, attackers can penetrate your network and abuse its protocols through network redirection attacks, also known as "poisoning attacks." Some protocols are particularly vulnerable to abuse. Learning what attackers might be planning and what antidotes are available can help mitigate damage that poisoning attacks might inflict.

One protocol vulnerable to poisoning attacks is mDNS. The DNS translates human-readable names (such as "website.com") to their associated network locations, represented by an IP address ("x.x.x.x"). A DNS lookup transaction is usually unicast, meaning a single computer will ask a single server to translate a name to an IP address.

Instead of asking a single server, mDNS, a DNS-related protocol, sends out a packet to other hosts around it to essentially crowdsource the answer to the query, "Where is this thing located?" In addition, mDNS is used in conjunction with DNS

service discovery, which helps discover lists of available services via DNS. These features are helpful on home networks where local DNS servers don't exist and computers need to find other local resources such as printers. One serial user of the mDNS protocol is Apple's Bonjour service, meaning that mDNS can be observed in heavy use on networks containing MacOS and iOS devices.

Much like when attackers set out to abuse NetBIOS and LLMNR, mDNS can be abused via an attacker answering an mDNS request and impersonating a legitimate resource or computer on a network. The result is that the attacker can cause a device to send sensitive information directly to the attacker's machine, whether that be a print job for a document containing personal information or worse: a user's credentials. [4]

2.4. DNS Spoofing (DNS Cache Poisoning)

Domain name system (DNS) is the technology that translates domain names (e.g. doubleoctopus.com) to the IP address of the server it corresponds to. DNS is one of the most important infrastructural protocols of the internet and it is meant, among other purposes, to ease communications and relieve humans of the trouble of memorizing the IP address of every server they communicate with. When you type in the address of a domain in your browser, name resolution request is sent to a DNS server, which then looks up the domain name in its directory and returns the IP address of the corresponding server.

DNS spoofing is a type of attack in which a malicious actor intercepts DNS request and returns the address that leads to its own server instead of the real address. Hackers can use DNS spoofing to launch a man-in-the-middle attack and direct the victim to a bogus site that looks like the real one, or they can simply relay the traffic to the real website and silently steal the information. [5]

In regard to DNS, the most prominent threats are two-fold:

DNS spoofing is the resulting threat which mimics legitimate server destinations to redirect a domain's traffic. Unsuspecting victims end up on malicious websites, which is the goal that results from various methods of DNS spoofing attacks.

DNS cache poisoning is a user-end method of DNS spoofing, in which your system logs the fraudulent IP address in your local memory cache. This leads the DNS to recall the bad site specifically for you, even if the issue gets resolved or never existed on the server-end. [6]

Есть множество методов DNS-спуфинга или атак с отравлением кеша, например: man-in-the-middle duping, DNS server hijack, DNS cache poisoning via spam. В нашем исследовании нас интересует исключительно первый метод.

Where an attacker steps between your web browser and the DNS server to infect both. A tool is used for a simultaneous cache poisoning on your local device, and server poisoning on the DNS server. The result is a redirect to a malicious site hosted on the attacker's own local server. [6]

In order to better understand the danger of such attacks, it is worth mentioning

the losses that they bring.

Data theft can be particularly lucrative for DNS spoof attackers. Banking websites and popular online retailers are easily spoofed, meaning any password, credit card or personal information may be compromised. The redirects would be phishing websites designed to collect your info.

Malware infection is yet another common threat with DNS spoofing. With a spoof redirecting you, the destination could end up being a site infested with malicious downloads. Drive by downloads are an easy way to automate the infection of your system. Ultimately if you're not using internet security, you're exposed to risks like spyware, keyloggers or worms.

Halted security updates can result from a DNS spoof. If spoofed sites include internet security providers, legitimate security updates will not be performed. As a result, your computer may be exposed to additional threats such as viruses or Trojans.

Censorship is a risk that is actually commonplace in some parts of the world. For example, China uses modifications to the DNS to ensure all websites viewed within the country are approved. This nation-level block, dubbed the Great Firewall, is one example of how powerful DNS spoofing can be.

Specifically, eliminating DNS cache poisoning is difficult. Since cleaning an infected server does not rid a desktop or mobile device of the problem, the device will return to the spoofed site. Furthermore, clean desktops connecting to an infected server will be compromised again. [6]

2.5. Rogue (Fake) AP and Evil Twin

A rogue access point is a wireless access point that has been installed on a secure network without explicit authorization from a local network administrator, whether added by a well-meaning employee or by a malicious attacker.

Although it is technically easy for a well-meaning employee to install a "soft access point" or an inexpensive wireless router—perhaps to make access from mobile devices easier—it is likely that they will configure this as "open", or with poor security, and potentially allow access to unauthorized parties.

If an attacker installs an access point they are able to run various types of vulnerability scanners, and rather than having to be physically inside the organization, can attack remotely—perhaps from a reception area, adjacent building, car park, or with a high gain antenna, even from several miles away. [7]

Evil Twin is a more advanced version of the Fake AP attack. Rogue AP can be used in public places where people can easily connect to passwordless access points. The attacker at this time passes all traffic through himself, having the ability to decrypt and read it, receives user data: history of visited sites, logins and passwords, personal correspondence.

An evil twin attack involves an attacker setting up a fraudulent wireless access point – also known as an evil twin – that mimics the characteristics (including the SSID) of a legitimate AP. This attack has existed about as long as wifi has. Users may connect automatically to the evil twin or do so thinking the fraudulent AP is part

of a trusted wifi network. Attackers can expedite this process by affecting the connection to the legitimate AP their device is mimicking. Once users have connected to an evil twin, they may be asked to enter a username/password to gain access via a fraudulent form which goes to the attacker. Or the attacker can simply eavesdrop and intercept any unsecured information users transmit – all without their knowledge. [8]

In order for this attack to work, a few key requirements need to be met. First, this attack requires a user to do some ignorant things. If the target you are selecting is known for being tech-savvy, this attack may not work. An advanced user, or anyone with any cybersecurity awareness training, will spot this attack in progress and very possibly be aware that it is a relatively close-ranged attack. Against a well-defended target, you can expect this attack to be detected and even localized to find you.

Second, a victim must be successfully authenticated from their network, and be frustrated enough to join a totally unknown open network that just appeared out of nowhere and has the same name of the network they trust. Further, attempting to connect to this network (on macOS) even yields a warning that the last time the network was connected to, it had a different kind of encryption. [9]

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the research is the problem of wifi connections security, non-compliance with information security rules.

The subject of the research is home wifi networks, in particular, the resistance of the router to a packet injection attack, studying the functionality of wifi adapters, bypassing the existing network protocol.

The aim of this study is a visual demonstration of the vulnerability of a wifi connection to MITM attacks like Rogue AP and Evil Twin. Using this program, you can also track the influence of the human factor on the security of the network to penetration. Based on the results of the research, we will be able to provide a list of minimum precautions for users.

3.1. Research tools

The operating system Ubuntu 20.04 LTS (Focal Fossa) was chosen for the study. The work was carried out on wifi-adapters: Intel (R) Dual Band Wireless-AC 8265; two Tenda W311Ma adapters, on different chipsets. For an example of the attack, the Mercusys MW301R router was used.

For a successful MITM attack, you need to use several adapters that would support network monitoring functions, packet injection to the router, and the ability to install an access point. The adapter's functionality, as well as its compatibility with the operating system kernel, depends on the installed chipset. At the moment, there is no single reliable base of chips with supported functionality that would be relevant for any time. Using the aircrack-ng software package, you can test the wifi adapter chipset, monitor mode, and batch injection functionality.

```
root@mordekai-VivoBook-S15-X510UF:/home/mordekai# airmon-ng start wlx502b73dc1051
Found 4 processes that could cause trouble.
Kill them using 'airmon-ng check kill' before putting
the card in monitor mode, they will interfere by changing channels
and sometimes putting the interface back in managed mode

PID Name
903 avahi-daemon
908 NetworkManager
955 wpa_supplicant
959 avahi-daemon

PHY Interface Driver Chipset
phy0 wlan2s0 iwlwifi Intel Corporation Wireless 8265 / 8275 (rev 78)
phy2 wlx502b73a591d2 mt7601u Ralink Technology, Corp. MT7601U
phy1 wlx502b73dc1051 rt2800usb Ralink Technology, Corp. RT5370
Interface wlx502b73dc1051mon is too long for linux so it will be renamed to the old style (wlan#) name.

(mac80211 monitor mode vif enabled on [phy1]wlan0mon
(mac80211 station mode vif disabled for [phy1]wlx502b73dc1051)
```

Fig. 6. Switching one of the adapters to monitor mode, viewing chipsets.

```
root@mordekai-VivoBook-S15-X510UF:/home/mordekai# aireplay-ng --test wlan0mon
21:51:45 Trying broadcast probe requests...
21:51:46 Injection is working!
21:51:47 Found 3 APs

21:51:47 Trying directed probe requests...
21:51:47 00:72:63:3C:E2:70 - channel: 1 - '506'
21:51:49 Ping (min/avg/max): 1.253ms/7.649ms/17.633ms Power: -60.89
21:51:49 18/30: 60%

21:51:49 B0:BE:76:7D:85:5E - channel: 1 - 'TP-Link_855E'
21:51:54 Ping (min/avg/max): 1.809ms/8.353ms/15.010ms Power: -86.00
21:51:54 7/30: 23%

21:51:54 B0:48:7A:CE:BF:B4 - channel: 1 - 'TP-LINK_CEBFB4'
21:51:59 Ping (min/avg/max): 1.425ms/1.811ms/2.506ms Power: -88.00
21:51:59 3/30: 10%
```

Fig. 3. Batch injection from Tenda W311Ma adapter (MT7601U)

Using the hostapd program, we can deploy a test access point and test the adapter in access point mode. To do this, just create and configure the hostapd configuration file.

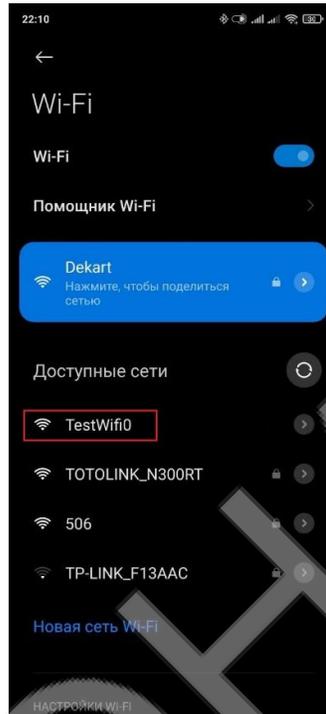


Fig. 4. Test AP display.

Intel (R) Dual Band Wireless-AC 8265 Laptop Internal Adapter provides all the features you need. External adapters are used to monitor the network and perform packet injection on the router.

IV. RESULTS

The program is written in the python programming language for the Ubuntu 20.04 LTS operating system, bash scripts are launched by clicking different keys. Initially, the nearest wifi networks are monitored, the user chooses a target for the attack, as well as wifi adapters (at least two) for carrying out a MITM attack.

The original access point is jammed using aireplay-ng by performing batch injections into the router. Fake AP is installed using hostapd, it is configured in accordance with the data obtained during monitoring. In the configuration file hostapd.conf, the SSID of the original access point for the purpose of copying is written, the driver, channel, and other characteristics are configured. It was decided to use dnsmasq for issuing IP addresses. It is a highly configurable DNS, DHCP and TFTP server designed to provide domain names and related services to small networks.

Then you can choose the target of the attack - the original AP password, or tracking and decrypting traffic passing through the Fake AP.

In the first case, the person disconnects from the original access point and connects to the created one. The screen displays a message about the need to register in the network and a request to enter a password for confirmation. After that, the

point disappears, reconnecting the client to the original network, so you can get the password.

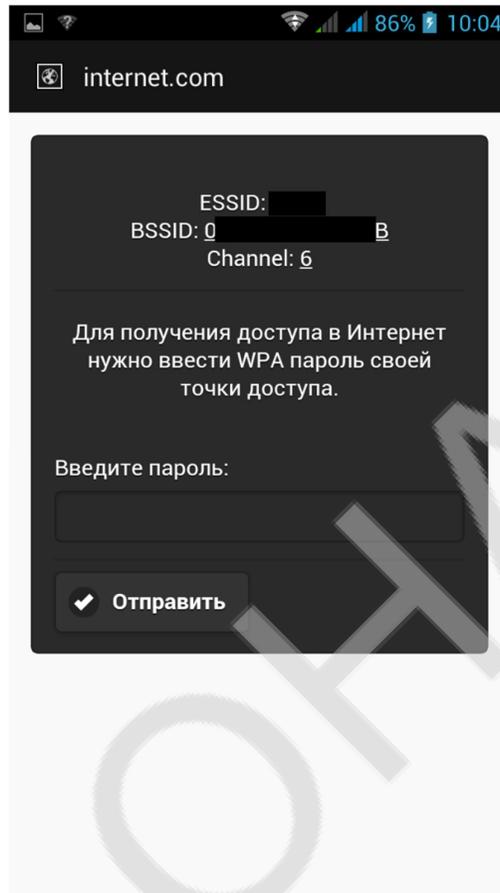


Fig. 5. False message about the need to register on the network.

To track outgoing traffic in the second case, you need to connect an access point to the Internet, this is done using Iptables, which is the standard interface for managing the Netfilter firewall (firewall). Since it is necessary to know the SSID and password of the network in order to intercept outgoing traffic, this is a sophisticated Evil Twin attack. The captured traffic is decrypted by Airdecap-ng. Airdecap-ng can decrypt WEP / WPA / WPA2 capture files and can also be used to mark up wireless headers from unencrypted wireless capture.

It outputs a new file ending in -dec.cap, which is the decrypted / split version of the input file.

Airdecloak-ng removes WEP cloning from pcap file. It works by reading an input file and fetching packets from a specific network. Each selected package is listed and classified (default status "unknown"). Filters are then applied (in the order specified by the user) in this list. They will change the status of the packages (unknown, unclosed, potentially hidden or hidden). The order of the filters is important because each filter will base its analysis on, among other things, the status of the packages, and different orders will give different results. [10]

The developed application is a tool for testing the system for security. In this

case, not only the resistance of the network to such attacks is checked, but also the

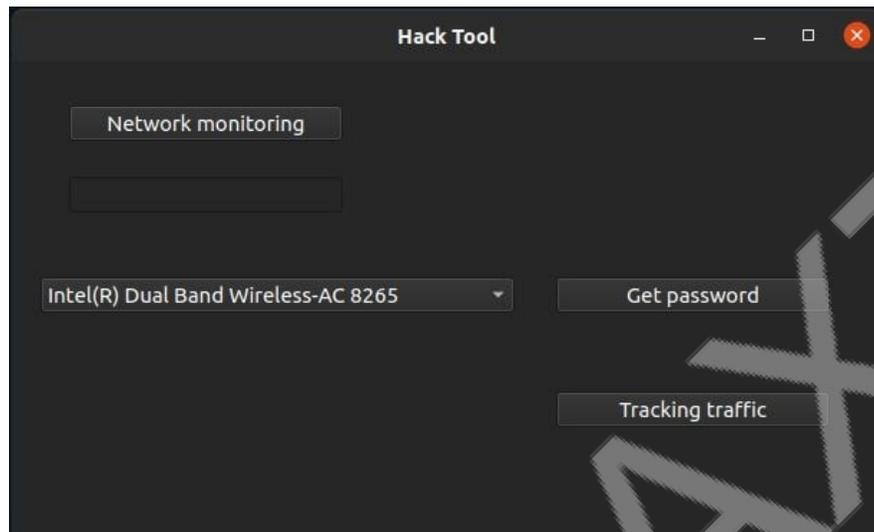


Fig. 6. Interface of the application.

impact of social engineering on people.

Fluxion, Wifiphisher, Aircgeddon, WiFi-Pumpkin are applications of this kind, but they only work correctly in Kali Linux. They do not have a graphical interface and work from the console. Due to the complexity of configuring and building dependencies, these applications do not work on Ubuntu. Also, when testing networks, difficulties arise associated with the functionality of wifi adapters. Conflicts arise between adapter chipsets and operating system kernel versions, and flashing takes additional time. These are the problems that we encountered in our research.

V. CONCLUSIONS

Man in the Middle is generally a type of attack aimed at violating confidentiality and, in some cases, information integrity. [11] MITM attacks are still being improved and supplemented, bypassing new protection protocols. Wi-Fi is one of the most vulnerable systems. To break them, no physical impact on communication channels and wires is needed. At the moment there are many software solutions for implementing MITM attacks, but each has its own drawbacks. The developed program can act as a simulator for beginners in information security, with the help of which students will develop an understanding of the mediator's attack algorithm. Information security on the client side plays a large role in repelling such attacks. It is difficult to counter this, but for a home network it is enough to at least hide the SSID of the network, removing it from the attacker's field of vision. Using encryption and Cisco WIPS, various IPS / IDS, UEBA, etc. will allow, if not to stop the work of the attacker, then hide it and take measures to catch the criminal, but such measures are more relevant for corporate networks, the work of which is monitored by the system administrator.

VI. REFERENCES

1. Understanding Man-In-The-Middle Attacks - Part 3: Session Hijacking Updated on 5 May 2010. [Electronic resource]. URL: http://www.windowsecurity.com/articlestutorials/authentication_and_encryption/Understanding-Man-in-the-Middle-Attacks-ARP-Part3.html/ (date of access: 21.09.20).
2. Все об атаке "Человек посередине" (Man in the Middle, MitM) [Electronic resource]. URL: https://www.anti-malware.ru/analytics/Threats_Analysis/man-in-the-middle-attack (date of access: 10.12.20).
3. ARP poisoning/spoofing: How to detect & prevent it [Electronic resource]. URL: <https://www.comparitech.com/blog/vpn-privacy/arp-poisoning-spoofing-detect-prevent/> (date of access: 12.12.20).
4. Poisoning Attacks, Round 2: Beyond NetBIOS and LLMNR [Electronic resource]. URL: <https://www.crowe.com/cybersecurity-watch/poisoning-attacks-round-2-beyond-netbios-llmnr> (date of access: 12.12.20).
5. What is DNS spoofing Man in the Middle Attack? | Security Wiki [Electronic resource]. URL: <https://doubleoctopus.com/security-wiki/threats-and-tools/dns-spoofing/> (date of access: 21.12.20).
6. What is DNS Spoofing and cache poisoning? | Kaspersky [Electronic resource]. URL: <https://www.kaspersky.com/resource-center/definitions/dns> (date of access: 21.12.20).
7. Rogue access point - Wikipedia [Electronic resource]. URL: https://en.wikipedia.org/wiki/Rogue_access_point (date of access: 21.12.20).
8. Evil Twin Attack [Electronic resource]. URL: <https://www.firewalls.com/blog/security-terms/evil-twin-attack/> (date of access: 23.12.20).
9. How to Hack Wi-Fi: Stealing Wi-Fi Passwords with an Evil Twin Attack «Null Byte» [Electronic resource]. URL: <https://null-byte.wonderhowto.com/how-to/hack-wi-fi-stealing-wi-fi-passwords-with-evil-twin-attack-0183880/> (date of access: 23.12.20).
10. Airdecap-ng and Airdecloak-ng - Kali Linux [Electronic resource]. URL: <https://kalinix.info/tools/airdecap-ng-and-airdecloak-ng.html/> (date of access: 17.01.21).
11. Сеть компании и MitM. Часть 1 [Electronic resource]. URL: <https://habr.com/ru/company/acribia/blog/438996/> (date of access: 17.01.21).

PORTABLE WEATHER STATION ON A MICROCONTROLLER

Author: *Lilia Bosenko*

Advisor: *Volchkov Igor*

Professional college of oil and gas technologies, engineering and service infrastructure of the Odessa National Academy of Food Technologies (Ukraine.)

Abstract. *In the modern world, a very relevant topic is modern developments that are used in technologies: "smart home". One of these developments is the development of a portable weather station using the Arduino-Uno microcontroller system. The portable weather station allows you to measure: temperature, humidity, atmospheric pressure. The results of these measurements are displayed on the liquid crystal display. The temperature and humidity sensor can be removed from the microcontroller unit by several meters, which allows you to place the microcontroller unit with a liquid crystal indicator in a convenient place in the room.*

The weather station is powered from a DC source with a voltage of 7 to 24 volts and the supply current does not exceed 100 milliamps.

A standard AC/DC 220V ~ /9V= adapter (converter) can be used as a power source, which makes the use of the weather station safe. Programming of the weather station is carried out using a standard computer via a cable via the USB 2.0 telecommunications port.

Keywords: *Arduino-Uno, smart home, humidity sensor, temperature sensor.*

I. INTRODUCTION

A smart home is a residential building organized for the convenience of people living using various high-tech devices.

The Smart Home understands specific situations occurring in the building and responds accordingly to them using pre-developed algorithms. At the same time, a person sets the desired environment with one command, and automation sets and monitors the operating modes of all engineering systems and electrical appliances in accordance with external and internal conditions.

The smart home itself adjusts the operation of all systems in accordance with the person's wishes, time of day, position in the House, weather, outdoor lighting to ensure a comfortable state inside the House. Creating a smart home involves having smart devices.

Smart home technology is an intelligent home management system that ensures automatic and coordinated operation of all life support and security systems. Such a system independently recognizes changes in the room and responds to them accordingly. The main feature of this technology is the integration of individual subsystems and devices into a single complex controlled by automation.

One of the main functions of a smart home is climate measurement, namely the use of temperature, pressure and humidity sensors. We will look at this function using the example of a portable weather station, the main component of which is the use of a DHT22 sensor that connects to the Arduino UNO microcontroller.

2. ARDUINO UNO MICROCONTROLLER

Arduino is a hardware computing platform for amateur design, the main components of which are a microcontroller board with I/O elements and a Processing/Wiring development environment in a programming language that is a simplified subset of C/C++. Arduino can be used both to create stand-alone interactive objects, and to connect to software that runs on a computer (for example: Processing, Adobe Flash, Max/MSP, Pure Data, Super Collider).

In this project, we used one of the varieties of Arduino microcontroller boards, namely the Arduino UNO board.

The Arduino Uno is a widely used Open Source microcontroller board based on the ATmega328P microcontroller. It includes everything you need for convenient operation with the microcontroller: 14 digital inputs/outputs (6 of them can be used as PWM outputs), 6 analog inputs, a 16 MHz Quartz resonator, a USB connector, a power connector, an internal programming connector (ICSP) and a reset button. To get started with the device, simply apply power from an AC/DC adapter or battery, or connect it to your computer using a USB cable.



Fig.1: Arduino UNO microcontroller.

Unlike all previous Arduino boards, the Uno uses an ATmega16U2 microcontroller instead of an FTDI chip as a USB-UART interface converter.

Table 1.

Basic value	Criteria
Analog inputs	6
Maximum output current 3.3 V	50mA
Maximum current of one output	40mA
Microcontroller	ATmega328
Supply voltage (limit)	6-20 V
Supply voltage (recommended)	7-12 V
Operating voltage	5 V
Clock speed	16 MHz
inputs / outputs	14 (6 of them can be used as PWM outputs) EEPROM 1 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Flash memoty	2 KB (ATmega328) of which 0.5 KB is used by the bootloader
SRAM	2 KB (ATmega328)

The Arduino Uno can be powered by USB or an external power source — the source type is selected automatically.

An AC/DC network adapter or battery/battery can be used as an external power source (not USB). The adapter plug (diameter — 2.1 mm, Center contact — positive) must be inserted into the appropriate power connector on the board. If the battery is powered, the wires must be connected to the Gnd and Vin pins of the POWER connector.

The voltage of the external power supply can be in the range from 6 to 20 V. However, reducing the supply voltage below 7 v leads to a decrease in the output voltage of 5V, which can cause unstable operation of the device. Using a voltage greater than 12 V may cause the voltage stabilizer to overheat and the board to fail. With this in mind, it is recommended to use a power supply with a voltage in the range from 7 to 12 V.

The ATmega328 flash memory capacity is 32 KB (of which 0.5 KB is used by the bootloader). The microcontroller also has 2 KB of SRAM memory and 1 KB of EEPROM.

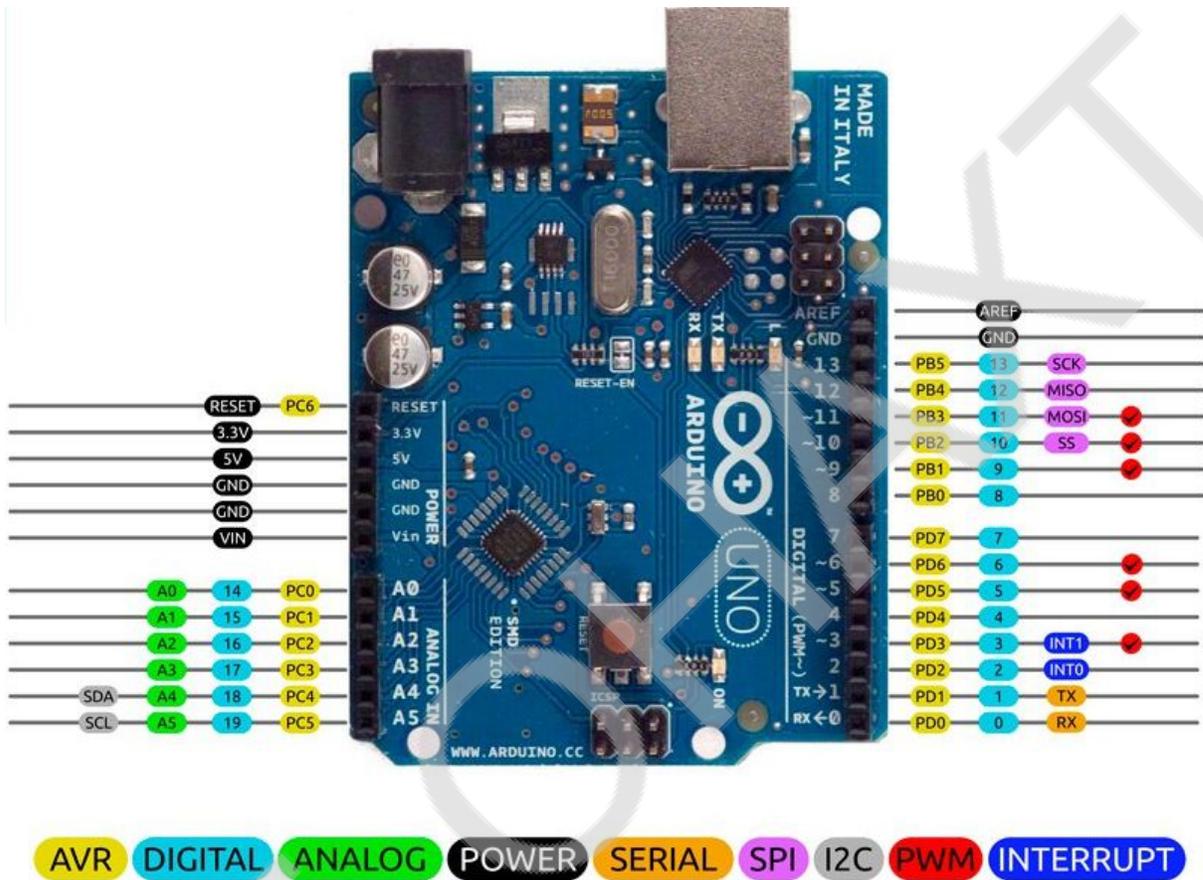


Fig. 2: Arduino Uno pin placement diagram.

The ATmega328 has a UART receiver that allows serial communication via digital outputs 0 (RX) and 1 (TX). The ATmega16U2 microcontroller on the board connects this receiver to the computer's USB port, and when connected to a PC, it allows the Arduino to be detected as a virtual COM port. On the Windows platform, only the appropriate one is required .inf file. The Arduino software package includes a special program that allows you to read and send simple text data to Arduino. When transmitting data via a USB-UART converter chip during a USB connection to a computer, the RX and TX LEDs will flash on the board. (When transmitting data in series using outputs 0 and 1, without using a USB converter, these LEDs are activated).

3. WEATHER STATION AND ITS COMPONENTS

A portable weather station is a small digital climate control device that allows you to accurately determine the ambient temperature and changes in atmospheric pressure.

The weather station I developed for this project consists of the following set of components:

1. DHT22 temperature and humidity sensor;
2. BMP180 Atmospheric Pressure Sensor;
3. 1602 LCD liquid crystal display;
4. Breadboard;



5. Connecting wires;
6. 100 Ohm resistor.

Fig. 3: components that are required for a portable weather station.

3.1. DHT22 sensor

The DHT22 sensor consists of a capacitive humidity sensor and a thermistor. In addition, the sensor contains a chip that converts an analog signal to a digital one. During the manufacturing process, the components included in the DHT module can receive various parameters, and in order for the sensor readings to be correct, the manufacturer calibrates each DHT sensor in the calibration chamber, and the correction factor is stored in memory and called when reading data.

General characteristics:

- low cost;
- power supply and I / O: 3-5V;

- determination of humidity 0 - 100% with an accuracy of 5%;
- temperature detection of 0 - 50 ° C with an accuracy of 2%;
- sensor polling frequency no more than 0.5 Hz (no more than once every 2 seconds);
- dimensions: 17 x 13 x 5 mm;

The advantages of this sensor are small size, low power consumption, high transmission range (up to 20 m), the disadvantages include relatively low measurement accuracy.

The sensor has 4 contacts:

1. VCC power supply;
2. SDA contact for data exchange between the sensor and the microcontroller;
3. NC-not used;
4. GND-ground.

To start receiving data from the sensor, the microcontroller must send a request to the sensor and wait for it to respond that the sensor is ready to transmit information. This happens as follows. When the microcontroller is going to receive data, it should pull the data line to zero for 18 Ms, then release it back to 1. at the same time, the microcontroller goes into standby mode and monitors what happens to the data line. After 20-40 microseconds, if everything is in order, the sensor responds by drawing the data line from its side to zero at 80 microseconds and releases it at 80 microseconds. In this way, the sensor lets the microcontroller know that everything is fine with it, and it starts transmitting data. Data is transmitted Bitwise. Depending on how many microseconds the sensor releases the line to 1, the microcontroller recognizes which bit was transmitted: if the duration of the time interval until the next attraction to zero is 26-28 microseconds, then 0 is transmitted, if 70 microseconds is transmitted 1.

The amount of transmitted information is 40 bits (5 bytes). The first and second bytes contain integer and fractional parts of humidity information, the third and fourth bytes contain integer and fractional parts of temperature information, and the fifth byte is a checksum that represents the last 8 bits from adding up the previous 4 bytes.

After transmitting a data packet, the sensor goes into sleep mode until the next request from the microcontroller.

To read DHT22 sensor data using Arduino, there is a ready-made DHT library that you need to import into the Arduino IDE.

3.2. BMP180 Atmospheric Pressure Sensor

The BMP180 sensor is a cheap and easy-to-use touch sensor that measures atmospheric pressure and temperature. It is usually used to determine the altitude and in weather stations. The device consists of a piezo-resistive sensor, a thermal sensor, an ADC, non-volatile memory, RAM, and a microcontroller.

General characteristics of the BMP180 sensor:

- Pressure measurement limits are 225-825 mm.

- Power supply voltage 3.3-5V;
- Current 0.5 ma;
- I2C interface support;
- 4.5 ms response time;
- Dimensions 15 x 14 mm.

3.3. Arduino LCD 1602 LCD display

LCD I2C display screen and adapter Arduino liquid Crystal Display (Liquid Crystal Display) LCD 1602 is a good choice for displaying strings of characters in various projects. It is inexpensive, there are various modifications with different lighting colors, you can easily download ready-made libraries for Arduino sketches. But the biggest drawback of this screen is the fact that the display has 16 digital pins, of which a minimum of 6 are required. therefore, using this LCD screen without I2C adds serious limitations to Arduino Uno or Nano boards. If there are not enough contacts, then you will have to buy an Arduino Mega board or save contacts, including by connecting the display via I2C.

Display specifications:

- Character display type, it is possible to load characters;
- LED backlight;
- HD44780 controller;
- Power supply voltage 5V;
- 16x2 character format;
- Operating temperature range-20c to + 70C, storage temperature range - 30c to +80c;
- 180-degree viewing angle.

ASSEMBLY AND PROGRAMMING

Next, we will take a closer look at connecting all the available elements and programming a portable weather station on the Arduino Uno microcontroller.

The DHT22 sensor, which will be used to receive data on ambient temperature and humidity, is connected as follows:

Table. 2.

VCC	5V
NC	Does not connect
SDA	Through a 10kohm K 5V resistor
GND	GND

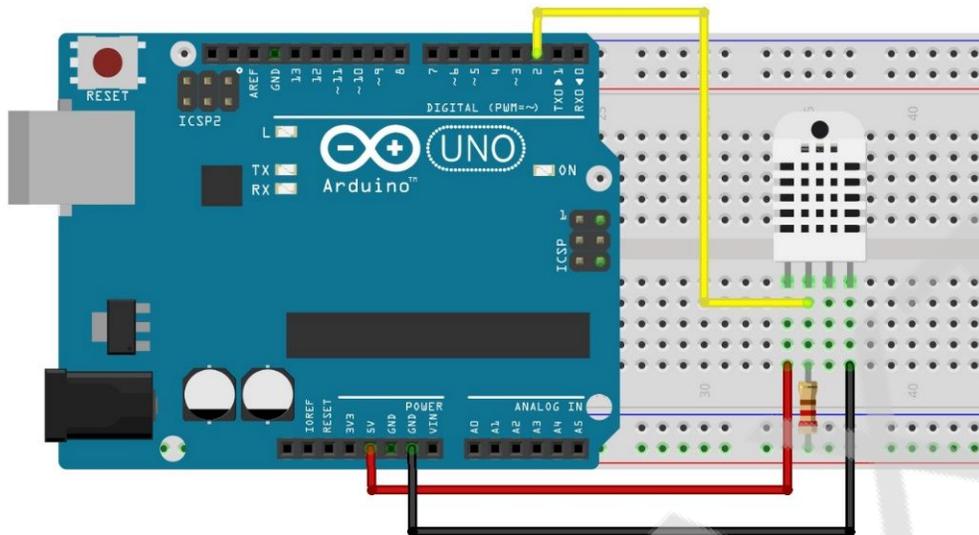


Fig. 4: connection diagram of the DHT22 humidity sensor.

Connecting the BMP180 sensor to the Arduino. To connect, you will need the BMP180 sensor itself, an Arduino UNO board, and connecting wires. The connection diagram is shown in the figure below.

Table. 2

VIN	5 B
GND	GND
SDA	A4
SCL	A5

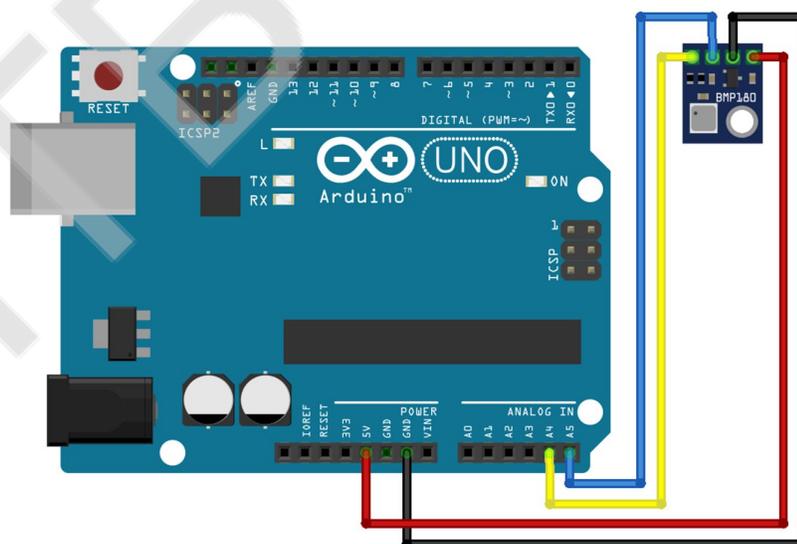


Fig. 5: Wiring diagram of the BMP180 sensor to the Arduino Uno.

Now we connect the LCD1602 IIC / I2C character display to the Arduino Uno, which will display information about temperature and humidity.

Table.3

Display 1602		Arduino Uno	Display 1602		Arduino Uno
1	GND	GND	9	DB2	Does not connect
2	VDD	5V	10	DB3	Does not connect
3	Contrast	To GND via resistor	11	DB4	Pin 2
4	RS	Pin 0	12	DB5	Pin 3
5	R/W	GND	13	DB6	Pin 4
6	Enable	Pin 1	14	DB7	Pin 5
7	DB0	Does not connect	15	Back LED+	To 5V via resistor
8	DB1	Does not connect	16	Back LED-	GND

The wiring diagram for connecting the DHT22 pressure sensor and the LCD 1602 display is shown in Figure 6.

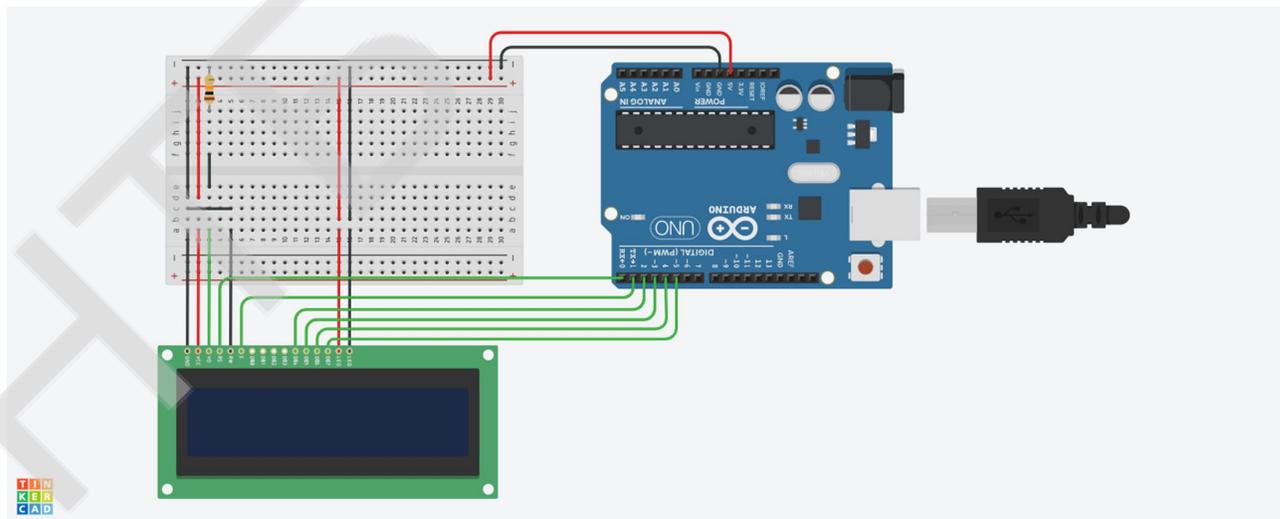


Fig. 6: connection diagram for the 1602 LCD display.

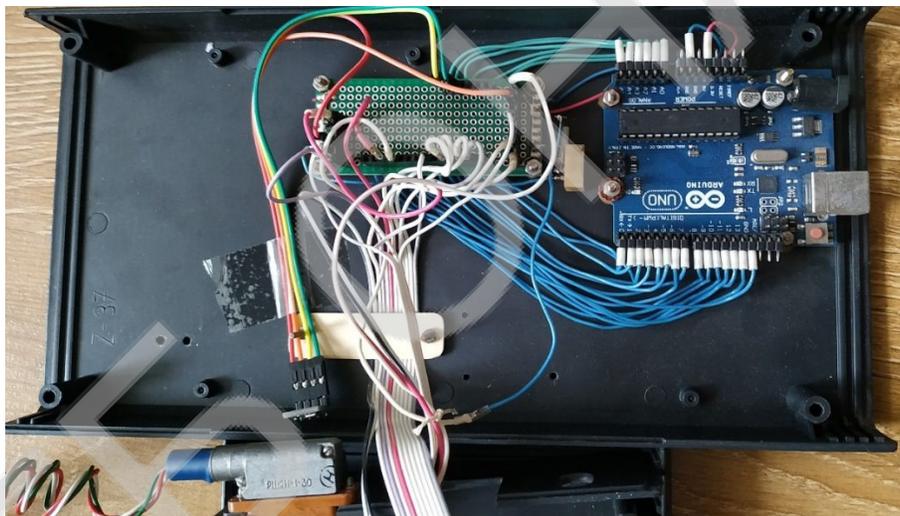
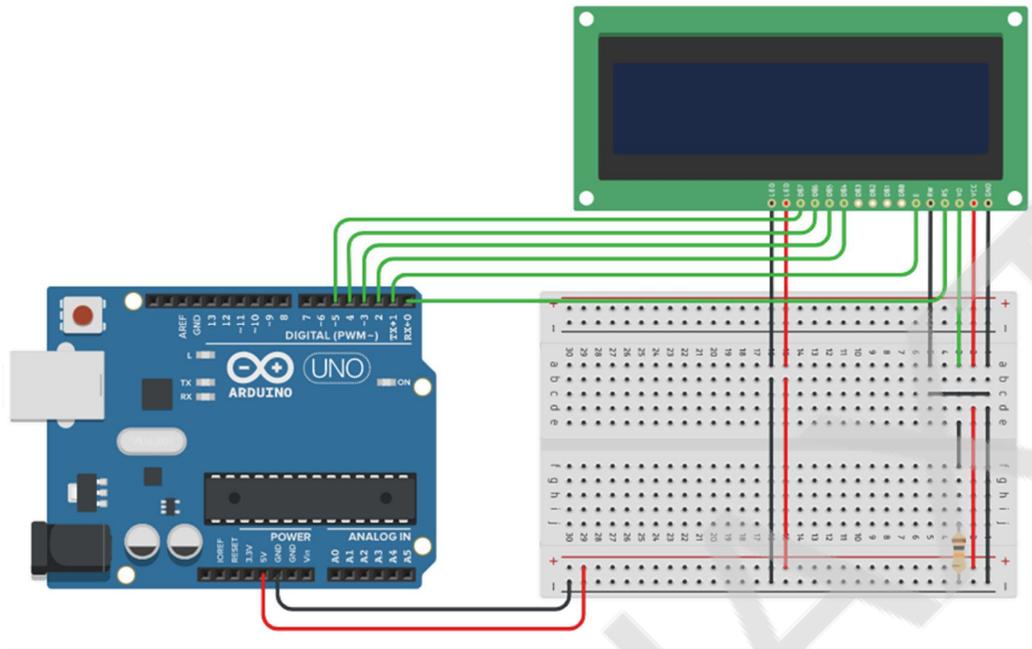


Fig. 7: connection diagram for DHT22 sensor and 1602 LCD display.

After we have assembled the connection diagram for all the necessary elements, you need to download a ready-made sketch or write it yourself using examples. A typical arduino sketch for working with the DHT22 temperature and humidity sensor and the LSD1602 display looks like this:

```

/*TEMPER_VLAGNOST_V2
CONNECTING THE TEMPERATURE AND HUMIDITY SENSOR TO THE LCD
1602. Connecting the LCD pins to ARDUINO_UNO/
LCD RS pin to digital pin 12

```

LCD Enable pin to digital pin 11
LCD D4 pin to digital pin 5
LCD D5 pin to digital pin 4
LCD D6 pin to digital pin 3
LCD D7 pin to digital pin 2
LCD R/W pin to ground
10K resistor:
ends to +5V and ground
wiper to LSD VO pin (pin 3)

```
*/  
  
// connecting libraries  
#include <LiquidCrystal.h>  
#include "DHT.h"  
#define DHTPIN 7  
// initials of the library to the controller contacts  
LiquidCrystal LCD(12, 11, 5, 4, 3, 2);  
#define DHTTYPE DHT22 // initializing the sensor  
DHT dht(DHTPIN, DHTTYPE); // initializing the sensor  
void setup() {  
  lcd.begin(16, 2); //initializing the 16X2 indicator  
  lcd.setCursor(0, 0); //set the cursor to 0, 0  
  lcd.print("TEMPERATURE-"); //display the word "temperature-"  
  lcd.setCursor(14, 0); //set the cursor to 14, 0  
  lcd.print("*C"); //display the words "*C"  
  lcd.setCursor(0, 1); //set the cursor to 0, 1  
  lcd.print("VLAGNO-"); //display the word "wet-"  
  lcd.setCursor(14, 1); //sets the cursor to 14, 1  
  lcd.print("%"); //display the word "%"  
  Serial.begin(9600); //activate the COM port at speed. 9600  
  Serial.print ("Test test!"); // display the word " Dthxxx test!"  
  dht.begin (); // start the temperature and humidity sensor  
}  
void setup() {  
  float h = dht.readHumidity(); //the variable h to assign the sensor reading  
  float t = dht.readTemperature(); //assign the variable t to the sensor readings  
  if (isnan(t) || isnan(h)) //conditional branch.....?  
  {  
    Serial.println("Failed to read from DHT"); //display on the screen "error reading  
    from sensor"  
  }  
  else//  
  {  
    Serial.print("Humidity: "); //display the word "humidity"  }  
}
```

```
Serial.print("h");//display the humidity reading
Serial.print("%t");//display the word "%t"
Serial.print("Temperature:");//display the word "temperature"
Serial.print("t");//display the temperature reading
Serial.print("*C");//display on the monitor screen, the word "*C"
}
//set the cursor to colum 0, line 1
//(note: line 1 is the second row, since counting begins with 0)
lcd.setCursor(8, 0);//set the cursor to 8, 0 //
lcd.setCursor(10, 1); // print the number of second since reset
lcd.print(t); // display the temperature reading lcd.setCursor (8, 1);//set the
cursor to 8, 1
lcd.print(h);//display the humidity display delay (3000); // pause for 3 seconds
}
```

4. Conclusions

In modern homes, the use of smart home technology is increasingly common, which helps the owner of the house to monitor its condition. Namely, to control the lighting, security system, climate control system, allows you to monitor all electronic devices in the house (independently turn them on and off).

This technology makes life easier for the owner of a house (apartment) to a greater extent, and makes his place of residence cozy and safe.

The climate control system is one of the components of a smart home. It provides simultaneous management of the operation of devices that carry out the processes of heating, ventilation and air conditioning in the building. In addition, it allows you to set the temperature for each room and constantly maintain it at a given level.

In this article, we looked in more detail at the climate control system using the example of a portable weather station that works using an Arduino Uno microprocessor, and consists of: a DHT22 pressure and temperature sensor and an LCD 1602 liquid crystal display. You can also make a wireless weather station on an Arduino Uno, using Bluetooth or radio modules to transmit information over a distance.

5. Literature

- 1.Petin V. A. "creating a smart home based on Arduino Uno" - Moscow: DMK press, 2018.
- 2.Makarov S. L. "Arduino Uno and Raspberry Pi 3: from circuitry to the Internet of things" - M. DMK Press, 2019.
- 3.Revich Yu. V. " interesting electronics. 5th ed.", Rework. and add. - St. Petersburg .: BHV-Petersburg, 2018.
4. <https://www.arduino.cc/>

APPLICATION OF ARDUINO MICROCONTROLLER SYSTEM IN THE EDUCATIONAL PROCESS

Author: *Yakovleva Katerina*

Advisor: *Volchkov Igor*

Professional college of oil and gas technologies, engineering and service infrastructure of the Odessa National Academy of Food Technologies (Ukraine.)

Abstract

This paper considers the possibility of using the microprocessor system "ARDUINO" in the learning process. In today's world, students of technical schools must be well versed in digital technology, programming and have some technical skills in the use of modern microcontrollers.

Microcontrollers are very complex devices and in order to understand the operation of these devices you need to spend a lot of time studying the technical documentation as well as a good knowledge of technical English. In addition, you need to know the programming language (eg C++) and have a programmer with which to program the microcontroller. This paper presents the development of a universal laboratory stand for learning the basics of programming and studying the hardware of microcontroller technologies.

Keywords: *Arduino, digital technologies, microcontrollers, programming.*

I. Introduction

The use of modern microprocessor systems for the educational process requires large financial costs for laboratory equipment and the purchase of certified equipment and software.

This problem can be simplified if applied to the learning process.

ARDUINO microprocessor system kit that allows you to study both hardware and programming (in a language that is very similar.

In the algorithmic language C++). The ARDUINO microprocessor system consists of separate modules that can be purchased separately as needed. The software is on the site and can be downloaded to your computer free of charge via the Internet. The software is focused on the operating system WINDOWS, Mac OS, LINUX. In the software There are a number of programs (sketches) that are test and can be used with various additional modules that can be purchased separately. Main module: this is the module on which the ATmega328 microprocessor and additional elements for its operation are located.

A standard USB cable is used to write the program (sketch) to the microcontroller board, which connects to the USB port of the computer and a USB detachable microcontroller board. The programming process takes a few seconds. The written program (sketch) can be controlled with the help of software before programming the microcontroller board. Manufacturers produce a range of microcontrollers devices. The cheapest costs 73 UAH, the most expensive device costs 260 UAH. Some devices, when connected to a computer, appear as an external drive (ie as an FLFSH drive), and some, more budget-friendly ones require the

installation of a driver on the SN-340 computer, which also distributed free of charge. The price of the microcontroller module is 30-40 percent cheaper with constant functionality. For connection of a board of the microcontroller with functional blocks conductors with contacts and various assembly boards which do not demand the soldering are provided. In the microcontroller, the manufacturer has already recorded the boot loader and a test program called BLINK. On the microcontroller board provided several light emitting diodes, one of which is a test. When connected via the power connector, the LED (on and off) starts working with a period of 1 second.

The purpose of this work is to develop a budget version of the laboratory stand based on the microprocessor system "**ARDUINO-UNO**" for the educational process of programming microprocessors and the development and installation of electronic circuits.

II. Features of the ARDUINO microprocessor system

The program from an incomprehensible set of English words turns into an algorithm for controlling a real device, just assembled with their own hands. It motivates, arouses interest in this activity. Application of Arduino in the learning process. In real conditions, the student does not have enough knowledge about only one microcontroller, device or sensor. In most cases, to solve practical problems, these devices need to be combined into large circuits, which is not always possible in the laboratory. When using the Arduino platform, this process is simplified. It is proposed to divide the work with Arduino into three stages:

The first stage of students' work is offered to write the algorithm of the device. This stage of work allows in practice to consolidate the skills of compiling algorithms for their further implementation.

In the second stage, a software implementation of the proposed algorithm should be developed. Since students did not have the skills to work in the development environment, although C / C ++ or other programming languages were familiar, standard code examples for a particular job of each of the devices used in development could be used to reduce uptime, but were slightly reworked. for the correct operation of all components of the device according to the proposed algorithm.

In the third stage of work, students must study the characteristics and interfaces of the proposed hardware components. By studying information from open sources on their own, they should assemble a working device and check its operability. What can the Arduino give to the learning process? First, it is, of course, consolidating programming skills in C ++. Second, the Arduino gives some idea of microelectronics. This is definitely a necessary knowledge for a software engineer, as they give an idea of the hardware platform for which the software is written. Third, the Arduino allows you to clearly demonstrate the operation of the code. By downloading the program to the board, you can see its effect on real physical objects (the operation of the LED, for example). Material costs (cost of used components) are about 1000 UAH. The use of simpler versions of Arduino (for example, Arduino Uno) will reduce costs to 400-500 UAH.

Modern education must interact with the use of modern technologies. One such novelty is the Arduino family of controllers. Arduino is a fairly simple tool for creating electronic devices and implementing various ideas. This platform is built on a printed circuit board with an integrated environment for writing software. At the heart of the hardware is a microcontroller family ATmega 328 and the minimum required for operation strapping.

III. Technical parameters of the microprocessor system "ARDUINO-UNO"

The ARDUINO-UNO board has the following parameters: ATmega328 microcontroller with a clock frequency of 16 MHz, operating voltage-5 Volts, FLASH memory - 32 KB (0.5K is used by the bootloader), number of analog inputs-6, SRAM memory -2 KB.

Number of digital inputs / outputs -14 (6 of which can be used as PWM), For analog information output.

Input voltage 7-12 Volts, memoryEEPROM-1KB /

The Arduino can receive digital and analog signals from different devices and has the ability to control various executable modules.

There are a large number of different microcontrollers. It is difficult to find the necessary and presented in an accessible form information about them, not to mention the implementation of any practical tasks with their use. Sometimes this results in a fairly long learning process with deep immersion in the slums of circuitry and microelectronics. Arduino, in turn, simplifies the process of working with microcontrollers and has a number of undeniable advantages over other devices for teachers, students and amateurs:

- low cost. Arduino boards are relatively cheap compared to other platforms.
- cross-platform. With Arduino you can work on systems running Windows, Mac OS and Linux.
- simple and clear programming environment. The development environment is designed for beginners unfamiliar with software development. However, this does not prevent experienced users to create quite complex projects. The environment is an application that includes a code editor, compiler and a special module for firmware. The programming language used in the Arduino is a **Wiring** implementation. Simply put, it is C / C ++, supplemented by some libraries.
- the possibility of hardware expansion. The capabilities of Arduino boards can be expanded with the help of special schemes called "shields". Shields are installed on top of the main board and provide new opportunities. For example, there are expansion cards for connection to the local network and the Internet (Ethernet Shield), to control powerful motors (Motor Shield), to obtain coordinates and time from GPS satellites (GPS module) and many others.

Students, having created the program, can immediately observe the results of their activities. The program from English words turns into an algorithm for controlling a real device, just assembled with your own hands. This motivates and arouses interest in this activity.

IV. Application of microprocessor system "ARDUINO-UNO"

What can the Arduino give to the learning process?

The first is, of course, the consolidation of C ++ (**Wiring**) programming skills.

Second, the Arduino gives an idea of how microelectronics work. This is definitely a necessary knowledge for an engineer, as they give an idea of the "iron" for which the software is written.

Third, the Arduino allows you to clearly demonstrate the operation of the code. By downloading the program to the board, you can see its effect on **real physical objects** (flashing LEDs, for example).

In the College of Oil and Gas Technologies, Engineering and Service Infrastructure of the Odessa National Academy of Food Technologies of Odessa

It is planned to use Arduino in the educational process of students from 2020, in particular in laboratory work, which will allow students to better understand the principles of electronics. As well as interested and talented students to show their abilities in designing and implementing their own developments.

A significant problem in the field of "Telecommunications and Radio Engineering" is the limited use of modern advances in science and technology in the educational process, including the use of unified microcontroller platforms, as it is difficult to imagine a radio device that would not control a microcontroller or microprocessor. The problem is partially solved by using software packages for electronic circuit simulators, which have the ability to debug programs for microcontrollers in real electrical circuits. However, theory without practice is quickly forgotten and work in such electronic stimulators becomes uninteresting for students, it is increasingly difficult to find ways to stimulate students to learn. To solve the problem, it is proposed to introduce platforms such as Arduino in the educational process. The main advantage of these platforms is that their practical use will deepen and consolidate knowledge of the principles of microprocessor systems, design and construction of electronic units and modules with microcontroller control, and in the postgraduate period on the basis of these platforms students can design devices with different the level of complexity of the functions performed: from LED panel switches to systems for selection, pre-processing and visualization of signals. In general, the use of the Arduino platform can significantly increase students' interest in the learning process, and provide basic knowledge on the design of electronic devices with microcontroller control.

V. Laboratory stand based on microprocessor system "ARDUINO-UNO"

At the College of Oil and Gas Technology, Engineering and Infrastructure service of the Odessa National Academy of Food Technologies of Odessa developed a laboratory stand based on the microprocessor system "ARDUINO-UNO" with additional modules that are located compactly on the circuit board.

On the circuit board are:

- module microprocessor and "ARDUINO-UNO"
- board with LEDs in the amount of ten pieces and one color RGB LED.
- potentiometer for work with analog input.

- acoustic generator and switch.
- button to simulate the signal.
- cross board to which all the main foams of the microcontroller board are connected.

On a cross-board the power supply +5 Volts and contacts for connection of additional modules is deduced, in addition. The digital outputs of the microcontroller from the cross-board are connected by a cable to the board on which the LEDs are located. If necessary, this cable is disconnected and various other modules are connected to the cross-board by means of standard conductors with contacts which are provided for this purpose. From above the microprocessor module "ARDUINO-UNO" is closed by a transparent protective cover (for protection against damages). The power source can be a standard USB port that outputs + 5 Volts, but the current should not exceed 0.5 Amps, or an external DC power supply with a voltage of +7.0 volts to +12.0 Volts.

On this laboratory stand it is possible to perform a number of laboratory works and conduct various experiments using both digital inputs-outputs of the microcontroller and analog inputs, it is also possible to conduct experiments with RGB LED, getting different colors and shades, writing and configuring the program (sketch). . At the same time, students will be able to clearly see how red, green and blue can be obtained many different shades of colors.

The laboratory stand has dimensions: 140x120x40 millimeters and weighs 200 grams, and does not require additional equipment other than a standard USB cable.

To connect to a computer. The cost of all components does not exceed 300 hryvnias. Photos of the laboratory stand and some components are provided in the appendices: 1-3. An example of a written sketch is given in the appendix: 4.

The use of the ARDUINO hardware and software complex in the innovative activity of future specialists in the field of telecommunications and radio engineering is of great practical importance and is very expedient because it does not require large material costs.

Students, performing a variety of laboratory work have the opportunity to immediately see the results of their work, the opportunity to quickly correct the program (sketch), or hardware.

This paper considers the problem of using information tools in educational and research activities of students - future professionals in the field of telecommunications and radio engineering .. Highlights the educational capabilities of the hardware and software complex Arduino in the context of training future professionals and organizing student innovation, in particular, on specific examples show the possibility of its use for setting and solving various problems, as well as for students to create their own innovative products. Research and testing of educational capabilities of the Arduino hardware and software complex were conducted during an experimental scientific group of students - future specialists in the field of telecommunications and radio engineering - at the College of Oil and Gas technologies, engineering and service infrastructures of the Odessa National Academy of Food Technologies of Odessa (in the disciplines: "Telecommunication

transmission systems, telecommunication switching systems.", as well as in extracurricular activities). The possibility of using the Arduino complex in the innovative activities of students, which is unfolding in the educational process, was also studied. These studies have shown that the Arduino hardware and software complex can play an important role in extracurricular educational and cognitive activities of future professionals (in particular, to enhance their innovative activities). This indicates the expediency of acquaintance with this complex in technical educational institutions.

The hardware part of the complex is an I / O board for analog and digital data based on a programmable Atmega microcontroller of various modifications. Depending on the modification, the board has from 6 to 12 analog inputs (inputs of analog-to-digital converters, otherwise - digital voltmeters) and up to 20 digital inputs / outputs, 6 of which can be used in the mode of pulse-width modulation). The I / O board operates programs written in a language very close to C ++, which can be easily mastered by a person far from professional programming (especially students). To write, configure and download programs (they are called "sketch") uses a special programming environment (IDE), which includes a program test editor, compiler and program loader. A special boot module is written in the memory of the microcontroller. It allows you to download created sketches without the use of additional programmers, as is usually done on other types of controllers. The measurement results can be displayed as a table in the serial port monitor window, stored in f or on the SD card or, when using the SerialPortPlotter program, be displayed on a computer monitor graphically (up to three graphs). On the ARDUINO UA website you can find a detailed description of Arduino boards of different types and corresponding sensors, a programming manual, examples of sketches, etc. Among the possible experimental problems that can be solved with the Arduino complex, the following should be noted:

1. Registration of time change of data from three sensors with their output on the computer monitor in the form of graphs. These data can be, for example, the following physical quantities: temperature at three different points, • illumination at three different points, humidity at three different points, • temperature, illumination and humidity at a selected point.

2. Obtaining the dependences of some physical quantities on others (with their graphical representation). For example, the dependence of the resistance of the photoresistor on the illuminance; the dependence of the resistance of the thermistor on temperature; charge-discharge curves.

VI. Conclusions

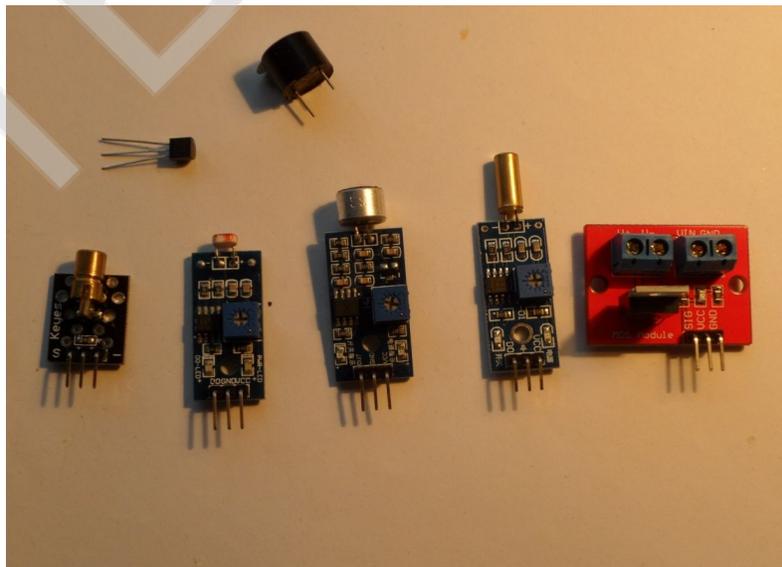
The use of the ARDUINO-UNO microcontroller system in the educational process has positive consequences. First, the availability of components that can be purchased in a store or ordered online (it will be cheaper). Secondly, a large number of different modules and signs for microcontroller boards are made. Third is open and free software, which is constantly being improved and distributed, as well as a large amount of educational material in accessible, free technical literature and in the form of videos in Yor Tube.

Developed laboratory stand based on microprocessor system ARDUINO-UNO allows students to perform a variety of laboratory work to study programming, algorithms and mastering electronics and circuitry. The laboratory stand itself is safe from the point of view of safety because there are no large electrical voltages (5 volts are used when powered by a computer and 12 volts when powered by an adapter). The laboratory stand can be applied in that complete set that is, or to use additional modules having connected their conductors to the laboratory stand.

As the initial experience of application of a laboratory stand in a student's circle on studying of electronics and circuit engineering showed at students there is a lively interest in writing of programs and carrying out experiments.

The use of the developed laboratory stand has a positive result in the educational process and research work.

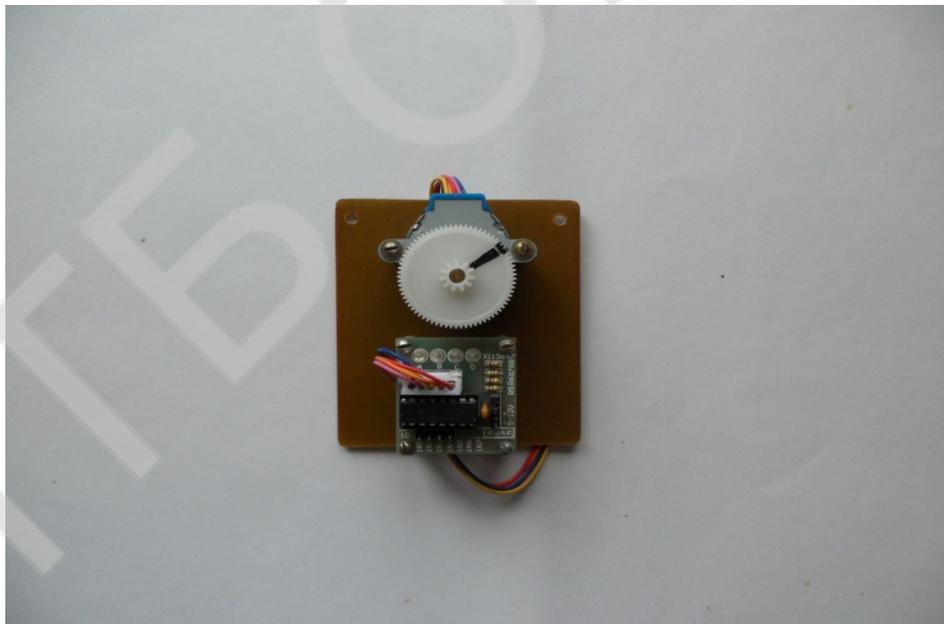
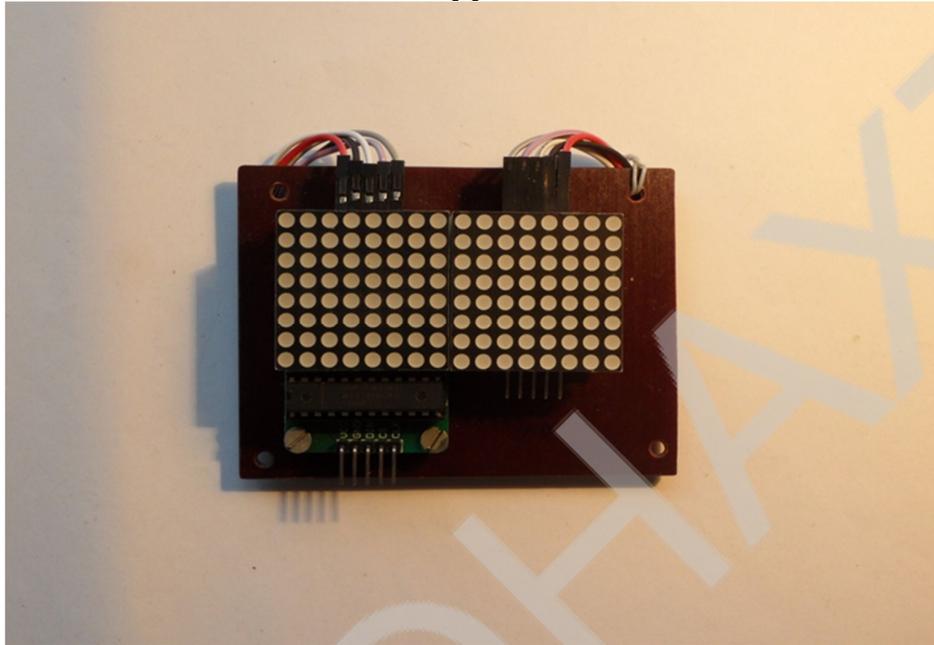
III. Supplements: Supplement I



On the top photo there is a laboratory stand with the module “ARDUINO-UNO”.

On the bottom photo there are flexible modules that can be connected to the stand.

Supplement II



On the top photo there is a single 8x16 matrix.

On the bottom photo there is a small dvigun with a keruvannya board.

Supplement III



On the top photo there is an electrical adapter 220/12 Volt, 1 Ampere.
On the bottom photo there is a USB -2.0 cable for connecting the ARDUINO-
UNO module to a computer.

Supplement IV

Butt written by programs (sketch)

```
// CONTROL SERVO DRIVE FROM THE POTENTIOMETER
```

```
#include <Servo.h>
```

```
Servo myservo; // create servo object to control a servo
```

```
int potpin = 0; // analog pin used to connect the potentiometer
```

```
int val; // variable to read the value from the analog pin
void setup()
{
  myservo.attach(9); // attaches the servo on pin 9 to the servo object
}
void loop()
{
  val = analogRead(potpin); // reads the value of the potentiometer
(value between 0 and 1023)
  val = map(val, 0, 1023, 0, 179); // scale it to use it with the servo (value
between 0 and 180)
  myservo.write(val); // sets the servo position according to the
scaled value
  delay(15); // waits for the servo to get there
}
```

VII. References

1. Massimo Banci ARDUINO M, 2012.
2. Jeremy Bloom Studying Arduino BHV-Petersburg, 2015.
3. Brian W. Evans Arduino programmer notebook S.F. 2007
4. www.arduino.cc
5. www.wiring.org.co
6. <http://cslibrary.stanford.edu/101/>

ATDH-REMOTE

Authors: *Yevhenii Khytruk, Roman Didenko, Andrii Rozhanskyi*
Advisors: *Tetiana Makhometa, Ivan Tiahai*
Pavlo Tychyna Uman State Pedagogical University (Ukraine)

Abstract. *The paper considers the hardware and software of the developed ATDH-Remote device based on the Arduino UNO board. The operation of sensors that can measure body temperature and environment, humidity, atmospheric pressure, as well as automated antiseptic spraying is described.*

Keywords: *Arduino UNO, sensors, infrared jammer, non-contact thermometer, barometer.*

I. INTRODUCTION

The development of technology, automation and robotization of production makes a significant contribution to the lives of people in the XXI century. It is impossible to imagine the life of modern society without various mechanisms that simplify, improve performance or completely replace a person in a particular field of

activity.

Due to the spread of coronavirus infection COVID-19, the urgent issue is to combat the disease, to find ways to ensure personal hygiene, to prevent contact with people with signs of the disease. Antiseptics, non-contact thermometers, have become a mandatory tool to prevent the spread of the disease. That is why, in order to avoid tactile interaction with protective equipment, it was decided to create a device that will measure temperature by non-contact method, disinfect hands when raising them to the technical hole and display information about temperature, humidity on the display.

II. LITERATURE ANALYSIS

The issues of development of technical and creative thinking due to design activity were considered by a number of scientists: G. Altshuller, A. Davydenko, T. Kudriavev, E. Millerian, V. Moliako, I. Roitman, P. Jacobson and others. P. Andre, F. Lot, J.-P. Tayar [1], A. Korendiasev [5], J. Williams [7], S. Monk [8]. studied the control systems of robotics, as well as technical systems and complexes.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The object of research is the operation of sensors based on the Arduino UNO board.

The subject of the research is an automated sensor control system based on the Arduino UNO board.

The aim of the work is to develop a device based on the Arduino UNO board, which will allow contactless contact with humans to measure the temperature of the object and the environment, humidity, atmospheric pressure, as well as automated spraying of antiseptics.

Research methods: analysis of components and methods of building automatic control systems for optimal selection of the most appropriate hardware, software development tools for the controller and human-machine interface, development of algorithms for controlling the operation of the object and implementation of these algorithms in software for the controller.

IV. RESULTS

The Arduino platform can be used to develop systems that control sensors and switches. Such systems, in turn, can control the operation of a wide range of indicators, motors and other devices. Arduino-based modules can be either stand-alone or interact with software running on a personal computer.

Table 1 shows the electronics that were used to implement the device at the hardware and software level.

The Arduino UNO R3 controller is selected to control the device. The *Atmega328p* microcontroller has additional *SDA* and *SCL* contacts (*I2C* interface), these outputs in our product are used to connect *i2c* devices: BME280 barometer, MLX90614 contactless thermometer module and 1602 + *i2c* LCD display module.

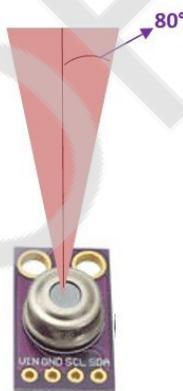
Barometer BME280 – measures room temperature, humidity and atmospheric pressure. Accuracy of temperature measurement is from 0.5 to 1° C, humidity measurement: 3%, pressure measurement: 1gPa.

Used electronics Table 1

No	Name	Quantity, items
1	Arduino UNO R3 ATmega328P	1
22	Barometer BME280	1
33	Water pump for immersion 3-6V 120 l/h	1
44	Infrared jammer (YL-63)	2
55	Laser module for Arduino	1
66	Contactless thermometer module MLX90614	1
77	Display module LCD 1602+i2c	1

The MLX90614 non-contact thermometer module is designed for non-contact measurement of the absolute temperature of the object, the ambient temperature for calibration of the value of the object temperature. Features of the MLX90614 sensor are as follows: object temperature range: from -70°C to 382.2°C ; ambient temperature range: from -40°C to 125°C ; expansion/accuracy: 0.02°C

One of the questions to which the technical characteristics do not give a direct answer is the measurement of the distance between the sensor and the object. The value of this distance is defined by the term Field of View (FOV), for our sensor the field of view is about 80°



The sensitivity range should be conical from the point of the sensor, as shown above. Thus, as you move away from the measuring object, the sensitivity zone doubles. That is, for every 1 cm we move away from the object, the sensitivity zone increases by 2 cm. In our device, we placed a laser diode next to the sensor to know where the sensitive area of the sensor is currently directed. During the tests, it was found that the values were reliable if the hand is placed at a distance of 2 cm from the device, and as you remove the accuracy decreases.

The connection diagram of the devices is shown in Figure 1

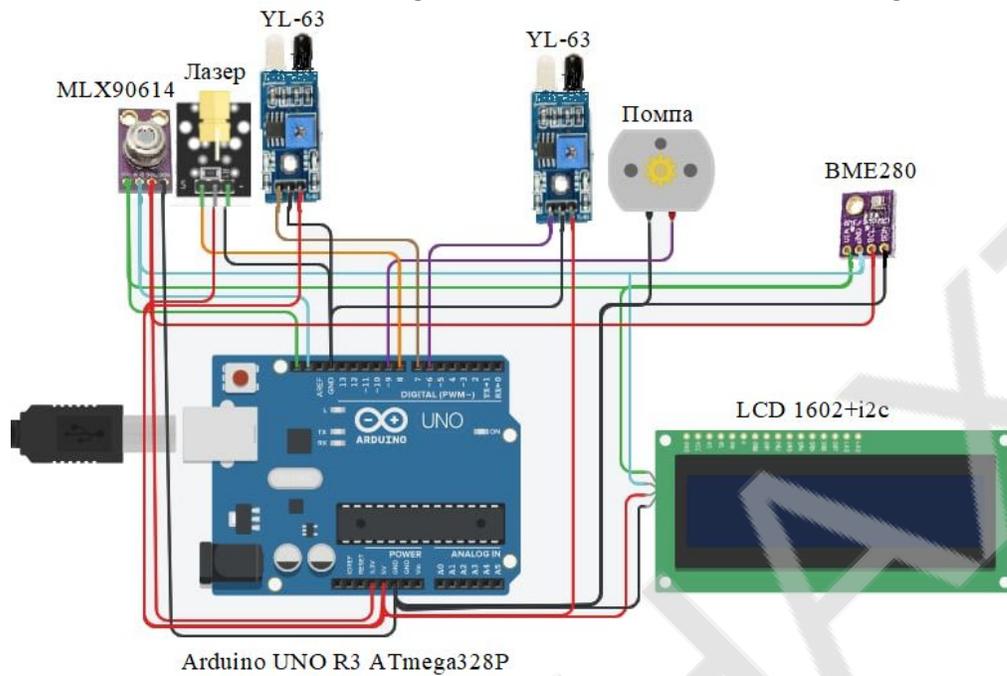
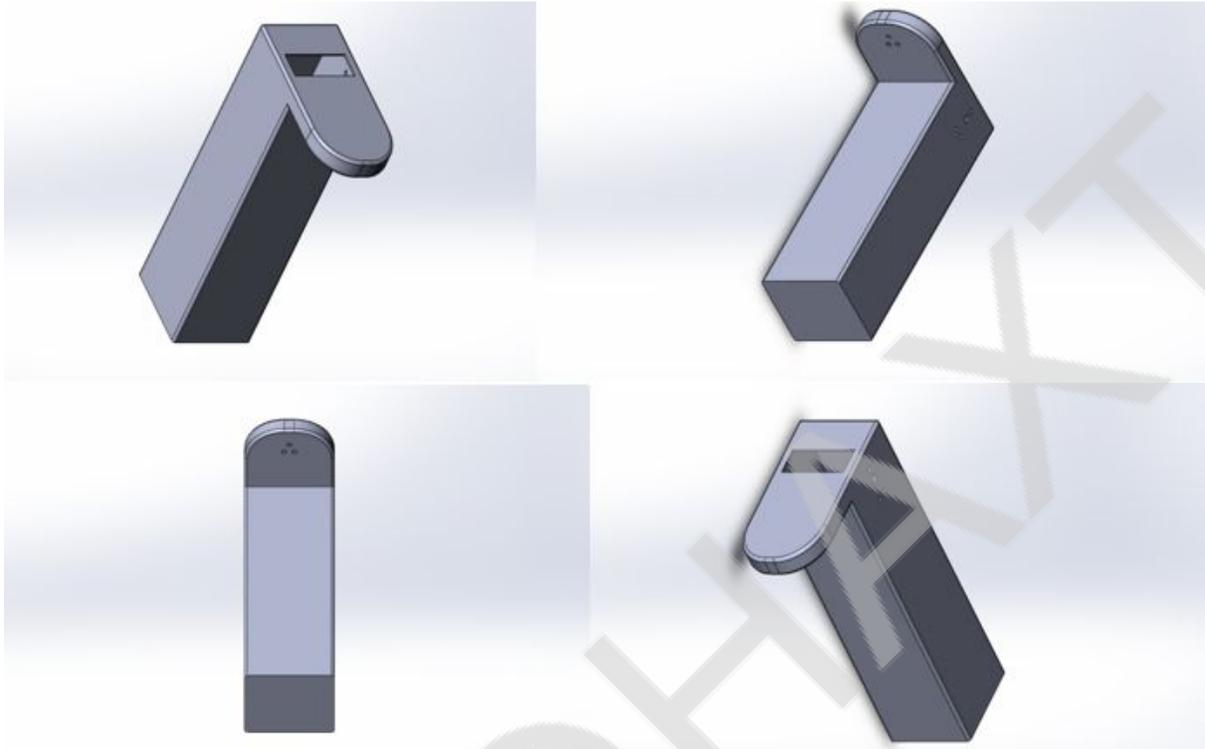


Photo of the device



3D model device



The program for Arduino receives data from the BME280 sensor and displays on the LCD 1602 + i2c display. Upon receiving a signal from the YL-63 infrared jammer, the laser diode and the MLX90614 sensor, which outputs information to the LCD display module, starts operating. The water pump is immersed in a disinfectant solution and sprays a dose of solution when receiving a signal from another infrared jammer YL-63.

The full code of the device on the Arduino is presented below.

```
#include <Wire.h>
#include <SparkFunMLX90614.h>
#include <SPI.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BME280.h>
#include <LiquidCrystal_I2C.h>
#define SEALEVELPRESSURE_HPA (1013.25)

IRTherm therm; // Create an IRTherm object to interact with throughout
LiquidCrystal_I2C lcd_27(0x27, 16, 2);
Adafruit_BME280 bme; // I2C
unsigned long delayTime;

void setup()
{
  pinMode(7,INPUT);
```

```
pinMode(6,INPUT);
pinMode(8,OUTPUT);
pinMode(9,OUTPUT);
therm.begin();
lcd_27.begin ();
lcd_27.backlight();
lcd_27.setCursor(1-1, 1-1);
lcd_27.println(F("BME280 testing ")); //BME280 testing
delay(2000);
lcd_27.clear();
  if (! bme.begin(0x76, &Wire)) {
    lcd_27.print("not find BME280");
    while (1);
  }
lcd_27.print("BME280 OK");
delay(2000);
lcd_27.clear();

lcd_27.setCursor(1-1, 1-1);
lcd_27.println(F("MLX90614 testing")); //MLX90614 testing
delay(2000);
lcd_27.clear();
Wire.begin(); //Joing I2C bus
  if (therm.begin() == false){ // Initialize thermal IR sensor
    lcd_27.print("not find MLX90614");
    while(1);
  }
lcd_27.print("MLX90614 OK");
delay(2000);
lcd_27.clear();

  therm.setUnit(TEMP_C); // Set the library's units to Farenheit
  // Alternatively, TEMP_F can be replaced with TEMP_C for Celsius or
  // TEMP_K for Kelvin.
  therm.setEmissivity(0.98);
  pinMode(LED_BUILTIN, OUTPUT); // LED pin as output
}

void loop()
{
  bme.takeForcedMeasurement(); // has no effect in normal mode
  BME280();
  delay(delayTime);
}
```

```
if ((digitalRead(7))==0){ // 7 input signal starting MLX
  lcd_27.clear();
  digitalWrite(8,HIGH);
  MLX();
  delay(3000);
  lcd_27.clear();
  digitalWrite(8,LOW);
  delay(1000);
}
if ((digitalRead(6))==0){
  lcd_27.clear();
  lcd_27.setCursor(2-1, 1-1);
  lcd_27.print("Wait disinfect");
  lcd_27.setCursor(4-1, 2-1);
  lcd_27.print("you hands");
  digitalWrite(9,HIGH);
  delay(1000);
  digitalWrite(9,LOW);
  delay(2000);}
}

void BME280() {
  lcd_27.setCursor(1-1, 1-1);
  lcd_27.print("T=");
  lcd_27.print(bme.readTemperature());
  lcd_27.println(" ");
  lcd_27.setCursor(9-1, 1-1);
  lcd_27.print("H=");
  lcd_27.print(bme.readHumidity());
  lcd_27.println("%");
  lcd_27.setCursor(1-1, 2-1);
  lcd_27.print("P=");
  lcd_27.print(bme.readPressure() / 100.0F);
  lcd_27.print(" hPa");
}

void MLX(){
  digitalWrite(LED_BUILTIN, HIGH);
  lcd_27.setCursor(1-1, 1-1);
  lcd_27.print("You temperature");
  lcd_27.setCursor(1-1, 2-1);
  // Call therm.read() to read object and ambient temperatures from the sensor.
  if (therm.read()) // On success, read() will return 1, on fail 0.
  {
```

```
lcd_27.print("now: " + String(therm.object(), 2));  
lcd_27.setCursor(12-1, 2-1);  
lcd_27.println("C  ");  
}  
digitalWrite(LED_BUILTIN, LOW);  
delay(1000);  
}  
Link from video: https://cutt.ly/7kujnZg
```

V. CONCLUSIONS

At present, robotics is a popular and effective method for studying important branches of science, design and is based on the active use of modern technologies in the production and everyday life.

The created device has the necessary stability in work and the reduced cost in comparison with analogs. Carrying out this development will allow to measure the temperature of the object and the environment, humidity, atmospheric pressure, as well as to carry out automated antiseptic spraying without contact with a person. The created device can be easily upgraded according to time requirements.

VI. REFERENCES

1. [Arduino Software Release Notes. 2020. https://cutt.ly/LkeOHGJ](https://cutt.ly/LkeOHGJ)
2. [Arduino. https://cutt.ly/AkeOZ9d](https://cutt.ly/AkeOZ9d)
3. [BME280 Combined humidity and pressure sensor. https://cutt.ly/MkeOFnN](https://cutt.ly/MkeOFnN)
4. [SparkFun MLX90614 Arduino Library. https://cutt.ly/skeOP4C](https://cutt.ly/skeOP4C)
5. [Infrared thermometer on Arduino and MLX90614. https://cutt.ly/4keOY3T](https://cutt.ly/4keOY3T)
6. [BME280. https://cutt.ly/5keOM7y](https://cutt.ly/5keOM7y)
7. [Projects with use: Arduino controller. 2nd edition, revised and added. - SPb .: BHV-Petersburg, 2015.-464 p .: illustrated - \(Electronics\). https://cutt.ly/WkeOEMa](https://cutt.ly/WkeOEMa)
8. [Review and prospects of using the Arduino Nano 3.0 platform in higher education / Kryvonos O.M., Kuzmenko Ye.V., Kuzmenko S.V. / Institute of Informational Technologies and Teaching Aids of the National Academy of Pedagogical Sciences of Ukraine, University of Education Management of the National Academy of Pedagogical Sciences of Ukraine; Editor in Chief.: V. Yu. Bykov. -2016.-№ 6 \(56\) .- p. 77 - 87. https://cutt.ly/ikePzZY](https://cutt.ly/ikePzZY)
9. ROBOTICS IN SCHOOL. Kryvonos O. M. <https://cutt.ly/1kePnhc>

CRYPTOCURRENCY AS ELEMENT OF DIGITAL ECONOMY

Author: *Dzmitry Pashkevich*

Advisor: *Ekaterina Dudko*

BSEU(Belarus)

***Abstract.** Today, new digital technologies and innovative business models are penetrating all spheres of the economic life of society, influencing the very essence of the economy, forming qualitative structural changes in it. As a result, the digital economy is formed as a subsystem of the traditional economy, characterized by the active use of digital technologies and the circulation of specific electronic goods. The level of development of the digital economy is closely correlated with the country's competitiveness, which requires special attention from the state and business to its development. It has been established that today the electronic economy is already going beyond purely economic processes. Digitalization is being introduced into social processes, the successful life of people increasingly depends on it, in addition, there is a large-scale introduction of digital technologies into the work of government organizations and structures.*

In this work, a closer look will be taken at the general legal status of cryptocurrencies in the modern world, particularly in the largest economies of the world. Also, a specific case of using cryptocurrencies and blockchain technology will be analyzed on the example of Russian ICO-Project "Storiqa".

***Keywords:** Blockchain, Cryptocurrency, Digital Economy, Legal status, Digital Marketing, IT*

I. INTRODUCTION

The relevance of the chosen topic is explained by the fact that the rapid development of digital technologies against the background of the globalization of the economy served as the basis for the digital revolution. In scientific research, discussions about blockchain and cryptocurrencies do not subside: their impact on the modern economy, pros and cons, development prospects.

During local economic crises, the bitcoin rate on local sites often rises above the market average. For example, cryptocurrency is super popular in Argentina and Venezuela.

When people lose confidence in their national currencies, they try to find alternatives to save their money. Bitcoin, despite insane volatility, is not subject to inflation and, moreover, hyperinflation. Therefore, it looks like a great investment option.

In order to start trading bitcoin, you do not need to have special licenses or knowledge. It is enough to go through the registration procedure on a crypto exchange or download an electronic wallet. However, this is fraught with the fact that many people far from the world of finance lose money on literally blind investments. Bitcoin is used not only for investment or cheap transfers. Also, users with the help of cryptocurrency can purchase illegal substances or launder criminal proceeds. But even if an ordinary user does not use cryptocurrencies for criminal purposes, he can

still suffer. For example, if you buy “dirty cryptocurrency” from an exchanger or from another person. In this case, the funds may be frozen. But this can be avoided by checking transactions using special services.

Bitcoin is a decentralized system that does not have a single governing body. Because of this, BTC holders are not immune to errors. For example, if an investor forgets the password for his digital wallet or loses access to it, it will not be possible to return the cryptocurrency, it is simply impossible. An irrecoverable loss of funds will also occur if the user sends them to the wrong address: the transaction cannot be canceled in the blockchain. In this case, one can only hope that the recipient will return them at his own request.

One of the drivers of growth in the value of bitcoin is considered to be its recognition in society: the higher demand, the higher the price. However, the spread of digital money is slowing down due to a controversial reputation. Often, BTC and other cryptocurrencies are used in criminal schemes, for example, for money laundering, buying illegal substances, or building financial pyramids. This causes negative associations and forces the government to take prohibitive measures.

The rapidity of the spread of the digital economy is explained by the following figures: in the world, the Internet is used by about 4 billion people (almost half of the population), of which 53% use the mobile Internet; across OECD countries, Internet users are: 97% (80% in the world) of young (16 to 24 years old) and 63% of older people (55 to 74 years old); 5.5% of employees are ICT specialists among men and 1.4% among women; 90% of businessmen contact via the Internet, although only 20% use digital technologies in production. By 2020, according to Google forecasts, the number of Internet users in the world will exceed 5 billion people.

The purpose of the work is to analyze the features of using blockchain technologies in modern international business

II. LITERATURE ANALYSIS

2.1 Regulatory system and legal status of cryptocurrencies

To understand what role the cryptocurrencies already play in the modern world, we may analyze their current regulation and legal status in some of the most prominent countries. The USA, China, Russia, Japan, Germany and EU were used as an example in this work.

United States of America. Consider the history and facts of the adoption of elements of the digital economy in the United States. In March 2013, the FinCEN Financial Crimes Commission announced that transactions for exchanging any cryptocurrency for fiat money should be regulated in the same way as transactions for exchanging fiat money among themselves (for example, dollars for euros). Not only bitcoin exchanges, but also exchange offices must register as financial service providers (Money Service Business) and report suspicious transactions to law enforcement agencies. In official reports from the World Bank and the FBI, Bitcoin is considered a "virtual currency". According to the classification of the FinCEN Commission under the US Treasury Department, Bitcoin is referred to as “decentralized virtual currencies” [1]. The US Securities and Exchange Commission

has decided to equate ICO with securities. Companies that fail to register a cryptocurrency release or ICO will be punished. In August 2013, a judge for the Eastern District of Texas (USA) made the following decision. Because bitcoins can be used as money to pay for goods or exchanged for common currencies such as the US dollar, euro, yen, or yuan, bitcoin is a currency or form of money. On March 25, 2014, the US Internal Revenue Service released a guide to taxing transactions with bitcoins and other virtual currencies. Miners who mine bitcoins on their own hardware are also subject to taxation. The miner is required to include the fair market value of the mined cryptocurrency in his annual gross income. The legal policy in relation to cryptocurrencies in the states of the country differs. In the state of New York, licensing of the activities of persons involved in the circulation of cryptocurrencies is carried out, the license costs about \$ 5,000. California has passed amendments to legislation previously approved by the State Senate declaring bitcoin and other cryptocurrencies “legal tender”. This law allows any transactions in the state in any electronic currency, including bitcoins [2]. Thus, the United States has now institutionally recognized all objects of the digital economy and began to regulate this process by law, including in the field of taxation.

China, in spite of the actions in the United States related to the legalization of cryptocurrency, the Chinese government has become unable to regulate the new free world of cryptocurrency, although its rate has grown significantly due to the speculative demand for coins in this country. Consider how the Chinese government authorities regulate the issue of determining the legal status of cryptocurrencies and their use in different ways. In 2013, the value of bitcoin increased 89 times, which led to increased attention to e-currency from Chinese investors as an alternative means of payment. In this regard, the People's Bank of China (PBOC) imposed a ban on transactions with bitcoin by financial companies, including the publication of quotes, as well as insurance of financial products related to this cryptocurrency. According to Interfax, the NBK justified this ban on the lack of legal status of bitcoin as a currency. At the same time, the prohibition did not apply to individuals who could use bitcoin in Internet transactions, taking on all the risks associated with the use of this means of payment [3]. The key event of 2017 was the ban by the People's Bank of China on holding ICOs for Chinese companies. In addition, the NBK obliged local ICO platforms and companies that have already issued tokens to return all funds raised [4]. According to the official position of the NBK, all ICOs in the state from September 4, 2017 began to be considered illegal. In the future, the regulator intends to punish such violations. He threatened with legal consequences, including for already completed ICOs. According to the Chinese National Committee of Experts on Financial Security Technologies on the Internet, as of July 2017, 43 ICO platforms were operating in China, 65 ICOs were completed by July 18, the placement of tokens allowed companies to raise \$ 398 million [5]. The cryptocurrency market received a very negative news about the ICO ban in China. According to Coindesk, Bitcoin dropped 5% in trading, while Ethereum lost 15% of its value [6]. The introduction of this restriction in China provoked a correction, the scale of which for bitcoin reached 40%, but this did not last long. The head of the CryptoFund,

Alexander Boyarintsev, indicated that the introduction of barriers in a single country leads to the flow of capital to other markets [6]. This is what happened in this situation. Forex Club analyst Irina Rogova noted that Chinese traders have switched to the exchanges of Hong Kong and Japan. As a result, trading volumes on the Hong Kong exchange Gatecoin jumped 24%.

In addition, Japan began to host Chinese ICO startups [7]. On October 24, 2017, the 19th Congress of the National Congress of the Chinese Communist Party ended in China. As a result of the congress, some temporary rules and regulations were canceled. Presumably, they included a ban on bitcoin trading [8]. Along with Beijing's actions regarding the closure of bitcoin exchanges and the prohibition of token sales and ICOs, we note that China is striving to spread blockchain technology. Active work is underway to create a distributed ledger, and the Ministry of Information Technology of China is supporting the blockchain laboratory, which was created after the bans on cryptocurrency exchanges. In addition, bans in China are associated by a number of experts with the readiness of the NBK to issue its own state cryptocurrency, as evidenced by the creation of a research institute for the study of cryptocurrencies [9]. Thus, the events taking place in the field of cryptocurrencies in foreign countries can serve as an experience for determining the status of cryptocurrencies and ICOs in Russia, since today there is no legal regulation of the Bitcoin network and operations with cryptocurrencies.

A characteristic feature of the state policy in the field of cryptocurrencies in Russia is that its course is formed based on the positions of a number of federal agencies (Central Bank, Ministry of Finance, Rosfinmonitoring, Ministry of Economic Development, General Prosecutor's Office), which do not have a single position. At the beginning of 2014, the Central Bank classified bitcoin and other virtual currencies as a “money surrogate”, which will have the status of dubious money laundering and criminal activities. The head of the Central Bank of the Russian Federation Elvira Nabiullina considers it inappropriate to legalize cryptocurrencies on Russian exchanges and defines “cryptocurrency” as a digital asset, not a virtual currency [10], but does not deny the prospects for the development of the blockchain technology that underlies it. According to her, the regulator is considering the possibility of creating a platform for transmitting financial messages using the blockchain, as well as creating a national cryptocurrency based on it [11]. From 2014 to March 2016, the Ministry of Finance recognized cryptocurrencies as a “monetary surrogate” and tightened measures on transactions with them, from fines to imprisonment [12]. However, already in August 2017, the Ministry of Finance recognized the need to amend the legislation on operations with cryptocurrencies in connection with their active use and legalization in some of the leading countries of the world (USA, Switzerland, Japan) [59]. According to the President of the Russian Association of Cryptocurrencies and Blockchain Yuri Pripachkin, ICO seriously reduces the cost of raising funds and speeds it up, as well as ICO removes a number of barriers between investors 'and issuers' money, and will serve the further development of the economy [13].

Sberbank CEO German Gref noted that blockchain is such an explosive technology, the implementation of which is necessary. According to him, this technology is already being used by Sberbank to implement a number of processes. In addition, in 2015, he announced that he possesses a small amount of cryptocurrency [14]. According to the President of the Russian Federation Vladimir Putin, it is unacceptable to create barriers to improve the financial system, and it is necessary to formulate regulatory measures. In this regard, the task of the Ministry of Finance is to develop a framework bill on the regulation of cryptocurrencies by the end of 2017. Also, the Government of the Russian Federation and the Central Bank need to change the legislation of the Russian Federation on the regulation of public attraction of cryptocurrencies and funds through the placement of tokens (ICO) by analogy with the regulation of the initial placement of securities before July 1, 2018 in the framework of the Digital Economy program. In addition, the head of state instructed them to develop requirements for the organization of “mining”, determine its taxation and registration of miners [15]. The Russian government expects to legalize bitcoin and other cryptocurrencies in the country in order to reduce the risks associated with illegal transfers and “money laundering,” as Deputy Finance Minister Alexei Moiseev explained [16]. Government agencies are interested in the development of efficient blockchain-based technologies. On October 20, 2020, the Prosecutor General of the Russian Federation Igor Krasnov announced that, based on the adopted law on virtual currency, officials from 2021 will have to indicate the presence of cryptocurrency in their income declarations

On October 22, 2015, the European Court of Justice (ECJ) ruled that exchanges of bitcoins for fiat currencies are exempt from VAT. The court decision specifies that the VAT law applies to the supply of goods and the provision of services. Bitcoin transactions have been classified as payment transactions in currencies, coins, and banknotes and are therefore not subject to VAT. The court recommended that all EU member states exclude cryptocurrencies from the list of assets subject to taxation.

In Germany, at the end of August 2013, the Ministry of Finance of the Federal Republic of Germany made a statement that bitcoin cannot be classified as an electronic or foreign currency, but rather fits the definition of private money, with which multilateral clearing operations can be carried out.

Until March 2014, the Bank of Japan did not have any plans to regulate bitcoin circulation. However, after the collapse of Mt.Gox, based in Tokyo, the Japanese authorities announced the need to regulate this market. Development of taxation norms is expected. Bank of Japan Governor Haruhiko Kuroda said the Banking Institute for Monetary and Economic Research is currently conducting research into Bitcoin. Bitcoin has been legal tender in Japan since March 2016.

2.2 Marketing campaign organization for "Storiqa" project

Online shopping has become an integral part of modern society. The convenience of shopping without leaving home is also due to the fact that most of the trading platforms have adapted their processes for different platforms: users can place orders using their laptops, desktop computers, tablets, smartphones and even smart

speakers like Alexa.

An online marketplace or platform is a website or application that facilitates purchases from different stores. The operator of the trading platform does not own the goods offered on the platform, his task is only to provide the users of the site with the goods of the stores and control the money transfers. eBay is a great example of an online marketplace, the platform allows you to sell and buy all kinds of goods for all tastes.

Of course, marketplaces have some drawbacks. Since these sites offer products from a large number of stores, information about them is often inaccurate and delivery times vary. Keeping the online marketplace running smoothly means bringing in multiple vendors at the same time and ensuring that the site's services run smoothly for consumers — a result that is quite difficult to achieve.

There are currently three types of online trading platforms:

- vertical;
- horizontal;
- global.

A vertical marketplace sells similar products from a variety of sources. For example, TrueFacet.com only sells jewelry and related products. The site guarantees the authenticity of jewelry, which is extremely important considering that jewelry is a very expensive item. Of course, such a guarantee is included in the added value of the goods.

The horizontal marketplace sells products of different types, but they all have a common characteristic. For example, Dote's online store offers women who don't want to download individual retail apps the ability to shop at the same time from multiple retailers including Madewell, Forever 21, J. Crew, Lululemon, Brandy Melville, Topshop, Free People, Ann Taylor. Loft, Zara, etc. Users can see products from different retailers at the same time in one application. Dote focuses on a specific type of customer and offers them several products in different types of retail chains.

The global marketplace sells everything. eBay is a prime example. eBay has 167 million users, over 1 billion products to sell, over 80% of new products, and nearly \$ 90 billion in merchandise sold this year. The attractiveness of the site lies in the breadth of the assortment. Bob Coopbens, VP of Seller Relations at eBay, said on Shoptalk, "Scale determines price transparency. If there are enough products to be bought and sold, users can see what the price must be to be considered fair; they feel like they are paying fair value. "

Storiqa is a Russian project created with the aim of launching an international trading platform based on blockchain technology.

The position of cryptocurrency in the modern world is growing rapidly: the aggregate market capitalization of all cryptocurrencies has more than tripled since the beginning of 2016, reaching almost \$ 150 billion in August 2017. According to the latest data, the number of active cryptocurrency users is now constantly increasing. The number of users of cryptocurrency wallets is estimated at about 6 million. Based on this state of affairs, the problem of using cryptocurrency arose.

Crypto is a means of payment, but it cannot pay for goods in stores, buy

groceries or clothes. While more and more merchants are beginning to accept cryptocurrency as a means of payment, those who own some bitcoins or “altcoins” still cannot use them in their day-to-day financial transactions.

The idea of creating an online trading platform came to the project team after the success of the crowdfunding platform, where small industries and startups found funding to develop their projects and implement ideas. Over 5 years, Boomstarter has helped finance more than 1,500 projects that have become full-fledged profitable commercial ventures. This prompted the Storiqa team to think that small-scale industries with significant potential do not have the opportunity to declare themselves on the global market. Through the control and study of their work from the inside, we understood what prevents them from participating in world trade.

The main reasons for the failure of projects in the global market were:

- lack of trust of potential customers to an unknown seller who offers goods of unconfirmed quality;
- impossibility of providing services at the level of an international company;
- lack of multilingual 24/7 customer support;
- lack of a functional "package" of goods and multilingual localization;
- lack of knowledge in international marketing.

Building an e-commerce system is not an easy task. The company must spend a lot of resources on team building and distribution channels. In addition, you need to know how to promote a product in the light of new trends and the specifics of a particular market.

With the easy-to-use Storiqa online store builder, any seller will be able to create their own point of sale using a wide range of platform functions for a minimal fee. Storiqa offers ample opportunities for private entrepreneurs, small producers, family businesses and handicraft manufacturers; such as tools for customer feedback, accounting, sales analysis, advertising and promotion, as well as a convenient, intuitive interface.

An online store builder that allows you to create a multi-platform online sales channel and promotes goods is a convenient solution for a small business. Storiqa provides a ready-to-use interface and promotes e-commerce by providing high quality service.

The goal of such a platform is to create an environment in which any user can create a personal online store and receive technical support without wasting time and a huge amount of resources on activities that can distract from the production of high-quality goods.

However, there is currently no solution on the market that combines an advanced e-commerce system and new technologies such as smart contracts, cryptocurrency payments, multi-platform integration and comprehensive 24/7 customer support.

In the current market situation, business owners have to use their resources ineffectively: spend time managing an online store and conducting advertising campaigns without outside help. In addition, the entry of small manufacturers into the global market requires significant early-stage investment and additional monthly

maintenance costs for online store functions. In addition, manufacturing faces bureaucratic difficulties and transaction fees when making international payments. Few small businesses can afford this expense while still being prepared for the risk of international sales and new market entry.

Storiqa has focused its project on small-scale producers, which typically produce around 50 units and operate in a local or regional market. The staff of such a company usually includes from two to ten people. Each of them combines several responsibilities and functions within the company. Customer support and marketing are often run by the business owner or one or two employees.

Problems faced by small producers:

- Lack of round-the-clock multilingual customer support.

Selling goods internationally means the need to constantly maintain customer-seller feedback to be able to assist customers in different time zones, and the lack of real-time customer support makes communication much less effective;

- lack of localization.

Small manufacturers cannot provide translation of product descriptions and characteristics, taking into account the specifics of different countries, which makes it impossible to enter the international market;

- high commissions on existing platforms and various additional fees of payment systems.

Existing platforms retain a significant portion of the transaction cost, not to mention transaction fees and taxes;

- lack of buyer's trust in an unknown seller.

The client prefers trusted sellers who offer goods of confirmed quality, and unknown sellers with no established reputation and client base are forced to compete with them;

- impossibility of automating the process.

In addition to all of the above problems, the owner of a small production facility is financially and technologically not ready to fully automate the online store;

- competition with global corporations.

International corporations have a wide range of tools for marketing high-quality goods around the world, to which small industries do not have access, which makes it impossible for them to enter the world market;

- shortage of funds.

Companies receive money from sales only after a certain delay, and increasing sales without taking this delay into account will sooner or later prove to be an impossible task.

On the other hand, there are a number of challenges associated with the customer experience with small scale manufacturers:

a. search for goods.

Many unique products produced by small businesses do not have adequate descriptions or photographs, making it difficult to find the right product. In addition, many good quality small-scale products cannot be ordered online;

b. lack of reliable reviews.

Without some way of verifying the authenticity of reviews posted on specialized sites of online stores, buyers cannot form a realistic impression of the product;

in. no guarantees.

Many online stores offer prepaid products, but not all shoppers are willing to risk sending money to an unfamiliar online store, which may turn out to be a fly-by-night site.

With the global economic growth, online commerce is gradually taking over the international retail market and increasing the number of users of e-commerce platforms, both among buyers and sellers.

Global e-commerce is gaining momentum, with a turnover of \$ 2.2 trillion in 2018. The growth rate is 20% (Figure 1)[17].

Every year, the number of people who regularly shop online is growing steadily. According to market research Global E-commerce Report by Nielsen (a marketing measurement company), online shoppers are growing by an average of 16% annually and currently stands at 1.66 billion worldwide.

There are over 1.5 billion online market users worldwide (Figure 2)[18].

The volume of global e-commerce is trillions of dollars a year. The leaders in terms of spending are China, the United States, the United Kingdom and Japan.

With the constant growth of consumer demand in the field of e-commerce, more and more small and medium-sized companies need the help of marketplaces to bring their products to new markets and attract new customers.

The Storiqa project was able to pinpoint the shortcomings of modern e-commerce and propose a solution that could take the current economic situation to a new level.

Most small businesses and private producers are unable to enter the global market. The huge expense it takes to start an online store is impossible for a small business. However, there is a demand for exclusive products and users are willing to buy products. Storiqa used a very clever strategy: focusing its platform on small businesses and individual entrepreneurs, it secured itself not only a customer base, because, as mentioned earlier, people are always ready to buy, but also a client base in the face of small businesses.

The marketing of the project was quite productive: Storiqa were active on social media such as Twitter, Medium and YouTube video hosting. Also, the so-called STQ token airdrops were constantly carried out - free distribution of tokens for registration and participation in voting.

The most successful marketing move was the early launch of the beta version of the platform at the end of May 2018: the cost of STQ tokens more than doubled (Figure 3)[19].

The highlighted fragment of the diagram clearly shows how the popularity of the token increased after the launch of the beta version of the platform.

Based on the analysis of the organization of marketing campaigns for ICO projects “Vertex” and “Storiqa”, we can draw several conclusions. The creation of projects within the blockchain and, directly, for the development of the system is the

most clearly visible trend among new ICO projects. Successful projects are aimed at cryptocurrency owners and provide an opportunity to implement these funds.

A huge number of projects using blockchain technology use artificial intelligence to control the operations performed and perform basic functions and transactions on platforms. Smart contract technology is gaining popularity: contracts that transfer funds automatically after the terms of the contract are fulfilled by both parties. Smart contracts are used in all types of ICO projects: secondary market platforms, Ethereum-based online stores, even blockchain-based video games use smart contracts to transfer funds

Online shopping is a convenient and modern way of shopping, and their number has increased dramatically in recent years. Opening an online trading platform is one of the most lucrative businesses right now, as users access vendor inventory electronically without the site needing to own a store to offer their products. In addition, statistics have shown that shoppers do not like to use branded apps from individual stores. Considering how much of the blockchain's work is automated due to new technologies, it is logical to assume that it needs at least some form, if not control, but a method to streamline everything that happens within the system. The emergence of projects like "Vertex" proves that this assumption is true.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of research — cryptocurrency

Subject of research — cryptocurrency as part of the modern digital economy and its development trends

Research methods: generalization, method of description, systematization and classification, analytical method, statistical and graphical method.

IV. RESULTS

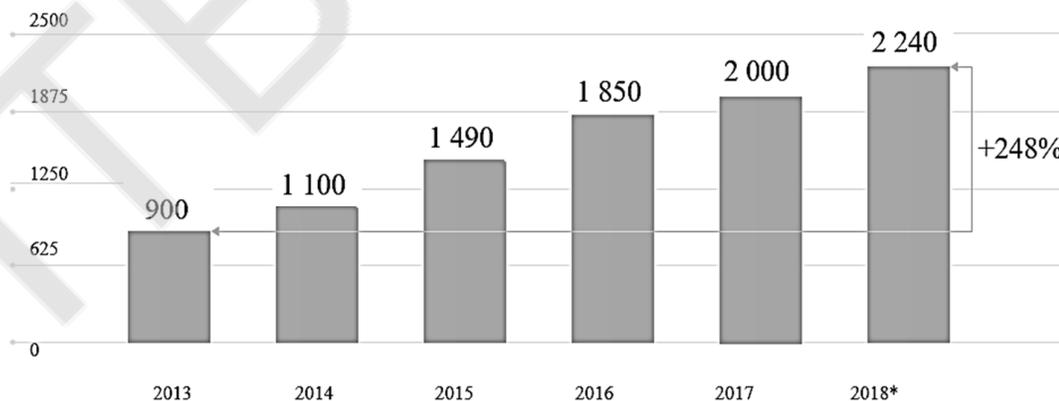


Fig. 1. Global e-commerce turnover (trillion dollars)

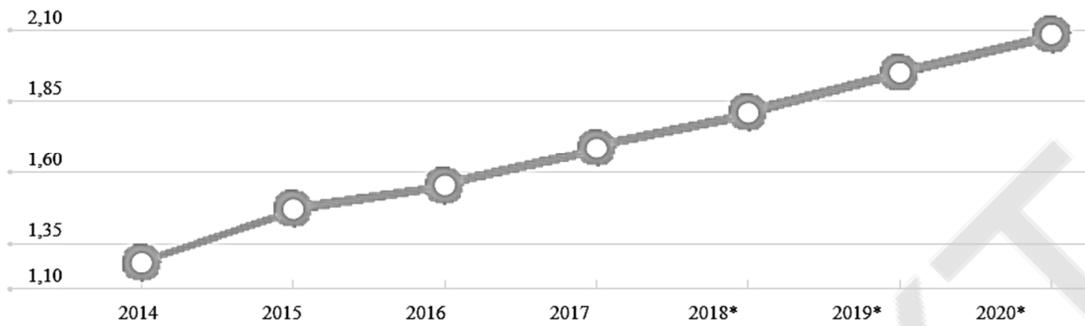


Fig. 2. Number of users on online trading platforms (billion)



Fig. 3. Price dynamics of STQ token after the launch of the beta version

V. CONCLUSIONS

The legal status of cryptocurrencies, in particular the Bitcoin system, varies considerably in different countries. In a number of countries, operations with cryptocurrencies are officially allowed. They are usually treated as a commodity or investment asset or money and are subject to relevant legislation for tax purposes.

The volume of global e-commerce is trillions of dollars a year. The leaders in terms of spending are China, the United States, the United Kingdom and Japan. With

the constant growth of consumer demand in the field of e-commerce, more and more small and medium-sized companies need the help of marketplaces to bring their products to new markets and attract new customers. The Storiqa project was able to pinpoint the shortcomings of modern e-commerce and propose a solution that could take the current economic situation to a new level. Most small businesses and private producers are unable to enter the global market. The huge expense it takes to start an online store is impossible for a small business. However, there is a demand for exclusive products and users are willing to buy products. Storiqa used a very clever strategy: focusing its platform on small businesses and individual entrepreneurs, it secured itself not only a customer base, because, as mentioned earlier, people are always ready to buy, but also a client base in the face of small businesses. The marketing of the project was quite productive: Storiqa were active on social media such as Twitter, Medium and YouTube video hosting. Also, the so-called STQ token airdrops were constantly carried out - free distribution of tokens for registration and participation in voting. The most successful marketing move was the early launch of the beta version of the platform at the end of May 2018.

In general, it is obvious that cryptocurrencies have become an important part of the economy of many countries, and are becoming a tool for achieving profit for many new startups and companies, and this process will only gain speed in the future.

VI. REFERENCES

1. Aryanova, T. (2017, July 17th). *The US Securities and Exchange Commission has decided to equate ICO with a securities issue*. IHODL. <https://ru.ihodl.com/topnews/2017-07-26/komissiya-po-cennym-bumagam-i-birzham-ssha-reshila-priravnyat-ico-k-vypusku-cennyh-bumag/>
2. Vrublevski, P. (2017, May 10th). *Blockchain ICO - a third world war threat?* Forbes. <https://www.forbes.ru/kompanii/343901-blokcheyn-ico-ugroza-trety-mirovoy>
3. Gatinsky, A. (2017, September 4th). *The Central Bank of China has banned banks from operations with Bitcoin*. RBC. <https://www.rbc.ru/money/04/09/2017/59ad1d529a79474e01c39333>
4. Astapkovich, V. (2017, September 13th). *China claims that cryptocurrencies are increasingly used for money laundering*. RIA <https://ria.ru/20170913/1504715078.html>
5. Antipov, G. (2017, September 15th). *China Trouble: Cryptocurrency Market Below \$ 100 Billion*. Coinspot <https://coinspot.io/analysis/perepoloh-v-kitae-kriptovalyutnyj-rynok-nizhe-100-mlrd/>
6. Chen, L., Lee, J. (2017, September 4th). *Bitcoin Tumbles as PBOC Declares Initial Coin Offerings Illegal*. Bloomberg. <https://www.bloomberg.com/news/articles/2017-09-04/china-central-bank-says-initial-coin-offerings-are-illegal>
7. Boyarintsev, A. (2017, October 10th). *Bitcoin skyrocketed 60% in a month and surpassed \$ 5000*. Finanz. www.finanz.ru/novosti/valyuty/bitkoin-vzletel-na-60percent-za-mesyac-i-prevysil-5000-1003979925
8. Novožilov, E. (2017, September 20th). *China finishes off cryptocurrencies*. Freedmanclub. <https://freedmanclub.com/kitai-dobivaet-kriptovalyuti/>
9. Shmyrova, V. (2017, April 12th). *Ministry of Finance: Bitcoins will be legalized in Russia in 2018*. CNEWS. https://www.cnews.ru/news/top/2017-04-12_v_2018_g_v_rossii_legalizuyut_bitkoiny
10. Seliverstova, N. (2017, June 2nd). *Virtual future: the Central Bank began to develop a national cryptocurrency*. RIA. <https://ria.ru/20170602/1495675131.html>

11. Igumenov, V., Rusyaeva, P. (2017, October 26th). *Digital avalanche: why the ICO market is growing so fast.* RBC. <https://www.rbc.ru/magazine/2017/11/59e62b5d9a7947de527907d4>
12. Balashova, A., Lee, I. (2017, October 4th). *In Russia, raising money for ICO is to be legalized soon.* RBC. https://www.rbc.ru/technology_and_media/04/10/2017/59d4e0f29a7947d74c4aca6b
13. Russian news agency TASS (2017, October 9th). *The Ministry of Economic Development proposed to develop laws on cryptocurrency in "legal sandboxes".* Russian news agency TASS <https://tass.ru/ekonomika/4630885>
14. Ovechkin, O. (2017, May 26th). *German Gref called for the legalization of Bitcoin and other cryptocurrencies in Russia.* RB. <https://rb.ru/news/grefcoin/>
15. Losev, A. (2017, October 23rd) *The secret ruble: why the Russian economy needs a national cryptocurrency.* RBC. <https://www.rbc.ru/opinions/economics/23/10/2017/59edb53a9a79477502fc7ee1>
16. Kazarnovsky, P., Istomina, M. (2017, August 28th). *Bitcoin is not for everyone: the Ministry of Finance proposed to prohibit "ordinary people" from buying cryptocurrency.* RBC. <https://www.rbc.ru/business/28/08/2017/59a3cd869a7947835e1300d1>
17. Content Marketing Institute (2020, Dec 10th). *What is content marketing?* <https://contentmarketinginstitute.com/what-is-content-marketing>
18. Statista (2020, Dec 16th). *2018 B2C ecommerce sales worldwide.* <https://www.statista.com/statistics/261245/b2c-e-commerce-sales-worldwide>
19. Coingecko (2021, Jan 8th). *Price chart for STQ tokens in USD.* https://www.coingecko.com/en/price_charts/storiqa/usd

DEVELOPMENT OF A MILLING MACHINE WITH COMPUTER NUMERICAL CONTROL

Author: **Serhii Shevchenko**

Advisor: **Serhii Kochuk**

National Aerospace University M. E. Zhukovsky «Kharkiv Aviation Institute»
(Ukraine)

Abstract. *The use of computer numerical control (CNC) machines makes it possible to reduce labor intensity and increase labor productivity by reducing the time required to prepare a product for production, reducing rejects, and ensuring the interchangeability of parts. Therefore, the design and further improvement of CNC machines is an urgent and priority task.*

The paper shows one of the possible approaches to the design and manufacture of a CNC milling machine based on a portable personal computer and an "open control system".

Stepper motors are selected as actuators, which are controlled by special drivers. Machine control programs can be written in the G-code language.

The machine is made in a single copy, has been working for 3 years and is constantly being improved through the introduction of new hardware and algorithmic components of the control system.

Keywords: CNC, milling, production automation, stepper motors, coordinate table, machining, machining accuracy.

I. INTRODUCTION

The emergence of CNC machines in the 50s of the twentieth century was due to the need to increase labor productivity (while ensuring stable quality) in industries with mass and large-scale production. The continued use of humans as the main element of the machine control system began to restrain the growth of equipment productivity. The subsequent half-century of experience in using CNC machines not only confirmed the correctness of the initial ideas, but also significantly supplemented and continues to complement the numerous advantages of these machines in comparison with manual machines or mechanical semiautomatic devices and automatic machines. Modern machine-building production is unthinkable without the widest possible use of machine tools, equipment, as well as CNC machining centers.

The use of CNC machines made it possible to obtain a significant economic effect and free up a large number of universal equipment. The efficiency of CNC machines, according to domestic and foreign data, is characterized by an increase in productivity; reduction of the terms of preparation of production and technological equipment; decrease in marriage; ensuring the interchangeability of parts; reduction or complete elimination of marking and fitting and fitting works; the introduction from the beginning of the launch of a new product of calculation and technical standards and thereby ensuring a significant reduction in labor intensity and an increase in labor productivity.

The experience of using CNC machines has shown that the efficiency of their use increases with increasing accuracy, complicating processing conditions, if necessary, in the process of processing the mutual movement of a part and a tool in five to six coordinates, with multi-tool multi-operation processing of parts from one installation, etc.

Precision machining, surface quality, productivity, as well as reliability and cost – all highly dependent on the drive. The main parameters of the servo drive are power, speed, speed and accuracy. In some cases, efficiency, cost, and ease of use are also considered. Particular attention is paid to the overall dimensions and weight per unit length [1].

Tracking drives are used both in contour programmed control systems (PCS) and in positional ones. The main reason for using a servo drive in contour PCS is the need for continuous control of variable speeds of movement of the working bodies of machine tools with significant required powers and high specified accuracy of movements along several simultaneously controlled coordinates.

The use of CNC machines in almost all branches of mechanical engineering in recent years has become one of the main directions in the field of processing automation [2].

In recent years, the development of CNC systems has reached a completely new level of accuracy and speed (Fig. 1.).



Figure 1. – Modern complex with CNC

II. LITERATURE ANALYSIS

There are currently many books and articles written about CNC machine tools. In the bottom you can find various information – about the main units of machine tools, methods of developing control programs, how to improve the accuracy of machine tools, etc. However, not a single book has been written on how to make a CNC machine at home and from available materials. This topic is reaped only on numerous forums, where information is very scattered and not structured. Therefore, the purpose of this work was to describe the creation of a CNC machine at home and to demonstrate the result – a part made on this machine.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the research is numerical control system. The subject of the research was a numerically controlled milling machine. To study the subject, computer modeling methods were used in SolidWorks and Matlab (for mechanical assemblies) and Multisim (for electrical circuits). A working CNC milling machine was also created to check the accuracy of all calculations and supplement the study with experimental data.

IV. RESULTS

4.1. CNC milling machines

CNC milling machines are designed for processing flat and spatial surfaces of blank with complex shapes. The designs of CNC milling machines are similar to those of traditional milling machines (Fig. 4.1a), the difference from the latter is the automation of movements according to the control program during shaping. The classification of CNC milling machines is based on the following features:

- location of the spindle (horizontal or vertical);
- the number of coordinate movements of the table or milling head;
- the number of instruments used (single or multi-instrumental);
- method of installing tools in the machine spindle (manually or automatically).

By arrangement, CNC milling machines are divided into four groups:

- vertical milling with a cross table;
- console milling;
- longitudinal milling;
- broadly versatile instrumental.

In vertical milling machines with a cross table (Fig. 4.1b, a), the table moves in the longitudinal (X-axis) and transverse (Y-axis) horizontal directions, and the milling

head in the vertical direction (Z-axis). In console milling machines (Fig. 4.1b, b), the table moves along three coordinate axes (X, Y and Z), and the headstock is stationary.

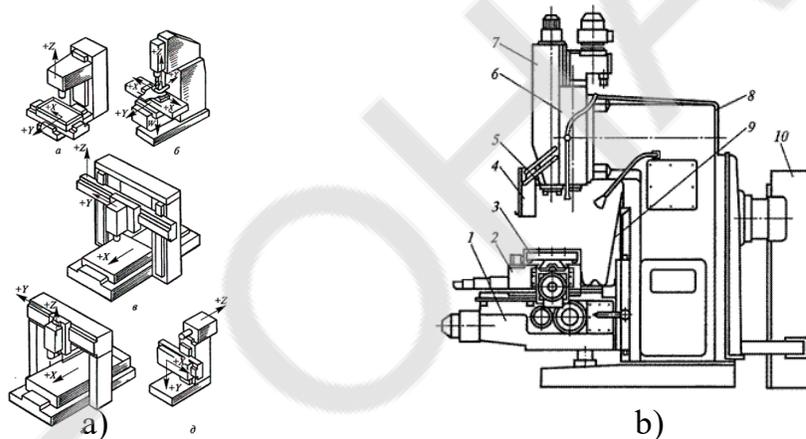


Figure 4.1 – a) Arrangements of CNC milling machines b) CNC milling machine: 3– table; 5–spindle; 6– milling headstock; 8– bed

In bed-type milling machines with a movable cross-bar (Fig. 4.1b, c) the table moves along the X-axis, the spindle head along the Y-axis, and the cross-bar along the Z-axis. In bed-type milling machines with a fixed cross-bar (Fig. 4.1b, d), the table moves along the X axis, and the spindle head along the Y and Z axes. In universal tool milling machines (Fig. 4.1b, e), the table moves along the X and Y axes, and the spindle head along the Z axis.

The number of controlled coordinates is usually three, and in some cases, four or five. with contour control, the shaping movement is carried out at least along two coordinate axes simultaneously. In CNC milling machines, asynchronous motors (in these cases, there is a gearbox) or DC motors are used as a drive for the main movement. Drives of movement of feeds of CNC milling machines have short kinematic chains, transferring movement from the motor directly to the executive body.

4.2. Functional components of CNC

In order to make a CNC machine out of a conventional machine, it is necessary to introduce certain components into its structure (Fig. 4.2). It is not enough just to connect the machine to a computer so that it works according to the program – it is necessary to modernize the mechanical and electronic "stuffing" of the machine.

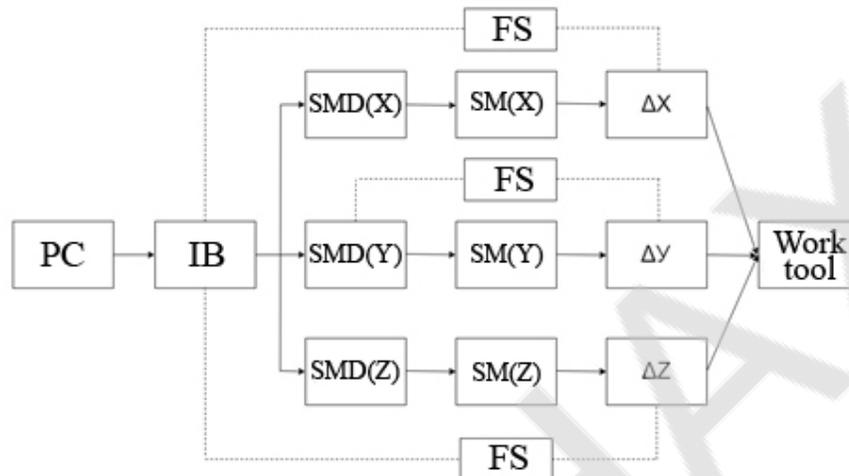


Figure 4.2 – Functional diagram of a CNC machine: PC – personal computer; IB – interface board; FS – feedback sensor SMD – stepper motor driver; SM – stepper motor

Conventionally, the PCS (Program Control System) can be divided into three subsystems:

- control subsystem;
- drive subsystem;
- feedback subsystem.

The control subsystem is the central part of the entire control system. On the one hand, it reads the control program and issues commands to various machine units to perform certain operations. On the other hand, it interacts with a person, allowing the operator to control the processing process. The heart of the subsystem is the controller (processor), which is responsible for controlling all the electronic components of the machine. The control system can be either closed or open. Closed systems have their own algorithms and work cycles. Closed systems cannot be modified. Open systems are being introduced more and more into production. the operator has full access to all algorithms and work cycles, and allows you to change the processing program.

Subsystem of drives (Fig. 4.3) – a system of motors and transmissions, which ensures the execution of commands of the control subsystems.

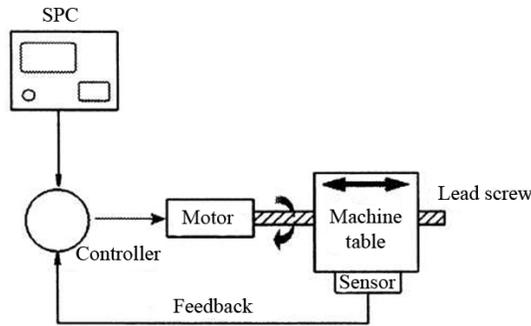


Figure 4.3 – Subsystem of drives

The feedback subsystem is designed to provide information to the control subsystem about the current state of the machine tool and the workpiece using various sensors [4].

The developed machine implements the following functional diagram (there is no feedback) (Figure 4.4)

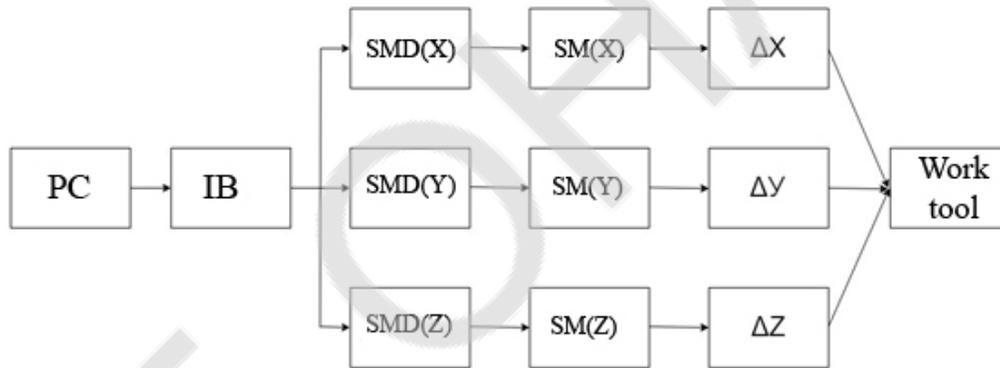


Figure 4.4 – Functional diagram implemented on the machine

4.3. The main components and assemblies of the developed CNC machine tool

Let us consider the appearance and main units and assemblies of the developed CNC milling and engraving machine (Fig. 4.5a): by its design, the machine is a longitudinal milling machine with a fixed cross member.

Bed 1 provides the machine with the required rigidity. A movable table, portal, stepper motors, Z-axis and a spindle will be installed on it. To create the supporting frame, 10mm plywood was used. All elements are connected with each other using aluminum corners. To strengthen the structure, an additional square frame made of wooden beams was made inside the main frame.

At the ends of the frame 1, holes are drilled and bearing blocks 2 are installed to install the drive screw of the movable table. Table 3 is attached to the bed through four furniture rails of full extension 5, they replace the combination of linear bearings

and shafts, and as practice has shown, the backlash when using them is not much greater.

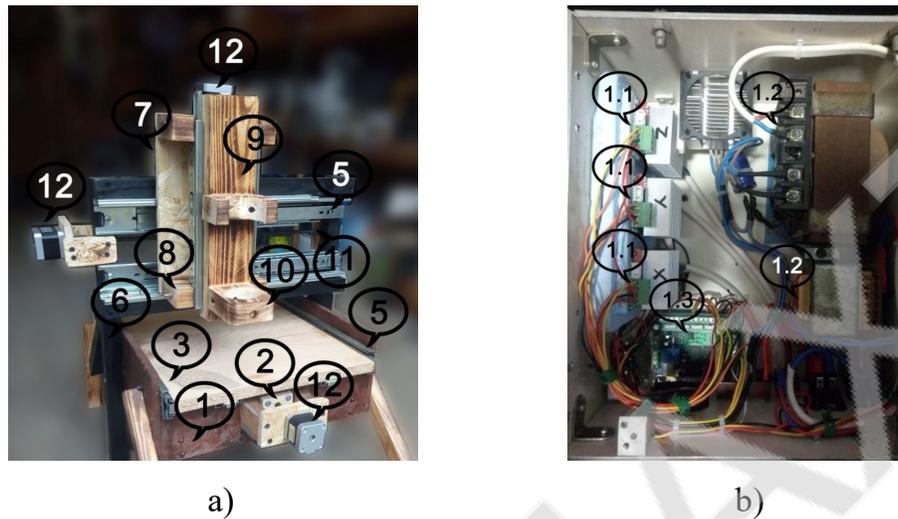


Figure 4.5 – a) External view of the developed CNC machine tool b) External view of the machine control unit

Portal 6 – in our case it is stationary, instead of a mobile portal, it was decided to use a movable table to reduce the load on the guides. The higher the portal, the thicker the blank that you can process. However, a high portal is less resistant to stresses that arise during processing. The high side posts of the portal play the role of levers relative to linear rolling bearings (furniture guides in our particular case).

In the design of the Z-axis 7, a panel was used, which is attached to the movable parts of the Y-axis full extension rails, which are located on a fixed portal; on two supports 8, three full extension guides are installed, which provide a smooth movement of the bar 9, with a mount for the spindle 10 in the vertical direction.

Screws 11 convert rotary motion from stepper motors 12 into the linear motion. When designing your machine, you can choose several options for this unit: a screw-nut pair or a ball-screw pair (ball screw). A screw nut is generally more exposed to frictional forces during operation and is also less accurate relative to the ball screw. If there is a need for increased accuracy, then it is definitely necessary to opt for a ball screw, but the price for this unit is quite high.

The design of the machine uses a screw-nut with a lock nut to eliminate backlash. This allows you to adjust the backlash, maintaining the correct ratio between the friction values in the screw-nut pair and the backlash.

Next, we turn to the analysis of the machine control unit device (Fig.4.5b):

The main components of the electrical circuit are:

1. Stepper motors (12);
2. Stepper motor drivers (1.1);
3. Power supply unit (1.2);
4. Interface board (1.3);
5. Personal computer or laptop;

6. Emergency stop button.

For the development of the machine, 3 Nema-17 stepper motors were purchased (Fig. 4.6a).

A stepper motor is an electric motor in which a pulsed supply of electric current causes the rotor to discretely rotate through a given angle of rotation. The stepper motor generates high torque at low speed and operates at half the torque at rest (Fig. 4.6b). It is controlled by discrete pulses that are generated on the stepper motor driver. Used in CNC machines to move the working tool along the axes.

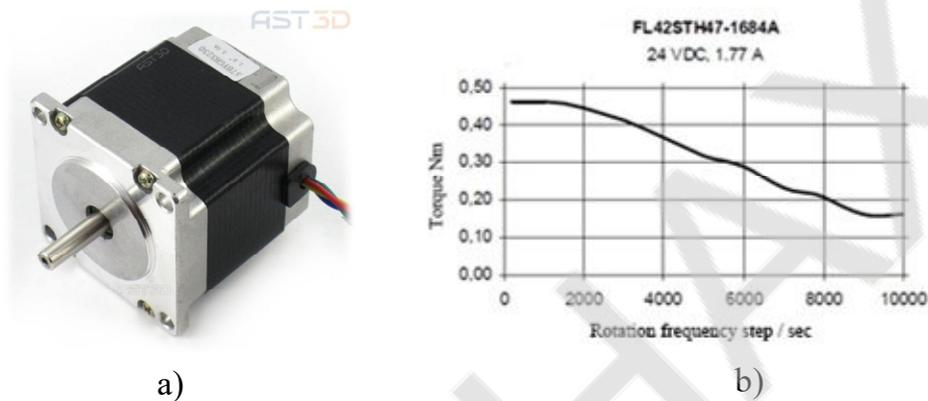


Figure 4.6 – a) Nema-17 stepper motor b) Dependence of the torque on the motor shaft on the speed

The next thing you need to design the machine is 3 suitable TB-6600 drivers (Figure 4.7)



Figure 4.7 – External view of the TB-6600 driver

A stepper motor driver is an electronic power device that, based on digital control signals, controls the high current / high voltage windings of a stepper motor and allows the stepper motor to take steps (rotate).

Stepper motor control is much more difficult than with a conventional collector motor, because it is necessary to switch the voltages in the windings in a certain sequence with simultaneous current control. Therefore, special devices have been developed for stepper motor control - stepper motor drivers. The stepper motor driver can control the stepper motor rotor rotation in accordance with control signals and electronically divide the stepper motor physical step into smaller half steps.

The power supply, the stepper motor itself (its windings) and control signals are connected to the stepper motor driver. The standard for control signals is STEP / DIR or CW / CCW and ENABLE.

STEP / DIR protocol signals have the following meaning:

STEP signal – Timing signal, step signal. One impulse leads to the rotation of the stepper motor rotor by one step (not the physical step of the stepper motor, but the step set on the driver - 1: 1, 1: 8, 1:16, etc.). Typically, the driver works out a step on the rising or falling edge of the pulse;

DIR signal – Potential signal, direction signal. Logic unit - SM rotates clockwise, zero - SM rotates counterclockwise, or vice versa. DIR signal can usually be inverted either from the control program or by swapping the connection of the stepper motor phases in the connection connector in the driver;

ENABLE signal – Potential signal, driver on / off signal. Typically, the logic of operation is as follows: logical unit (5V is applied to the input) – the stepper motor driver is off and the stepper motor windings are de-energized, zero (nothing is supplied or 0V to the input) – the stepper motor driver is on and the stepper motor windings are powered [5].

The last significant component in the control system of a CNC machine tool is the interface board, for communicating the computer and the machine through the LPT port (Figure 4.8)

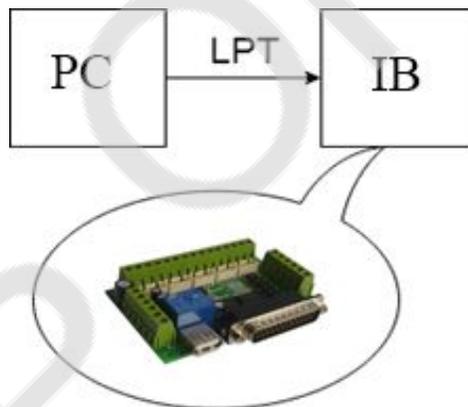


Figure 4.8 – Interface board, for communicating the computer and the machine through the LPT port

The power source for all electronics is a step-down mains transformer, at the output of which there is a voltage of 24V, a diode bridge and a smoothing capacitor are installed after the transformer to obtain a constant voltage to power the stepper motors, thus, the voltage supplied to the stepper motor fluctuates within 32-33V, which is optimal for this type of drivers and stepper motors. The logic part is powered by a voltage of 5V, obtained by means of a USB cable connected to a personal computer or a charger unit from a mobile phone.

V. CONCLUSIONS

The existing rates of development of modern production could not be achieved without the use of CNC systems. The technology of processing on CNC machines is intended to simplify the methods of obtaining parts during mechanical processing in conditions of serial and mass production. In most cases, CNC systems allow providing better accuracy, speed and repeatability in the machining of materials, leveling out some mechanical positioning errors on the machine, thereby improving the quality of products.

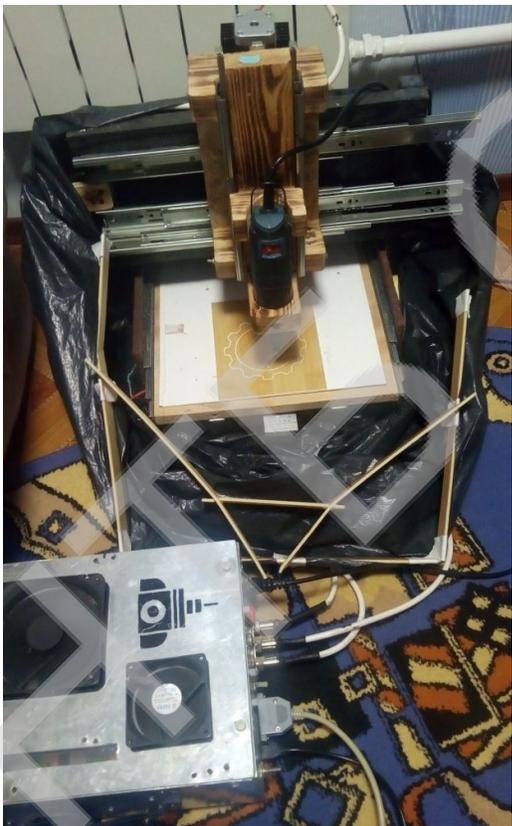
As part of this project, I developed my own CNC milling and engraving machine (Appendix A). Its main units are similar to industrial counterparts, but they are made of affordable and inexpensive materials, which could not but affect the accuracy of the developed machine. The maximum permissible deviations from the specified dimensions of the part are no more than 1 millimeter, and are caused by insignificant backlash in the screw-nut pair and insufficient hardness in some places of the material from which these or those units are made.

As an example of processing a part on the developed milling and engraving machine, the emblem of the department 305, engraved on white polystyrene foam with a brown coating, was chosen. The result of this work can be found in the video link (Appendix B).

VI. REFERENCES

1. Encyclopedia of Mechanical Engineering XXL [Electronic resource]. - Access mode: <https://mash-xxl.info/info/700868/>
2. [Electronic resource]. - Access mode: <https://studbooks.net / 2573944 />
3. Deryabin, A.L., Esterzon, M.A. Manufacturing technology of parts on CNC machines and in GPS: a textbook for mechanical engineering schools — Moscow: Mechanical engineering, 1989. — 288p.
4. PureLogic [Electronic resource]. - Access mode: http://wiki.purelogic.ru/index.php?title=Step_Motor_Driver

Appendix A - Appearance of the developed machine



Appendix B - The process of manufacturing a part on a CNC machine

<https://youtu.be/21e8CEpw7ek>



**THE MODERNIZATION OF THE INFORMATION MEASURING SYSTEM
OF POSITIONING OF THE OPTICAL GRINDING MACHINE**

Authors: *Cherniak Ann, Matveenکو Vladislav*

Advisors: *Isaev Alexander, Sukhodolov Yury*

Belarusian National Technical University (Belarus)

***Abstract.** The object of development is an automated control system for an optical grinding machine. The purpose is to modernize the existing control system of the optical grinding machine. During the development process, an automated control system for an optical grinding machine based on an STM32 microcontroller was designed and implemented, control boards were developed, and performance tests were carried out. The development stage: the system has been introduced into production.*

***Keywords:** microcontroller, optical grinding machine, encoder, control, automation.*

I. INTRODUCTION

In the 80-90s of the twentieth century, a large-scale modernization of production was carried out with modern equipment at that time. At the moment, the electronic part of this equipment is outdated and breaks down, however, the electromechanical part is serviceable and has a sufficient service life.

It should also be noted that the service life of the electronic components is limited by regulatory documents. In addition, the human factor plays an important role in the accuracy of operations performed during manual control of equipment, which causes an urgent need for highly qualified specialists, whose professional skills and experience allow them to perform operations with high accuracy in manual control mode.

Thus, at present there is a need for retrofitting equipment on the basis of a modern element base and the introduction of additional operating modes, including automatic mode.

The modern development of digital electrical engineering makes it possible to develop an information-measuring system for automatic control with minimal changes in the design of equipment, but at the same time ensuring greater accuracy and reliability of its operational characteristics.

This development is an engineering solution to the problem of automating existing equipment. In this work, the 395M optical grinding machine was modernized: the function of precise automatic control of the carriage drive was implemented.

II. LITERATURE ANALYSIS

2.1 Description and principle of operation of the optical profile grinding machine 395M

Profile grinding machines are designed for grinding surfaces, the generatrix of which is a curved or broken line. The process of processing on such machines is called profile grinding. This method, as a rule, is used to manufacture tooling, shaped cutting tools, copiers, templates, patterns, etc., sometimes machine parts.

Depending on the scheme of shaping the processed surface, profile grinding machines can be divided into two groups:

- Machine tools that process the surface at a given relative motion of the wheel and the workpiece: with kinematic profiling (Fig. 1).
- Machines that process the surface when copying a preliminary profiled grinding wheel.

In the first case, the profile of the machined surface is created when the wheel moves along line *a* (see Fig. 1), called the generatrix of the profile, and along line *l*, called the guide.

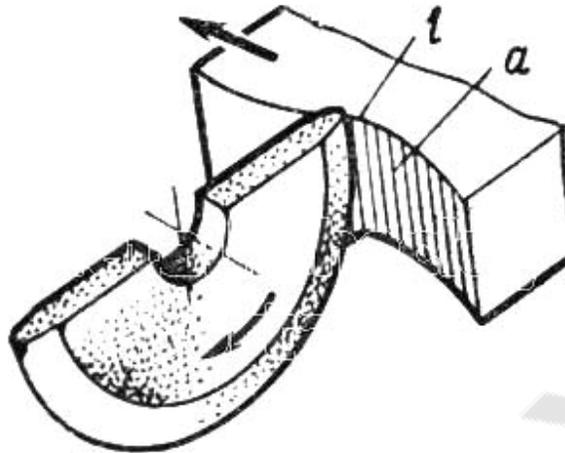


Figure 1 – Scheme of profile shaping

The generatrix is reproduced in the vertical plane with the reciprocating motion of the grinding wheel relative to the workpiece. Line 1 is formed in the horizontal plane with the mutual movement of the circle and the workpiece along a predetermined trajectory. In profile grinding machines there is a mechanism for shaping the guide, with the help of which the grinding wheel is guided along a predetermined trajectory relative to the workpiece or the workpiece relative to the grinding wheel.

In the second case, special devices can be used, the so-called "dressing", and then surface grinding machines for grinding. This method is called depth grinding, when the entire allowance is removed in one pass with a slow creeping table feed. Grinding with a wide profiled wheel is characterized by high productivity. In addition, the operator is relieved of the need to observe the wheel. Therefore, flat-profile grinding machines are promising for equipping them with CNC and inclusion in complexes and systems for unmanned processing.

In an optical profile grinding machine (Fig. 2), the operator moves the grinding wheel 1, acts on the handles 3. The enlarged image of the wheel 1 and the workpiece 5 is projected onto the screen 7, on which the profile guide is applied. The most common is a 50x magnification of an optical system with a screen size of 500x500 mm. With this magnification, the true dimensions of the image are only 10 x 10 mm.

Profile grinding machines have the following main components: grinding support, coordinate (cross) support for the part, table for installing the drawing and optical device.

The movements which are carried out on profile grinding machines:

- rotation of the grinding wheel;
- reciprocating movement of a support with a grinding wheel;
- adjusting movements of the coordinate slide with the workpiece in three directions;
- moving the grinding head.

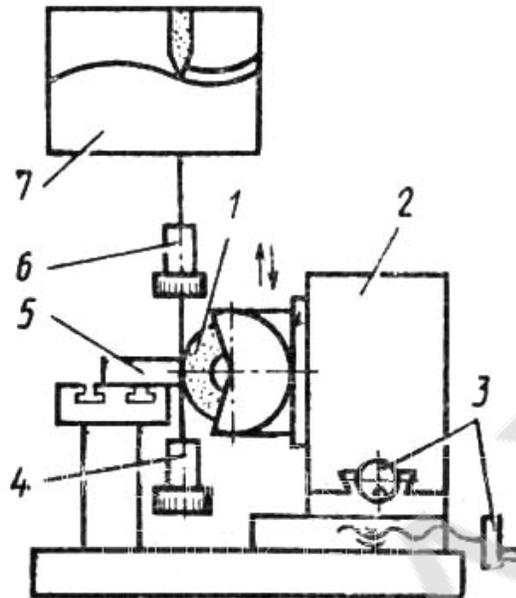


Figure 2 – Scheme of forming the profile guide on an optical profile grinding machine

The 395M machine was accepted for serial production in 1963, in 1978 it was replaced by a more advanced model 395M-1.

Optical profile grinding machine 395M is designed for grinding complex profiles, limited by straight lines, circular arcs and curves of various shapes, with high accuracy, and the material of the workpiece can be hardened.

The main feature of the machine is the presence of a screen on which, in an enlarged view, 50:1, the workpieces and the grinding wheel are projected using a special optical projection device.

A drawing of the part on tracing paper at a scale of 50: 1 is placed on the screen. Processing is carried out by combining the image of the circle with the outline of the drawing. The movement of the grinding wheel supports along the profile is carried out manually or mechanically using DC motors, the speed of which is regulated by rheostats.

The reciprocating movement of the grinding wheel slide is carried out automatically by an electric motor through the rocker mechanism. After grinding, the treated surfaces are finished.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of this development was the modernization of the control system for the carriage drive of the optical grinding machine.

The moving part of this machine (grinding wheel) is moved using two DC motors, each of which is responsible for the movement of the carriage along one of the axes (U, W) and which are controlled by means of pulse width modulation (PWM), which was the basis for the implementation automatic control systems.

The original control system consisted of a massive drive control unit for each of the axes, as well as a computer that displayed information about the movement of the carriage.

When developing the device, the following tasks were solved:

- It is possible to switch between automatic and manual control modes;
- The engine stops when the worm shaft is seized;
- The dimensions and the number of electronic components of the control system have been significantly reduced;
- The measurement accuracy using this system is $1\ \mu\text{m}$;
- In automatic mode, the control adjustment precision reaches $10\ \mu\text{m}$.

IV. RESULTS

4.4 The structural scheme

The structural scheme and the appearance of the drive control system are shown in Fig. 3, 4.

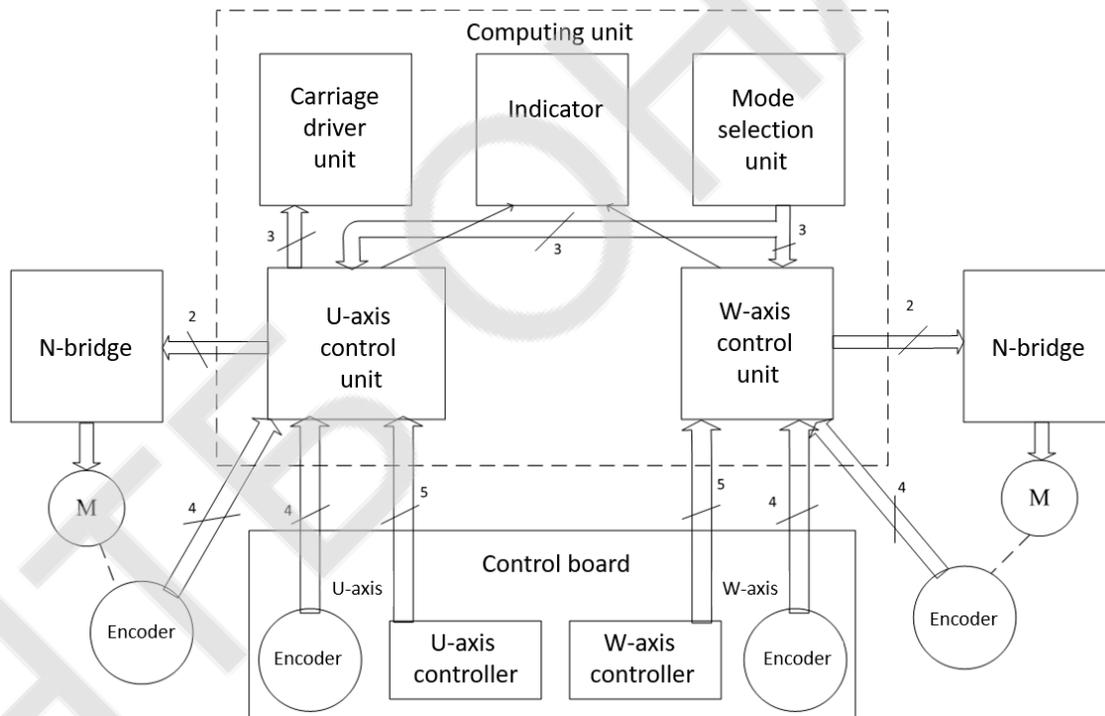


Figure 3 – The structural scheme of the device



Figure 4 – The front panel of the device

After modernization, the control system is a small block, consisting of a junction box, which contains the following functional blocks (Figure 5):

- Two small printed circuit boards for control of position encoders, which are located on the axes of the motors, and control encoders, used in manual operation; each of the PCBs controls movement along one of the axes (U-axis control unit, W-axis control unit in Fig. 3);

- The PCB, which is a computing unit built on the basis of an STM32 microcontroller, from which an electric motor control loop departs by means of two H-bridges made up of eight power transistors. There are two such boards, they are located one under the other to save space. Each PCB provides movement along one of the axes.

- Indication unit, which is an LCD display that displays information about the carriage position, preset parameters or the current state, as well as LEDs indicate the state of the machine.

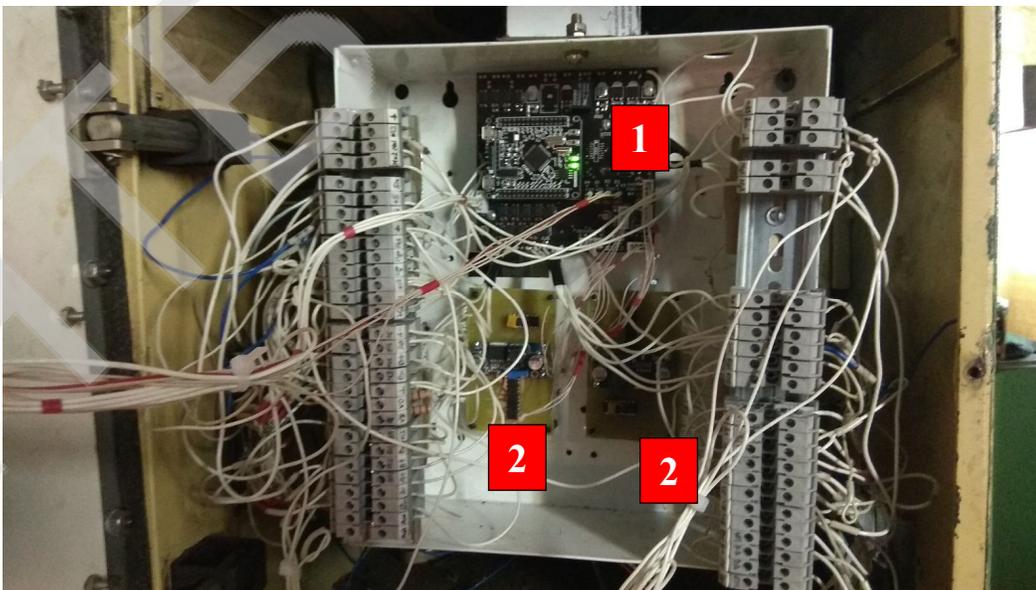


Figure 5 – Location of the drive control PCBs (1 – motor control board, 2 – encoder control board)

4.2 The block diagram

The block diagram of the device operation algorithm is shown in Figure 6.

START.

1. Power on;
2. Restoration of the original settings (PWM = 50%);
3. Is the operating mode manual?

If YES in step 3, go to step 4;

4. Change the position of the control encoder to Δl ?

If YES in step 4, go to step 5;

5. Counter-clockwise rotation?

If YES in step 5, go to Step 7;

7. Setting "PWM = 50 - Δn " (Δn is set manually);
9. Fixing the position;
10. Determination of position with the displacement encoder;
11. Output information about the position of the control encoder to the display;

END;

If NO in step 5, go to step 8;

8. Setting "PWM = 50 + Δn " (Δn is set manually);
9. Fixing the position;
10. Determination of position by the displacement encoder;
11. Output information about the position of the control encoder to the display;

END;

If NO in step 4, go to step 6;

6. Setting PWM = 50%;

END;

If NO in step 3, go to step 12;

12. Switch to parameter setting mode?

If YES in step 12, go to step 13;

13. Change the position of the control encoder?

If YES in step 13, go to step 14;

14. Setting the position of the control encoder;
15. Output of the set parameter to the screen;

END;

If NO in step 13, go to step 15;

15. Output of the set parameter to the screen;

END;

If NO in step 12, go to step 16;

16. Run in automatic mode?

If NO in step 16, go to step 17;

17. Displaying the current position on the screen;

END;

If YES in step 16, go to step 18;

18. Setting the delay;
19. Has the set limit been reached?

If YES in step 19, go to step 20;
 20. Completion of the passage;
 21. Reset to START state;
 END;
 If NO in step 19, go to step 22;
 22. Shift by 10 microns;
 23. The value of the physical limit is reached?
 If YES in step 23, go to step 20;
 If NO in step 23 go to step 24;
 24. Is the manual installation completed?
 If NO in step 24, go to step 25;
 25. Output of the current state to the screen;
 Go to point 18;
 If YES in step 24, go to step 20;
 20. Completion of the passage;
 21. Reset to START state;
 END.

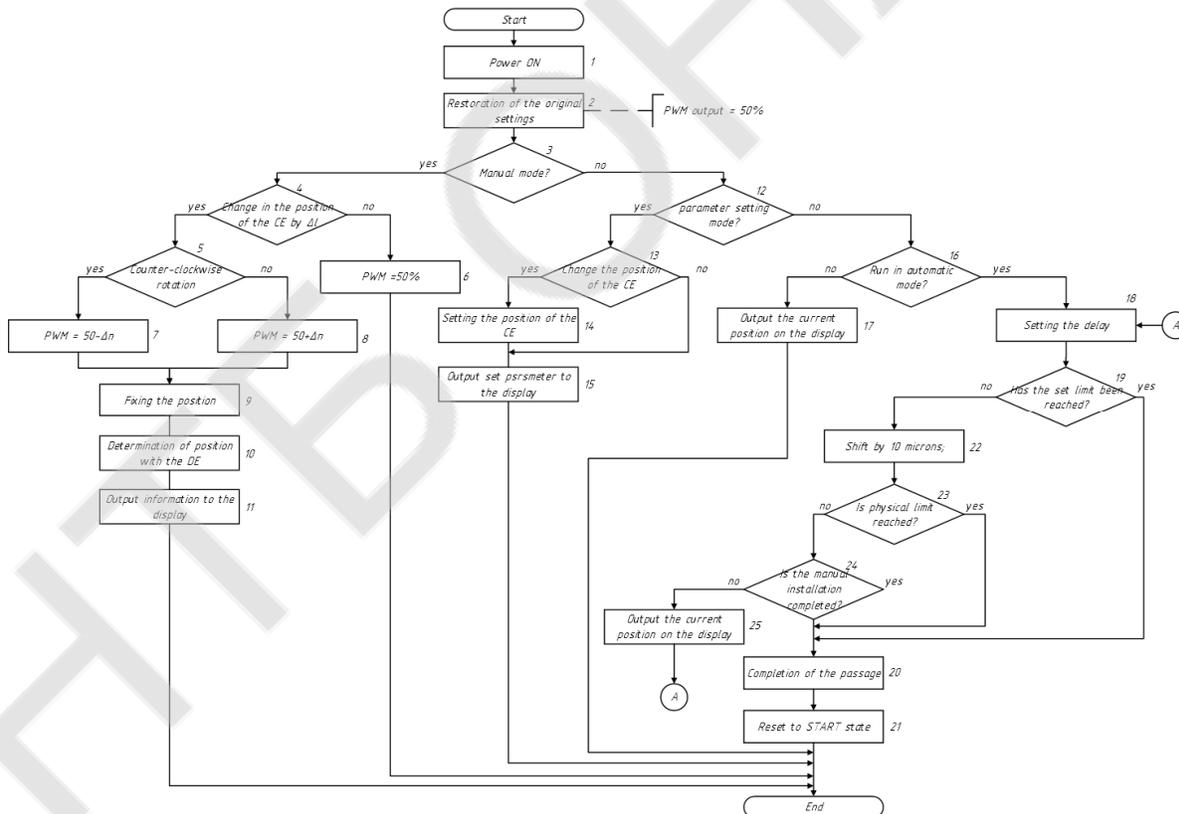


Figure 6 – The block diagram of the device operation algorithm.

4.3 Microcontroller selection

To implement the control unit, we use the STM32F103C8T6 microcontroller (Figure 7).

The STM32F103xx medium-density performance line family incorporates the high-performance ARM® Cortex®-M3 32-bit RISC core operating at a 72 MHz frequency, highspeed embedded memories (Flash memory up to 128 Kbytes and SRAM up to 20 Kbytes), and an extensive range of enhanced I/Os and peripherals connected to two APB buses. All devices offer two 12-bit ADCs, three general purpose 16-bit timers plus one PWM timer, as well as standard and advanced communication interfaces: up to two I2Cs and SPIs, three USARTs, an USB and a CAN.

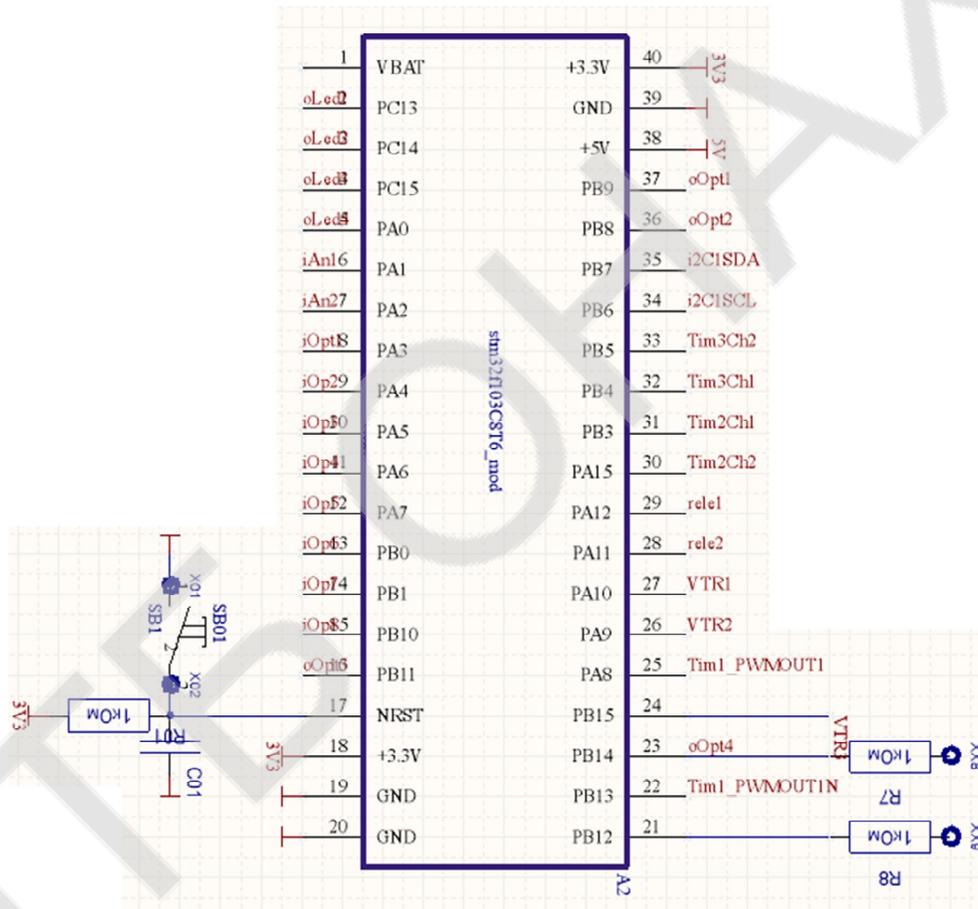


Figure 7 – Pinout MC STM32F103C8T6

The devices operate from a 2.0 to 3.6 V power supply. They are available in both the -40 to $+85$ °C temperature range and the -40 to $+105$ °C extended temperature range. A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F103xx medium-density performance line family includes devices in six different package types: from 36 pins to 100 pins. Depending on the device

chosen, different sets of peripherals are included, the description below gives an overview of the complete range of peripherals proposed in this family.

These features make the STM32F103xx medium-density performance line microcontroller family suitable for a wide range of applications such as motor drives, application control, medical and handheld equipment, PC and gaming peripherals, GPS platforms, industrial applications, PLCs, inverters, printers, scanners, alarm systems, video intercoms, and HVACs.

For STM32 Flash memory, read protection through the debug port can be set. When read protection is enabled, Flash memory is also write-protected to prevent the possibility of placing the incorrect code in the interrupt vector table. The STM32 also contains a real time clock and a small area of SRAM with battery power. The contents of this area are automatically cleared by an interrupt from the anti-tampering module.

The STM32 is equipped with general purpose I / O ports (GPIO) and can have up to 80 bidirectional pins. Each digital pin can be configured as a GPIO pin or as an alternative function pin. Each pin can simultaneously operate as one of 16 external interrupt lines.

To exchange information between components on a printed circuit board, the STM32 contains SPI and I2C interfaces. There is a CAN bus for communication between the various modules of the device, and a USB interface for communication with a PC. The STM32 also uses the popular USART interface.

Figure 7 also shows the MC reset circuit: it consists of a button, a capacitor and a resistor.

Ports are denoted by the Latin alphabet from A to E, and all tolerant to 5 V voltage. Many of external leads of the microcontroller instead of performing input / output functions can be switched service user peripherals such as a USART or I2C.

4.4 Engine control units

Figure 8 shows a schematic diagram of engine control units.

Galvanic isolation.

The PC817 optocoupler is used for galvanic isolation of the circuit (Figure 9).

Optocoupler PC817 consists of a LED and a phototransistor. Optocouplers PC817 allow to provide galvanic isolation of two parts of the circuit – high voltage and low.

The main characteristics of the PC817 optocoupler:

- Constant forward input voltage U_{in} : 1.2 V
- at input current I_{in} : 20 mA
- Maximum input current $I_{in,max}$: 50 mA
- Maximum collector power dissipation: 150 mW
- Operating temperature range: -30 ... + 100 °C

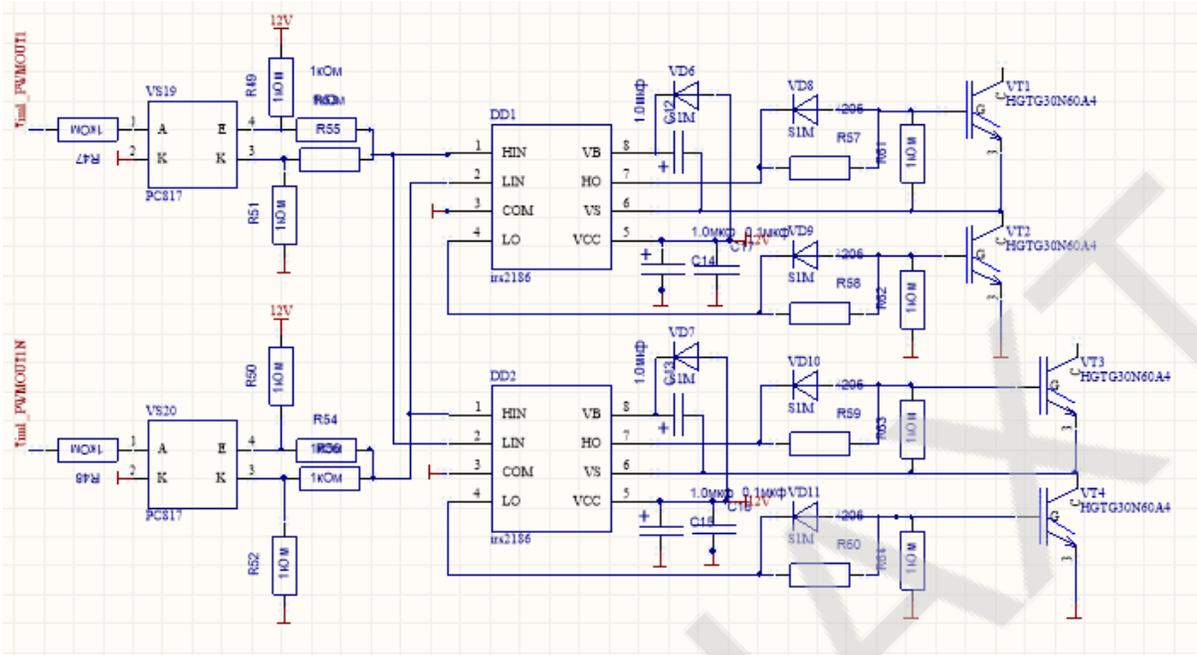


Figure 8 – Schematic diagram of the engine control unit



Figure 9 – Optocoupler PC817 in DIP-4 package

4.5 Indication unit

The device indication consists of an LCD display and LEDs. The schematic diagram is shown in Figure 10.

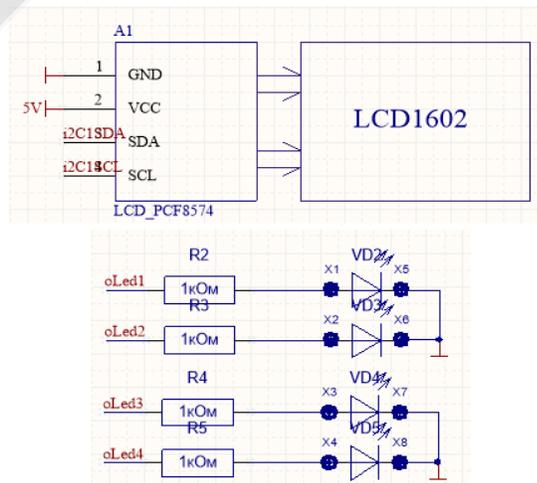


Figure 10 – Schematic diagram of the indication

Of all the LCD displays available on the market, the most commonly used is the LCD 1602A, which can display ASCII characters in 2 lines (16 characters in 1 line) each character in a 5x7 pixel matrix. For our circuit, we will select the SPLC780D display (Figure 11). The supply voltage: 5 V.



Figure 11 – Appearance of the LCD display

The LCD 1602A is an electronic module based on the Hitachi HD44780 driver. The LCD1602 has 16 pins and can operate in 4-bit mode (using only 4 data lines) or 8-bit mode (using all 8 data lines), and I2C interface can also be used. On the front of the module there is an LCD display and a group of contacts.

We chose GNL-3012HD LEDs (red) as LED indication. Their main characteristics are shown in Table 1.

Table 1 – Main characteristics of GNL-3012HD LEDs

Parameter	GNL-3012HD
Glow color	red
Wavelength, nm	700
Luminous intensity I_v , mKd	1,8
at a current I_{lim} , mA	20
Visible solid angle, deg	60
Lens size, mm	3
Voltage drop, V	2,1
Operating temperature, °C	-40...+80

4.6 Encoder control units

The schematic diagram of the encoder control unit is shown in Figure 12.

We use the PC817 optocoupler as a galvanic isolation. To amplify the input signal, we use the OPA2277 operational amplifier.

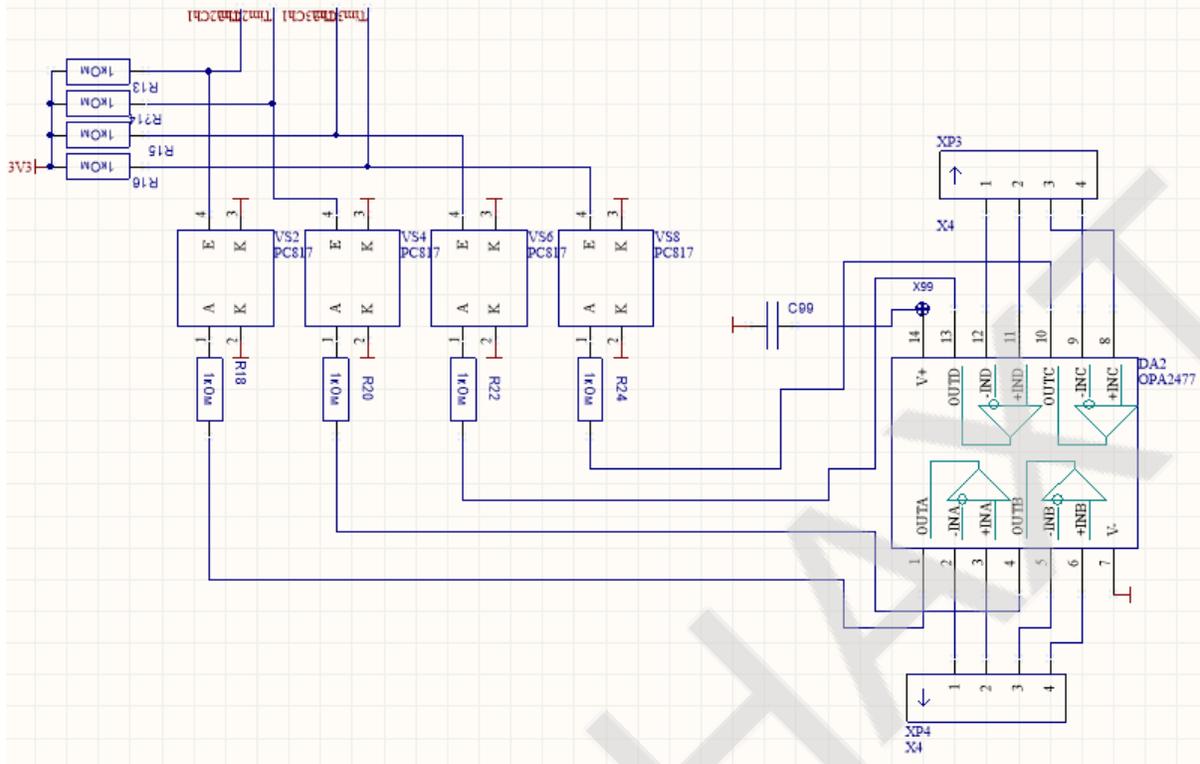


Figure 12 – Schematic diagram of the encoder control unit

4.7 Input and Output units

The schematic diagram of the output unit is shown in Figure 13.

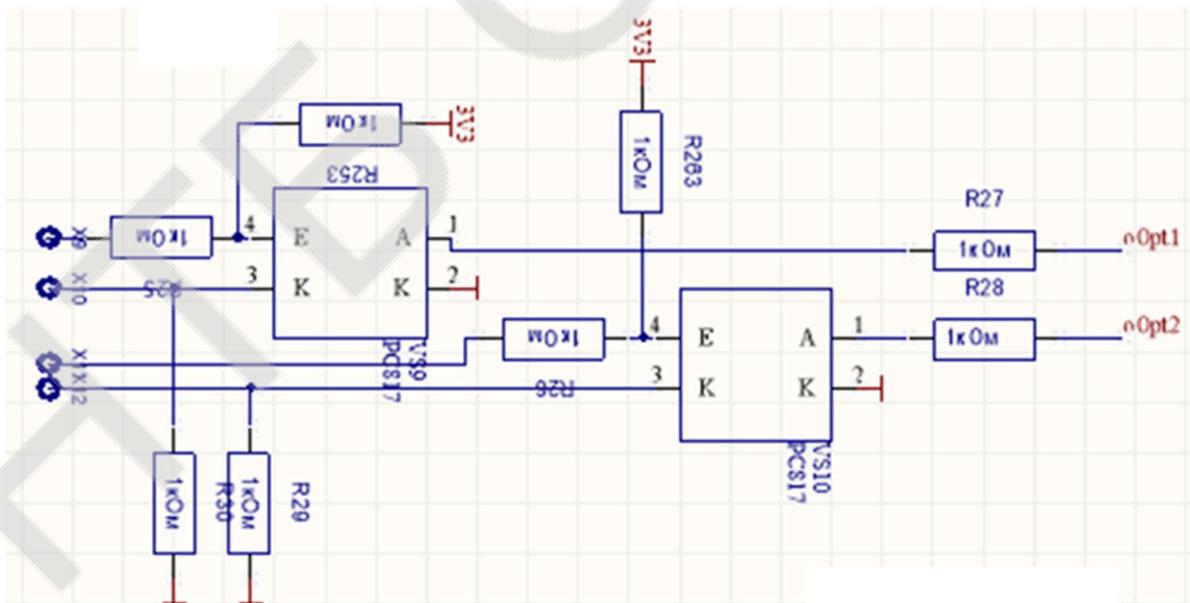


Figure 13 – Schematic diagram of the output unit

The input block contains a galvanic isolation (PC817 optocoupler) and has four inputs. The schematic diagram of the input unit is shown in Figure 14.

The first part of the circuit is responsible for processing signals from manual control encoders. The second part of the circuit is responsible for processing signals from position encoders, which operate in automatic control mode.

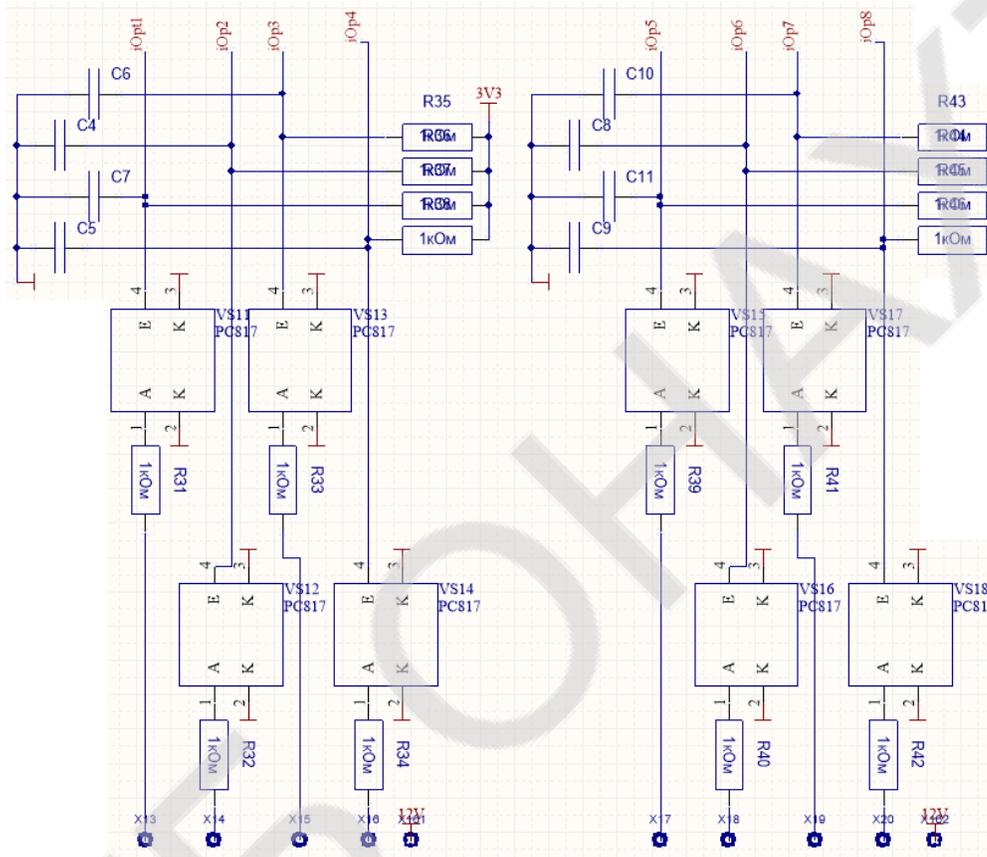


Figure 14 – Schematic diagram of the input unit

3.6 Other units

Figure 15 shows the matching circuit of the supply voltage (12 V) and the microcontroller power supply (5 V).

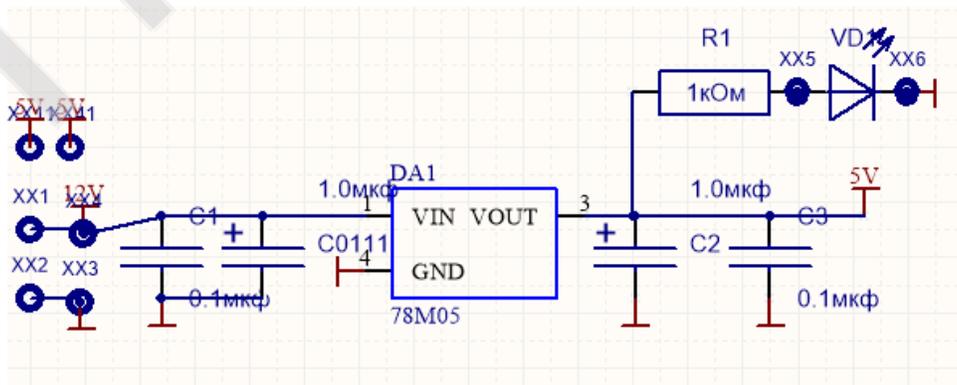


Figure 15 – Voltage matching circuit

The L78M05ABDT-TR chip with the following characteristics was chosen as a voltage stabilizer:

- Number of outputs: 1;
- Output voltage: 5V;
- Maximum load current: 0.5 A;
- Maximum input voltage: 35 V;
- Working temperature: -40... + 125 ° C.

To indicate the power supply, we chose the green GNL-3012GD LED.

To organize protection against unauthorized starting of the engine, the scheme shown in Figure 16 is used. This scheme excludes the possibility of starting the engine when the power supply of the microcontroller is disconnected, which allows the machine to be serviced safely.

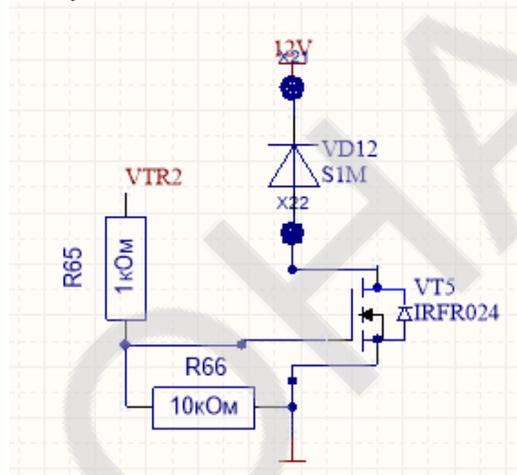


Figure 16 – Scheme of protection against unauthorized engine start

Figures 17 a, b show a general view of the control PCB made in the Altium Designer software.

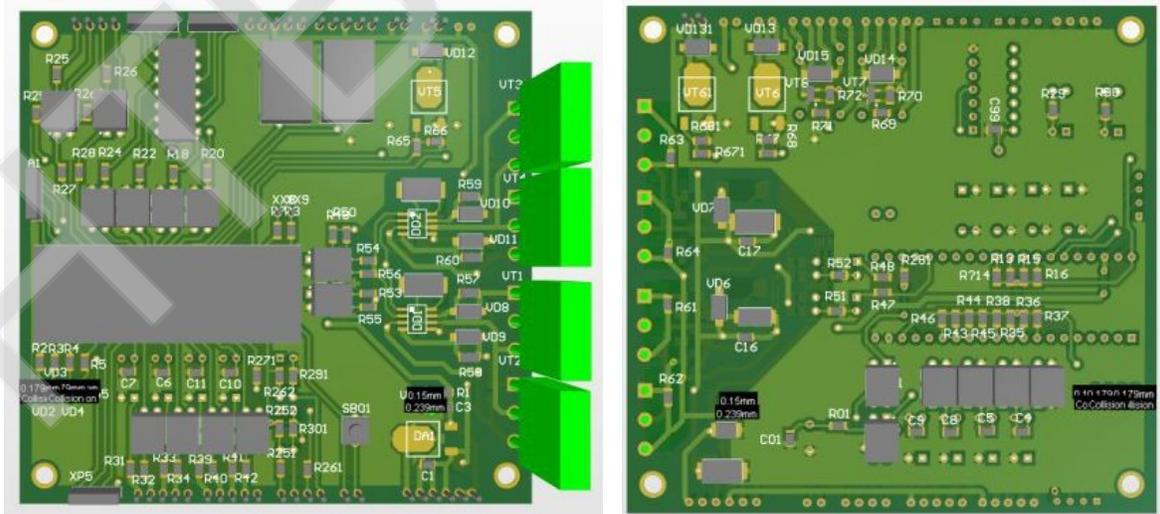


Figure 17 – General view of the control board: a) top view b) bottom view

V. CONCLUSIONS

The developed device meets the stated objectives: is cheap, easy to use and reliable. The developed control system is also accurate, which is important for the manufacture of tooling, shaped cutting tools, copiers, templates, patterns, etc., sometimes – machine parts.

This device allows to improve the quality of work performed, as well as to use the service life of equipment that is outdated in terms of control principles, but with a workable mechanical part.



Figure 18 – Appearance of the workplace after modernization

The developed control system has the following advantages:

- The ability to serve more standard equipment and machinery by one operator using an automatic control mode;
- The modern approach and element base allow you to adjust the parameters for specific requirements;
- The ability to control the machine in manual or automatic mode by the operator;
- It is possible to modify the system for upgrading positioning systems on different machines;
- The ability to operate the machine by operators with various qualifications: both operators who have the skills to work with numerically controlled machines (CNC), and highly qualified specialists, whose professional skills and experience allow them to perform operations with high accuracy in manual control mode;

Potential consumers can be metalworking enterprises: organization of equipment for metalworking machines with automatic control means.

INFORMATION AND TECHNOLOGICAL RESTART OF THE HOTEL AND RESTAURANT BUSINESS IN POST COVID-19 CONDITIONS

Authors: *Sofiia Ustymenko, Viacheslav Balko*

Advisor: *Tetiana Tkachuk*

Kyiv National University of Trade and Economics (Ukraine)

***Abstract.** The domestic market of hotel and restaurant services is developing unevenly. Therefore, a lot of hospitality companies are characterized by arrhythmic application of information technology capabilities.*

Nowadays the main problem of hotel and restaurant functioning is the existence of business opportunities in the market of services in general. It primarily happens due to external factors, in particular the COVID-19 pandemic, which has led to the closure of the greatest number of hotel and restaurant businesses and continues to have a negative impact on those companies that "survive" in a global pandemic.

***Keywords:** information technologies, hospitality industry, innovations, COVID-19 pandemic, adaptation of hotel and restaurant business, digitalization.*

I. INTRODUCTION

Information systems and technologies have become an integral part of the functioning of the hospitality industry. Today, they are used both by large and network establishments with a wide range of services, and by enterprises with limited supply. The degree of innovative solutions penetration into the context of the use of information technology in the activities of the hotel and restaurant business depends primarily on its goals and financial capabilities. The increase in the amount of information and the need for high speed processing and transmission encourage companies to informatize all key business processes. This is facilitated by the constant emergence of new specialized software products that are adapted to different models of hotel and restaurant business. The world practice of using IT in the activities of hospitality enterprises clearly reflects their wide range of opportunities in various areas, such as the accumulation of information about the guest, its storage and use by the hotel and restaurant, management of financial and economic activities of the enterprise, demand forecasting, reporting, video surveillance in the institution, relationship establishing between structural units, control over the performance of their work, personnel management, personnel selection, automation of marketing activities, establishing contact with the consumer, increasing his loyalty to the company; collaboration with partners and other organizations.

Modern pandemic conditions have made significant adjustments in the activities of hotels and restaurants, including the use of information technology to support communication and provide with quality operational services are the actual factors this scientific work in the chosen field is aimed at.

II. LITERATURE ANALYSIS

Automation of business entities has become an integral part of their effective functioning in most areas and types of economic activity, including hotel and restaurant business.

A large number of domestic and foreign scientists study the application of information systems and technologies.

2.1. Authors of works with a scientific approach

Scientific approaches to the definition of "information systems", "information technology" and related concepts are covered in the works: Lazora J., Yudkova K., Melnichenko S., Danilenko M., Senenko I [1].

At the same time, the substantiation of the above concepts taking into account the specifics of the hotel and restaurant business is reflected in the works of the following scientists: A. Perepelytsia, Dotsenko VF, Shidlovskaya OB, Medvid I., Bedusenko L., Fedosova K [2].

2.2. Classifications and characteristics

It is important to single out the issues of classification approaches and features of information technology. Today, such scientists as: Yudkova K., Chernyshyna G., Romanyshyna O., Kysil N., Gatalyak Z., Horbal N. are engaged in this direction.

2.3. Other approaches and features

Substantiation of types of audit of information systems and their features are covered in the works: Us R., Gurevich R., Monakhova V., Bogdanova I.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The research objectivity is the process of using information technologies of hotel and restaurant business in post Covid-19 conditions.

The research subjectivity is the hotel and restaurant business establishments.

The research methodology is experiment, survey, description, analysis, generalization.

IV. RESULTS

The pandemic has confronted the hospitality industry with an unprecedented challenge. Almost all restaurants were asked to limit their operations to only take-outs. The restrictions oriented to travelling and stay-at-home orders issued by the authorities led to sharp decline in hotel occupancies and revenues. However, the reopening process has begun slowly and the authorities have started to ease restrictions.

The analysis of statistical data also supplies with the information that around one-third of restaurant customers and around 40% of the hotel customers are willing to pay more for the increased safety precautions. While customers expect hospitality businesses to implement more rigorous safety/cleaning procedures, a portion of them are willing to pay for those added safety measures [3].

The analysis of statistical data also indicates that a large proportion of restaurant customers (64.71%) and the majority of hotel customers (70.42%) believe that the use of various technologies in service delivery will be necessary in the

COVID-19 environment in order to minimize human-to-human contact (the examples are service robots, contactless payment such as Apply pay or contactless bank cards, digital menus that can be viewed on personal mobile devices via QR codes, contactless digital payments, keyless entry, touchless elevators, etc.) [3]. These findings strongly suggest that technology integration and adoption into hospitality operations should be integral in the nearest future.

Recent developments in artificial intelligence (AI) and social service robot technologies have enabled the use of AI technologies in service delivery and the Covid-19 pandemic may precipitate the popularity of such technology for public safety reasons[4].

It is sure to be important for the hotel and restaurant business to provide it with the highest quality services. Nowadays, it is difficult to imagine any hotel or restaurant in which thousands of tasks of daily business would be carried out mechanically [5].

Modern innovations in the field of information technology, which are used in the hotel and restaurant business, play one of the key roles in the hypercompetitive struggle for a client. The theme of using the latest information technologies is especially relevant now that the whole world is in a common struggle for the survival due to the catastrophic impact of the COVID-19 pandemic not only on the industry of hotel and restaurant services, but also on all spheres and economic activities in general. Due to the closure or temporary suspension of activities during the first wave of quarantine, a large number of hotel and restaurant businesses were not prepared for such crisis conditions. So, there is an urgent need to adapt the business to today's conditions, find innovative technological solutions for further service of visitors to the institution, and also support the ways of communication with a personnel in the conditions of quarantine.

According to the results of research, obtained on the basis of analytical data of the world experts in the field of information technology, the share of work is performed at the expense of human resources, robotization of hotel and restaurant business enterprises by major business processes including the following percentage: 1) information and data processing - 53% due to the use of human resources and 47% due to the robotization of the same business processes; 2) performance of physical works - 69% and 31%; 3) administration - 72% and 28%; 4) treatment and interaction - 77% and 23%; 5) coordination, consulting - 81% and 19%; 6) decision making - 81% and 19%.

In conclusion, the application of the latest technologies in the hotel and restaurant industry allows hoteliers and restaurateurs to increase the efficiency of their activities, find new ways to improve the quality of service and compete in the market as a whole, especially in modern quarantine conditions.

It is important to point out the list of conveniences as a part of the adaptive innovative solutions in the information technology using in hotel and restaurant business activities in the domestic market of modern business conditions services. They are 5 G-Internet, Face ID to simplify the guest registration process, RFID bracelets that securely store guest payment information for cardless transactions, e-

Menu, which has become a channel of communication between customers and management, and allows the administration to quickly edit the menu and add new dishes, robotization of the main business processes at the enterprise, such as cleaning hotel rooms, luggage delivery to the room, customer service in the restaurant hall, etc.

These are the implementations of innovative solutions that have led to a mini-research, in which we have presented the detailed description.

The new 5G is ready to help guests download content and transfer data much faster than ever before. This connection is becoming increasingly important as hotels continue to innovate [6]. Face ID is used to scanning the faces of hotel guests and creating personalized room key cards. This makes check-in much faster and easier for all guests. Due to this technology, guests avoid constant contact with the keys, which can carry out many germs and other harmful substances. RFID bracelets help guests check in, securely store guest payment information for cardless transactions, and assist hotel staff with providing the quality services. But for RFID bracelets, the consumer would not have the access to opening the door and entering the room [7].

Robots in a hotel can help with household chores such as a floor hoovering and microbial destruction, which can be especially important for the safety of staying healthy and avoiding COVID-19. Some hotels also use robots to carry luggages, security system, room service and so on.

There is a chart below from which you can learn about the percentage of these innovations that are represented in the hotel business nowadays (Fig.1).

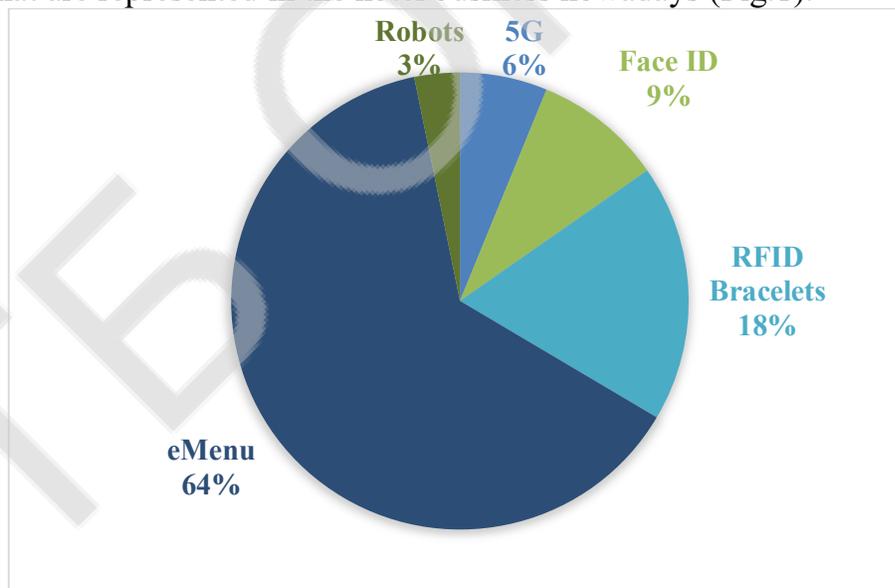


Fig.1. The information and technological solutions in the activities of the hotel business

Source: Compiled by the authors

Traditionally, the use of IT in the hotel business can be divided into two areas: for business management and for the formation of a system of interaction with consumers and partners [8]. The market of specialized programs to ensure the internal functioning of the hotel is represented by many proposals: Fidelio V8, Opera Enterprise Solution, Intellect Style, Servio HMS, Libra On Demand, Parus and

others. Each of them differs in functionality, set of modules and consumer characteristics [1].

The implementation of the second direction of the use of IT to establish a relationship with consumers is mainly due to a separate component of IT - Internet marketing. This is due to the ever-growing number of Internet users, the availability of Internet technologies for businesses and individuals and consumer convenience. There are now a significant number of internet marketing tools [1]. The most typical for the field of research are the following:

- website;
- search marketing;
- social media;
- mobile marketing;
- video marketing;
- online advertising.

It should be noted that the list of tools is constantly updated due to both the emergence of new and transformation of existing ones. For example, the merger of the Internet and mobile technologies has given rise to mobile marketing, and the combination of mobile marketing and social media has created an effective means of communication with consumers and within the enterprise - mobile social media [1].

After analyzing the most inherent research tools of Internet marketing, trends can be identified graphically (Fig.2).

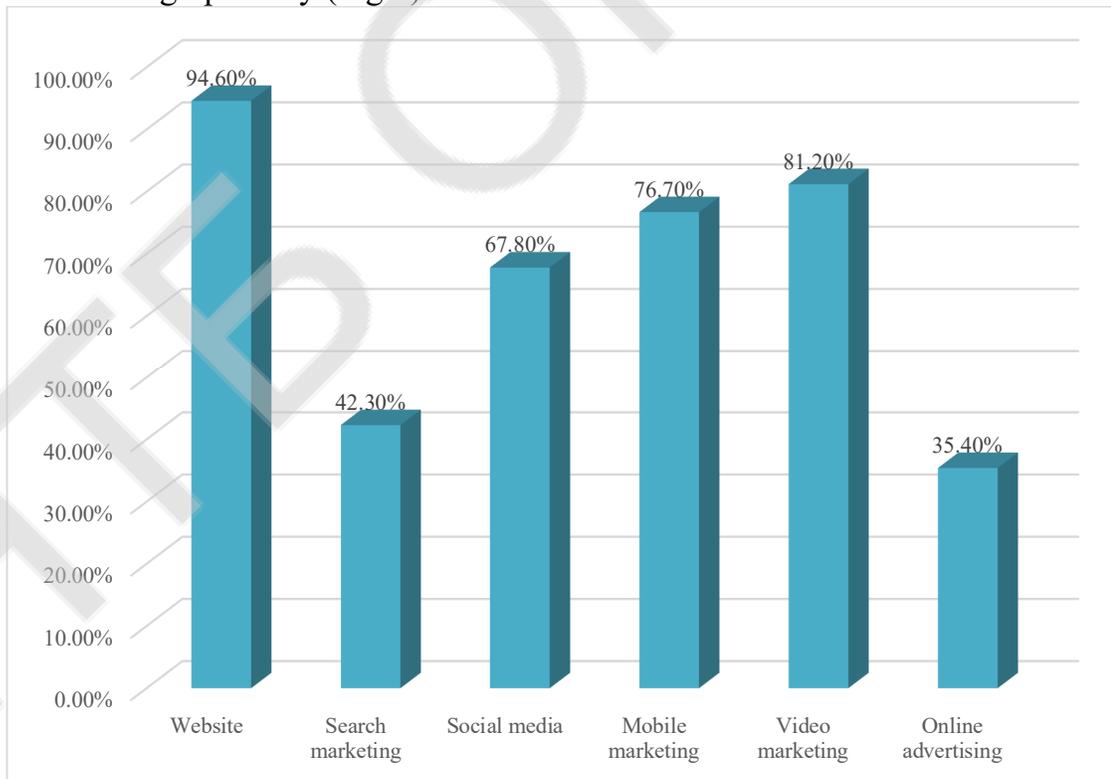


Fig.2. Internet marketing tools in the hotel and restaurant industry

Source: Compiled by the authors

The website is the most popular internet marketing tool and is not inferior to its position. As for the rest of the tools, most of them are also widely used.

The above issues and the current pandemic conditions of the hotel and restaurant business have led to a survey (students, friends, parents) to determine the current areas of IT use right now.

A survey of potential customers and consumers of hotel and restaurant services revealed that young people predominate among them (57.1%). 33.3% - persons aged 21 to 30 years.

It turned out that the majority of women surveyed - 52.4%. Men - 47.6%. The difference is not large, so we can say that both women and men equally use IT technology in the hotel and restaurant business (Fig.3).

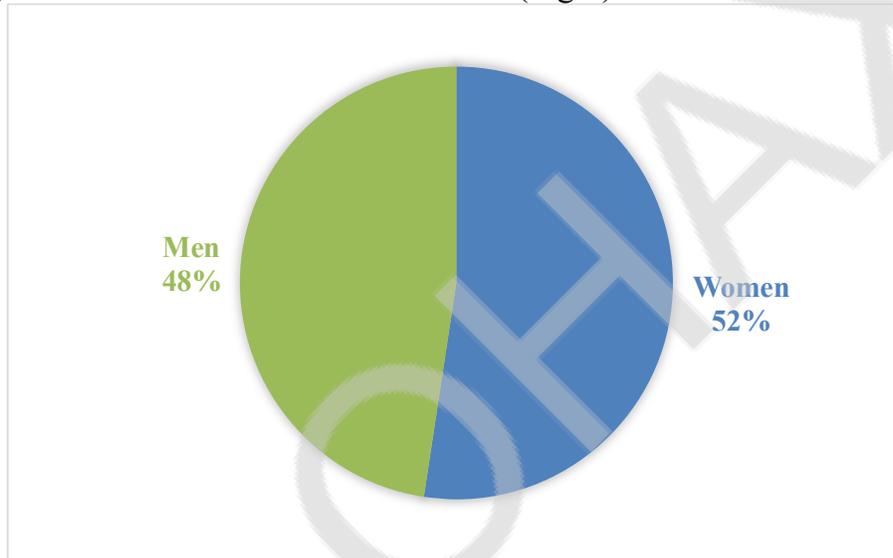


Fig.3. Percentage of women and men

Source: Compiled by the authors

The most popular means of booking hotel services today is the online booking system. Fax, correspondence and the hotel website are not so popular means of communication with the company. Half of the respondents consider the presence of such institutions in social networks a vital condition.

Almost 62% browse their websites, web pages, online magazines and publications before visiting the hotel. Therefore, hotel businesses need to update information from time to time, post news, notifications of discounts, offers, etc., follow the advertising on social networks.

For the majority (61.9%) the use of IT technology in the hotel business is very convenient, because it saves time, it is easy and affordable. IT technologies play a significant role in this area, which greatly facilitates the work for both consumers and staff.

The introduction of electronic menus has become the most popular in restaurants. Having pandemic conditions nowadays, this innovation is more relevant than ever. As a result, contact with a waiter has been reduced to minimum [7]. There are many benefits of using the menu on the iPad in restaurants (Table 1).

Table1. Advantages of using the menu on the iPad in restaurants

№	Benefits for guests	Benefits for restaurants
1	Convenient, clear touch interface.	Prompt and clear execution of orders.
2	Bright and color photos.	Reducing the burden on staff.
3	Easy navigation and quick access to the desired menu category.	Increases loyalty of regular customers.
4	All information about the dish: photo, description, ingredients, calories, etc.	Increases the overall efficiency of the business in general.
5	Access to games, the Internet in general.	Games and a bright interface will interest the youngest visitors and their parents.

Source: Compiled by the authors

To satisfy a customer demands this menu allows:

- to choose wine from the wine list of the institution according to the price, year release, region, bouquet as addition to a dish from the menu;
- to calculate the caloric content of the suggested dishes;
- to see the final check of the order as quick as possible when choosing dishes from the menu;
- to play games, learn the latest news, chat on social networks while waiting for the order.

In addition to the electronic menu, there are several other innovations in the field of IT that are widely used in the post-codification period:

- audio-visual displays;
- mobile payment;
- online and mobile ordering.

After conducting a mini-research, a diagram was formed, which shows the percentage of implementation of these innovations (Fig.4).

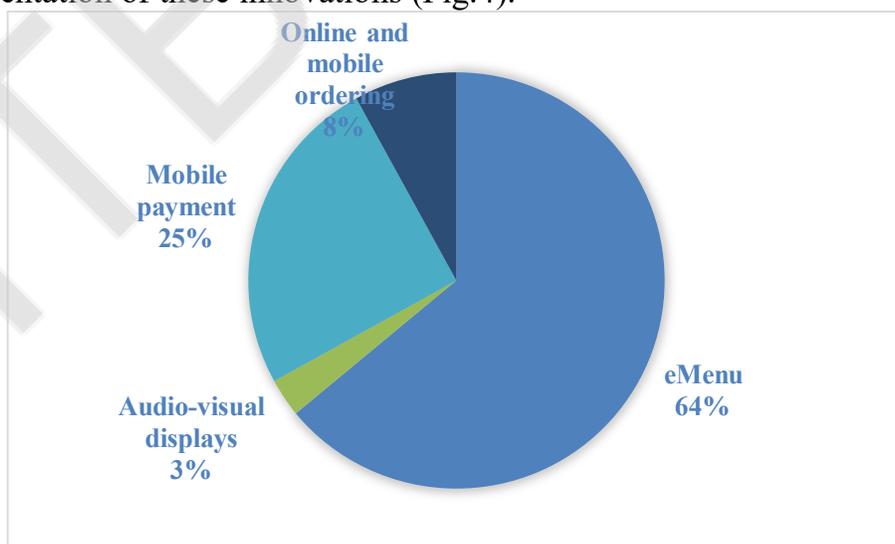


Fig.4. The information and technological solutions in the activities of the restaurant business

Source: Compiled by the authors

These innovations will facilitate the process of collecting and issuing orders for both visitors and staff. One of the innovations that can help the staff of the institution may be Dish Sanitizing Technologies. Dish sanitizing technologies provide restaurant a dishwashing system that runs continuously, streamlining the cleaning process.

V. CONCLUSIONS

The dynamic development of information technology plays an important role in the formation of the hospitality industry, especially in those quarantine conditions in which the world market of hotel and restaurant services is. So, you can see the high level of competition, the variety of basic and additional services and the service level increasing in the market of hotel services nowadays. The active introduction of modern information technologies in the activities of hospitality enterprises is a guarantee and a necessary condition for their productive work. It will help modern business to build an effective management system at the enterprise, reducing operating costs, improving hotel and restaurant service with the Internet marketing tools, increasing income, profitability and, accordingly, the profitability of the enterprise, as well as gaining competitive advantage through quality and fast customer service.

In post Covid-19 period hotel and restaurant businesses need to focus on protecting the health of guests and staff. The hotels can deal with service work, contactless payments such as Apply Pay or contactless bank cards, digital electronic menus that can be viewed on personal mobile devices using QR codes, contactless digital payments, keyless access, contactless elevators and so on. Restaurant establishments need to carry out additional cleaning of premises, disinfection, ventilation as well as use electronic menus to minimize communication with staff. If it is necessary, it is possible to rearrange the tables if they are close to each other, use contactless payments such as Apply Pay or contactless bank cards, to organize active delivery. These implementation mechanisms and technologies are necessary for the hotel and restaurant industry in a pandemic condition.

VI. REFERENCES

1. Danylenko M., Senenko I., Tkachuk T. Ukraine and the world: The tourism system. [collective monograph / ed. A. Mazaraki]; T. M. Tkachuk and others. - Prague, 2019. 324 p. (Personal contribution of the author: Part 2. «Development and features of the system of administrative management.» - P. 168-184).

2. Dotsenko, V., Shydlovska, O., Medvid, I. and Biedusenko, L. (2020), "Information technologies in Ukraine's hotel industry: realities and perspectives", *Investytsiyyi: praktyka ta dosvid*, vol. 1, pp. 51–57. DOI: 10.32702/2306-6814.2020.1.51

3. Gursoy, D., Chi, C.G., & Chi, O.H. (2020). COVID-19 Study 2 Report: Restaurant and Hotel Industry: Restaurant and hotel customers' sentiment analysis. Would they come back? If they would, WHEN? (Report No. 2), Carson College of Business, Washington State University.

4. Gössling, S., Scott, D., & Hall, C. M. (2020). Pandemics, tourism and global change: A rapid assessment of COVID-19. *Journal of Sustainable Tourism*, 1–20.

5. Kravets O. Innovative processes and their impact on the efficiency of the enterprise. [Text]: Part 1. - K.: NMC "Ukooposvita", 2016. - 184 p. - P.140-143.

6. Tech Thursday: Inside the Latest Hospitality Technology Innovation [Electronic resource] - URL: <https://www.socialtables.com/blog/hospitality/technology-innovation/> (access date: 08.11.2020).

7. Tkachuk T., Ustymenko S. Adaptive innovative solutions in the practice of hotels and restaurants. - I International Scientific and Practical Internet - Conference "Innovative Solutions in Modern Science, Education and Practice", Kyiv, November 17-18, 2020.

8. HRS - Hospitality & Retail Systems. Access mode: <http://www.hrsinternational.com/> (access date: 30.09.2019).

RESEARCH APPLICATION OF THE SPAM FILTERING ALGORITHM ON SOCIAL MEDIA

Author: *Vasyl Oliinyk*

Advisors: *Andrii Podorozhniak, Nataliia Liubchenko*

National Technical University «Kharkiv Polytechnic Institute» (Ukraine)

Abstract: Today there are a lot of different social networks and messengers, which in today's society, especially in times of pandemic corona-virus have become an integral part of our daily lives, including work activities. At the same time there is a lot of unnecessary information coming to users every second, so the problem of dealing with spam messages in social networks and messengers is now very relevant.

By spam we mean any messages that a person, or an entire company, considers unnecessary in a particular text stream.

The project is devoted to solving the scientific and applied problem of detecting spam messages in the text context of any social network or messenger using various spam detection algorithms. Three algorithms were implemented and investigated: an algorithm using naive Bayesian classifier, Support-vector machine and multilayer perceptron neural network.

The main idea is to develop a spam detection algorithm that is fast and easy to integrate in a messenger (social network). It is proposed to use the obtained solutions for IT companies. The developed algorithm should recognize spam based on the context of a particular firm and quickly remove or mark it. Since the spam detection task is essentially the task of sorting messages into A and B classes, the developed algorithm can be used not only for spam filtering but also, for example, for monitoring chat rooms for the messages that are important to a particular employee of the company.

Keywords: spam, social network, naive Bayesian classifier, Support-vector machine, multilayer perceptron neural network.

I. INTRODUCTION

In 2019, the percentage of spam in global mail traffic was 56.51%, which is 4.03% more than in 2018 [1] (Fig. 1.1).



Fig 1.1. Percentage of spam in email traffic in 2019

Unlike inboxes, most social media chat rooms do not have built-in anti-spam algorithms. Although there is not as much spam in chat rooms as in email services, the cost of an extra message can cost a particular firm a lot of money. For example, when a spam message contains a link to a resource that infects a user's computer and penetrates a company's internal network. The effects of such interference can be very costly for a firm. Therefore, there is the issue of monitoring the incoming text stream in social networks and messengers arises.

By being able to filter spam messages in messengers and social networks, firms can save their employees' time and prevent losses information.

To solve the problem we were used algorithms using naive Bayesian classifier, support vector method and multilayer perceptron neural network. An approach with integrated application of the investigated algorithms can begin to solve the problem of spam in social networks and messengers.

II. LITERATURE ANALYSIS

2.1 Characterization of spam. Ways to deal with spam

Spam is a mass mailing of correspondence of an advertising to people who have not expressed a desire to receive it [2].

The various types of spam generally include: advertisements; Nigerian emails; phishing; other types of spam. Other types of spam include: mass mailings of letters with religious content; mass mailings to put the mail system out of service (causing

the system to fail); mass mailings on behalf of another person in order to cause a negative attitude towards that person; mass mailings of letters containing computer viruses (for their initial spread).

The basic ways of spam spread today include [2]: e-mail; Usenet; messengers; substitution of Internet traffic; SMS messages; phone call, etc.

Spam messages cost the perpetrator virtually nothing, but the recipient of the spam usually has to pay the Internet provider for the time used to receive the spam. The mass spread of spam also complicates the operation of information systems and resources, and there is a very large amount of unnecessary load on them. Due to mass mailings the user has to spend unnecessary time filtering the messages. To avoid this, users use anti-spam filters to save time. But spam filters can also accidentally erase an important message by recognizing it as spam.

The surest way to deal with spam is to prevent spammers from getting hold of your email address.

Auto-Spam Detection Software is called Anti-Spam Filters. They can be applied by end-users or on servers. This software has two main approaches [3]:

1) the content of the message is analyzed and based the algorithm decides whether it is spam or not. If a message is classified as spam, it can be marked, moved to another folder, or even deleted. Such software can run both on the server and on the client computer. With this approach you don't see the spam filtered, but you continue to pay the full cost for receiving it, because the anti-spam software receives each spam message anyway (wasting your money) and only then decides whether to show it or not;

2) it classifies the sender as a spammer without looking at the text of the message. This software can only work on the server which directly receives the messages. With this approach it's possible to reduce the cost - money is only spent on communicating with spam mailers (i.e. refusing to accept the messages) and on contacting other servers for verification. The gain, however, is not as great as you might expect. If the recipient refuses to accept the message, the spammer program tries to bypass the protection and send it another way. Every of such attempt has to be handled separately, which adds to the overhead on the server.

This project discusses a statistical Bayesian spam filtering, method using a support vector method and a multilayer perceptron neural network.

2.2 Analysis of spam detection algorithms. Naive Bayesian classifier

A naive Bayesian classifier is a probabilistic classifier that uses Bayes theorem to determine the probability of an observation (sample element) belonging to one of the classes under the assumption of (naive) independence of the variables [4]. Examples of how this method works are: recognizing spam, analyzing emotional coloring of texts, detecting racism in text voters, any information processing systems and the like.

If it is possible, based on the values of the variables, to unambiguously determine which class an observation belongs to, the Bayesian classifier will report the probability of belonging to this class [5].

In other cases, when an observation can belong to different classes with different probabilities, the result of the classifier will be a vector whose components are the probabilities of belonging to one or another class [6].

The advantage of this approach is that the sample size requirements are reduced from exponential to linear. The disadvantage is that the model is accurate only when the assumption of independence is satisfied. Otherwise, strictly speaking, the calculated probabilities are no longer accurate (and even more, their sum may not equal one, making it necessary to normalize the result).

The probabilities involved in Bayes' theorem may have different interpretations. In one of these interpretations Bayes' theorem is used directly in a particular approach to statistical speculation. In the Bayesian interpretation of probability, this theorem expresses how a subjective measure of certainty should rationally change when accounting for evidence: it is a Bayesian view that is fundamental to Bayesian statistics [7]. However, Bayes' theorem has numerous applications in a wide range of calculations involving probability, not just Bayesian using.

Mathematically Bayes' theorem is [8]:

$$(2.1) \quad P(A | B) = \frac{P(B | A) P(A)}{P(B)}$$

where A and B are events:

- P (A) and P (B) are the probabilities of A and B without relation to each other;
- P (A | B) is the probability of observing event A if B is true;
- P (B | A) is the probability of observing event B if A is true.

2.3 Analysis of spam recognition algorithms. Support-vector machine

In machine learning, Support Vector Method (SVM) is a data analysis technique for classification and regression analysis using supervised learning models with linked learning algorithms, called support vector machines [9, 10]. For a given set of training samples, each marked as appropriate to one or the other of two categories, the SVM training algorithm builds a model that assigns new samples to one or the other category, making it a probabilistic binary linear classifier. The SVM model is a representation of samples as points in space, reflected in such a way that samples from individual categories are separated by a net gap, which is the widest. New samples are then mapped into the same space and predictions are made about their category membership based on which side of the gap they fall on (Fig. 2.1).

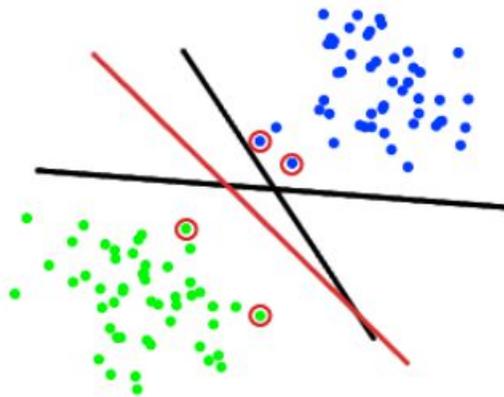


Fig. 2.1. Operation of the method with linearly separate data

But there are situations where the data are not linearly separable. For this reason, it has been proposed to map the primary finite-dimensional space into a space with more dimensions, presumably making splitting easier in this space (Fig. 2.2).

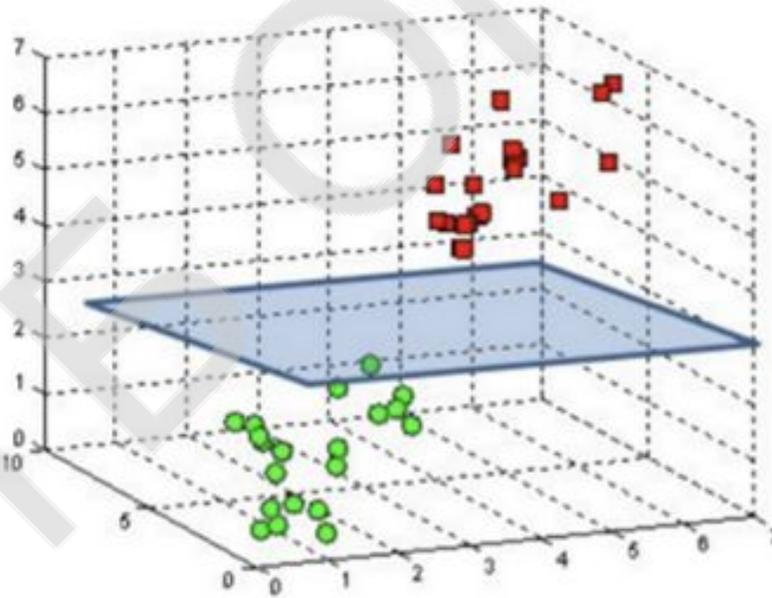


Fig. 2.2. Linearly inseparable data

You can also visually see the algorithm work (Fig. 2.3).

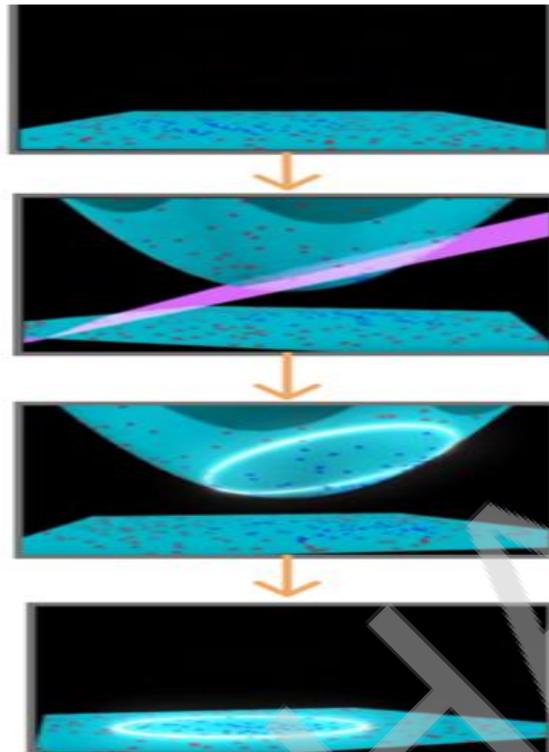


Fig. 2.3. The SVM method operation

2.4 Analysis of spam recognition algorithms. Perceptron

The Perceptron is a mathematical or computer model of information perception by the brain (cybernetic brain model), proposed by Rosenblatt in 1957 and implemented as the Mark-1 electronic machine. The main mathematical problem it can cope with the linear partitioning of arbitrary non-linear sets [11].

A perceptron consists of three types of elements, namely signals from sensors are fed into associative elements, and then into reactive elements. In this way, perceptron allows the creation of a set of "associations" between input and the desired output response. In biological terms, this corresponds to transforming, for example, visual information into a physiological response of motor neurons

Fig. 2.4 shows a model of an elementary perceptron.

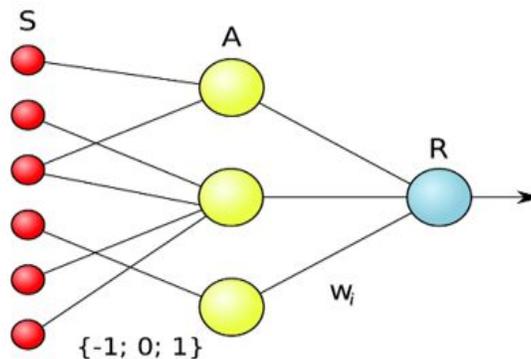


Fig. 2.4. Logic diagram of an elementary perceptron

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The aim of the work is to study the possibility of using different algorithms in the development of software for filtering spam in the textual content of social network messengers and speed response to unnecessary messages.

The aim is to do the following tasks: a) the analysis of the special possibilities of the recognition of spam messages; b) the analysis of the existing methods of spam recognition c) the realization of the methods of combating spam based on the naive Bayesian Classifier, the method of reference vectors and multilayers perceptron neural network; d) the analysis of the used algorithms.

The object of the research is the process of identifying spam in the text context of SOCIAL networks messengers.

Subject of study – the process of filtering spam messengers in SOCIAL networks using the base of methods for recognizing spam.

Research methods: classification theories, probabilistic classifiers, the theory of neural quantities, statistical methods of analysis of linguistic methods.

Scientific novelty – improved methods for the recognition of spam in the messenger using text messages of a particular text stream.

IV. RESULTS

As a training dataset was chosen the dataset of spam messages from the kaggle SMS Spam Collection Dataset, but the dataset of messages from a particular company can also be used to train the algorithm [12]. To implement the spam filtering algorithms we used the Python 3.6 programming language, the PyCharm. programming environment and the Keras, NumPy, Sklearn and Pandas libraries [13].

The simulation was performed on a LifeBook E744 notebook with 8Gb RAM, an Intel Core i7 CPU (up to 3.2 GHz) and an Intel HD Graphics 4600 video processor.

The spam messages dataset contains two columns, the first one contains the message class (ham – normal message, spam – spam messages). Let's first convert the first class column to an array of integers. A 1 will indicate that the given message is spam, a 0 – normal message.

To turn the whole text of the messages into numbers (vectorization), we need to make a dictionary of words, an array of words [11, 13]. Each word in the dataset is converted to lower case. Since our set could get punctuation marks, the next step is to clear the dictionary of unnecessary words.

After that, each word is brought to the infinitive (permanently -> permanent).

Having analyzed the resulting set of data, we can see some words are repeated very often, and others, on the contrary, very rarely. We will remove from the resulting set of words that are repeated more than 1000 and less than 5 times.

Then, on the basis of the obtained set of words we will create a dictionary, deleting all repetitions (i.e. every word in the dictionary is unique). The vectorizer from sklearn library was used for this purpose.

The created vocabulary included 1191 words. The sentences of the dataset are vectorized using the dictionary. After transformation, the data can be fed to the input classifiers. Also, some part of the dataset (about 600 messages), which is not part of the training data, was rejected for further testing of algorithms.

By testing each of the algorithms, we will count the number of mistakes and percentage of the mistakes.

The general scheme of execution of the developed software application is given in fig 4.1 [14].

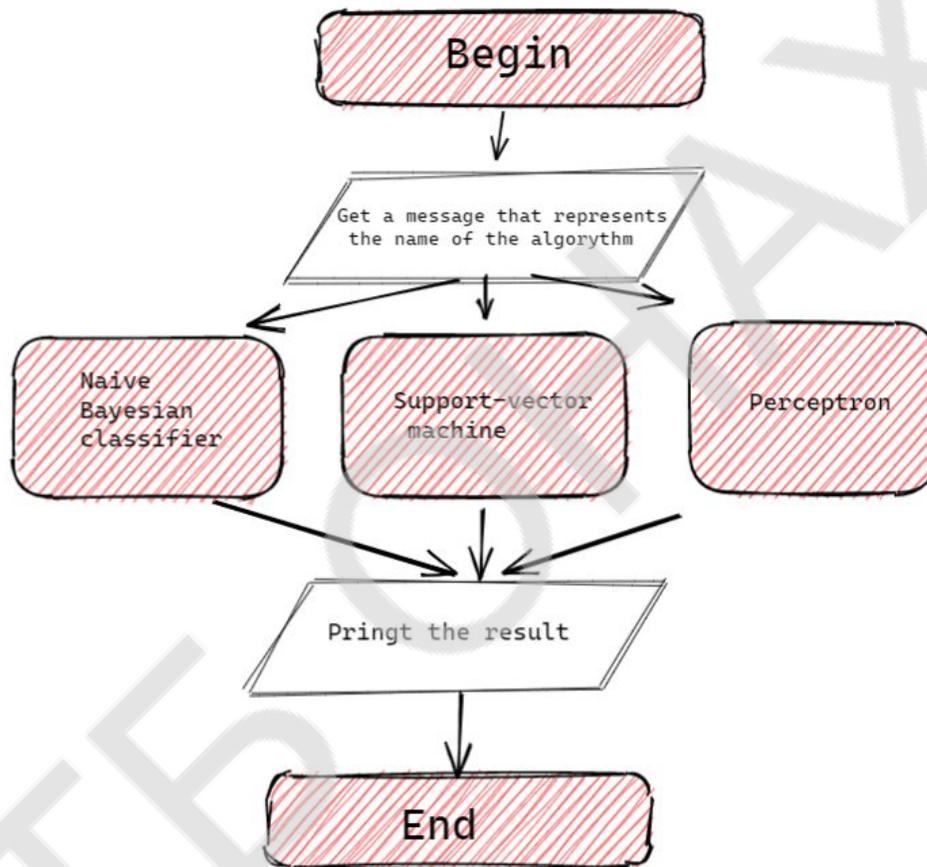


Fig. 4.1. The general scheme of execution of the developed software application

Algorithm of analyzing spam messages contains the following steps:

- 1) the user enters into the software application the initial text that should be analyzed;
- 2) software application parses the initial text into array of words, then each word is converted to the infinitive, then the resulting set of words is vectorized and transmitted to the input to the selected algorithm;
- 3) the algorithm analyzes the received data and returns the result as the probability of belonging the received data to the class (our algorithm has two classes: spam and non-spam);

4) the received data is analyzed and converted to a human readable representation;

5) the software application displays the result of the analysis and the probability of belonging the message to the spam-class;

6) the results of the analysis can be saved to the selected file if it is needed.

Firstly we have tested a perceptron multilayer neural network, which consists of 4 layers: 1 input, 2 hidden, and 1 output (Fig. 4.2).

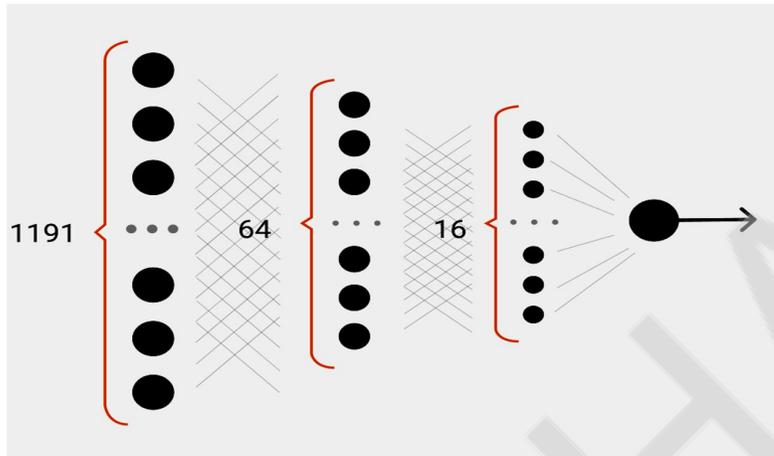


Fig. 4.2. Schematic model of the perceptron neural network

Having tested the created model we get:

Count mistake: 12
Mistake: 2.086957 %

Fig. 4.3. Results of the perceptron neural network

As can be seen on Fig. 4.3 the average number of perceptron mistakes is 12 out of about 600 messages, and the average mistakes probability is 2%.

Using the same input data, let us test an algorithm based on the naive Bayesian classifier (Fig. 4.4) and the Support Vector Method (SVM) (Fig. 4.5).

Count mistakes: 10
Mistake: 1.739130

Fig. 4.4. Results of the naive Bayesian classifier

Count mistakes: 6
Mistake: 1.043478

Fig. 4.5. The results of the method of support vectors

From the obtained data let's draw a graph in Fig. 4.6.

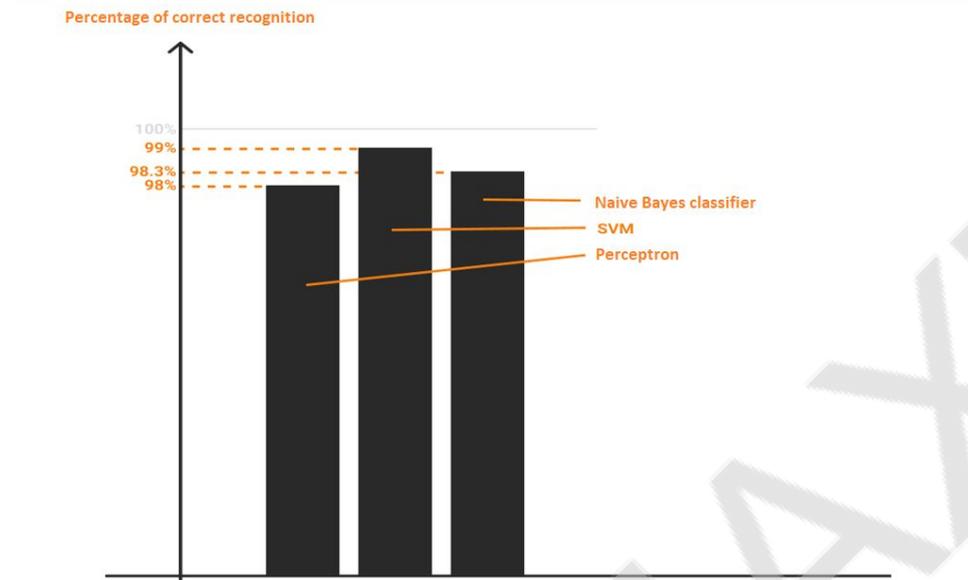


Fig. 4.6. Comparative graph

The analysis shows that the most accurate for the given dataset of spam messages is the application of the support vector method.

The work of the algorithms was also tested in the popular messenger Telegram [15].

V. CONCLUSIONS

As part of this research, the scientific and applied problem of determining spam in the textual context of social networking messengers was solved by the example of Kaggle SMS Spam Collection Dataset using chatbots in the popular messenger Telegram.

1. Considered the relevance of spam detection and possible problems due to spam intervention.

2. Considered the basic methods of spam recognition, namely naive Bayesian classifier, the method of support vectors and multilayer perceptron neural network.

3. It was developed the program to filter spam in the messenger Telegram, that uses three implemented algorithms for spam recognition.

4. A comparative analysis of the three most popular methods for recognizing spam messages was performed and it was shown that the most effective method is the support vectors algorithm with a mistake of only 1.044%. In second place was the algorithm based on the naive Bayes classifier with a mistake of 1.739%. The third place for our case was taken by the multilayer perceptron neural network with a mistake of 2.087%.

VI. REFERENCES

1. Vergelis, M., Shcherbakova, T., Sidorina, T., & Kulikova, T. (2020, April 8). Spam and phishing in 2019. <https://securelist.ru/spam-report-2019/95727>.

2. Chaudhry, S., Dhawan, S., & Tanwar, R. (2020). Spam Detection in Social Network Using Machine Learning Approach. In: U. Batra, N. Roy, & B. Panda (Eds.), *Data Science and Analytics. REDSET 2019. Communications in Computer and Information Science* (pp. 236-245). https://doi.org/10.1007/978-981-15-5830-6_20.
3. (2008, July 29). Ways to combat spam. *Ostriv znan.* <http://korysne.ostriv.in.ua/publication/code-24F002FC35B8C/list-1420E79CF27>.
4. Zhang, W., & Gao, F. (2013). Performance analysis and improvement of naïve Bayes in text classification application, *Proceedings of the IEEE Conference Anthology*, China, pp. 1-4. <https://doi.org/10.1109/ANTHOLOGY.2013.6784818>.
5. Liu, B., Blasch, E., Chen, Y., Shen, D., & Chen, G. (2013). Scalable sentiment classification for Big Data analysis using Naïve Bayes Classifier. *Proceedings of the IEEE International Conference on Big Data*, USA, pp. 99-104. <https://doi.org/10.1109/BigData.2013.6691740>.
6. McCallum, A., & Nigam, K. (1998). A Comparison of Event Models for Naive Bayes Text Classification. *AAAI 1998: Learning for Text Categorization* (pp. 41-48). http://courses.washington.edu/ling572/papers/mccallum1998_AAAI.pdf
7. Sarkar, S.D., Goswami, S., Agarwal, A., & Aktar, J. (2014). A Novel Feature Selection Technique for Text Classification Using Naive Bayes, *International Scholarly Research Notices*, 2014, Article 717092. <https://doi.org/10.1155/2014/717092>.
8. Tychynska, L.M., & Cherepashchuk, A.A. (2016). Bayesian formula. https://web.posibnyky.vntu.edu.ua/fitki/4tichynska_teoriya_jmovirnostej/17.htm
9. Nguyen, L. (2017). Tutorial on Support Vector Machine. *Applied and Computational Mathematics*, 6(4), 1–15. <https://doi.org/10.11648/j.acm.s.2017060401.11>
10. Sharma, N. (2020, January 31). Understanding the Mathematics behind Support Vector Machines. *Heartbeat*. <https://heartbeat.fritz.ai/understanding-the-mathematics-behind-support-vector-machines-5e20243d64d5>
11. Chollet, F. (2018). *Deep learning with python*. Manning Publications. <https://www.manning.com/books/deep-learning-with-python>
12. SMS Spam Collection Dataset [Data set]. <https://www.kaggle.com/uciml/sms-spam-collection-dataset>.
13. Applications for Python. *Python Software Foundation*. <https://www.python.org/about/apps/>
14. Oliinyk, V., Podorozhniak, A., & Liubchenko, N. (2020). Method of comprehensive spam recognition in social networks. *Proceedings of the 8th international scientific and technical conference Problems of informatization*, Ukraine, Vol. 2, p. 39. http://repository.kpi.kharkov.ua/bitstream/KhPI-Press/50565/1/Conference_NTU_KhPI_2020_Problemy_informatyzatsii_Ch_2.pdf
15. Oliinyk, V., Liubchenko, N., & Podorozhniak, A. (2020). Research of the method of complex spam recognition in social networks. *Proceedings of the XIV International scientific-practical conference of undergraduates and graduate students "Theoretical and practical research of young scientists"*, Kharkiv, Ukraine, p. 8. <http://web.kpi.kharkov.ua/masters/wp-content/uploads/sites/135/2020/12/TPRYS-2020.pdf>.

APPLICATION OF THE METHOD OF GRADUAL FORMATION OF SETS OF ADMISSIBLE VALUES FOR SOLVING COMBINATORIAL OPTIMIZATION PROBLEMS

Author: *Mariia Mushyn*

Advisor: *Olexandr Shportko*

Academician Stepan Demianchuk International University of Economics and Humanities (Ukraine)

Abstract. *This article describes a method of gradual formation of sets of admissible values as an alternative to backtracking and account for changes methods. The mechanism of algorithms that apply these methods to solve combinatorial optimization problems is substantiated. Fragments of programs that implement these algorithms in C# programming language are given and the results of their testing in a remote computing environment are analyzed. Test results show that the implementation of the method of gradual formation of sets of admissible values cardinally reduces the execution time of programs, indicating its effectiveness.*

Keywords: *method of gradual formation of sets of admissible values, backtracking, taking changes into account method.*

I. INTRODUCTION

As known, combinatorics solves problems of selecting and permutating elements of a set in accordance with given conditions. It is used, for example, in cryptography, machine learning, competitive programming, or in solving problems from other spheres of life. The formulas of combinatorics can be simple for algorithmization, but their use for large input data can significantly slow down the work of separate programs and computing systems in general. That is why the development of existing and creation of new methods of optimization of combinatorial problems is currently an important scientific task that is carried out within the framework of combinatorial optimization [1].

II. LITERATURE ANALYSIS

*Combinatorial optimization [1] considers optimization problems in which the set of feasible solutions is discrete or can be reduced to discrete. The purpose of such tasks is to find an optimal object from a finite set of objects when the well-known brute force search methods take an unacceptable amount of time to execute [1]. Traditionally, to speed up an exhaustive search, **the method of taking into account changes** [2] is used, which calculates the next variant of a solution, not from the very beginning, but only taking into account changes compared to the previous variant of a solution.*

But the most famous method for solving combinatorial optimization problems is **backtracking** [3]. It implies that a partial solution expands and incomplete candidates for the solution is further analyzed. If the next candidate is unacceptable, the algorithm moves to another candidate or returns to another partial solution, or

continues the search in other ways. According to this method, all steps of finding the optimal solution are recorded so that in the case of changes that do not satisfy the constraints of the problem, it is possible to return to an acceptable candidate [4]. Implementations of this method are usually faster than a brute force search, which is not always possible in a reasonable time [2] because during their execution invalid candidates not added to the complete solution.

In general, nowadays, when programming solutions to combinatorial optimization problems, the main attention is paid to discarding inadmissible candidates, and, in our opinion, the computational complexity is not analyzed sufficiently [5]. It is in vain because measures of computational complexity "give an idea of the execution time of algorithms" [6, c. 57] and allow one to understand why one algorithm will work much faster than another and teach future programmers to take into account not only the correct solution of the problem but also its efficiency, not only the program execution time but also the memory usage. It is by analyzing the computational complexity in this article we will define the feasibility of using proposed algorithms.

In general, the idea of using sets of valid values has been used in programming for several years.

For example, it is expedient not to compare elements with each other to sort an array of integers in ascending order with a small values range but only to count the frequencies of individual values and write to the resulting array each value from smallest to largest as many times as found in the input array [7, 8]. It is clear that it is advisable to do this when the range of values is commensurate with the size of the array. We use the analysis of sets of admissible values to solve combinatorial optimization problems.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of research — methods for solving combinatorial optimization problems.

The subject of the work — the influence of improvements of combinatorial optimization algorithms on their computational complexity.

The purpose of the study is to describe and substantiate the feasibility of applying the method of gradual formation of sets of admissible values for solving combinatorial optimization problems.

The task of the work is to create programs that implement algorithms of different methods for solving one of the typical combinatorial problems and compare their effectiveness for different test cases to establish the feasibility of each of these methods.

In the process of creating algorithms, general scientific methods of analysis and synthesis were used. To solve the problem of combinatorial optimization, we used the method of backtracking, the method of taking into account changes and our proposed method of gradual formation of a set of admissible values.

It is clear that the developed programs can be tested on local workstations, but it should take into account computing environment characteristics and the ability to

adapt programs to known test cases. Therefore, we consider it appropriate to test the developed programs in remote computing environments. Such testing is a way to develop logical thinking and optimization skills in solving atypical problems. One of the sites that provide access to tasks and the remote computing environment is <https://www.e-olymp.com>. This work is written using its resources. The advantages of E-olymp are the following:

- a significant number of tasks from different sections;
- grouping problems by different levels of complexity;
- the ability to compare its results with the results of other users;
- 15 programming languages are supported;
- availability of training materials;
- ability to compare the runtime and the RAM usage for every single test using different approaches to solving each problem.

IV. RESULTS

4.1. Formulation of the problem for the approximation of combinatorial optimization methods

We will demonstrate the application of various methods for solving combinatorial optimization problems on the example of the problem "CD" (№ 1266) from the site <https://www.e-olymp.com>. The condition of this problem is formulated as follows:

You have a long drive by a car ahead. You have a tape recorder, but unfortunately, your best music is on CDs. You need to have it on tapes so the problem to solve is: you have a tape N minutes long. How to choose tracks from CD to get most out of tape space and have as short unused space as possible.

The program should find the set of tracks which fill the tape best and print it in the same sequence as the tracks are stored on the CD. **Input data** have any number of lines. Each one contains value N, (after space) number of tracks and durations of the tracks. The program should show for each line the string "**sum:**" and a sum of duration times.

Assumptions:

- number of tracks on the CD. does not exceed **100**
- no track is longer than N minutes
- length of each track is expressed as an integer number
- N is also integer ($0 \leq N \leq 200$).

Time limit 1 second for executing each test by program, memory limit is 122.81 Mi/B.

4.2. Using the exhaustive search method with elements of backtracking

To find the set of tracks that fill most of an available tape space, we may need to analyze all possible variants for their including for each test because any combination of tracks might be better. The execution can be completed before it only if a combination is found in which the length of the tape is fully occupied (equal to N).

According to the condition of the problem, the number of tracks is equal to S . Each of them can be in only two states - taken into account in the sum of the current combination or not. Therefore, **each variant of including of tracks can be written as an S -bit binary number**, and their amount is 2^S . To analyse each possible variant, we need to generate all S -bit binary numbers except 0 because this is the maximum sum by default. To calculate the tracks record length of following possible variant, we will convert its number into the binary numeration and analyze the individual bits. Therefore the computational complexity of the algorithm is $2^S * S$. In the next sum, we will add only that lengths of tracks, for which the corresponding bits in the variant number are equal to 1. To solve the problem, we will output that maximum sum of variants, which is not greater than N .

Also, we should note that adding the length of the next track to the sum of the current version makes records longer than the length of the tape, it infringes the condition of the problem (because the track lengths are non-negative), and therefore the program can move to the next option and form a new sum. This, in fact, implements the idea of a backtracking algorithm.

For example, we trace the mechanism of formation of the maximal acceptable sum of tracks for a tape length 10 ($N = 10$) using four tracks ($S = 4$) with lengths 2, 4, 8, 4 (tab. 1). We see, for example, that setting the first bit on the right in the binary variant number leads to the adding to the current sum the length of the first track. In this case, the search for the maximum sum ends before the calculation all variants of occurrences of tracks ($2^4 = 16$), because the found maximal acceptable sum is equal to the length of the tape. If this did not happen, the program would continue to work until all variants are found. The maximal fill (10) was found after five search steps.

Table 1. The use of binary variants numbers representation to generate track combinations for $N = 10$, $S = 4$ and track lengths 2, 4, 8, 4

Variant's number in the decimal system	Variant's number in binary	Tracks are taken into account	The sum of the current version of included tracks	The maximum sum is known for now
1	0001	2	2	2
2	0010	4	4	4
3	0011	2, 4	6	6
4	0100	8	8	8
5	0101	2, 8	10	10

Here is the code of the program for solving the problem by exhaustive search with backtracking elements. The C# programming language was used because nowadays it is one of the main programming languages for applications.

```

while(true)
{string line = Console.ReadLine(); // Read the next line with the conditions of the
problem
if (String.IsNullOrEmpty(line)) return; // There are no more problems
string[] str = line.Trim().Split(new char[] { ' ' });
if (str.Length < 2)
return; // The problem cannot be solved without the length of the tape or the
number of tracks
int n = Convert.ToInt32(str[0]); // The total length of the tape
int s = Convert.ToInt32(str[1]); // Number of tracks
long i, j, sum, maxSum = 0, remainder; // Remainder - the remainder of a division
int[] track = new int[s];
for (i = 0; i < s; i++)
// Reading the length of each track
track[i] = Convert.ToInt32(str[i + 2]);
/* Generating all s-bit numbers, where the i-th bit will indicate whether (1) the i-th
track is taken into account in the sum or not (0). This will get every possible variant
of including their lengths */
// Counting the number of all possible variants of tracks occurrence
BigInteger variantsNumber = (BigInteger)1<<s; // 1<<s is equal to 2^s
// Conversion of each number of a variant of occurrences of tracks in a binary
// representation, calculating the appropriate sum to find the maximal acceptable
for (j = 1; j < variantsNumber; j++)
{sum = 0; // Each iteration the sum for the next variant of track inclusion will be
// calculated
remainder = j; // It is in order not to affect the counter value
for (i = 0; i < s; i++) // The option of selecting tracks is interpreted as binary
// S-bit number, the length of which corresponds to the number of tracks (S).
{if (remainder % 2 == 1) // If the i-th track is included in the sum
{sum += track[i];
if (sum > n) // Exceeding the total length of the tape is not allowed
break; }
}
remainder /= 2;
} // We move on to the next track
if (sum <= n && sum > maxSum) // If the amount found does not exceed
// the total length of the tape and greater than maximal of the previous ones
{maxSum = sum;
if (maxSum == n) break; }} // The best variant is already found
Console.WriteLine("sum:" + maxSum.ToString()); }

```

The program testing results provided on the site e-olymp.com are shown in figure 1.

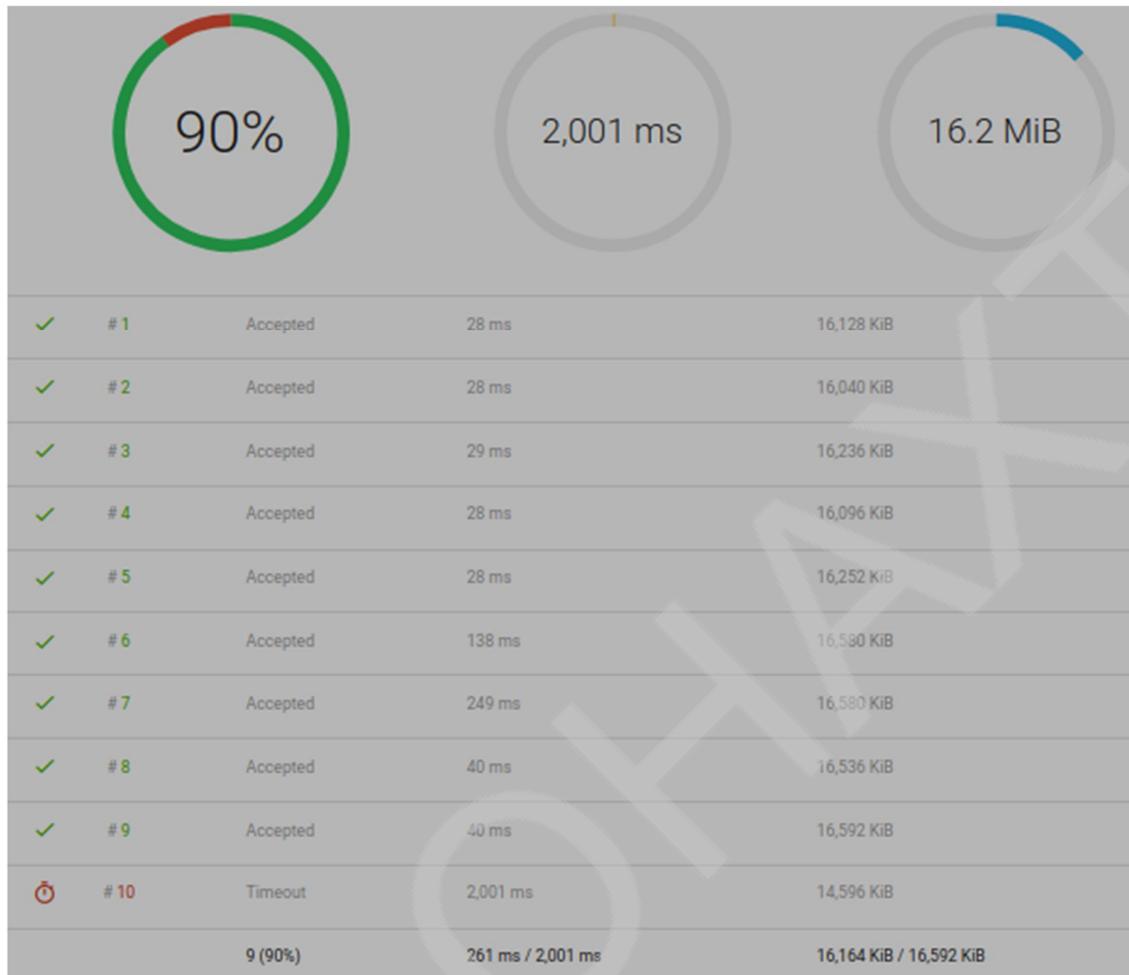


Fig 1. Results of testing the program that implements the exhaustive search

We see that the given program correctly execute nine tests, but exhausts the time limit when passing the last test.

4.3. Implicit application of the idea of a return search method

To speed up the above program, consider that the cycle for converting the variant number to bits of the binary representation is performed S times for each variant. It causes extra operations, as not all variant numbers are s -digit binary numbers. For our algorithm, this will mean that for the next version, there are no more tracks that are included in the current sum. In essence, this is an implicit application of the idea of a backtracking method. To implement it, we will add the next code to the previous program after the line marked with the symbol \triangleright :

```
if(remainder == 0) break; // No more tracks included in the sum
```

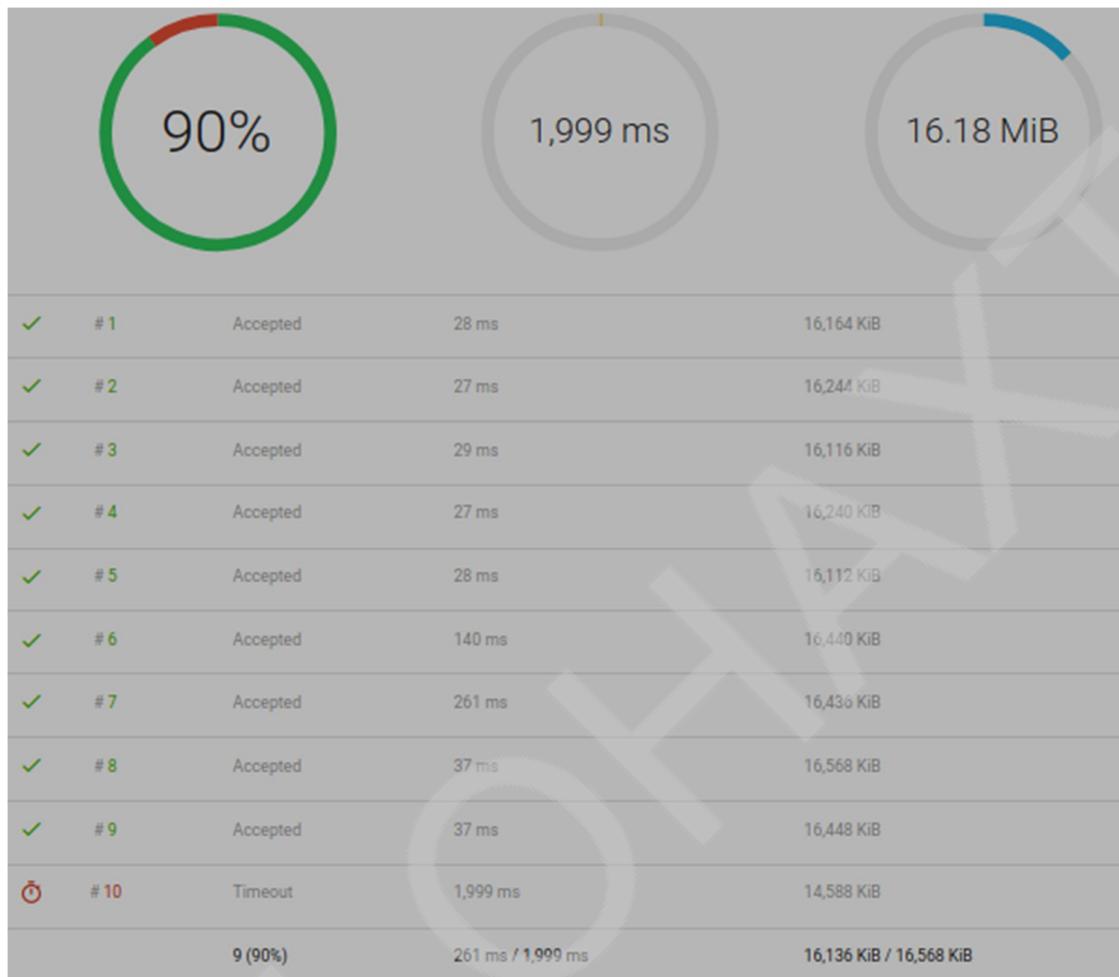


Fig. 2. Results of testing the program that implements the exhaustive search with taking into account a length of a variant number in the binary number representation

This change significantly affects the runtime speed with a large S in cases of considering small variants numbers for including tracks (figure 2). We see that the execution of the last test still exhausts the time limit. The computational complexity of the algorithm is now $2^{S-1} * S$, ie halved, but practically, the execution time of the program is not significantly reduced, because the search interrupts with returns do not affect the increase in subtotals. If we could also reject some of the solutions when performing this check, it would be a classic backtracking implementation.

4.4. Taking changes into account method usage

We will implement the method of taking into account changes. When calculating the sum of the tracks lengths program will relate to the sum of the previous variant. The current sum should decrease relative to the previous one by the length of those tracks, in the binary representation of which the number instead of 1 became 0. And it should increase by the length of the first of the tracks, where instead

of 0 became 1. The order of selecting tracks bit numbers, but the values of individual bits will not be calculated each time, and save in the array occurrence of $S + 1$ element. This will avoid excessive divisions by two and solve the problem for any non-negative S . We will complete the search when 1 appears in the additional element of this array, ie all S -bit binary numbers will be searched. To implement this algorithm, replace the lines between the markers • in the code of the previous program with the following code:

byte[] occurrence = **new byte**[s+1]; */* i-th element of the array indicates is taken into account (1) or not (0) the i-th track to the sum. Using this array instead of binary variants numbers allows the program to process any number of tracks. Generating the next variant of tracks inclusion in the array of occurrence corresponds to the principle of increasing the number by 1 in the binary number system: adding one converts all ones from right to left to zero, and the first right zero replaces to one. Accordingly, the sum of track lengths relative to the previous sum will decrease by the length of the track, if the occurrence array instead of 1 became 0 and increase by the length of the track if the array occurrence instead of 0 became 1. Initially, all values in the array are 0, i. e. the in first variant tracks inclusion no one track is taken into account. The last variant of track inclusion corresponds to the occurrence array, in which all elements are equal to 1, i. e. all tracks are taken into account. Completion of the search of track selection options is performed when setting 1 in the additional left position of the array (overflow of the option number). */*

```
while (occurrence[s] == 0) // While additional left position of the array is empty
{j = 0; // track index, which changes in sum
while(occurrence[j] != 0)
{occurrence[j] = 0; // The track is no longer taken into account
// therefore, the total sum decreases by the length of this track
sum -= track[j++]; }
occurrence[j] = 1; // Reached the track, which is already taken into account,
//so the total duration increases by the length of this track
if (j < s) sum += track[j];
if(sum <= n && sum > maxSum) // The best variant is already found
{maxSum = sum;
if (maxSum == n) break; }}
```

Such changes to the program have sped its execution for all tests, but the last test execution still takes too much time (figure 3). In fact, this version of the program does not only process **adjacent unincluded** tracks on the right but all **adjacent unchanged** tracks on the right.

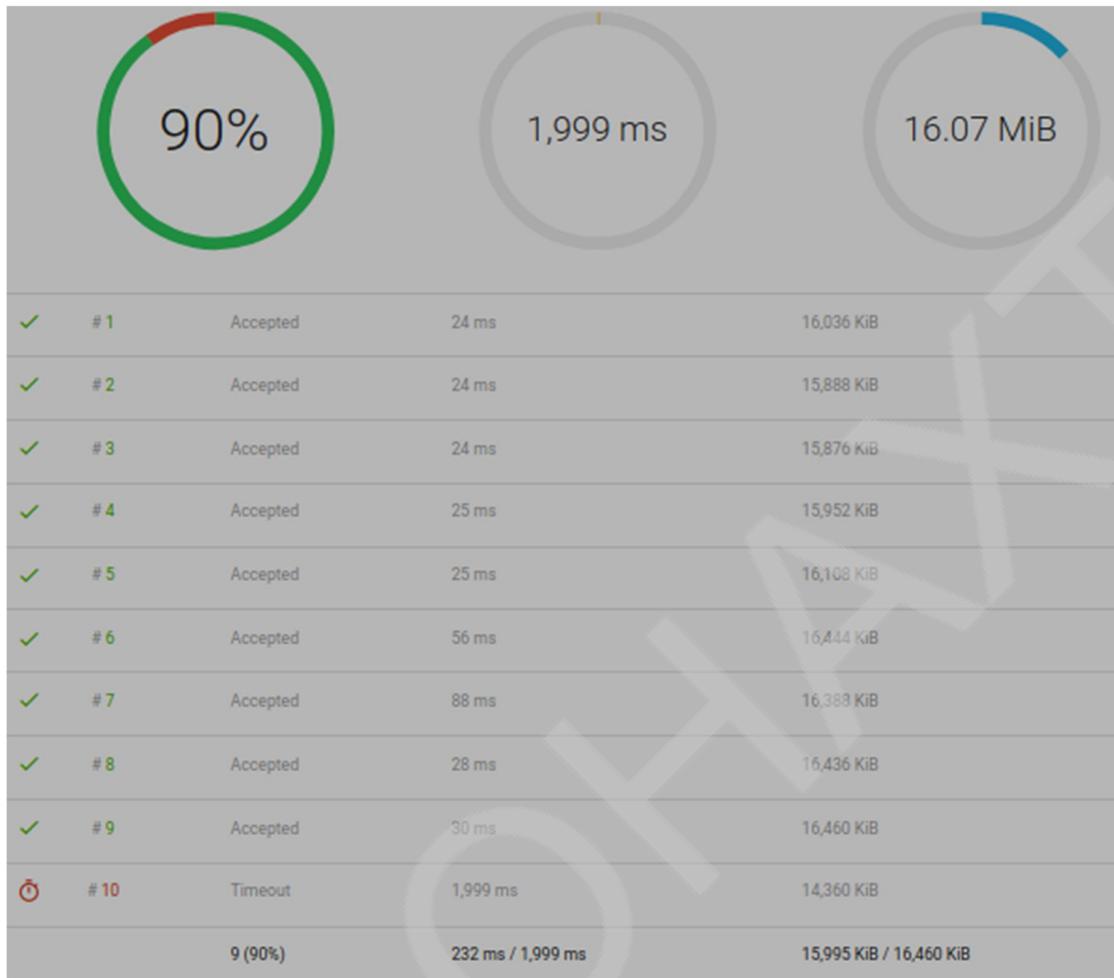


Fig. 3. Results of testing the program that implements the taking into account changes method

4.5. Description and substantiation of the method of gradual formation of sets of admissible values

Let's ask the question: how does the set of possible sums of track lengths change after considering the next track? In other words: how to get the set of possible (acceptable after summation) lengths of tracks E_i , knowing the allowable lengths of the sums of previous tracks E_{i-1} and the length of the next track $track_i$ (i means that the tracks from the initial to the i -th inclusive)? If the next track $track_i$ is not taken into account, then the set of allowable sums of track lengths will stay the same, i. e. $E'_i = E_{i-1}$. If the next track is taken into account, then new acceptable lengths will appear, formed by increasing the previous lengths by the length of the next track. That is, $E''_i = \{e''_{i,j} : e''_{i-1,j} + track_i\}$. Obviously that

$$E_i = E'_i \cup E''_i. \quad (1)$$

If no track is taken into account, then the sum of the track lengths is 0. If we consider the initial track, the sums of lengths is 0 (initial track is not taken into account) and $track_0$ (if the initial track is taken into account) is acceptable That is,

$E_0 = \{0; track_0\}$, and the following sets of allowable track sums are calculated according to (1).

For example, for the above-mentioned sequence of track lengths 2, 4, 8, 4, we consistently get the following sets of allowable sums:

$E_0 = \{0; 2\}$ (zero track is taken into account or not taken into account).

$E'_1 = \{0; 2\}$ (the first track is not taken into account), $E''_1 = \{4; 6\}$ (the first track is taken into account), and, according to (1) $E_1 = E'_1 \cup E''_1 = \{0; 2; 4; 6\}$ (first track is taken into account or not taken into account).

$E'_2 = \{0; 2; 4; 6\}$ (second track is not included), $E''_2 = \{8; 10; 12; 14\}$ (second track is included), $E_2 = E'_2 \cup E''_2 = \{0; 2; 4; 6; 8; 10; 12; 14\}$.

$E'_3 = \{0; 2; 4; 6; 8; 10; 12; 14\}$. (the third track is not taken into account), $E''_3 = \{4; 6; 8; 10; 12; 14; 16; 18\}$ (the third track is taken into account), $E_3 = E'_3 \cup E''_3 = \{0; 2; 4; 6; 8; 10; 12; 14; 16; 18\}$.

Since the allowable sums increase every time, it makes no sense to calculate those that are greater than N (in this example, the allowable amounts over 10 could be ignored). From the remaining allowable amounts, we have to choose the maximal one after considering all the tracks, or equal to N , if such sum found earlier (in this case, the allowable amount of 10 appears after considering the third track). On the example of the formation of the third set of admissible sums, we also see that the number of elements of the set does not exactly double each time, because it is possible to duplicate the elements in E' and E'' .

We will implement a program version of the gradual formation of sets of acceptable sums. The set of admissible sums E_i after consideration of the next element depends only on the set E_{i-1} . Therefore it is not necessary to store all sets - iteratively is enough, having the previous set, to form the following set, and for the following iteration to assign to the previous set the following, and the following - the previous. Interestingly, the next set can be omitted - the valid values of any set will always be valid for subsequent valid sets. To store the previous and next sets of allowable sums on each iteration, we use arrays, where the value of 1 in each element will indicate its entry into the set of allowable values, and 0 - the absence of it in the set. In order to quickly reassign arrays, we will not swap their elements, but **links** to arrays. Given these considerations, the implementation of the method of gradual formation of sets of admissible values for the problem under study can be as follows:

```
byte[] nextSum = new byte[n+1], prevSum = new byte[n+1]; /* Previous and following elements of sets of admissible sums greater than N are not considered */
```

```
byte[] interim;
```

```
nextSum[0] = 1; // Before tracks analysing, only 0 sum is available
```

```
for(i = 0; i < s; i++) // Cycle on tracks
```

```
    { /* Each track may or may not be included in the sum. Accordingly, the possible sums of track lengths after considering the next track will be all previous sums (when the current track is not taken into account) and previous sums increased by the length of the current track. */
```

```
interim = prevSum; /* An intermediate reference to the array is required so that
prevSum is not lost during permutation */
prevSum = nextSum;
nextSum = interim; /* When we going consider the next track, the previous possible
sums are taken from the available next ones and the next possible sums are
calculated. For faster permutation of arrays their values are not reassigned, and
references to them change places */
for(j = 0; j <= n; j++) /* Cycle on possible sums of lengths of record on a tape. The
index of the array and is the value of the sum. */
{if(prevSum[j] == 1) // Found a valid sum relative to previous tracks
{nextSum[j] = 1; /* The next track is not taken into account - the previous
possible amount does not change */
if(j+track[i] <= n) /* If the next track together with the possible previous sum can
be placed on the tape */
nextSum[j + track[i]] = 1; /* Adding the length of the next track to the previous
possible sums allows you to determine the new possible sums without adding all the
track lengths again. */
}}}
i = n;
while(nextSum[i] == 0) i--; /* Find the maximum of the allowable sums of tracks.
Search from the end, because the larger the index, the larger the sum */
```

These program test results are shown in figure 4. We see that all the tests execute in the allotted time and at the same time use the least RAM of the presented programs. Accelerating the solution of the problem is not accidental. After all, the computational complexity of the algorithm is now SN , which is much less than $2^{S-1} * S$, taking into account the limitations of our problem ($100 * 200 \ll 2^{99} * 100$). In conclusion, we note that the method of gradual formation of sets of admissible values finds only the solution (extremum) of this problem of combinatorial optimization, but does not determine the tracks at which this solution is obtained. Other (perhaps discussed above) methods should be used to find these tracks, but even finding the extremum speeds up the solution of optimization problems in the classical case.

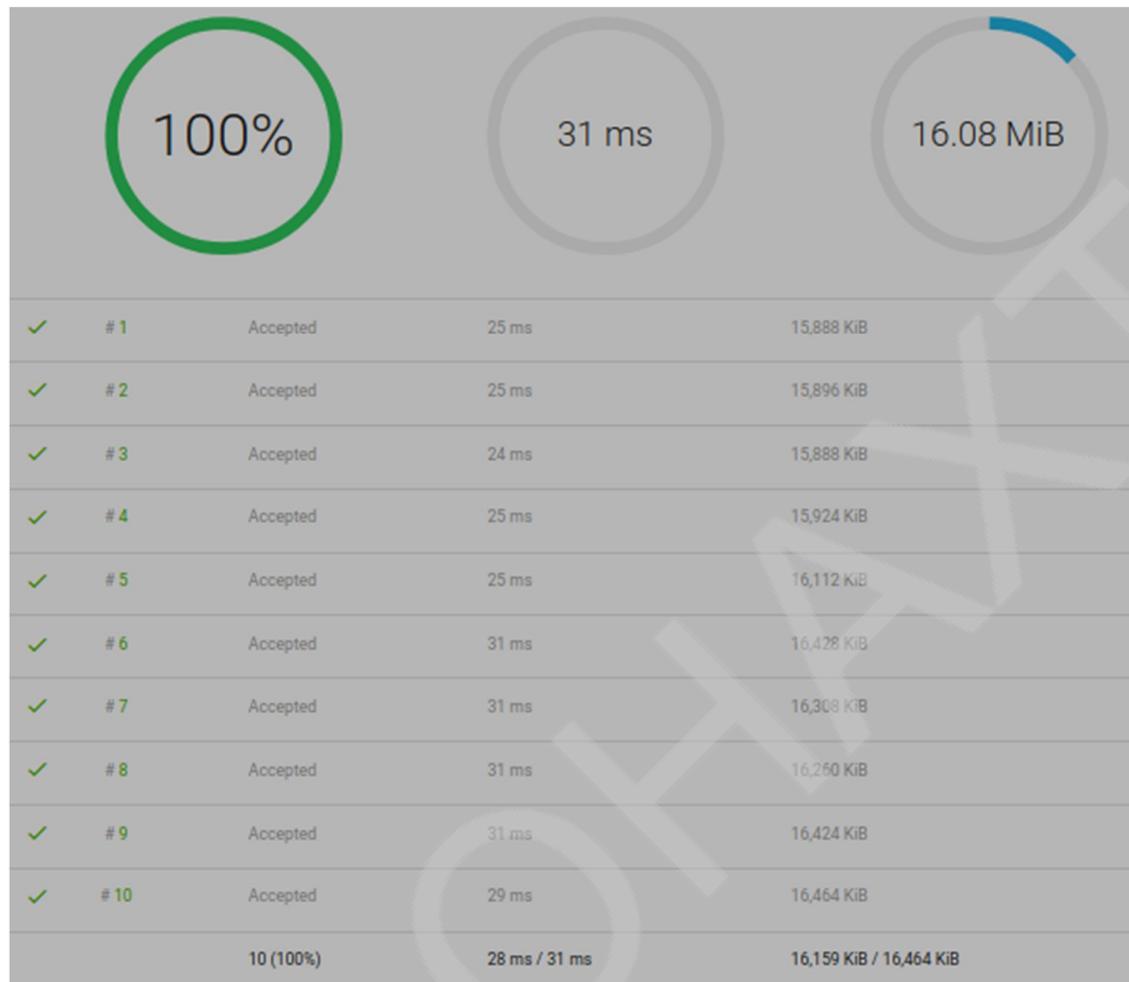


Fig. 4. Results of testing the program that implements the method of gradual formation of sets of admissible values

V. CONCLUSIONS

1. To determine the most effective way to solve the problem of combinatorial optimization, it is not enough to compare time on known test sets, but one should try to analyze their computational complexity.

2. The method of gradual formation of sets of admissible values is an effective alternative to methods of backtracking and taking into account changes in solving combinatorial optimization problems if the range of admissible values is discrete and the solution is similar to the method of dynamic programming.

3. To model sets of elements in programming, it is advisable to use logical arrays. Then, to reassign sets, it is sufficient to swapped by changing links to arrays, rather than reassign individual elements.

4. To speed up a solution of combinatorial optimization problems, it is not enough to bypass some options of complete search, and it is necessary to minimize the runtime of each variant, taking into account limitations of a problem.

VI. REFERENCES

- 1 [Combinatorial optimization](https://en.wikipedia.org/wiki/Combinatorial_optimization). Retrieved from https://en.wikipedia.org/wiki/Combinatorial_optimization [in English]. (2020, January 25).
- 2 Mnozhyynni typ [Pruei type]. Retrieved from <https://studfile.net/preview/7079855/page:12/> [in Ukrainian]. (2020, January 27)
- 3 Poshuk z vertanniam [Backtracking]. Retrieved from https://uk.wikipedia.org/wiki/Пошук_з_вертанням [in Ukrainian]. (2020, January 25).
- 4 Alhorytmy z povnenniam. Rozviazok zadachi pro rukh konia [Backtracking algorithms. Solving the problem about a horse movement]. Retrieved from <https://studfile.net/preview/7079855/page:20/> [in Ukrainian]. (2020, January 27).
- 5 Obchysliuvalna skladnist [Computational complexity]. Retrieved from https://znaimo.com.ua/Обчислювальна_складність#link0 [in Ukrainian]. (2020, January 25).
- 6 Otsinka skladnosti alhorytmiv, abo shcho take $O(\log n)$ [Computational complexity of an algorithm evaluation or what is $O(\log n)$]. Retrieved from <https://echo.lviv.ua/dev/53> [in Ukrainian]. (2020, January 27).
- 7 Knuth D. E. (1997). The Art of Computer Programming (vol 2), (2nd ed.). Addison Wesley Longman.
- 8 Shportko A. V., Shportko L. V. (2019). Acceleration of large integer arrays sorting using ranges of values and frequencies of elements. Information Extraction and Processing, no. 47(123), 73-79. DOI:<https://doi.org/10.15407/vidbir2019.47.073>

DIGITAL PATH OF INDUSTRIAL DEVELOPMENT IN THE REPUBLIC OF BELARUS

Author: *Nina Stoma*

Advisor: *Olga Dovydova*

The Belarus State Economic University (Minsk, Belarus)

Abstract. *The article discusses the theoretical foundations of digitalization, highlights the main advantages and current trends in the digital transformation of industry. The aim of the work is to study the relationship between the introduction of digital and innovative technologies in the industry and the change in the studied indicators. The relevance is reflected in the analysis of the impact of digital transformation and innovation on the main indicators of industrial development in the Republic of Belarus. As a result of the conducted research, the advantages and prospects of development, as well as the problems facing the transformation of the industry, are identified.*

Keywords: *digitalization; digital transformation; innovative activity; industry; manufacturing industry; «Industry 4.0».*

I. INTRODUCTION

In the modern world is clearly visible digital transformation of the economy, which seeks to provide opportunities for the development of society, new ideas and discoveries, to improve the quality of life, to ensure higher safety standards, to empower healthcare, to allow products and services of higher quality, to promote environmental protection.

The essence of digital transformation is reduced not only to the large-scale use of information and communication technologies, but also to the main goal-to transfer the economy to a new level of economic, technological and social development based on innovation.

The main driving forces today are new products and services, the latest information and management technologies, innovative business models and industry-specific digital platforms.

One of the latest trends in the modern world in the development of digital transformation of the economy is «Industry 4.0» – the integration of the links of the industrial production chain using «the latest information and communication technologies». In developed countries, development has moved a step forward and is moving towards «Society 5.0» – the development of technologies aimed at creating an accessible connection between people and technology.

II. LITERATURE ANALYSIS

The term «digital economy» was first used by Don Tapscott, a Canadian researcher at the University of Toronto, in his book of the same name, *The Digital Economy* in 1994.

Later, in 1995, Nicholas Negroponte, a computer scientist and founder of the Media Lab at the Massachusetts Institute of Technology, introduced the phrase to the scientific community. [1]

For the first time, the concept of «Industry 4.0» was introduced by German scientists – Kagerman, Lukas and Walster in 2011, when the German government raised the question of the need to expand the use of information technologies in production.

Later, in 2016, the founder of the World Economic Forum, Klaus Schwab, introduced the term into mass use. In his book «Technologies of the Fourth Industrial Revolution», he confirms that «Industry 4.0» is a close concept to the fourth stage of the industrial revolution [2].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the study was the industrial complex of the national economy of the Republic of Belarus.

The subject of the research is digital processes of industrial transformation.

The following research methods were used: study of the literature on the research topic, analysis and synthesis of information, measurement and analysis of statistical data, generalization of the data obtained.

IV. RESULTS

The global digitalization of the economy is seen as a driving force for economic growth, which can lead to significant economic shifts and have an impact on entire areas of business, the labor market and the way of life of people.

The term «digitalization», used in the manufacturing sector, implies the implementation of measures and measures aimed at making production more flexible, adapted to modern requirements and competitive in the «digital world».

One of the latest trends of the modern world in the development of digital transformation of the economy is «Industry 4.0» or «The Fourth Industrial Revolution», which is the integration of the links of the industrial production chain using «the latest information and communication technologies».

The central element of the functioning of production systems is the Internet technology, which provides communication between people, machines and products.

«Industry 4.0» defines the vision and principles of the «Smart Enterprise». Such an enterprise uses a modular structure, cyber-physical systems manage physical processes, creating a kind of virtual copy of the real world, and make decentralized decisions.

Thus, the authors of the Sretensky Club claim that «Industry 4.0» as part of the digital economy is the era of the «industrial Internet of things», in which there will be full access to every stage of production using a global network and sensors [3].

The development of practical experience has led to the understanding that «Industry 4.0» is a complete transformation of production, affecting both the management mechanisms and the production process itself, from the supply of raw materials to sales.

It is worth noting that many developed countries have reached a new level in this direction and are following the path of development of «Society 5.0», which is focused not on digital transformation, but on people's communication and created digital technologies.

The Republic of Belarus is at the stage of transition to Industry 4.0, so it is necessary to pay attention to the main features and characteristics of the digital transformation of the industry, which has already been implemented and is currently in the plans for implementation in the economy.

The analysis of the relationship between the introduction of digital and innovative technologies in the industrial sector and changes in the studied industrial indicators is carried out. The data for the study are taken from the official website of the National Statistical Committee of the Republic of Belarus [4].

There are several areas in which the dynamics can be traced most clearly:

- the number of innovative and active organizations in the total number of;
- structure of expenditures on technological innovations;
- the volume of innovative products shipped by industrial organizations;
- dynamics of the receipt of patent applications and their issuance;
- the structure of the volume and gross value added of industrial production by the level of manufacturability.

Digitalization in the industrial sector is reflected in the transition from the raw materials and industrial economy to a new form based on information and communication technologies and the latest achievements of scientific and technological progress, with the predominant role being taken by innovation, intellectual labor, information goods and services.

The introduction of new digital technologies and the formation of innovative and technological production directly depends on the research activities carried out. Therefore, it is worth studying the number of innovative and active industrial organizations.

The analysis of their number and share in the total number of innovative organizations will allow us to assess the compliance of the industry sector with the trends of digital transformation of the economy.

The current trend and the relationship can be judged by the dynamics of the indicators in Table 1. Graphically, the information is presented in Figure 1.

Table 1. The dynamics of innovation-active organizations of the industry

Indicators	Number of innovation-active organizations, units			The share of innovation-active organizations in the total number of surveyed organizations, percent		
	2017	2018	2019	2017	2018	2019
Years						
Industry	347	380	405	21.0	23.3	24.5

The number of innovation-active organizations has a positive growth rate of 16.7% over three years. The share of the total number of organizations surveyed increased by 3.5 percentage points.

The positive dynamics indicates an increase in demand for innovative and technically advanced products, which encourages enterprises to apply the latest achievements of digitalization and scientific and technological progress, improve technological processes, thereby becoming innovative and active.

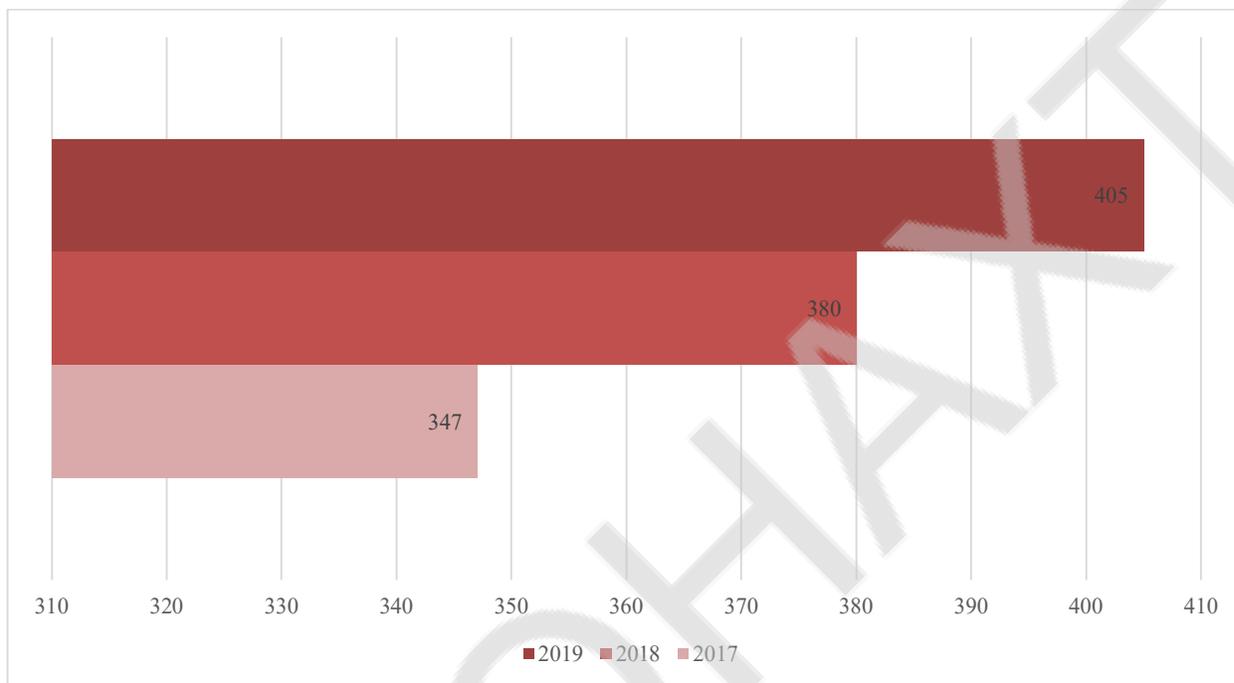


Fig. 1. The dynamics of innovation-active organizations of the industry

Indicators of the costs of technical innovations can serve as an indicator of the growing demand for the restructuring of innovative organizations in the context of the digital transformation of the economy. Analyzing the cost structure, you can make an analysis of the directions of development of organizations. The data is presented in Table 2 and Figure 2.

The structure of total costs for five years has changed in a positive direction – the growth rate was 30.9 %.

The growth rate of innovative products responsible for the development and implementation of technologically new and technologically advanced products was 27.6 %. And the growth rate of technological innovations, including the development and implementation of technologically new and improved production methods, was 36.1 %.

If you look at the share of innovation in costs, product innovation still holds the leading position, having decreased by 1.6 percentage points in five years due to the increased cost of technological innovation.

Table 2. Dynamics of the cost structure for technological innovations in industrial organizations (bel. rub)

Indicators	2015	2016	2017	2018	2019
Costs of technological innovation	1 061.7	774.6	1 222.6	1 134.9	1 390.3
product innovations	645.3	405.1	951.4	846.4	823.5
process innovation	416.4	369.5	271.1	288.5	566.8
Costs of technological innovation (as a percentage of the total)	100	100	100	100	100
product innovations	60.8	52.3	77.8	74.6	59.2
process innovation	39.2	47.7	22.2	25.4	40.8

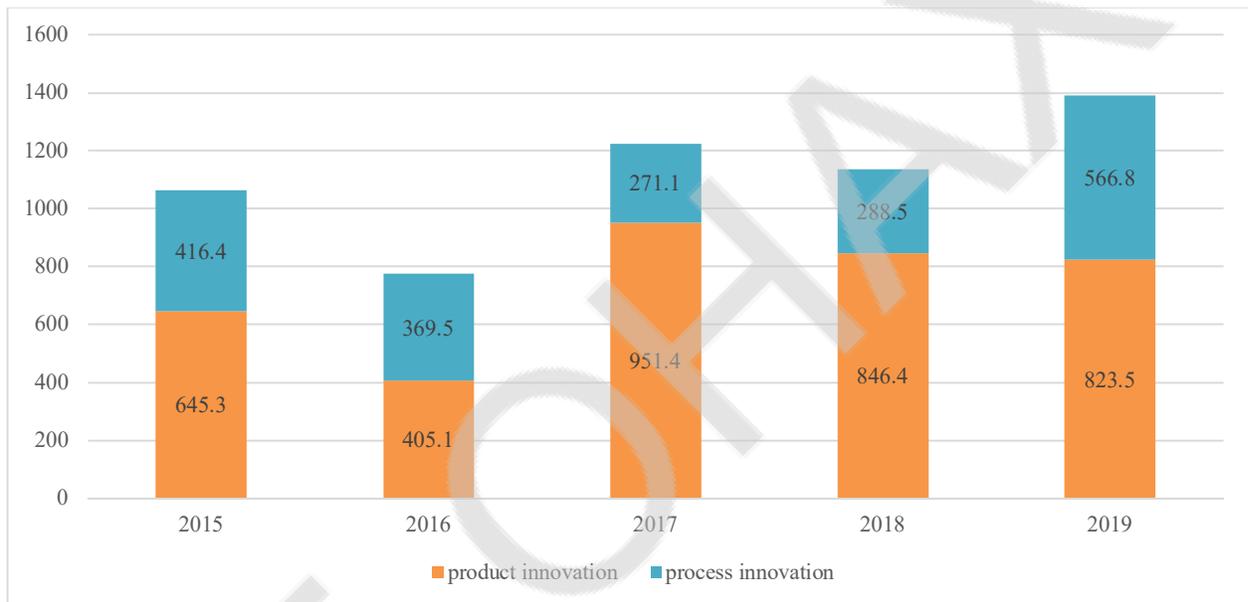


Fig. 2. Dynamics of the cost structure for technological innovations in industrial organizations (bel. rub)

Therefore, we can judge the positive dynamics of the costs of technological innovations, which are also associated with digital transformation. This trend allows enterprises to produce higher-quality and technically new products, improving their own production and increasing their competitiveness in the market.

One of the factors of a successful transition to a digital and innovative economy is the volume of innovative products shipped. The analysis allows you to evaluate the effectiveness of innovative and active organizations. The dynamics of the indicators are presented in Table 3 and Figure 3.

The growth rate for three years of the volume of shipped innovative products was 17.2 %, but compared to 2018, it decreased by 5.4 %. This was also reflected in the decrease in the specific weight in the total volume of products shipped.

Innovative products are usually understood as new products for the external market. Products are considered new on the market for no more than three years, after which they lose their competitive qualities.

Table 3. Dynamics of the volume of innovative products shipped by industrial organizations

Indicators	The volume of innovative products shipped, million rubles			Specific weight in the total volume of products shipped, as a percentage		
	2017	2018	2019	2017	2018	2019
Industry	13 040.7	16 171.0	15 288.7	17.4	18.6	16.6

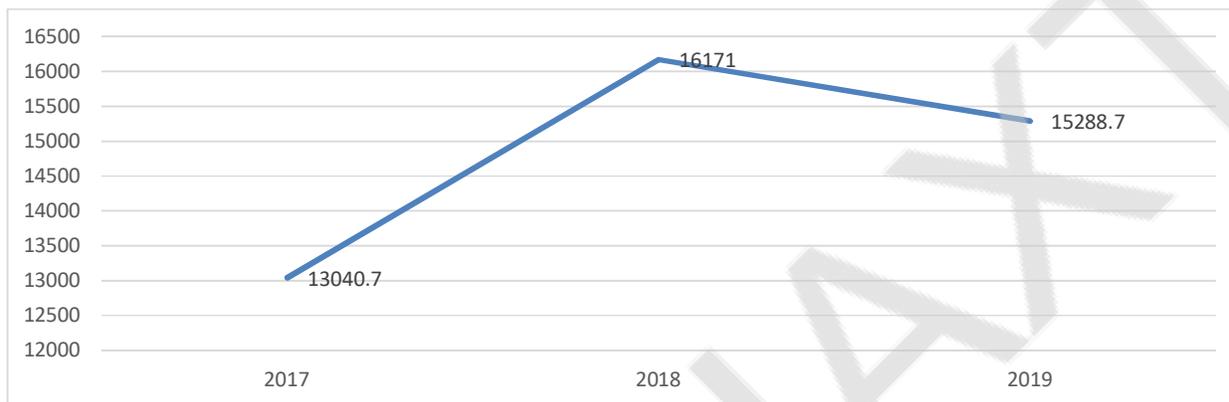


Fig. 3. Dynamics of the volume of innovative products shipped by industrial organizations

The growth rate for three years of the volume of shipped innovative products was 17.2 %, but compared to 2018, it decreased by 5.4 %. This was also reflected in the decrease in the specific weight in the total volume of products shipped.

Innovative products are usually understood as new products for the external market. Products are considered new on the market for no more than three years, after which they lose their competitive qualities.

The main domestic enterprises that produce newly purchased products and have the largest share in the volume of products going to the foreign market are enterprises of the chemical industry, the production of machinery and equipment, and the potash industry.

Any changes in the system of production and sales of products directly affect the volume of innovative products shipped.

The development of innovative products can be hindered by a number of negative factors that affect the level of development of the industry as a whole.

Among them: wear and tear and insufficient working capital, low productivity and high production costs, the presence of a large stock of finished products in warehouses, a low level of quality management system, low competitiveness and other factors that hinder sales in foreign markets.

The negative trend may also be the result of a decrease in the receipts and issuance of patents, data for which are presented in Table 4 and Figure 4.

The number of applications submitted in three years has increased by only 4.3 %, and this figure has increased due to an increase in the number of foreign applicants. The number of issued patents decreased by 33.5 %, and the number of active patents – by 21.9 %.

Table 4. Dynamics of patent application receipts and grant of patents (units)

Indicators	2016	2017	2018
Applications for patenting of inventions were filed, total	521	524	547
National applicants	455	434	454
Foreign applicants	66	90	93
Patents for inventions issued, total	941	850	625
National	892	772	524
Foreign	49	78	101
Valid for patents	2 735	2 414	2 135

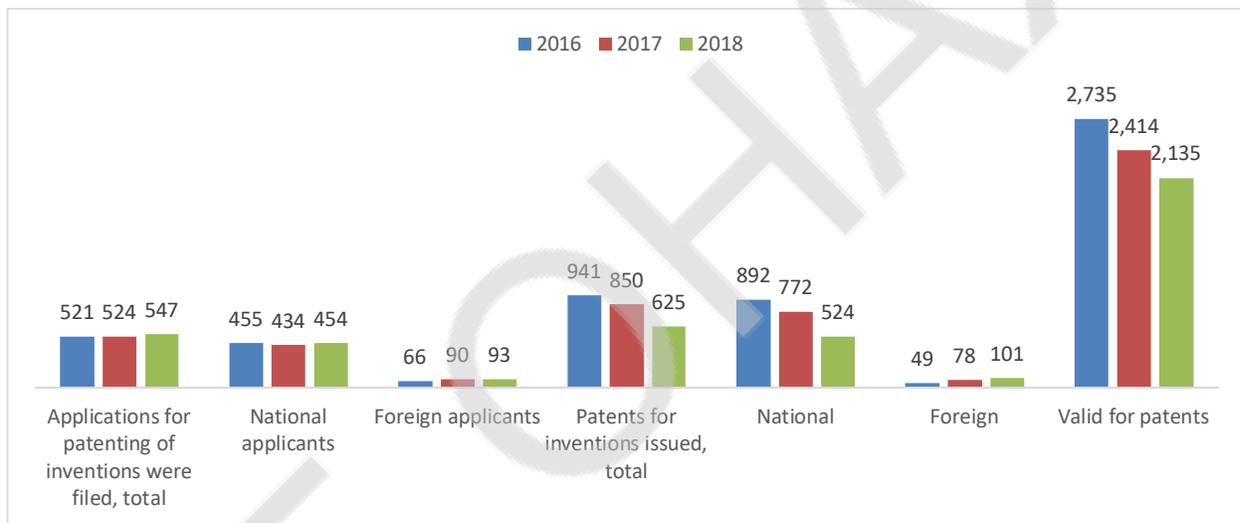


Fig. 4. Dynamics of patent application receipts and grant of patents (units)

The decline is a negative factor of innovation activity, indicating the non-participation of researchers and practitioners in the creation of new inventions, utility models and industrial designs, and also indicates a general low level of innovation activity and, as a result, indicates unfavorable conditions for conducting scientific research.

Low readiness of industrial production for digital transformation and the production of innovative products will be observed until a number of issues are resolved to improve the organization of enterprises and create favorable conditions for the development of innovative activities.

The state of digital transformation in the industrial sector can also be studied on the example of indicators of industrial production in terms of technological efficiency, as well as the gross value added of the largest segment – the manufacturing industry. The dynamics over the past five years allows us to study the degree of integration of advanced technologies and modern principles of business process organization in production.

In the Table 5 and Figure 5 shows the dynamics of the share of manufacturing industry in the total volume of industry by the level of manufacturability, divided into low -, medium - and high-tech industries.

According to the data obtained, the structure of production has changed slightly compared to the base year, so the previous values of the shares remained in low - and high-tech industries.

Table 5. Changes in the structure of industrial production by level of technological efficiency (as a percentage of the year-end)

Indicators	2015	2016	2017	2018	2019
Industry, total	100	100	100	100	100
the manufacturing industry in terms of technological efficiency:					
low-tech manufacturing	33.9	35.1	34.5	32.9	33.9
medium-tech production (low-level)	29.5	27.7	29.5	30.5	29.2
medium-tech production (high-level)	20.8	20.0	21.1	22.4	22.8
high-tech production facilities	2.8	2.9	3.0	2.8	2.8

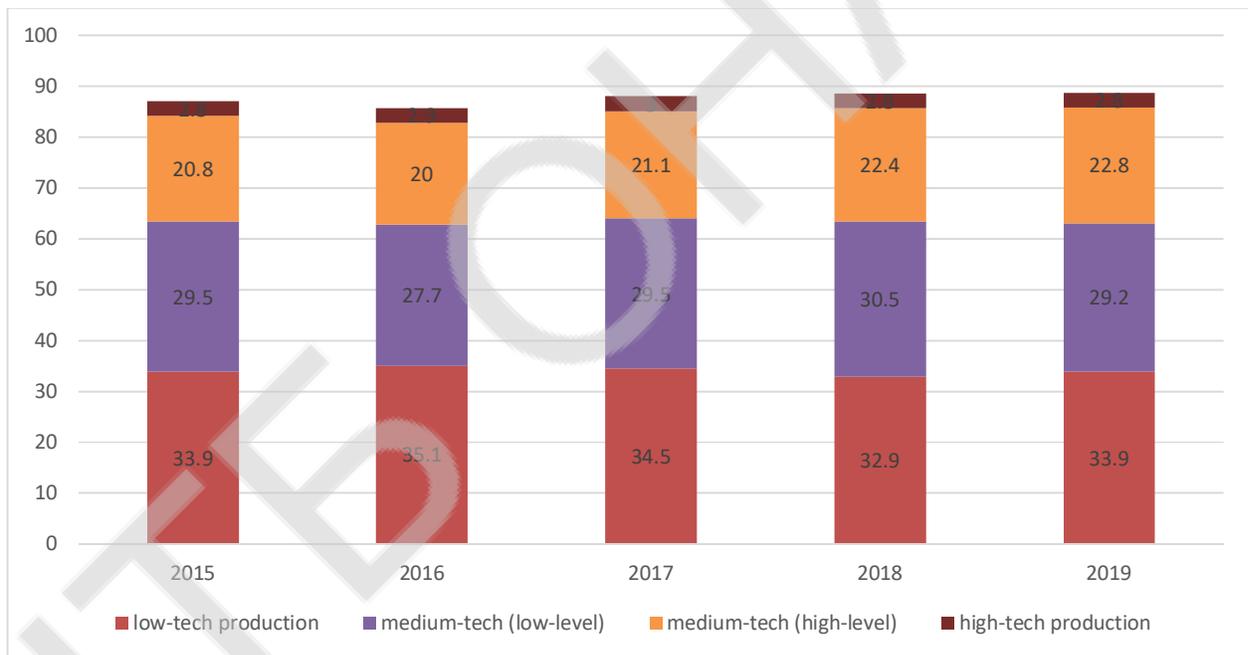


Fig. 5. Changes in the structure of industrial production by level of technological efficiency (as a percentage of the year-end)

It is worth noting that for five years, the share of high-tech industries remains the lowest, while low-tech manufacturing has the highest share. This trend indicates the predominant use of low technologies, low production efficiency and low competitiveness of products belonging to the «traditional» category.

However, the positive dynamics can also be traced in the average level of technological efficiency: low-level medium-tech production decreased by 0.3 percentage points, and high-level production, on the contrary, increased by 2

percentage points by 2019. The share of technological production in the manufacturing industry increased by 1.7 percentage points from 87 % in 2015 to 88.7 % in 2019. This slight increase indicates a slow but steady transition to an increase in industrial production with higher technological efficiency.

An important indicator that characterizes the processes of digital transformation of the economy is the share of gross value added (hereinafter – GVA). Table 6 shows the dynamics of the GVA structure only in the manufacturing industry by the level of manufacturability.

Table 6. Dynamics of the structure of the gross value added of the manufacturing industry by the level of manufacturability (percent)

Indicators	2015	2016	2017	2018	2019
Manufacturing industry	100	100	100	100	100
low-tech manufacturing	35.8	41.9	39.2	39.2	38.3
medium-tech production (low-level)	24.6	23.0	22.8	20.2	21.4
medium-tech production (high-level)	34.9	29.5	32.5	35.3	35.2
high-tech production facilities	4.7	5.6	5.5	5.3	5.1

The state is interested in increasing the GVA as a source of filling the budget with employees, since wages are an integral part of this indicator. Entrepreneurs are interested in profit, which is also included in the GVA, since it creates conditions for expanding production.

High-tech production allows you to create products with the highest added value, thereby creating positive factors for the sale of such goods and services. Compared to 2015, this indicator increased by 0.4 percentage points, taking a share of 5.1 % of the total volume.

Despite the fact that the preservation of low-tech production makes it difficult to switch to more high-tech products, its share in the GVA structure is growing and is the largest (increased by 3.5 percentage points). In terms of the share of gross value added, the second place is occupied by high-tech medium-tech production, the difference between the indicators in 2019 was 3.1 percentage points.

Both in terms of industrial output and the share of gross value added, low-level medium-tech production is declining (by 3.2 percentage points), while high-level production is growing (by 1.3 percentage points).



Fig. 6. Dynamics of the structure of the gross value added of the manufacturing industry by the level of manufacturability (percent)

V. CONCLUSIONS

Thus, it should be concluded that digitalization can be defined as a modern innovative stage of economic development that allows you to rebuild modern production, solving a whole range of important tasks: improving the quality and efficiency of goods and services, improving security and reliability, increasing the flexibility of business processes and consumer response, product launch speed and accelerated information processing.

In the course of the work, the main directions of the digital transformation of the industry through the introduction of new innovative technologies were identified. When further analyzing the data on the dynamics of digital processes in the industry, the following conclusions were made:

Indicators of the volume of production and gross value added of the manufacturing industry are important indicators that demonstrate the development and adaptation of industrial production in the context of economic transformation, the transition to a new level of innovative technologies based on digitalization.

The volume of manufactured and shipped products is growing not only in the context of the national market, but also in the external market, so the products are competitive. This factor can also be attractive for investors and individuals from abroad, which will allow them to finance production.

A general conclusion can be drawn about the growing digital transformation of the industrial sector, which is expressed in an increase in the number of innovation-active organizations and the positive dynamics of production and technological costs.

However, it is worth noting the decline in the rate of shipment of innovative products and the slow transition to high-tech production.

The reflected dynamics of the indicators in general allowed us to draw conclusions about the development prospects and predict further improvement of the indicators, as well as to present the challenges and problem areas in the industries that need to be paid attention to when developing state programs to support the development of digital transformation.

Thus, the total volume of output can serve as a conclusion about the need to follow the global trends of digitalization and develop programs and conditions for creating new sectors of the digital economy, production and service organizations to a new level of work in the context of widespread penetration of electronic and network technologies.

The state needs to support small and medium-sized businesses in the development of the digital economy, take measures that will allow enterprises that have been operating in the market for a long time to adopt and implement global trends.

At the state level have been developed and implemented such programs support the digitalization of «State program for the development of the digital economy and information society for 2016-2020», the Decree № 8 «On the development of the digital economy», the «National strategy for sustainable development–2030», and supported the main subject of the innovative infrastructure, high-tech Park.

Implementation of state programs contributes to the formation and rapid development of high-tech sectors of the economy, strengthening the position of the country in high-tech markets, the competitiveness of traditional sectors of the economy on the basis of their innovation development and the introduction of advanced technologies, the formation of market research products and favorable innovative environment.

The Republic of Belarus has real opportunities for the development of an economy based on knowledge, information and digitalization with the rational and full use of all elements of the national innovation system.

VI. REFERENCES

1. Golovenchik, G. G. (2020). Digital economy: educational and methodological complex (1 electronic opt. disk (CD-ROM)). ISBN 978-985-566-847-4. <https://elib.bsu.by/bitstream/123456789/242300/1/Goloventchik.pdf>.
2. Tatiana Zykova (2017, May 31). Rise of the Machines. The concept of «Industry 4.0» will make the latest technologies familiar. *Ekonomika* № 117(7283). <https://rg.ru/2017/05/31/gleb-nikitin-u-industrii-40-i-reindustrializacii-odni-i-te-zhe-celi.html>.
3. Zinchenko V. V. (2020). Digitalization as a factor of the company's sustainable development. [Master's dissertation, Ural Federal University named after the first President of Russia B. N. Yeltsin]. https://elar.urfu.ru/bitstream/10995/86571/1/m_th_v.v.zinchenko_2020.pdf.
4. National Statistical Committee of the Republic of Belarus (National Statistical portal of the Republic of Belarus). <https://www.belstat.gov.by/en/>.

ANALYSIS OF LIP-SYNC TECHNOLOGIES AND POSSIBLE WAYS TO IMPROVE THEM

Authors: *Isaiko Svitlana, Pohorieltsev Pavlo*

Advisor: *Muntian Iryna*

Professional College of Industrial Automation and Information Technologies
of the Odessa National Academy of Food Technologies (Ukraine)

Abstract. *Lip-sync technology advanced over the years. From hand drawn and synced images of first animated movies, to human live performances on stage, then on screen and finally – using advanced neural networks and variety of other techniques, to automate this process.*

This work covers a bit of a history behind the lip-sync, dives into technologies of present and discusses about future possible growth ways.

The objective of this work is to provide reader with information about past and present techniques of lip-sync.

Keywords: *lip-sync, neural networks, wavelet transform, animation, translation, GAN, LST.*

I. INTRODUCTION

Lip-sync can be described in different ways: a) transferring the voice actor's articulation to a cartoon character; animating the mouth; b) synchronizing the sound and visuals. In this work, we will look at how lip-sync has evolved, what it has come to, and finally, how it might evolve.

II. LITERATURE ANALYSIS

2.1. Lip-sync appears.

The idea of lip-sync, or sound dubbing, emerged almost immediately with the advent of sound movies. It's believed that one of the first films in which songs were recorded separately in the studio, was the legendary American musical Broadway Melody of 1929.

During production, studio executives were unhappy with the sound of one of the musical's most dynamic and striking numbers, Painted Doll. Sound engineer Douglas Shearer suggested a solution that was a real breakthrough - to record the song separately. The actors, in their turn, would perform the number to the already prepared track. This helped preserve the technical complexity and visual impact of the performance without sacrificing quality.

Then in the 50's with the development of cinema, lip-sync became even more popular. The technique was also popular for use in various television programs. The viewers' skepticism of lip-sync slowly subsided and attitudes improved. Its use became common practice.

The normalization of lip-sync and "Scopitons" - music machines invented in France that could play video - also normalized. In the 60's they were installed in bars and cafes. The user could choose the video himself. Most often it was the

performances of artists, in which they sang along with the soundtrack. We can say that these were the first prototypes of music videos. In 1981, a channel with music videos MTV appeared. Partly because of this, lip-sync finally gained a foothold in the music medium. [1]



The use of lip-sync can also be found in animation. The example of Disney's first full-length animated film "Snow White and the Seven Dwarfs" shows that it was a very difficult and long process. More than 100 animators worked on the project for three years, more than a million drawings were made, but the final version of the cartoon included about 250,000 [2].

Due to the fact that nothing stands still and everything evolves, the animation process is now more streamlined. Nowadays, Disney uses computer animation, and the first groundbreaking cartoon was "Rapunzel: The Tangled Story. Animations that evolved from a million drawings came to computer animation, that is, in its own way a breakthrough.



2.2. Neural networks.

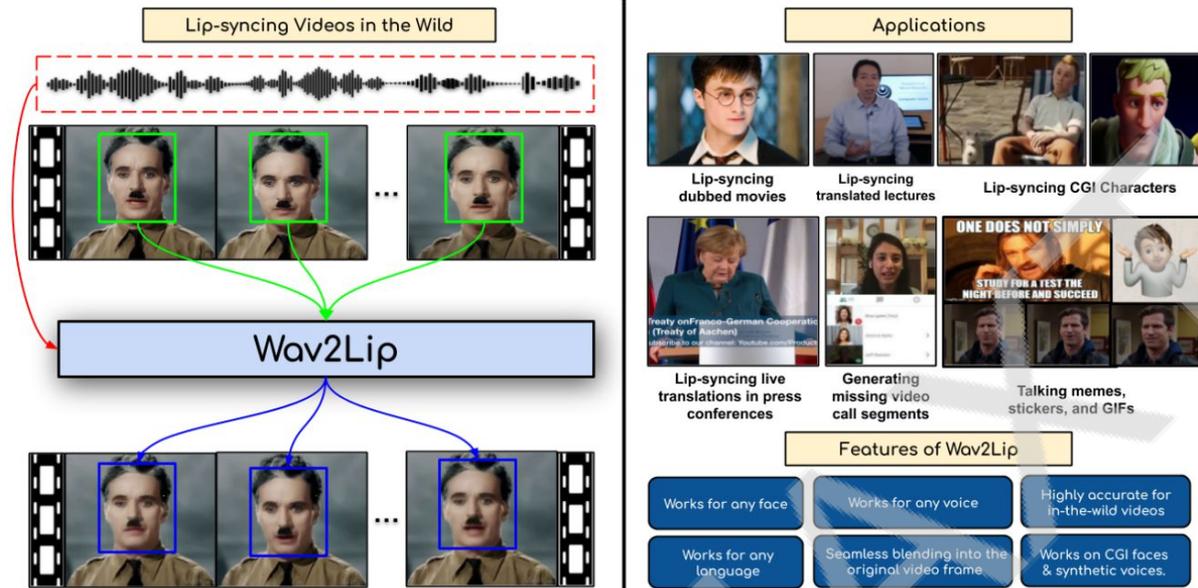
As you may have noticed earlier - lip sync is a complex and painstaking work of actors and animators, but even such material can easily be ruined by mistakes on the part of both the actors and the people behind the voiceover.

Therefore, there was a need for a quality lip sync with minimal cost to the creator, and at the same time - a high quality of the material.

As in many other industries, it is logical to use neural networks to solve such complicated tasks.

So to solve translation problems, a Wav2Lip [3] -like neural network can be used, which analyzes both audio and video signals to find the face of the person speaking and analyzing the sound to find the spoken sounds that have a bright

articulation.



The main difference between this neural network and all the subsequent networks that are specified in this paper is the presence of several neural networks for one common goal, but two different tasks.

So the main task is the phoneme recognition and face generation, but there is also a second network, which analyzes and evaluates the quality of the generated material, concerning the presence of artifacts images, and artifacts generated by the speech apparatus.

The same neural network shows the best results on test material, in the synchronization and quality sections of the generated material. The result becomes a little worse if the second network responsible for evaluating of the material is given more frames to evaluate. LipGAN uses only one frame, and while this makes a more synchronized video, in practice the quality of the articulation plays a greater role for people, taken into consideration that the time errors are not that great. As shown in table, if you increase the number of frames to analyze them from 1 to 5, the accuracy drops from 79% to almost 92%, and the other metrics become better about a third.

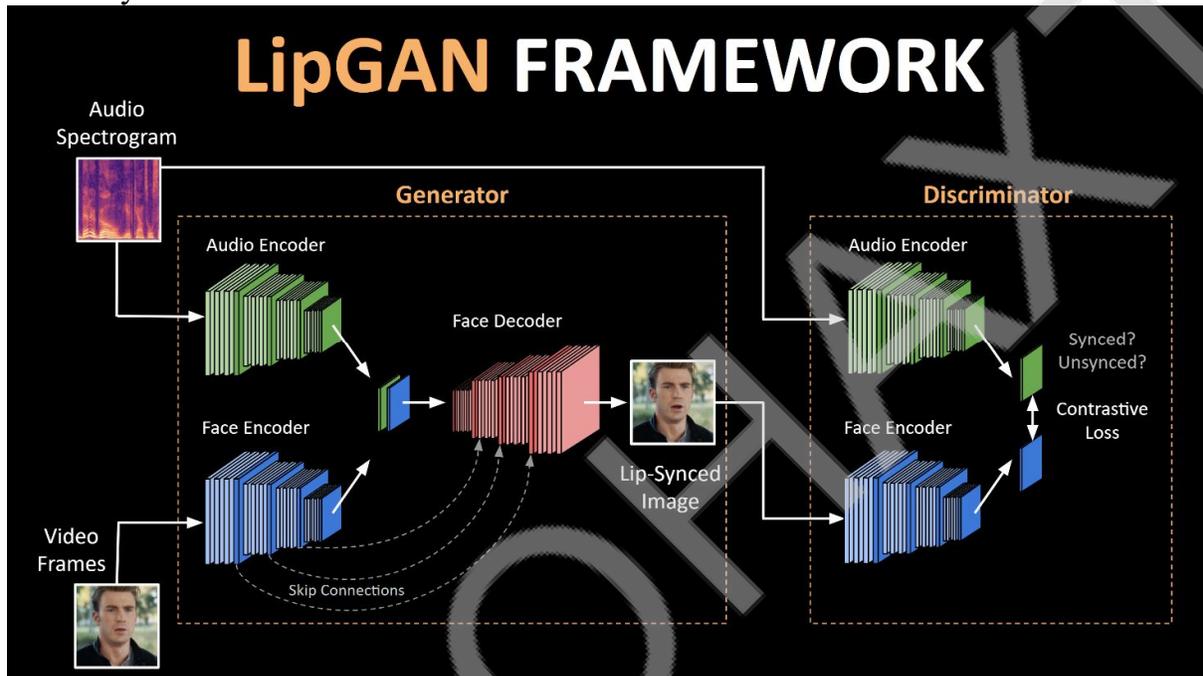
Model	Fine-Tuned?	Off-sync Acc.	LSE-D	LSE-C
LipGAN $Tv=1$	✓	55.6%	10.33	3.19
	×	79.3%	8.583	4.845
$Tv=3$	✓	72.3%	10.14	3.214
	×	87.4%	7.230	6.533
$Tv=5$	✓	73.6%	9.953	3.508
	×	91.6%	6.386	7.789

It is also clear that such a neural network is applicable only to those works where the talking person is a human being.

However, it is not always necessary to translate a work or a speech, for example, if during the training it became necessary to show a historical figure with his quote; earlier you would have to draw a face, or to stick the drawn out lips to the

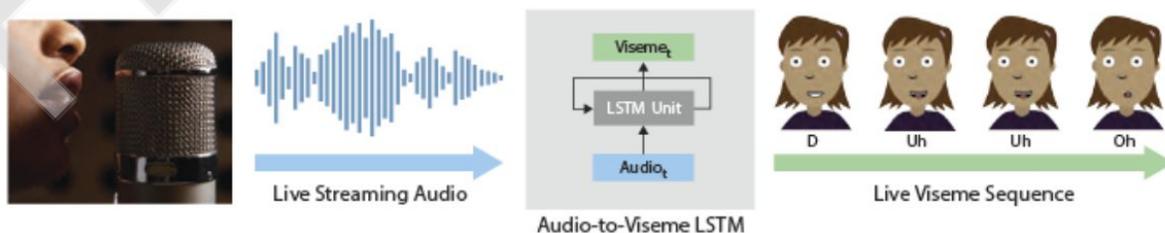
portrait of the personality, which spoils the overall importance of the quote and gives comical effect.

Using LipGAN [4] you can solve this problem, and a few others along the way. LipGAN neural network analyzes the video stream, which can be a static picture and the sound track, and outputs a realistic video with synchronized mouth and sound movements. So, for example, you can "animate" Elizabeth I and give her own quote at history class.



The same technology, according to the authors, will allow game developers to create believable facial animations for the characters of their games with multiple localizations.

However, if you are the author of your own animations or a streamer that doesn't want to show his face, CharacterLipSync [5] can help you. This neural network uses pre-drawn emotions and sounds to create a video stream in real time. It can be used with or without face tracking. Like all neural networks above, it analyzes the audio track, but the video signal here is completely generated without tracking (which is often done during streaming), so the neural network not only analyzes the audio and picks up the mouth for the character it needs now, but also creates a transition between each shift, which manually takes much longer time to do even if all the mouths were placed at once.



One of the phoneme detection techniques can be the use of a wavelet transformations [6], which use neural networks to adjust the coefficients. Using these

transformations, it is possible to find the boundaries of phonemes. A phoneme is the one of the smallest units of speech that make one word different from another word. It is possible to select phoneme from sound library, and this is also a good job for neural networks. Selection of the threshold coefficient shows how small is the difference between the sounds should be in order to differentiate the phonemes. For example, when the coefficient is small, some closely spaced sounds can repeat the previous ones, or form fused phonemes. Therefore, choosing the right ratio is important in order to properly identify the current sound, which will allow us to make a better-looking lip-sync.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of study: Methods of lip-sync (-s), history of lip-sync (-s).

Subject of study: Possible improvements to current lip-sync methods (-a).

Research methods used in this research: analysis of scientific literature and publications, generation of possible ways to improve current methods.

IV. RESULTS

Using the above mentioned methods in combination with, for example, a silent access interface(SAI), it is possible to increase the accuracy of phoneme recognition, which will increase both the quality of their placement due to the fact that the neural network will spend less time searching for them, and the visual quality due to the released time. The same without the use of SAI, but taking advantage of some features of the organism, which were investigated during the creation of such interfaces. Having a picture of proper quality, you can analyze the shifts of the throat during a conversation, or, if possible, analyze the movements of the tongue and changes in the shape of the mouth. The last two tips are much better applicable to people voicing recordings, but the combination with SAI will improve accuracy for all sides of the recording.

We can also point out that with a better machine vision algorithm and more accurate calibration of the estimation for the Wav2Lip network, better generation quality results and more accurate timing can be achieved.

And since the world's technology giants like Nvidia, Samsung and others have recently created products using this technology, there is a possibility of its improvement in the near future.

V. CONCLUSIONS

In conclusion, we can say that lip-sync technology has evolved since the middle of the last century, and continues to evolve to this day. Using modern methods of analysis and synthesis it is possible to create creative works faster and easier than ever before. What a time to be alive!

VI. REFERENCES

1. Julia Zaykova (2020, June 19). [Read Your Lips: A Brief History of Lip-sync. Heroine.](https://heroine.ru/chitaj-po-gubam-kratkaya-istoriya-lipsinka/)
<https://heroine.ru/chitaj-po-gubam-kratkaya-istoriya-lipsinka/>

2.RBK.(2017, December 17). How Disney created the first feature-length cartoon [Video]. YouTube. <https://www.youtube.com/watch?v=-8LiVIufw4k>

3. Prajwal K.R., Rudrabha Mukhopadhyay, Namboodiri V. P., Jawahar C.V. (2020). A Lip Sync Expert Is All You Need for Speech to Lip Generation In the Wild. <https://arxiv.org/pdf/2008.10010.pdf>

4. Prajwal K.R., Rudrabha Mukhopadhyay, Jerin Philip, Abhishek Jha, Vinay Namboodiri, Jawahar C.V. (2019) Towards Automatic Face-to-Face Translation <https://dl.acm.org/doi/10.1145/3343031.3351066>

5. Deepali Aneja, Wilmot Li (2019). Real-Time Lip Sync for Live 2D Animation <https://arxiv.org/pdf/2008.10010.pdf>

6. Medvedev M.S. (2004). Phone segmentation of a speech signal using a wavelet transform <http://www.ict.nsc.ru/ws/YM2004/8614/Medvedev.html>

CYBERSECURITY AS A METHOD OF COMBATING UNAUTHORIZED INFLUENCE IN THE FIELD OF INFORMATION SECURITY

Author: *Ilia Burykin*

Advisor: *Iryna Muntian*

Professional College of Industrial Automation and Information Technologies
of the Odessa National Academy of Food Technologies (Ukraine)

Abstract: *The article describes the main problems, the protection of user's data, methods of combating unauthorized impact in the field of information security. Comparison of antivirus programs.*

This work demonstrates that at the moment there are still many people who can be cyberattacked in obtaining important information.

Keywords: *cybersecurity, password, protection, data, hacking, phishing, antivirus.*

I. INTRODUCTION

Today we cannot imagine our life without technologies. They have flooded the world, helping, entertaining, educating us. Almost everyone has his own smartphone, laptop or computer, which contains confidential information. But many of us make mistakes that can cause to obtaining that information, by third persons. Just then we think of cybersecurity. It has become an important component of our digital lives.

Unfortunately, every year some of the most popular passwords make it to the top are: 123456, 123456789, qwerty and so on (full list[1]). This means that many devices are exposed to threats of hacking and obtaining confidential information. At the same time, everyone knows not to use easy passwords, and many sites and applications are already prompting about the security of the passwords entered, and are trying to prevent logging in with simple passwords. Also one of the most popular ways of obtaining data is phishing, which is a type of Internet scam aimed at gaining

access to confidential user data. Namely, these are fake emails, links from famous brands whose aim is to lead you to a site that is virtually indistinguishable from the original.

Also, don't forget that you may not be a specific user for the hack, but only a bridge to the main target. Protection of a community of people is much more complicated than a simple computer password. You may be endangering the company where you work, your friends, your family. So it's worth to paying attention to your cybersecurity situation, your devices, your accounts, and fix it as soon as possible, get efficient knowledge, and skills in this area.

II. LITERATURE ANALYSIS

Cybersecurity is the activity aimed at systems protection, networks and programs against digital attacks. The purpose of such [cyber attacks is](#) usually to gain access to confidential information, alter or destroy it, extort money of users, or disrupt normal business processes. [5]

Types of cybersecurity threats:

1. *Phishing* is sending of fake emails that look like messages from trusted recipients. The purpose of this type of fraud is to steal sensitive data, such as credit card numbers and credentials. [5] This is the most common type of cyberattack. You can protect yourself from phishing by using user education or a solution that blocks malicious emails. For example, fakebook.com or faebook.com or any other URL that is very similar to the original one. When a user visits such a page, he might not pay attention to the wrong page address because of the similarity of the page address to the original one. And may take this phishing page as a real Facebook login page and use the login form without any fear. [6]

2. *Ransomware* is a type of malware. They extort money by blocking access to files or computer systems until a ransom is paid. [5] Paying a ransom does not guarantee access to the files or that systems will be restored. For example, Petya, an attack using the encryption virus Petya (not to be confused with ExPetr) was detected in 2016, and in 2017 the attack was repeated as GoldenEye. Petya encrypts not the files themselves, but the victim's entire hard drive. It does this by encrypting the MFT table, a database with information about all the files stored on the disk, making it impossible to access the files. Petya gets on the PC "pretending" to be a letter to HR from a candidate for this or that position. The HR professional receives a fake email with a link to Dropbox, which he supposedly can go to and download the "resume." [7]

3. *Malware* is a software designed to gain unauthorized access to a computer or cause damage. [5] Examples of malware:[8]

- viruses;
- macro viruses for Word and Excel;
- boot viruses; script viruses, including batch viruses that infect Windows shells, Java applications, etc;
- keyboard spies;

- password stealing software;
- backdoor Trojans;
- Crimeware is a malware designed to automatize the commission of financial crimes;
- spyware;
- adware and other types of malware

4. *Social engineering* is used by cybercriminals to trick you into revealing sensitive information. They might ask you to make a money transfer or give you access to sensitive data. Social engineering can be combined with any of the above mentioned types of threats to make you more likely to click links, download malware, or trust a malicious source. [5] An example of taking advantage of social engineering (an example of a competent social engineer). An intruder needs to get some amount of money from you. Suppose he found your cell phone and social network. Doing a search on the Internet, he also found that you have a brother. He found his social network and started looking into it to get into his way of thinking. He also found his cell phone for insurance and opened his correspondence, where he found messages with you. He studied them and learned various personal facts about you, which he added to his awareness after looking at your social media. Then a plan was made, which included the following: the abuser calls you late at night and pretends to be your brother, saying that he had his head bashed in and was thrown out somewhere in the street, his phone stolen as well as all the money with the cards (so he justifies why someone else's number is calling you). It is important that he addressed you not by name, but by the nickname he saw in your personal correspondence - this is a very important point. Next, for plausibility, he says, for example, that he was sitting with some of your common friends in a place you often go to - a bar, a club, whatever (photos and geo-references to help). Next, after such a story, he says that the main thing is not to tell his parents! My father has ill health (found out from the hacked dialogue). After that, goes by something like: "Throw me 500 grn for a cab to the hospital" - and gives his card number, saying that there was a kind girl who helped him, only she has no money, but the card. In 8 cases out of 10 after such a competent approach, our fictional sister will transfer the money, and then from her account all the money will be withdrawn, not just 500grn. For a technically competent hacker this is not a problem at all. [3]

5. A *denial-of-service attack* (DoS attack) or distributed denial-of-service attack (DDoS attack) is an attempt to make a computer resource unavailable to its intended users. Another way of understanding DDoS is seeing it as attacks in cloud of computing environment that are growing due to the essential characteristics of cloud computing. Although the means of carrying out, motives for, and targets of a DoS attack may vary, it generally consists of the concerted efforts to prevent an Internet site or service from functioning efficiently, temporarily or indefinitely. According to businesses who participated in an international business security survey, 25% of respondents experienced a DoS attack in 2007 and 16.8% experienced one in 2010. DoS attacks often use bots (or a botnet) to carry out the attack. [9]

Antivirus program (antivirus) - any program for detecting computer viruses, as well as undesirable (considered as malicious) programs in general and restoring files infected (modified) by such programs, as well as for prevention - preventing the infection (modification) of files or the operating system by malicious code. [10]

A cyberattack is a malicious, deliberate attempt of a person or organization to penetrate into the information system of another person or organization. As a rule, by disrupting the victim's network, the hacker seeks to gain profit. [12]

Internet security is a branch of computer security specifically related not only to Internet, often involving browser security and the World Wide Web, but also network security as it applies to other applications or operating systems as a whole. Its objective is to establish rules and measures to use against attacks over the Internet. The Internet represents an insecure channel for exchanging information, which leads to a high risk of intrusion or fraud, such as phishing, online viruses, trojans, worms and more. [11]

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The purpose of the research of this paper: to make people aware of the problem of cybersecurity, in order to reduce the acquisition of confidential information by third persons. The main methods to help you to protect your data.

Object of study: different methods of unauthorized access to data.

Subject of study: various devices (laptop, phone, PC), accounts.

IV. RESULTS

Basic data protection methods:[13]

The currently known general methods for ensuring information security consist of organizational and technical, economic and legal methods. Organizational and technical methods of information security (IS) include:

- information security system (by this we mean a set of measures (internal rules for work with data, regulations of data transfer, access to them, etc.) and technical means (the use of programs and devices to maintain data confidentiality));
- development (creation of new), operation and improvement of existing means of information protection;
- permanent control over the effectiveness of measures taken in the field of information security.

The last point is particularly important. Without an evaluation methodology, it is very difficult to determine the effectiveness of the IS. If the efficiency drops, it is necessary to take urgent make adjustments (this is what permanent control is for).

Information security is always a complex system, all components of which are designed to prevent the leakage of confidential information through technical channels, as well as to prevent unauthorized access to data carriers. Respectively, all this, guarantees the integrity of data during its handling: processing, transmission and storage, which should be carried out compulsory in the legal field. Being competently organized technical measures allow to determine the use of special electronic devices

of unauthorized removal of information, placed both in the premises and in the means of communication.

Stages of IS praision of the enterprise



Fig. 1: Stages of IS provision at the enterprise

The main rules of a successful information security system:

- permanence of the action of the established rules;
- completeness of the measures taken;
- comprehensiveness;
- consistency;
- effectiveness.

To ensure the information security of data stored and transmitted by technical means:

- authentication;
- regulate access to objects;
- encrypting file system;
- keys; secure connections;
- Ipsec are used.

Let's dwell on each of these forms of information security in more detail. All users of operating systems have encountered such an element of information security as login and password. This is authentication. It is the most common way to ensure data security, including information messages stored on a server or PC. Regulating access to objects (folders, files stored in the system) may also be based on authentication, but other algorithms are often used (the system administrator defines rights and privileges, according to which they can either familiarize themselves with certain objects, or, besides familiarization, make changes to them, or even delete them). File encryption (another component of information security) is performed by the EFS system using a key. Speaking of ensuring secure connections, information channels of the "client-client" or "client-server" type are used for this purpose. This method of information security is widely used in the banking sector. And to conclude about IPsec. This is a set of protocols for ensuring information security of data transmitted over IP.

Methods of protection

In practice, several groups of protection methods are used, namely:

- an obstacle on the way of an alleged kidnapper, created by physical and software means;
- control, or influence on the elements of the protected system; masking, or transformation of data, usually by cryptographic means;

- regulation, or the development of regulations and a set of measures designed to encourage users interacting with databases to behave properly;
- constraint, or the creation of such conditions in which the user will be forced to comply with the rules of data handling;
- inducement, or the creation of conditions that motivate users to behave in a proper way.

Each of the methods of information protection is implemented by different categories of means. The main means are organizational and technical.

Organizational protection of information[14]

The development of a set of organizational means of information protection should be in competence of the security service. Most often, security specialists:

- develop internal documentation that establishes the rules for working with computer equipment and confidential information;
- conduct briefings and periodic inspections of personnel;
- initiate the signing of additional agreements to employment contracts that specify the responsibility for the disclosure or misuse of information that has become known through work;
- delineate areas of responsibility to avoid situations where arrays of the most important data are at the disposal of one employee;
- organize work in common workflow programs and make sure that critical files are not stored off network drives;
- implement software products that protect data from being copied or destroyed by any user, including the organization's top management;
- make plans to recover the system in case it fails for any reason.

If a company does not have a dedicated IS service, it can invite to a security an outsourcing specialist. A remote employee will be able to audit the company's IT infrastructure and make recommendations for its protection from external and internal threats. Outsourcing in IS also implies the use of special programs for the protection of corporate information.

Technical means of information protection

The group of technical means of information protection combines hardware and software. The basic are:

- backup and remote storage of the most important data arrays in the computer system - on a regular basis;
- duplication and redundancy of all network subsystems that are important for data preservation;
- Creating the ability to reallocate network resources in cases of malfunction of individual elements;
- ensuring that backup power systems can be used; ensuring safety against fire or water damage of the equipment;
- installation of software that protects databases and other information from unauthorized access.

The set of technical measures also includes measures to ensure the physical

inaccessibility of computer network objects, such as practical methods of equipping the room with cameras and alarms.

Authentication and identification[14]

To prevent unauthorized access to information, methods such as identification and authentication are used.

Identification is a mechanism of assigning one's own unique name or image to a user who interacts with information.

Authentication is a system of ways to verify that a user matches the image to which access is granted.

These tools aim to grant or, conversely, deny access to the data. Authenticity, as a rule, is defined in three ways: program, machine, person. In this case, the object of authentication can be not only a person, but also a technical means (computer, monitor, media) or data. The simplest way of protection is a strong password.

Comparison of antivirus programs

According to AV-Test Labs, 2020 conducted comprehensive anti-virus testing[4]:



The best Windows antivirus software for home users

Manufacturer	Product	AV-TEST-Certificate	Protection (max. 6 pts.)	Performance (max. 6 pts.)	Usability (max. 6 pts.)	Total Score (max. 18 pts.)
AhnLab	V3 Internet Security	TOP	6.0	6.0	5.5	17.5
Avast	Free Antivirus	AV	5.5	5.5	6.0	17.0
AVG	Internet Security	AV	5.5	5.0	6.0	16.5
Avira	Antivirus Pro	TOP	5.5	6.0	6.0	17.5
Bitdefender	Internet Security	TOP	6.0	6.0	5.5	17.5
BullGuard	Internet Security	TOP	6.0	6.0	5.5	17.5
ESET	Smart Security	AV	5.5	5.5	6.0	17.0
F-Secure	SAFE	TOP	6.0	6.0	6.0	18.0
G Data	Internet Security	AV	5.5	5.5	5.0	16.0
K7 Computing	TotalSecurity	AV	5.5	6.0	5.5	17.0
Kaspersky	Internet Security	TOP	5.5	6.0	6.0	17.5
Malwarebytes	Premium	AV	4.0	4.0	4.5	12.5
McAfee	Total Protection	AV	5.0	6.0	6.0	17.0
Microsoft	Defender	AV	5.5	5.5	6.0	17.0
Microworld	eScan internet security suite	AV	3.0	6.0	5.5	14.5
NortonLifeLock	Norton 360	TOP	6.0	5.5	6.0	17.5
PC Matic	PC Matic	AV	5.5	6.0	3.0	14.5
Protected.net	Total AV	AV	5.0	5.0	6.0	16.0
Trend Micro	Internet Security	TOP	6.0	6.0	6.0	18.0
VIPRE Security	AdvancedSecurity	AV	5.5	6.0	5.5	17.0

HOME USERS WINDOWS

AV-TEST: April 2020 www.av-test.org

Fig. 2. Comparison of antivirus programs

The symbols on the graph:

- Protection - the level of antivirus protection.
- Performance - the capacity of the application.

- Usability is a usability parameter, which is evaluated by the level of false positives.

V. CONCLUSIONS

The paper describes the main methods of unauthorized access to data, unfortunately, the list of methods is growing every year, but also cybersecurity does not stand behind and every year is improving. Everyone can increase his own security, the basic requirements:

- Update your software and operating system. Using new software, you get the latest security patches.
- Use antivirus programs. Security solutions, such as Kaspersky Total Security, can help identify and eliminate threats. For maximum security, update your software regularly.
- Use strong passwords. Do not use combinations that are easy to pick or guess.
- Do not open email attachments from unknown senders - they may be infected with malware.
- Do not click on links received in the mail from unknown senders or unknown websites - this is one of the standard ways malware spreads.
- Avoid unsecured Wi-Fi networks in public places, where you are vulnerable to Man-in-the-Middle attacks.

VI. REFERENCES

1. The most popular passwords. [Electronic resource]: Access mode: URL: <https://www.tadviser.ru/index.php/%D0%A1%D1%82%D0%B0%D1%82%D1%8C%D1%8F:%D0%9F%D0%B0%D1%80%D0%BE%D0%BB%D0%B8#.2A2020:.D0.9D.D0.B0.D0.B7.D0.B2.D0.B0.D0.BD.D1.8B.D1.81.D0.B0.D0.BC.D1.8B.D0.B5.D0.BF.D0.BE.D0.BF.D1.83.D0.BB.D1.8F.D1.80.D0.BD.D1.8B.D0.B5.D0.BF.D0.B0.D1.80.D0.BE.D0.BB.D0.B8.D0.B2.2020.D0.B3.D0.BE.D0.B4.D1.83>
2. Internet security [Electronic resource]: Access mode: URL: https://en.wikipedia.org/wiki/Internet_security
3. Example Social Engineering [Electronic resource]: Access mode: URL: <https://emisare.medium.com/socialnaya-ingeneria-9f16e0ba7fa5>
4. AV-Test 2020 [Electronic resource]: Access mode: URL: <https://www.comss.ru/page.php?id=6963>
5. What is cybersecurity? [Electronic resource]: Access mode: URL: https://www.cisco.com/c/ru_ru/products/security/what-is-cybersecurity.html
6. Пример фишинга [Electronic resource]: Access mode: URL: https://hetmanrecovery.com/ru/recovery_news/what-is-phishing-overview-and-examples.htm
7. Example ransomware viruses [Electronic resource]: Access mode: URL: <https://www.kaspersky.ru/resource-center/threats/ransomware-examples>
8. Example malware [Electronic resource]: Access mode: URL: <https://www.kaspersky.ru/resource-center/preemptive-safety/faq>
9. Denial-of-service attack (DoS attack) [Electronic resource]: Access mode: URL: https://en.wikipedia.org/wiki/Denial-of-service_attack#:~:text=In%20computing%2C%20a%20denial%20of,host%20connected%20to%20the%20Internet.

10. Antivirus program [Electronic resource]: Access mode: URL: https://ru.wikipedia.org/wiki/%D0%90%D0%BD%D1%82%D0%B8%D0%B2%D0%B8%D1%80%D1%83%D1%81%D0%BD%D0%B0%D1%8F_%D0%BF%D1%80%D0%BE%D0%B3%D1%80%D0%B0%D0%BC%D0%BC%D0%B0
11. Internet security [Electronic resource]: Access mode: URL: https://en.wikipedia.org/wiki/Internet_security
12. Кибератака [Electronic resource]: Access mode: URL: https://www.cisco.com/c/ru_ru/products/security/common-cyberattacks.html
13. Basic methods of data protection [Electronic resource]: Access mode: URL: <https://searchinform.ru/analitika-v-oblasti-ib/Issledovaniya-v-oblasti-ib/metody-obespecheniya-informatsionnoj-bezopasnosti/>
14. Organizational means of information protection [Electronic resource]: Access mode: URL: <https://searchinform.ru/informatsionnaya-bezopasnost/zaschita-informatsii/sposoby-zaschity-informatsii/>

SIMULATION OF MOTION OF AN UNMANNED AERIAL VEHICLE FOR MEASURING PURPOSES AND PROTOTYPING OF ITS KINEMATIC DIAGRAM

Author: *Oh Suchan*

Advisor: *Leshkevich S.V.*

Belarus State University (Belarus)

***Abstract.** The work is devoted to the development of an unmanned aerial vehicle, loaded with optical and radio measuring equipment, whose task is to identify and correct manufacturing defects in parts of wide-aperture antennas. The aim of the work is to create a simple, relatively autonomous aircraft with satisfactory aerodynamic qualities, the efficiency of which is ensured through the use of the latest achievements in electronics and radio communications. As the basis of the UAV, the Rogallo wing was used. To control the flight, a robot of the SCARA type was used, which ensured the parallel displacement of the steering trapezoid in the horizontal plane.*

***Keywords:** unmanned aerial vehicle, flight control system, SCARA, Rogallo wing, microcontroller.*

I. INTRODUCTION

In areas such as space communications and radio astronomy, the received signals are extremely weak due to the large distances, so large apertures are needed to obtain sufficient signal energy. Typically a large aperture is implemented as a massive direct focus parabolic antenna that rotates mechanically. This somewhat outdated antenna architecture limits the use of parabolic antennas for many other applications. A more efficient antenna system design can improve the performance of all communication systems. With an increase in the aperture dimensions of the

mirrors and the transition to higher frequency ranges, the requirements for the accuracy of manufacturing the shape of the mirrors increase significantly, since the effect of wind and temperature deformations on it increases. At the same time, to lighten the weight and reduce the windage of structures, mesh antennas are often used, the mirrors of which have a relatively low rigidity. Ultimately, the deviation of the mirror shape from the theoretical profile reduces the efficiency of the antenna system. Also, external factors that reduce efficiency include random phase errors that occur when radio waves propagate through an inhomogeneous atmosphere. The solution to these problems is possible through the use of adaptive phased antenna arrays, by analogy with optics, where adaptive systems have long and successfully been used to compensate for phase distortions of a signal in the atmosphere and to increase the resolution limit of optical systems. When creating an antenna, it is necessary to quickly carry out antenna measurements, and this is convenient using an unmanned aerial vehicle (UAV). The aim of the work is to create a simple, relatively autonomous aircraft with satisfactory aerodynamic qualities, the efficiency of which is ensured through the use of the latest achievements in electronics and radio communications. When performing the work, it is supposed to solve the following tasks: to simulate and test the device.



Fig. 1. Wide-aperture direct focus parabolic antenna.

II. UNMANNED AERIAL VEHICLE

2.1. Creation of UAV measuring purpose

All unmanned aerial vehicles (UAVs) can be roughly divided into 2 classes - helicopter-like (or copters) and aircraft-like. Each of these classes has its own merits [1,2]:

- the aircraft-like UAV has superiority in speed, duration and flight range, simpler design and control systems;
- helicopter-type vehicles are capable of hovering in the air and do not require much space to perform a maneuver.

For work, a variant of an aircraft-like UAV was chosen (Rogallo wing, balance glider or delta-flying), which will have all the advantages of aircraft-like UAVs. With a sufficiently high rigidity and load capacity, it is easy to manufacture, which allows it to be assembled and tested as quickly as possible. The principle of flight control is based on displacement of the center of mass relative to the suspension point to create a roll in the desired direction and, due to this, turn the aircraft and change the angle of attack to climb or descend. The UAV wing maintains its shape only due to the incoming air flow. In flight, its surface takes the form of two conical surfaces aligned at the top. It is controlled by moving the mass of the load relative to the steering linkage, rigidly connected to the frame (balance control method).



Fig. 2. UAV model.

2.2. UAV design

The prototype of the design is a hang-glider [3] - a motorized aircraft with a flexible delta wing and balance control, equipped with a landing gear. It is a load-bearing frame (usually three duralumin pipes connected at the front point), forming a fan in the horizontal plane with an angle of 90-140 degrees, covered with a light, but dense and durable synthetic fabric. A motor with a propeller and a trolley are suspended from the central tube at a certain place located near the center of mass of

the apparatus. The device is controlled by means of a trapezium, the design of which consists of three pipes, in the front view it is a triangle with a horizontal base, fixed in space with guy wires (Fig. 2).

2.3. Flight control system

The flight control system is based on the interaction of a set of aircraft surfaces associated with control devices and mechanisms (electronic computing, electrical, mechanical) that ensure the selection and maintenance of the direction of flight of an aircraft (unmanned aerial vehicle). The block diagram of the system is shown in Figure 3.

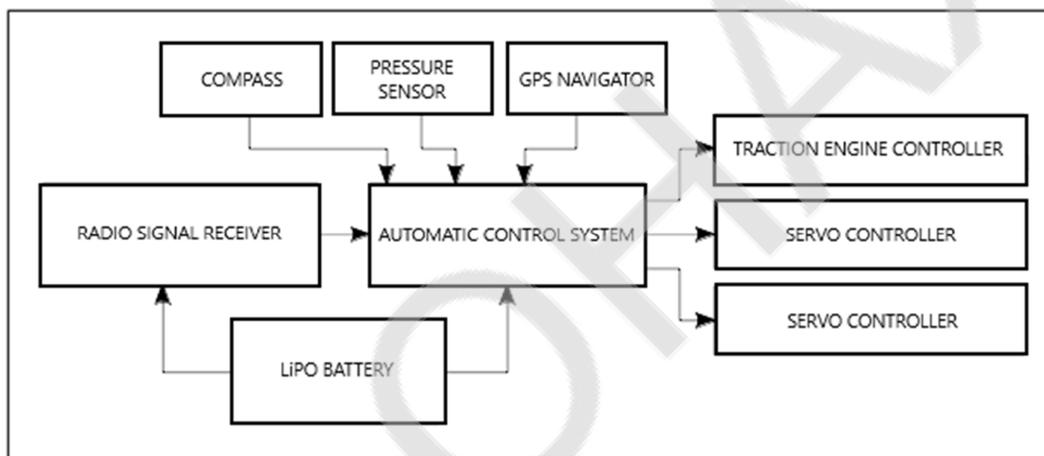


Fig. 3. Block diagram of the flight control system.

The block diagram shows the main components of the UAV complex and their interconnection. Along with the main object of the complex - the automatic control system, which ensures the autonomy of the flight of the aircraft, the on-board system of the aircraft also includes:

- radio signal receiver that receives a transmitter signal for manual control of the apparatus;
- motor and servo controllers that accept a pulse width modulation (PWM) input from the control system and set the target mode for each motor;
- lithium polymer (LIPO) battery for powering motors and DC-DC converters built into the motor controllers, for powering the control system and radio signal receiver.

III. UAV MODELING

3.1. SCARA – type robot

To control the glider, a parallel displacement of the steering linkage in the horizontal plane is required. The two degrees of freedom required for this can be provided by a SCARA robot [4], the kinematic diagram of which is shown in Figure 4.

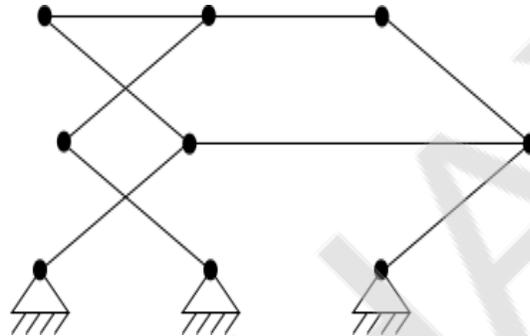


Fig. 4. Kinematic diagram of a SCARA-type robot, which should provide parallel displacement of the steering linkage in the horizontal plane.

The entire mechanism can be flat-mounted. It is lightweight and takes up little space. Modern SCARA robots provide very high travel speeds, which is an undoubted advantage for the aircraft in question. In addition, SCARA mechanics are characterized by high repeatability of movement results without changing accuracy. The load (in our case it will be basically a battery on a trolley) is shown in Figure 4 as a fulcrum. Simultaneous movement of two servos in the same direction allows the load to be deflected from the point of application of the lifting force to the left/right, creating a roll, and movement in opposite directions deflects the load forward / backward, allowing to decrease/gain flight altitude accordingly. This control option involves securing and deflecting the load using a lever arm. At the same time, transferring to the computing device the distance by which the load should deflect in the plane, we actually solve the inverse problem of kinematics, which consists in finding the angles of rotation of the joints of the manipulator for a given kinematic diagram and a given position in space of all elements of the manipulator.

The model of the SCARA robot is shown in Figure 5. The mechanism consists of two 2 independent servo drives that control the system of levers, interconnected so that the structure is rigid in the working plane and the parallel movement of the lever connected to the steering link is maintained. The servos are controlled by a PWM signal from the controller.

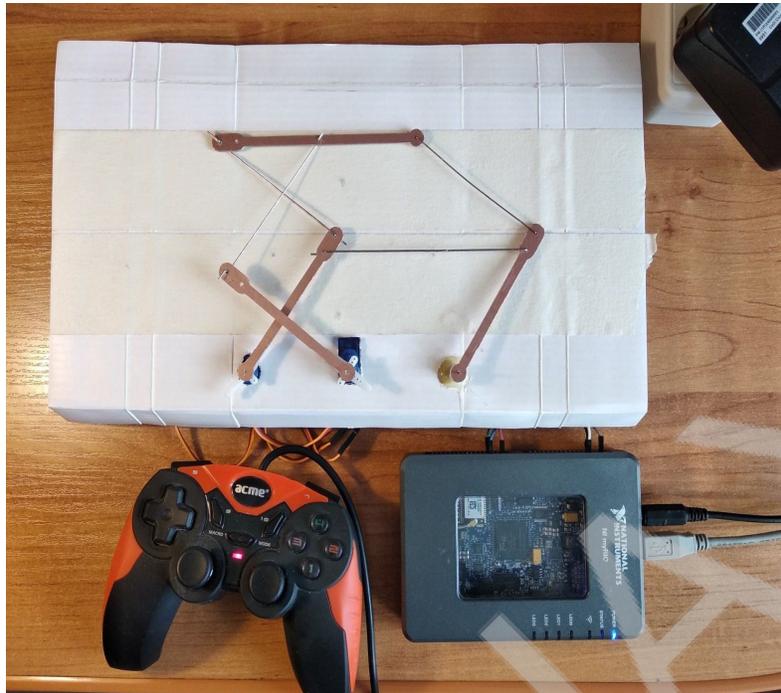


Fig. 5. SCARA robot model for flight control system.

3.2. Microcontroller

A microcontroller plays for the automatic control system. This work uses the NanoPi Neo Core2 microcontroller. The mini single board computer NanoPi Neo Core2 is an alternative to the Nano Pi Neo2 that acts like a processor board with pin-headers. In addition, NEO Core2 can have optional on-board eMMC flash and ESD protection for connectors and ports, which is especially preferable for industrial users. NanoPi NEO2 is as small as a cookie but faster than the RaspberryPi. Compared to NanoPi NEO2, NanoPi NEO Core2 performs more reliably with much less overheating. It is a good platform for IoT applications, monitoring systems, intelligent control systems, cluster computing and AI applications [5].

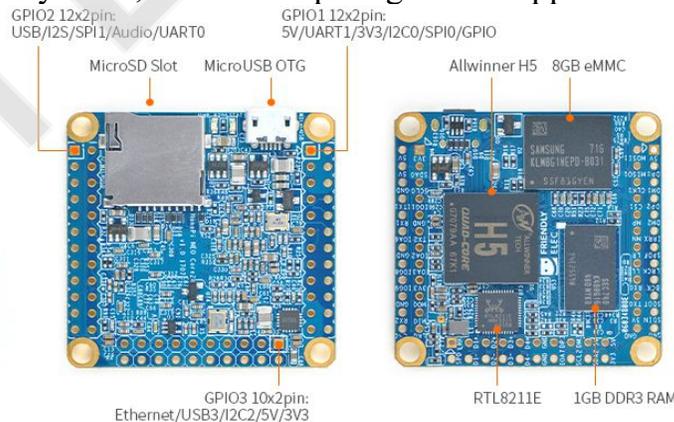


Fig. 6. NanoPi Neo Core2 layout.

Also, the main advantage of the NanoPi Neo Core 2 is its size - 40 x 40 mm, which essentially fits into a UAV.

From Figure 3, we connect the microprocessor to other used devices. Figure 7 shows the connection diagram.

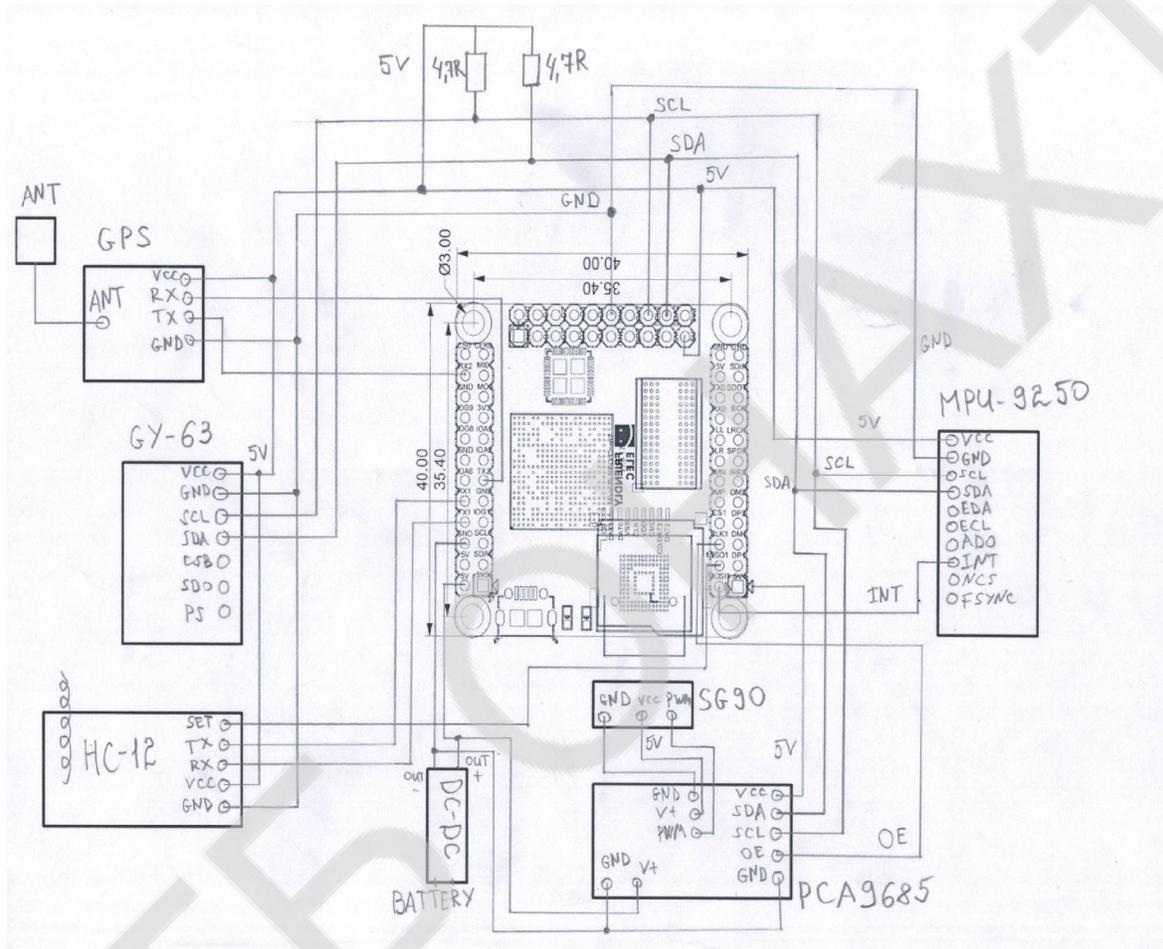


Fig. 7. Wiring diagram of the microcontroller NanoPi Neo Core2 with other used devices.

List of other devices used:

- PCA9685 - 16-Channel 12-bit PWM/Servo Driver. With the help of a PWM controller, you can control the brightness of LEDs, servos, and other devices where a PWM signal is used as a control signal. The PWM/Servo Driver uses I2C-bus;
- MPU9250 – 3-axis accelerometer & gyroscope and magnetometer sensor module, designed to measure the position of the UAV;
- GY-63 – high performance pressure and temperature sensor module with I2C and SPI interface, designed to measure the height of the UAV;

- HC-12 – 100mW multi-channel wireless transceiver, used for communication between two microcontrollers, computers at a distance of up to a 1 kilometer;
- GPS(GY-NEO6MV2) – GPS module with antenna, designed for UAV navigation through a computer;
- SG90 – servo, controlled like a lever, left/right, creating a roll for the UAV;
- DC – DC – converter that steps down 7 V (from batteries) to 5 V to power all devices at the output of the converter.

IV. RESULTS

The result of the connection diagram of the NanoPi Neo Core2 microcontroller with other used devices is shown in Figure 8.

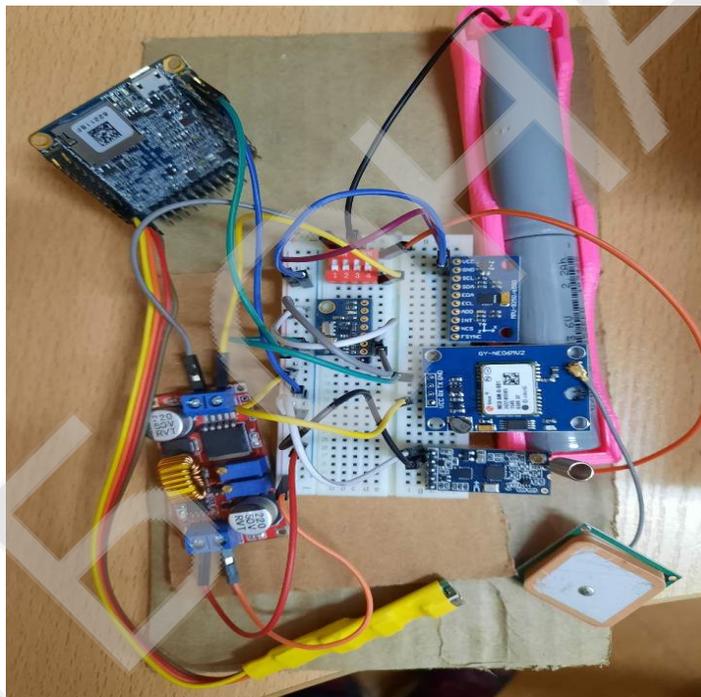


Fig. 8. The result of the connection diagram of the NanoPi Neo Core2 microcontroller with other used devices.

V. CONCLUSIONS

A Rogallo wing was used as the basis for the UAV, and a SCARA-type robot was used for flight control, which provided a parallel displacement of the steering trapezoid in the horizontal plane. This device will be able to automate antenna measurements and will contribute to the creation of more efficient designs of wide-

aperture antenna systems that will increase the performance of space communication systems.

This device will be designed to perform rural work related to measuring the parameters of wide-aperture antennas and research work related to their development.

VI. REFERENCES

1. Miriam McNabb (2016, April 08). *Changing Forecasts: The Drone Industry Surprise*. DroneLife. <https://dronelife.com/2016/04/08/comparing-drone-industry-forecasts/>
2. Wikipedia (2021, January 27). *Unmanned Aerial Vehicle*. https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle
3. Ordodi Marton (1984). *Hang gliding*. Fly-history. <http://fly-history.ru/books/item/f00/s00/z0000012/index.shtml>
4. Richard Vaughn (2013, December 02). *The difference between Cartesian, Six-Axis, and SCARA robots*. MachineDesign. <https://www.machinedesign.com/mechanical-motion-systems/article/21831692/the-difference-between-cartesian-sixaxis-and-scara-robots>
5. Wikipedia (2019, November 07). *NanoPi Neo Core2*. https://wiki.friendlyarm.com/wiki/index.php/NanoPi_NEO_Core2

DEVELOPMENT OF ELECTRONIC APPLICATION FOR RENDERING OF BEZIER CURVES

Author: *Andrii Kurhanskyi*

Advisor: *Nadiia Olefirenko*

H. S. Skovoroda Kharkiv National Pedagogic University (Ukraine)

Abstract. *The work is devoted to the development of a program for rendering one of the types of parametric curves - Bezier curves. These curves have already become an important part of computer design. In the course of the work, the author developed an electronic application using the C++ / CLI programming language. This app helps to demonstrate the process of rendering a Bezier curve. The paper shows the historical and mathematical aspects of the topic, talks about writing code and using Bezier curves.*

Key words. *Bezier curves, de Casteljau algorithm, development, electronic application, C++/CLI, Windows Forms, GUI.*

I. INTRODUCTION

Bezier curves have influenced computer graphics a lot. They are in almost every computer graphics processor. But none of them can show us the process of rendering Bezier curves, which is a very interesting process, especially for students of a secondary school.

The purpose of work is to develop electronic application for demonstrating the process of rendering Bezier curves. For this purpose, we offer to use the geometric

interpretation of recursive de Casteljau algorithm in algorithmic part of work, the Visual C++/CLI 17 WinForms on platform .NET Framework v.4.7.2. with SDK v.10.0 as hard tools for development of the application and Microsoft Visual Studio 2019 Community as IDE.

II. LITERATURE ANALYSIS

2.1 History of creating of Bezier curves

In order to solve CAD/CAM mathematical problems, many solutions have been offered, each adapted to specific matters.

Around 1960, designers of stamped parts, that is, car-body panels, used french curves and sweeps, but in fact, the final standard was the "master model," the shape of which, for many valid reasons, could not coincide with the curves traced on the drawing board. This resulted in discussions, arguments, haggling, retouches, expenses, and delay. Obviously, no significant improvement could be expected so long as a method was not devised that could prove an accurate, complete, and undisputable definition of freeform shapes.

Computing and numerical control (NC), at that time, had made great progress, and it was certain that only numbers, transmitted from drawing office to tool drawing office, manufacturing, patternshop, and inspection could provide an answer; of course, drawings would remain necessary, but they would only be explanatory, their accuracy having no importance, and numbers being the only and final definition.

Certainly, no system could be devised without the help of mathematics—yet designers, who would be in charge of operating it, had a good knowledge of geometry, especially descriptive geometry, but no basic training in algebra or analysis.

However, in the 1960s a mathematician and engineer named Pierre Bezier changed everything with his newly developed CAGD tool called UNISURF. This new software allowed designers to draw smooth looking curves on a computer screen, and used less physical storage space for design materials.

In France, at that time, very little was known about the work performed in the American aircraft industry; the papers from James Ferguson were not much displayed before 1964; Citroen was secretive about the results obtained by Paul de Casteljau, and the famous technical report MAC-TR-41 (by S. A. Coons) did not appear before 1967; The works of W. Gordon and R. Riesenfeld were printed in 1974.

At the beginning, the idea of UNISURF was oriented toward geometry rather than analysis, but with the idea that every datum should be exclusively expressed by numbers.

2.2 Usage of Bezier curves

Bezier curves are widely used in computer graphics to model smooth curves, in animation to create two-dimensional and three-dimensional paths for moving objects and in fonts for drawing curved shapes.

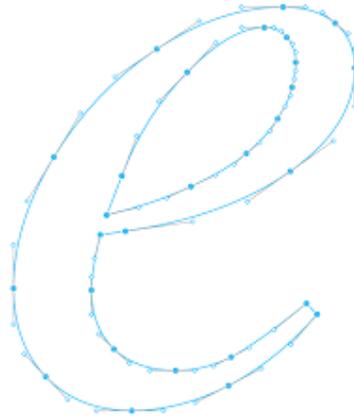


Fig. 1. Letter “e” made with Bezier curve



Fig. 2. In game “Angry birds” path of fly is Bezier curve

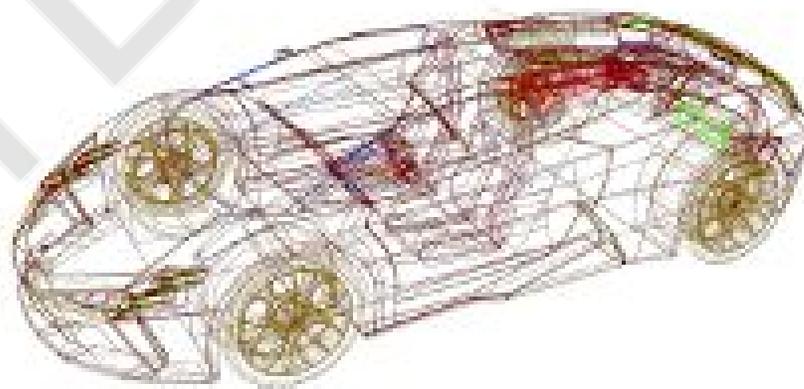


Fig. 3. Model of a sport car, designed with Bezier curves

2.3. Mathematical basics of building of Bezier curves

Bezier began with the idea that any point $p(u)$ on a curve segment should be given by an equation such as the following:

$$p(u) = \sum_{i=0}^n p_i f_i(u) \quad (1)$$

where $0 \leq u \leq 1$, and the vectors p_i are the control points.

The $n + 1$ functions, that is the $f_i(u)$, must produce a curve that has certain well-defined characteristics. Here are some of the most important ones:

1. The curve must start on the first control point, p_0 , and end on the last, p_n . Mathematically, we say that the functions must interpolate these two points.

2. The curve must be tangent to the line given by $p_i - p_0$ at p_0 and to $p_n - p_{n-1}$ at p_n .

3. The functions $f_i(u)$ must be symmetric with respect to u and $(1 - u)$. This lets us reverse the sequence of control points without changing the shape of the curve.

Other characteristics can be found in more advanced works on this subject.

A family of functions called Bernstein polynomials satisfies these requirements. They are the basis functions of the Bezier curve. (Other curves, such as the NURBS curves, use different, but related, basis functions.) We rewrite Equation 1 using them, so that

$$p(u) = \sum_{i=0}^n p_i B_{i,n}(u) \quad (2)$$

where the basis functions are

$$B_{i,n}(u) = \binom{n}{i} u^i (1 - u)^{n-i} \quad (3)$$

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

Object: Modeling of parametric curves.

Subject: Creating the program for rendering Bezier curves.

Methods of research: In this work were used methods of analysis of literature in this topic, creating of personal electronic application to have dynamic process of rendering Bezier curves for any amount points build curve of needed power, even if hull is two-dimensional projection of three-dimensional geometric solid.

IV. RESULTS

4.1. Development of application's graphical user interface

First of all, GUI (Graphical User Interface) should have picture box to opportunity enter points and display process of rendering of Bezier curves, also interface should have two buttons: "Build" and "Clear". When someone press button "Build" after entering random amount of points program has to demonstrate process of building of Bezier curves with given parameters, this button erases additional lines which should be changed for every frame. And button "Clear" has to complete options which have shown in its name – clear workspace, it can be released with filling workspace with white color.

However, it is possible to add another one button – "Build with lines", that is similar to button "Build" but differ from first button this one does not erase additional

lines, thanks to this process of rendering goes easily than such process in case of pressing button “Build”.

All buttons are included in control panel. This component of interface also contains label for demonstrating amount of points which were entered in picture box with pressing of left mouse button.

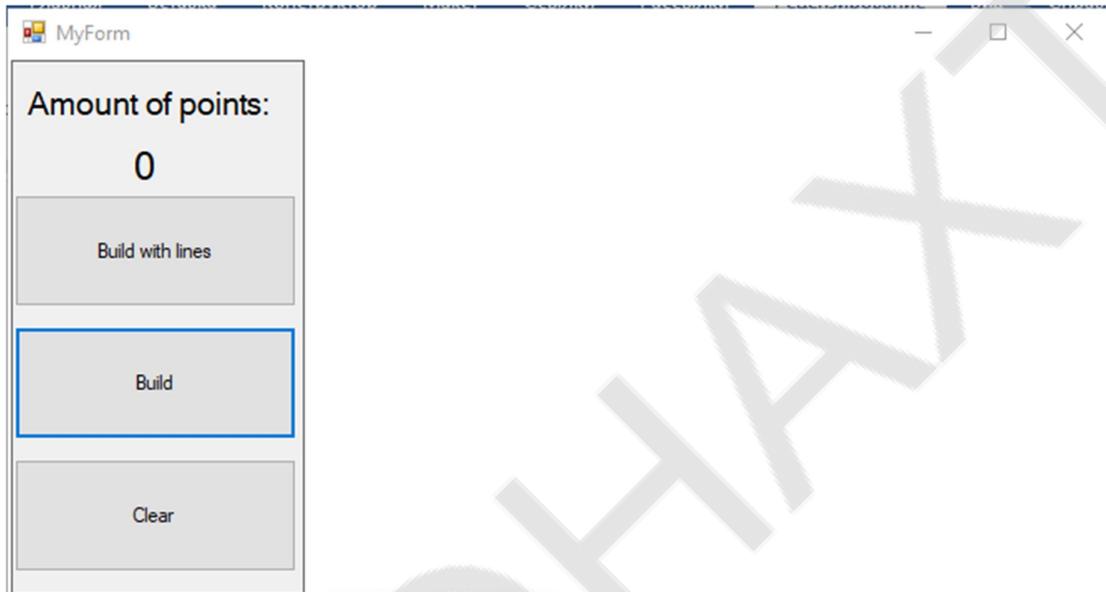


Fig. 4. View of program’s GUI

Figure 1 shows graphical user interface when user has just opened program. All elements that included in window. It is possible to resize window and make in full screen size. Figure 2 demonstrates that all elements are extendable to fit of the window size.

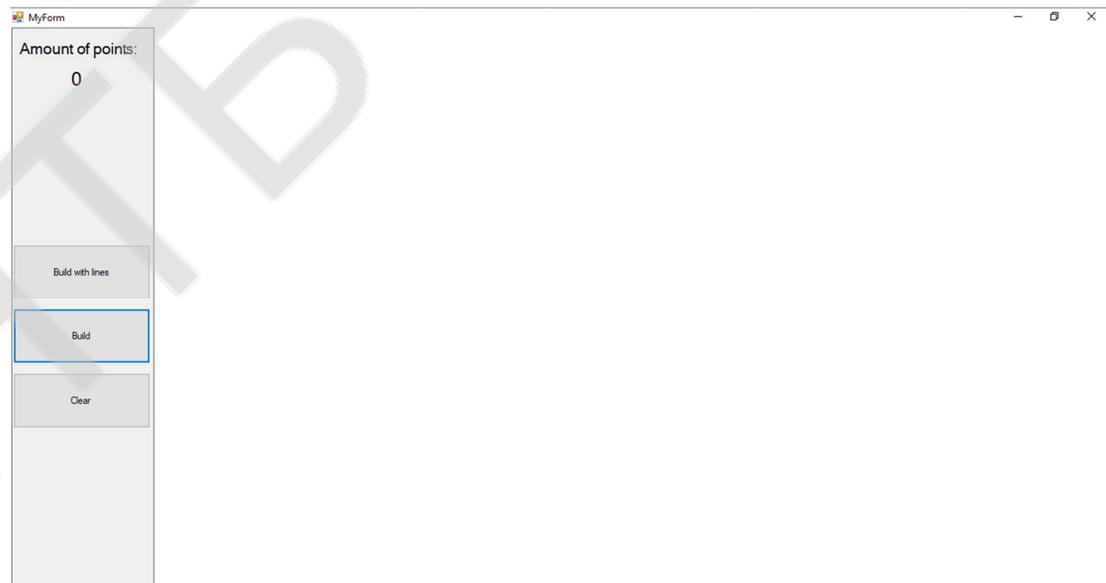


Fig. 5. Fullscreen view of program’s GUI

4.2. Development of program structure

In modern programming practice, it's desirable to use object-oriented style of coding. It helps to protect data from changing outside of class body.

Main file of project initializes window (form), runs it, contains including of headers and commands to use system namespaces.

Source code of MyForm.h contains namespace which has class to initialize all components of form, also this class defines private void methods to rule the behavior of users' actions. But hole namespace does not define constants for window settings, it makes in header which goes with IDE - windows.h.

Class includes such methods as "BuildLine1", "Newcord", "BuildLine2", "FindBezier", "DrawBezier", "DrawEllipses", "workofbuttonbuild", "workofbuttonbuildwithlines", "button1_Click", "button3_Click" and "pictureBox1_MouseDown".

4.3. Development of basic program's class methods

```
private: void BuildLine1() {
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode =
System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    Pen^ pen2 = gnew Pen(Brushes::Black);
    pen2->Width = 2.0f;
    for (int i = 1; i < points; ++i) {
        Point a, b;
        a.X = cordx[i - 1];
        a.Y = cordy[i - 1];
        b.X = cordx[i];
        b.Y = cordy[i];
        g->DrawLine(pen2, a, b);
    }
}
```

Listing 1. Source code for method "BuildLine1"

In listing 1 we create private void class method with name "BuildLine1". It has no parameters. Next line creates and initializes descriptor for pictureBox1. After it goes setting of high-quality smoothing mode. Next, we create and initialize pen for drawing and set black color to this one. Set width of pen 2 pixels. And in loop for define structures as point and initialize them, draw line between two points and repeat it for all points (for point we take this one and previous).

```
private: void Newcord(int j, double t) {
    double lambda = t / (1 - t);
    for (int i = 0; i < points-1; ++i) {
        ncordx[j][i] = (ncordx[j][i] + lambda * ncordx[j-1][i + 1]) / (1+lambda);
        ncordy[j][i] = (ncordy[j][i] + lambda * ncordy[j-1][i + 1]) / (1+lambda);
    }
}
```

Listing 2. Source code for method “Newcord”

In listing 2 we create private void class method with name “Newcord”. It has two parameters, number of current iteration and parameter for Bezier curve. Initialize variable lambda as double type for dividing line. Next, divide all lines in given relation.

```
private: void BuildLine2(int j) {
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode =
System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    Pen^ pen2 = gnew Pen(Brushes::Green);
    pen2->Width = 2.0f;
    Point a, b;
    for (int i = 1; i <= points - j; ++i) {
        a.X = ncordx[j][i - 1];
        a.Y = ncordy[j][i - 1];
        b.X = ncordx[j][i];
        b.Y = ncordy[j][i];
        g->DrawLine(pen2, a, b);
    }
}
```

Listing 3. Source code for method “BuildLine2”

In listing 3 we create private void class method with name “BuildLine2”. It has one parameter, number of current iteration. Next line creates and initializes descriptor for pictureBox1. After it goes setting of high-quality smoothing mode. Next, we create and initialize pen for drawing and set black color to this one. Set width of pen 2 pixels. And in loop for define structures as point and initialize them, draw additional line between two points for this iteration and repeat it for all points (for point we take this one and previous).

```
private: void FindBezier(double t) {
    double lambda = t / (1 - t);
    beziercordx.push_back((ncordx[points-1][0] + lambda * ncordx[points-1][1]) / (1
+ lambda));
    beziercordy.push_back((ncordy[points-1][0] + lambda * ncordy[points-1][1]) / (1
+ lambda));
}
```

Listing 4. Source code for method “FindBezier”

In listing 4 we create private void class method with name “FindBezier”. It has one parameter, parameter for Bezier curve. Initialize variable lambda as double type for dividing line. Next, divide all additional lines in given relation to find coordinates of point in Bezier curve.

```
private: void DrawBezier() {
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode =
System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    Pen^ pen1 = gcnew Pen(Brushes::Red, 4);
    Point a, b;
    for (int i = 1; i < beziercordx.size(); ++i) {
        a.X = beziercordx[i - 1];
        a.Y = beziercordy[i - 1];
        b.X = beziercordx[i];
        b.Y = beziercordy[i];
        g->DrawLine(pen1, a, b);
    }
}
```

Listing 5. Source code for method “DrawBezier”

In listing 5 we create private void class method with name “DrawBezier”. It has no parameters. Next line creates and initializes descriptor for pictureBox1. After it goes setting of high-quality smoothing mode. Next, we create and initialize pen for drawing and set black color to this one. Set width of pen 2 pixels. And in loop for define structures as point and initialize them, draw additional line between two points in Bezier curve for this iteration and repeat it for all points (for point we take this one and previous) to draw part or hole Bezier curve.

```
private: void DrawEllipses() {
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode =
System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    Pen^ pen1 = gcnew Pen(Brushes::Black);
    pen1->Width = 5.0f;
    for (int i = 0; i < points; ++i) {
        g->DrawEllipse(pen1, cordx[i], cordy[i], 5, 5);
    }
}
```

Listing 6. Source code for method “DrawEllipses”

In listing 6 we create private void class method with name “DrawEllipses”. It has no parameters. Next line creates and initializes descriptor for pictureBox1. After it goes setting of high-quality smoothing mode. Next, we create and initialize pen for drawing and set black color to this one. Set width of pen 5 pixels. And draws all points entered by user for next iterations.

```

private: void workofbuttonbuild() {
    try {
        if (points < 2) {
            String^ s = "Exception 1: Not enough points. Put at least 2 points";
            throw s;
        }
        if (points > 20) {
            String^ s = "Exception 2: Too much points. Put less points";
            throw s;
        }
        Graphics^ g = pictureBox1->CreateGraphics();
        g->SmoothingMode =
System::Drawing::Drawing2D::SmoothingMode::HighQuality;
        g->Clear(Color::White);
        DrawEllipses();
        BuildLine1();
        ncordx.resize(points);
        ncordy.resize(points);
        for (int i = points; i > 1; --i) {
            ncordx[points - i].resize(i);
            ncordy[points - i].resize(i);
        }
        ncordx[0] = cordx;
        ncordy[0] = cordy;
        ncordx[1] = cordx;
        ncordy[1] = cordy;
        beziercordx.clear();
        beziercordy.clear();
        for (double i = 0.0f; i < 1; i += 0.004) {
            for (int j = 2; j < points; ++j) {
                ncordx[j] = ncordx[j - 1];
                ncordy[j] = ncordy[j - 1];
                Newcord(j, i);
                BuildLine2(j);
            }
            FindBezier(i);
            DrawBezier();
            _sleep(60);
            g->Clear(Color::White);
            DrawEllipses();
            BuildLine1();
        }
        DrawBezier();
    }
    catch (String^ s) {
        MessageBox::Show(s);
    }
}

```

Listing 7. Source code for method “workofbuttonbuild”

In listing 7 we create private void class method with name “workofbuttonbuild”. It has no parameters. We use try – catch construction. In try part we check amount of entered points and throw exceptions to catch part. Next line creates and initializes descriptor for pictureBox1. After it goes setting of high-quality smoothing mode. Next, fill workspace with white color. Call methods “DrawEllipses” and “BuildLine1”. Resize vectors (dynamic arrays) and two-dimensional vectors. Initialize first and second elements of two-dimensional vectors. Clear vector of Bezier curve coordinates. Two loops “for” change elements of vector and call methods “Newcord” and “BuildLine2”. Next, in first loop “for” we call methods “FindBezier”, “DrawBezier”, wait for 60 milliseconds, clear workspace and call methods “DrawEllipses” and “BuildLine1”. After all we call method “DrawBezier”. In catch part we take exception message as pointer to string type and show messagebox with the text of exception.

Method “workofbuttonbuildwithlines” is similar to previous, but it does not clear workspace so all additional lines stay on it.

```
private: System::Void button1_Click(System::Object^ sender, System::EventArgs^ e) {
    th1 = gnew System::Threading::Thread(gnew
System::Threading::ThreadStart(this, &MyForm::workofbuttonbuild));
    th1->Start();
    thc1 = true;
}
```

Listing 8. Source code for method “button1_Click”

In listing 8 we create private void class method with name “button1_Click”. It has standard parameters. We create a new thread to call method “workofbuttonbuild”, next it starts and logical variable is set value true.

Method “button2_Click” work at the same way.

```
private: System::Void button3_Click(System::Object^ sender, System::EventArgs^ e) {
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode = System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    g->Clear(Color::White);
    points = 0;
    label1->Text = points.ToString();
    cordx.clear();
    cordy.clear();
    ncordx.clear();
    ncordy.clear();
    if (thc1) {
        th1->Abort();
        thc1 = false;
    }
    if (thc2) {
        th2->Abort();
        thc2 = false;
    }
}
```

Listing 9. Source code for method “button3_Click”

In listing 9 we create private void class method with name “button3_Click”. It has standard parameters. Next line creates and initializes descriptor for pictureBox1. After goes setting of high-quality smoothing mode. Next, fill workspace with white color, set zero to variable points, change text in label and clear all vectors (dynamic arrays). After that, abort started thread and set false to logical variable.

```
private: System::Void pictureBox1_MouseDown(System::Object^ sender,
System::Windows::Forms::MouseEventArgs^ e) {
    cordx.push_back(e->X);
    cordy.push_back(e->Y);
    Graphics^ g = pictureBox1->CreateGraphics();
    g->SmoothingMode = System::Drawing::Drawing2D::SmoothingMode::HighQuality;
    Pen^ pen1 = gnew Pen(Brushes::Black);
    pen1->Width = 5.0f;
    g->DrawEllipse(pen1, e->X, e->Y, 5, 5);
    points++;
    label1->Text = points.ToString();
    BuildLine1();
}
```

Listing 10. Source code for method “pictureBox1_MouseDown”

In listing 10 we create private void class method with name “BuildLine1”. It has standard parameters. Memorize coordinates of entered points. Next line creates and initializes descriptor for pictureBox1. After goes setting of high-quality smoothing mode. Next, we create and initialize pen for drawing and set black color to this one. Set width of pen 5 pixels. And draws point entered by user. Increment variable points, change label and call method “BuildLine1”.

4.4. Results of application’s work

All pictures in this chapter are screenshots, which were made during it was working. First picture in every row is broken line for building Bezier curve, second – is process of rendering and third - is result.

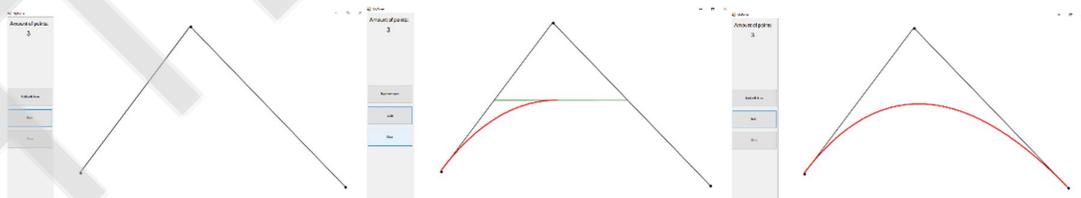


Fig. 6-8. Bezier curve of second power with convex hull

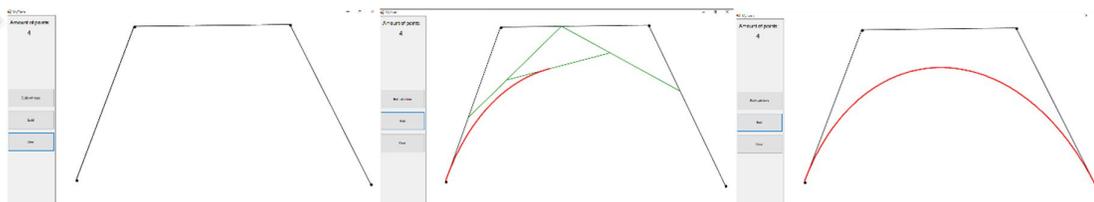


Fig. 9-11. Bezier curve of third power with convex hull

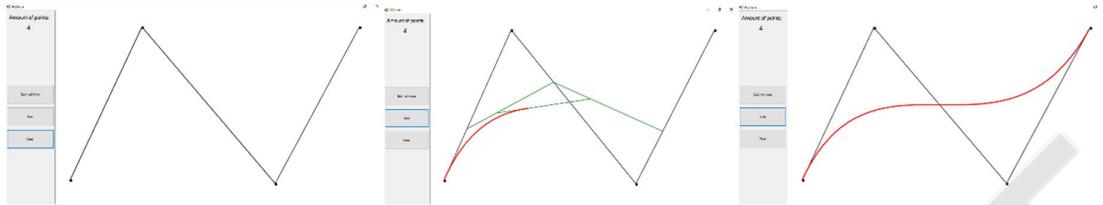


Fig. 12-14. Bezier curve of third power with non-convex hull

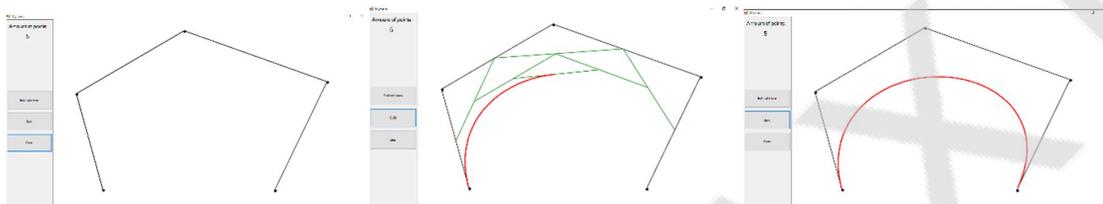


Fig. 15-17. Bezier curve of fourth power with convex hull

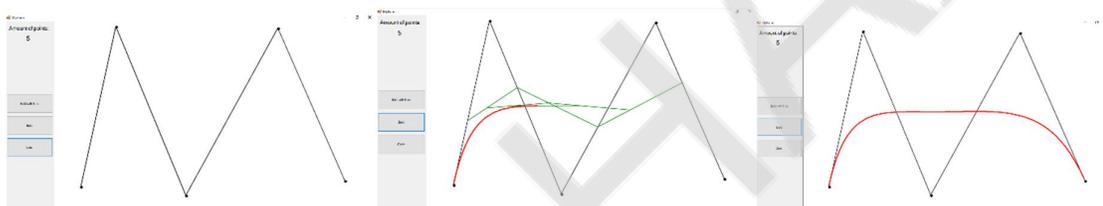


Fig. 18-20. Bezier curve of fourth power with non-convex hull

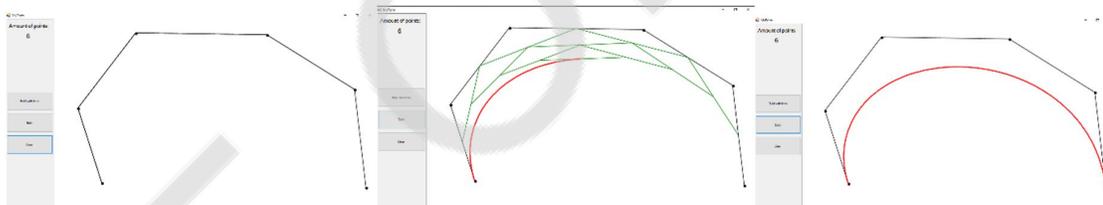


Fig. 21-23. Bezier curve of fifth power with convex hull

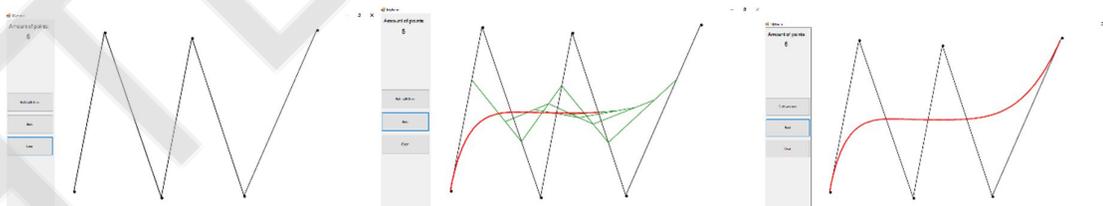


Fig. 24-26. Bezier curve of fifth power with non-convex hull

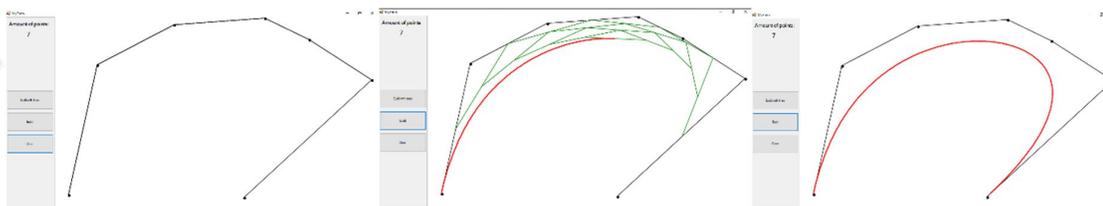


Fig. 27-29. Bezier curve of sixth power with convex hull

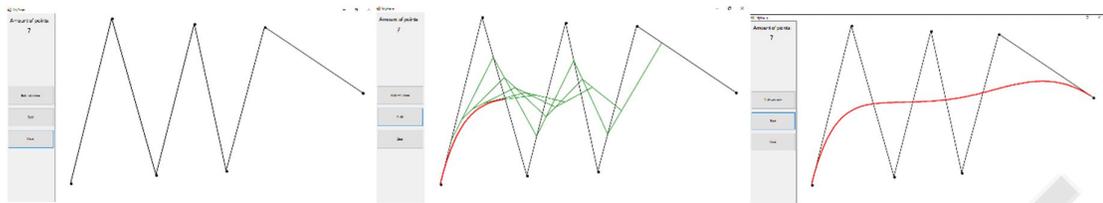


Fig. 30-32. Bezier curve of sixth power with non-convex hull

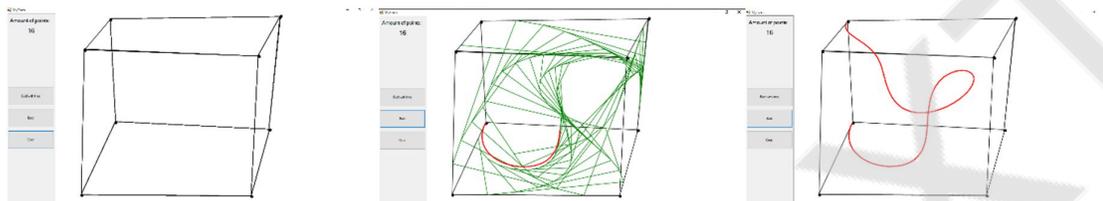


Fig. 33-35. Bezier curve built in hull of 2D projection of 3D cube

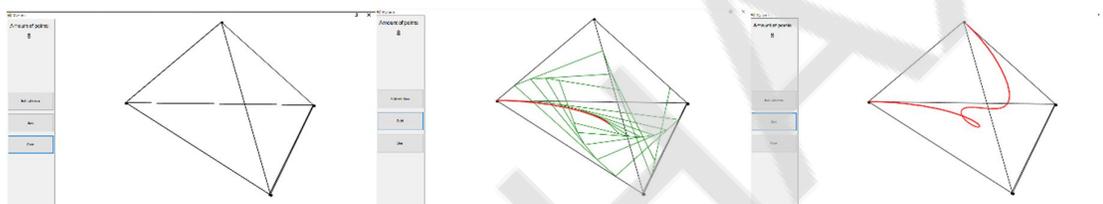


Fig. 36-38. Bezier curve built in hull of 2D projection of 3D pyramid

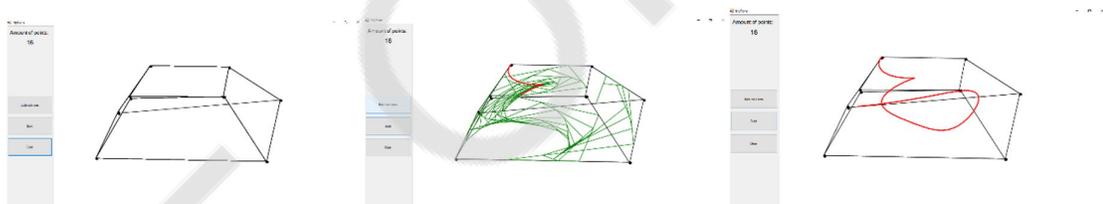


Fig. 39-41. Bezier curve built in hull of 2D projection of 3D truncated pyramid

V. CONCLUSION

Bezier curves are very interesting tool for computer graphics, animation and game design. In this work were invented e-application to show process of rendering this type of parametric curves and told about major historical and mathematical basics and how it possible to use them in life. So, Bezier curves are not just mathematical thing for modeling smooth curves, they became important part of modern graphical design, and most of people face up with these curves everyday when they open modern web-sites, play computer games and even look the weather or cloud drive (sign of cloud developed with Bezier curves).

To upload and try to use this program, go to the link below on GitHub:
<https://github.com/akurganskij/E-application-for-rendering-Bezier-curves>

VI. REFERENCES

1. Gerald Farin. Curves and Surfaces for CAGD A Practical Guide Fifth Edition. Arizona, MORGAN KAUFMAN N PUBLISHERS, 1999. – 499 p.
2. Michael E. Mortenson. Mathematics for computer graphics application. NY, Industrial Press, Inc., 1999. – 354 p.
3. <https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcT3nGmKA-pGWh47OuMUvTKhG7hfTuQbdMG3SQ&usqp=CAU>
4. https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRE-y3IzQO6lqrh5Jv10-FwoPh_0yGK6A3QfQ&usqp=CAU
5. <https://images.huffingtonpost.com/2012-06-08-angryBirds2.png>

INVESTIGATION OF THE INFLUENCE OF EXTERNAL FACTORS ON THE POTENTIAL PERFORMANCE OF A PERSON AT THE COMPUTER AND HIS BRAIN ACTIVITY

Authors: *Aleksandr Marchuk, Yaroslav Davydov*

Advisors: *Liudmyla Vasylieva, Ihor Staskevych*

Donbass State Engineering Academy (Ukraine)

Abstract. *This study aims to create tools to maximize the potential performance of a person at the computer. The effects of mental fatigue on efficiency and, consequently, on productivity is difficult to overestimate. People who work a lot at the computer are particularly prone to high cognitive load and, as a result, loss of motivation and poor performance. In this work, experiments were performed to change the usual parameters of the environment during the working day and investigated their impact on the efficiency of human interaction with the computer and its electrical activity of the brain. The hypothesis of a correlation between electroencephalographic data collected using a portable neurointerface and mental fatigue has been partially confirmed. The created software-hardware system based on the obtained results will be a useful tool for optimizing the working conditions of employees in the IT field and others.*

Keywords: *EEG, programming, mental fatigue, neurointerface, statistic analysis, efficiency.*

I. INTRODUCTION

Due to the technological boom in the last two decades, the percentage of jobs for people who are exposed to cognitive stress on their brain has increased many times, outweighing the percentage of jobs with physical activity. There is a growing demand for high-quality software to solve various problems in our world. At the same time, the profession of a programmer is currently one of the most paid and one

of the most popular in the world. To meet this above-mentioned need, and at the same time make good money, software developers are very often in suboptimal conditions, and do not have any opportunity and time to optimize these conditions.

All this puts developers in a situation where they have to work in a tired state. Software errors can be the result of poor developer performance, which is often a direct consequence of lack of attention or exhaustion, including due to unfavorable working conditions. They try to focus, but due to fatigue, even the simplest tasks take longer time. Most people do not even think about how monotonous work at the computer affects the biophysical and electrophysiological parameters of their body. Very noticeable and important changes can be seen both in the work of the brain, which is expressed by the rhythms of human brain activity, and in the performance of the person himself at the computer, which can be tracked by analyzing interaction with input devices.

Our overall goal of the study is to search for dependencies of human stylometry data, that is, the speed of interaction with a computer, its electrophysiological indicators, various subjective indicators from various factors that can affect a person and his fatigue rate during programming tasks, determining potential methods for predicting the onset of fatigue, creating possible algorithms for improving the potential performance of a person.

We also aim to determine whether there is a correlation between the speed of a person by working at a computer, as an objective indicator for determining the level of his fatigue and the electrical activity of the brain in order to answer the question: "Can the data of the human brain collected by electroencephalography method using a portable neurointerface be considered as an objective indicator for determining the level of mental fatigue of a person?".

II. LITERATURE ANALYSIS

Currently, the human-computer system can be considered as an adaptive system that requires its own study, especially in modern conditions. This system serves human-computer interaction and helps the computer user better interact with various aspects of the computer interface. During the research of a person, as part of an adaptive system, cognitive (measurements of electrical activity of the brain), cardiovascular measurements, and human stylometry measurements can be used, that is, quantitative assessment of the speed and accuracy of human interaction with a computer to assess the functional state of the operator. It is also worth to note that the use of many types of monitoring provides greater accuracy in assessing the human condition than in the case of any measurement separately. One of the promising methods, as noted by researchers such as B. Jap, S. Cheng, and L. Trejo is the use of electrophysiological indicators to assess changes in the functional state of an operator using electroencephalography (EEG) [1-3]. This information is collected through sensors in real time, in an attempt to identify moments of increased demand for the operator's cognitive resources and find a way to bring these resources to a level adequate to the requirements of the task performed by the operator.

In the case of studying the condition of worker who works with computer or computerized systems, it is advisable to use brain-computer interfaces (BCI), the principle of operation of which, for the most part, is based on EEG technology. In their paper, B. Lance and K. McDowell described potential BCI technologies that target communication and other applications. They also focused on possible future applications that will be based on relatively predictable breakthroughs in sensor, analytics, and computing technologies. Also, according to the authors, in the near future, applications that are being developed are likely to be focused on tasks where neural signals can provide information that is difficult or even impossible to obtain using other methods, on tasks where very high accuracy of interpretation of results will not be required (due to a very large number of obstacles that will arise in the near future) and on tasks that will assess the general state of mental fatigue of a person, instead of relying on separate data from different types of cognitive fatigue assessment. The authors also believe that in the near future, applications that will be developed are highly likely to be successful if they target a specific user using calibration or individual classification algorithms, instead of trying to perform work in broad groups or use normative population groups [4].

At the same time, BCI, as just one of the elements of the system that will help a person improve their performance at the workplace, should be compact, convenient and not very expensive. An example of research using such a tool is the work of H. Al-Libawy and W. Al-Nuaimi. Their proposed method measures the effect of fatigue in real time depending only on the EEG signal to the subject, that is, it is completely independent of the type of load, which makes it suitable for most applications, such as fatigue of truckers, pilots, machinists, programmers, general monitoring, etc. The proposed system will not be very expensive compared to other systems, since it is based on a relatively inexpensive device – MindWave Mobile. Under experimental conditions, the system showed a fairly accurate result, but still needs to be tested under real-world operating conditions. The authors of this article confirm and consider it quite important to use several fatigue monitoring systems to improve the reliability of an integrated system [5].

Another aspect of monitoring of a person's fatigue level can be used to assess the speed and accuracy of human interaction with a computer using a keyboard and mouse. The so-called human stylometry. In the work of A. Pimenta and co-authors, an approach to classifying the level of mental fatigue of people who uses a computer was presented by analyzing their interaction patterns, in particular aspects of using the mouse and keyboard. The most notable aspects of this paper are that it details a non-invasive and transparent approach to problem solving, while other approaches are based on questionnaires or physiological sensors, which have a number of drawbacks. The presented approach is based on an analysis of the behavior of a particular user [6]. In the works of A. Pimenta and S. Sarkar, the possibility of assessing the level of human fatigue based on monitoring its stylometry was thoroughly investigated, and how exactly mental fatigue affects the quality of work, including during solving programming problems. The obtained results prove not only

the effect of fatigue on the user's productivity during the day, but also that it is possible to measure and classify these effects in real time [7, 8].

L. Barker believes that the identification of states of increased mental load in an employee is an absolute priority, since excessive workload can have a bad effect on working information that is absorbed by the operator [9].

The use of several separate systems at once, which allow you to assess the level of cognitive fatigue of a person to one degree or another, in addition to increased accuracy of assessment, also provides almost unlimited opportunities for statistical processing of these data. That is, you can simultaneously track the level of correlation between indicators provided, for example, by electroencephalography and indicators provided by the system for tracking human interaction with the mouse and keyboard.

A study conducted by I. Khan and co-authors indicates that the level of cognitive fatigue and the rate at which this fatigue occurs can be directly influenced by various internal factors (a person's well-being, general physical condition) [10]. And the research of T. Shishelova and co-authors and the research of S. Folkard and P. Tucker show that this is also influenced by external factors (ambient temperature, pressure, humidity level, workplace illumination level, time already spent at work, the presence of background noise, music, etc.) [11, 12]. A. B. Jap and co-authors proved that the degree of psychological and physiological perception of acoustic stress is influenced by the type of higher nervous activity, individual biorhythmic profile, the nature of sleep, the level of physical activity, the number of stressful situations during the day, the degree of nervous and physical overstrain [1]. Therefore, the full task will be to develop a system that would make it possible to search for the dependence of a person's fatigue level on all the above indicators.

A system that will simultaneously have access to such a large amount of data can be successfully used to predict the future state of the user based on previously conducted analyses, to find the "strongest" factors in the level of influence on the rate of onset of human fatigue, to provide the user with advice during work when and how much he should take a break, and, as a result, to increase the level of labor productivity, the quality of work performed and reduce the overall load on the body.

A. Smith and C. Miles conducted a study that analyzed the effect of having lunch on cognitive alertness tasks, comparing the differences between participants who ate lunch and who remained hungry in the afternoon [13]. I. Khan and co-authors consider mood as a factor influencing the quality of software development results, which can also be used as an additional factor in analyzing the rate of fatigue onset in humans [10]. In addition to mood, stress, exhaustion, and drowsiness, some other factors that cause fatigue should be considered in the software industry. A number of studies show that mental fatigue affects various activities, such as reasoning, memory tasks, productivity, decision-making, and responsiveness [9, 14-17]. Fatigue, however, is usually described subjectively because of the variety of concomitant symptoms and causes that applies to a particular person. An industrial study would allow us to quantify the level of fatigue in the future and identify a number of objective symptoms of fatigue when performing general tasks related to

the field of programming. Works of D. Nanghaka and H. Makabee [18-19], blogs [20] highlight the impact of fatigue on developer performance in tasks such as program understanding and decision-making. The study of B.Schneiderman and R. Mayer showed possible links between mental fatigue and specific programming tasks, such as program construction, modeling, and debugging [21]. As mentioned above, for any activity, context and environment are also very important for determining the level of fatigue during the day. For example, are these work-related variables, such as motivation, stress, boredom, or distraction; or environmental factors, such as the atmosphere, including temperature, noise, lighting; or even life factors, such as food, energy substances, such as caffeine. It is important to consider these contextual variables, as they can contribute to the fatigue that a person experiences.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of this study is the interaction of a person with a computer or computerized device in tasks that require high concentration and lead to a high cognitive load.

The subject of the study is a statistical analysis of the influence of various factors on the potential performance of a person at a computer and its relation with the electrical activity of the brain.

Research methodology:

The current study involves five students aged 21-25 years. Each participant was selected in accordance with a number of requirements: the absence of serious medical or psychiatric disorders at the time of testing; a ban on the use of any medications during testing and 24 hours before it starts; a ban on the use of alcohol and caffeine in any form 48 hours before the start of testing; the mandatory absence of such a bad habit as smoking.

The following time conditions were set for all test participants: mandatory full 8-hour sleep before starting testing. Work starts at 9 o'clock, ends at 18 o'clock with a lunch break from 13 till 14 o'clock.

To prevent the occurrence of any artifacts in the electroencephalogram data related to the physical activity of the body, test participants had to remove the neural interface from themselves during weaning and stop collecting information at this time.

All test participants performed a variety of programming tasks, each working at home.

The first part of the study, which was conducted for 5 consecutive days, was performed by participants in equal, almost constantly specified conditions. Where the ambient temperature was in the range of 22-24 degrees Celsius, the light level was maintained in the range of 240-250 lux, the atmospheric pressure was in the range of 1000-1050 gigapascals, humidity in the range of 38-42% percent. During the whole work, all participants had to be free of background noise, such as music, movies, etc.

As input devices, i.e. keyboards and mice, all participants used their own devices, which they have already used in their work for at least one year, that is, which they quite got used to.

During the whole research, programmers' stylometry data was collected using background software and electroencephalography data was collected using the NeuroSky Mindwave Mobile 2 portable neural interface.

The purpose of this part of the study is to track how the above indicators change during the entire working day in equal conditions of different people, and to find out whether there is any relationship between the data on human fatigue, which reflects the performance indicators of his interaction with the computer, and between the brain activity that the data from the electroencephalogram will display.

The second part of the study consists of controlled changes in various factors during the whole working day, both environmental factors (light level, temperature, pressure, humidity) and working conditions (type of performed tasks, work schedule, presence of several breaks, meal schedule, presence of background music, if the participant considers this an improving factor).

During this part, participants were also taken survey using the NASA-TLX (Task-Load Index) method to obtain a subjective assessment of the level of comfort of working in certain conditions. Data on a person's potential performance under these variable conditions were compared with the reference data obtained in the first part of the study. There was also a comparison of data with the EEG.

The Arduino MEGA microcontroller platform with BMP-280 and GY-49 sensors and the NeuroSky Mindwave Mobile 2 portable neural interface are used as hardware tools for data collection. A software tool for recording and analyzing data is proprietary software created using the tools of the C# and .NET programming language.

The statistical tool for data analysis is correlation and variance analyse.

IV. RESULTS

Figure 1 shows graphs of keydown time (the average time that a person holds down the keyboard key) changes during the working day.

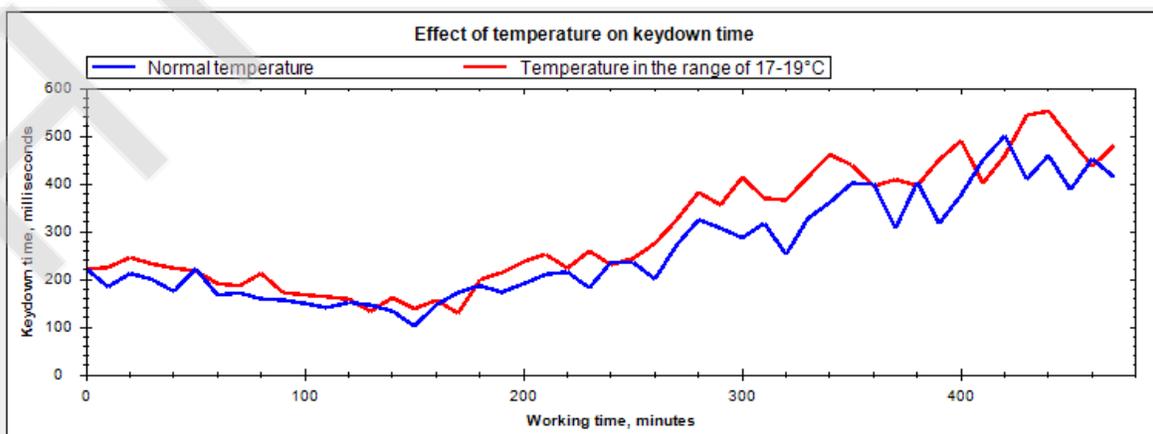


Fig. 1. The effect of temperature reduction on keydown time (less – better)

These graphs show that lowering the temperature from the usual 22-24 degrees Celsius for the home in winter to 17-19 degrees leads to an increase in average keydown time, especially it is noticeably closer to the evening, ie to the end of the working day. This can be explained by the fact that at the beginning of the working day the body still has energy, which allows you to fully warm the body despite the slightly colder conditions, and not allow the fingers to cool down.

Figure 2 shows graphs of mouse velocity (the average speed of the mouse cursor in pixels per second) changes during the working day.

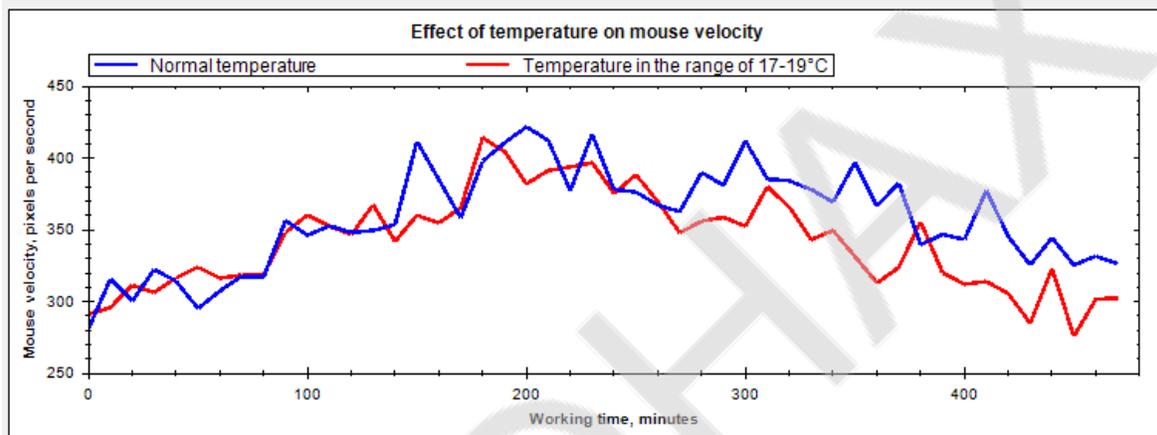


Fig. 2. Effect of temperature reduction on mouse velocity (more – better)

These graphs show that lowering the temperature leads to an increase in average mouse velocity, as in the previous case - it is especially noticeable near the end of the working day, which is also due to freezing of hands and loss of their control accuracy.

Figure 3 shows the results of NASA-TLX testing at the end of the working day under normal conditions and after changing the average temperature.

A subjective survey shows that when the temperature decreased, the most significant changes occurred in the physical load on the body, and the volunteer in the given conditions tried to finish his work as soon as possible, which may affect its quality. A subjective survey showed that the student's performance deteriorated significantly. The load level to achieve the required performance level has also increased. And the level of frustration became higher.

Figure 4 shows the graphs of EEG index changes (calculated index based on data from 5 ranges of brain rhythms, as the ratio of data from ranges corresponding to high brain activity to data from ranges corresponding to low activity) during the working day.

These graphs show that a decrease in the lighting level from the usual to the level of 10-30 lx leads to a slight decrease in the EEG index, especially noticeable in the morning, when the person is not fully awake, and we assume that bright light has a strong effect on awakening. And it's noticeable in the evening, when additional lack of lighting is a stimulus for drowsiness.

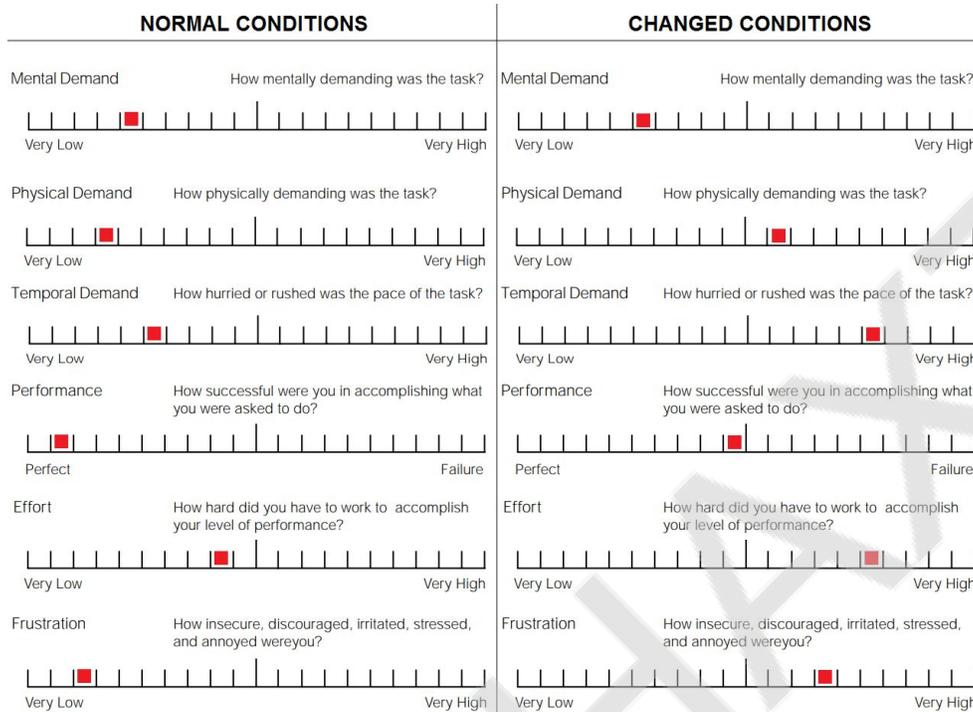


Fig. 3. Results of survey according to the NASA-TLX method before/after changing the average temperature

Figure 5 shows the results of NASA-TLX testing at the end of the working day under normal conditions and after reducing the lighting level.

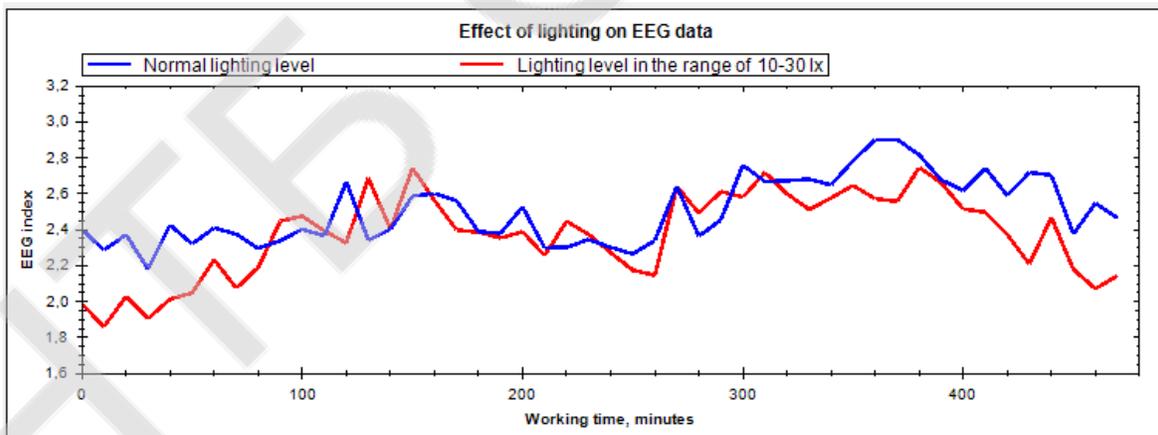


Fig. 4. Effects of reduced lighting level on EEG index (higher – better)

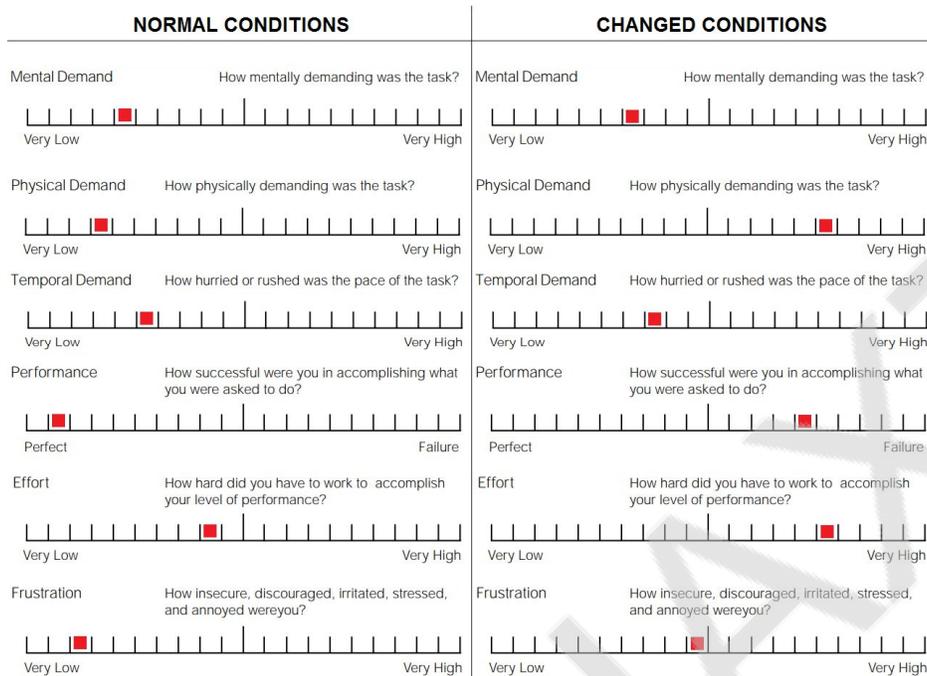


Fig. 5. Results of survey according to the NASA-TLX method before/after changing the lighting level

A subjective survey shows that with a decrease in lighting level, the most significant changes occurred in the physical load on the body. Working capacity has significantly deteriorated, and the level of workload has increased to achieve the same level of efficiency. The level of emotional comfort also deteriorated.

Figure 6 shows a comparison of keydown time and EEG index data graphs under normal conditions.

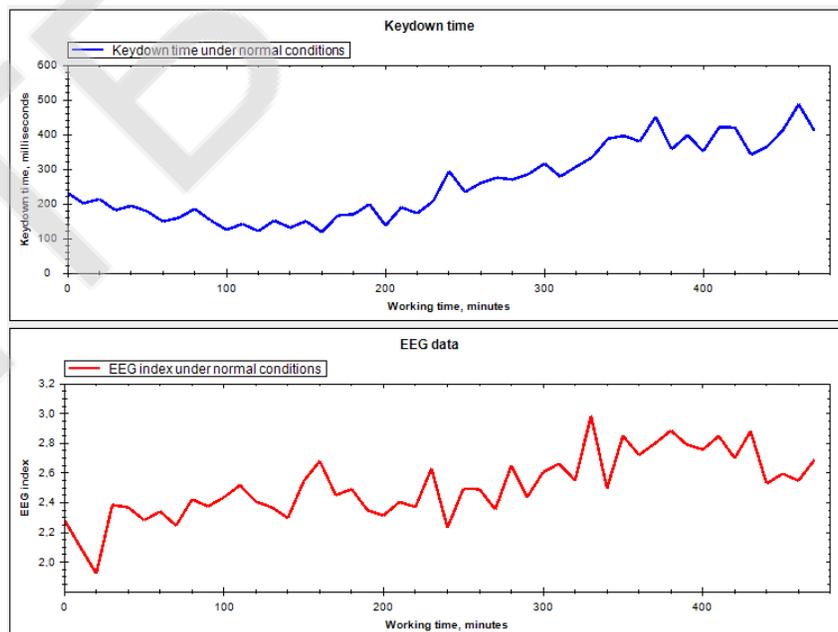


Fig. 6. Graphs of keydown time and EEG index changes during the working day

Examining these graphs, we can see a slight similarity between them, but very interesting is the fact that towards the end of the day with the deterioration of the efficiency of interaction with the keyboard also increases brain activity. This can be explained by the fact that when a person gets tired, he involuntarily begins to strain his mind more in order not to lose in the quality of the tasks performed, and this in turn can negatively affect his motor functions. Pearson's correlation coefficient with the current data set was 0.62.

Figure 7 shows a comparison mouse velocity and EEG index data graphs under normal conditions.

The next day we compared the results of mouse velocity and EEG index measurements, where the student mainly performed tasks in graphic design, where the mouse is very actively used. Looking at these graphs, it is difficult to draw any unambiguous conclusions. One can only notice that both mouse velocity and EEG index increase closer to the middle of the working day. Pearson's correlation coefficient with the current data set was 0.42.

V. CONCLUSIONS

In this study, with the help of the developed software-hardware system, the hypothesis about the influence of external factors on the potential performance of a person was tested. We have found that parameters such as air temperature and level of lighting can really have a significant effect on the effectiveness of human interaction with the computer. Furthermore, the effect of lighting level on the activity of the human brain was observed, from which it can be concluded that working with lack of lighting leads to a decrease in brain activity, especially in the morning and at the end of the working day. Moreover, we compared the dynamic of changes in human stylometric data with the dynamic of changes in brain activity. It may be the initial basis for confirming the assumption that human electroencephalogram data collected using a portable neurointerface can be considered as perspective effective indicator of mental fatigue, or at least used as an additional check of the psychophysiological state of man at work.

Further research should look more closely at the potential effects of changes in environmental parameters on a person's potential performance, both in terms of the effectiveness of interactions with the computer and in terms of brain activity. It will also be worthwhile to expand the scope of the study, namely to increase the number of people who will participate in the study, increase the time of the study and diversify the types of work performed. We consider that in addition to finding the above-mentioned dependencies, in the future we should focus on optimizing the conditions for each person for each specific type of work performed on the basis of previously obtained data. This is a good starting point for discussion and further research.

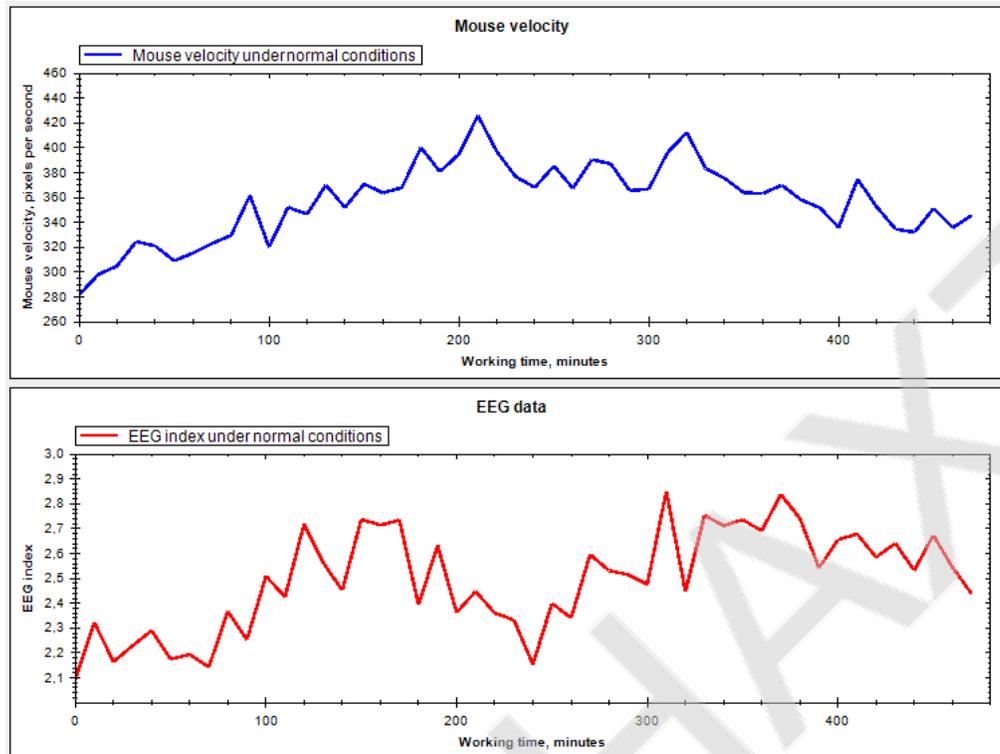


Fig. 7. Graphs of mouse velocity and EEG index changes during the working day

VI. REFERENCES

1. Jap B.T., Lal S., Fischer P., Bekiaris E. Using EEG spectral components to assess algorithms for detecting fatigue // *Expert Systems with Applications*. – 2009. – 36. – 2352-2359. DOI: [10.1016/j.eswa.2007.12.043](https://doi.org/10.1016/j.eswa.2007.12.043)
2. Cheng Shyh-Yueh, Hsu Hong-Te Mental Fatigue Measurement Using EEG, *Risk Management Trends*. Giancarlo Nota (Ed.), 2011. DOI: [10.5772/16376](https://doi.org/10.5772/16376)
3. Trejo L.J., Kochavia R., Kubitzb K., Montgomery L.D., Rosipala R., Matthews B. EEG-based Estimation of Cognitive Fatigue. – 2005, DOI: [10.1007/978-3-540-73216-7_23](https://doi.org/10.1007/978-3-540-73216-7_23)
4. Lance, B.J.; Kerick, S.E.; Ries, A.J.; Oie, K.S.; McDowell, K.; , "Brain-Computer Interface Technologies in the Coming Decades", *Proceedings of the IEEE* , vol.100, no. Special Centennial Issue, pp.1585-1599, May 13 2012. DOI: [10.1109/JPROC.2012.2184830](https://doi.org/10.1109/JPROC.2012.2184830)
5. Al-Libawy, H., Al-Ataby, A., Al-Nuaimy, W., & Al-Tae, M. (2017). A modular approach to personalise driver fatigue prediction. In *6th Int. Naturalistic Driving Research Symposium*. 6th Int. Naturalistic Driving Research Symposium. © 2014 DOI [10.1109/DeSE.2013.28](https://doi.org/10.1109/DeSE.2013.28)
6. Pimenta, A. et al. "Monitoring mental fatigue through the analysis of keyboard and mouse interaction patterns". *Hybrid Artificial Intelligent Systems*. Springer, 2013, pp. 222–231. DOI: [10.1007/978-3-642-40846-5_23](https://doi.org/10.1007/978-3-642-40846-5_23)
7. Pimenta, A. et al. "Analysis of Human Performance as a Measure of Mental Fatigue". *Hybrid Artificial Intelligence Systems*. Springer, 2014, pp. 389–401. DOI: [10.1007/978-3-319-07617-1_35](https://doi.org/10.1007/978-3-319-07617-1_35)
8. Saurabh Sarkar and Chris Parnin. Characterizing and predicting mental fatigue during programming tasks. In *Proceedings of the 2nd International Workshop on Emotion Awareness in Software Engineering*. IEEE Press, 32–37, 2017. DOI: [10.1109/SEmotion.2017.2](https://doi.org/10.1109/SEmotion.2017.2)
9. Barker, L. M. "Measuring and modeling the effects of fatigue on performance: Specific

- [application to the nursing profession”. PhD thesis. Virginia Polytechnic Institute and State University, 2009. DOI: 10.1007/978-3-642-40846-5_23](#)
10. Khan, I. A. et al. “Do moods affect programmers debug performance?” *Cognition, Technology & Work* 13.4 (2011), pp. 245–258. DOI: 10.1007/s10111-010-0164-1
11. Shishelova T.I., Malygina Yu.S., Suan Dat Nguyen. Influence of noise on the human body // *Successes of modern natural science*, 2009. N 8. – 15 p.
12. Folkard, S. & Tucker, P. “Shift work, safety and productivity”. *Occupational medicine* 53.2 (2003), pp. 95–101. DOI: 10.1093/occmed/kqg047
13. Smith, A. P. & Miles, C. “The effects of lunch on cognitive vigilance tasks”. *Ergonomics* 29.10 (1986), pp. 1251–1261.
14. Saito, K. “Measurement of fatigue in industries”. *Industrial health* 37.2 (1999), pp. 134–142. DOI: 10.2486/indhealth.37.134
15. Winwood, P. C. et al. “Development and validation of a scale to measure work-related fatigue and recovery: the Occupational Fatigue Exhaustion/Recovery Scale (OFER)”. *Journal of Occupational and Environmental Medicine* 47.6 (2005), pp. 594–606. DOI: 10.1097/01.jom.0000161740.71049.c4
16. Morris, T. & Miller, J. C. “Electrooculographic and performance indices of fatigue during simulated flight”. *Biological psychology* 42.3 (1996), pp. 343–360. DOI: 10.1016/0301-0511(95)05166-x
17. Kahneman, D. “Remarks on attention control”. *Acta Psychologica* 33 (1970), pp. 118–131. DOI: 10.1016/0001-6918(70)90127-7
18. Nanghaka, D. Developer Fatigue / [Электронный ресурс]. – Режим доступа: URL: <http://dndannang.blogspot.com/2012/07/developerfatigue.html>. 2012.
19. Makabee, H. Effective Software Design. / [Электронный ресурс]. – Режим доступа: URL: <http://effectivesoftwaredesign.com/2011/08/23/howdecision-fatigue-affects-the-efficacy-of-programmers/>. – 2011.
20. Dan. Top 10 Symptoms of Developer Burnout. / [Электронный ресурс]. – Режим доступа: URL: <http://tech.onthis.net/2011/06/16/top10-symptoms-of-developer-burnout/>. – 2011.
21. Shneiderman, B. & Mayer, R. “Syntactic/semantic interactions in programmer behavior: A model and experimental results”. *International Journal of Computer & Information Sciences* 8.3 (1979), pp. 219–238. DOI: 10.1007/BF00977789/

PROSPECTS OF INTELLIGENT AUTOMATION IN SOFTWARE TESTING PROCESS

Author: *Anna Bilovus*

National Technical University “Kharkiv Polytechnic Institute” (Ukraine)

Abstract. *This paper provides an overview of using Artificial intelligence (AI) for building test automation frameworks in a way with less human interventions. The analytical framework of the article is built on new modern enterprise prototypes.*

This article deals with opportunities as well as ideas to drive process of incorporation of AI in software testing process. The article provides analysis of areas to be augmented by use of Machine learning methods in testing tools (frameworks) from integrated reports as well as from own experience.

This article refers to improvement of software quality validation, discovering

potentiality and challenges of AI in terms of testing activities.

Schema of integrated process with use of AI technology and traditional testing techniques is presented. By engaging with presented ideas, the article contributes to creation of open-source automated tool with power of AI. The main contribution of this study is to identify hands-on perspectives of AI to test software.

Keywords: *artificial intelligence, automation testing, deep neural networks, testing, deep learning, DNN, AI, machine learning.*

I. INTRODUCTION

Artificial intelligence (AI) software is used in almost all industries, including healthcare, social media, and advertisements, fintech, autonomous cars, planning of smart cities' infrastructure.

AI becomes omnipresent and it is important to ensure reliability of AI-based and conventional software which mostly play safety-crucial contexts.

Companies have already started extending CI with incorporation of AI-assisted tools to their software development lifecycle (SDLC) pipeline. Introduction of AI will make regression testing quicker as well as decrease routine monotonous tasks being done by manual testers and thereby free up time for more creative work. As the result, focus will be shifted to scalability and security of incorporated AI, adopting more product-focused approach. There are already exist some scenarios that leverage power of AI, but they do not fulfill all technical aspects such as generating test scenarios based on user experience by reading production logs or relevant adaptation to changes in software, identification of critical areas in the code.

It is obvious that building automation framework with versatile functionality requires consideration bunch of criteria that are going to be covered in this paper.

Therefore, to stay in optimal condition and provide trustworthy software to the market quickly requires keeping track of innovative approaches, which main aspects are considered in this paper.

II. LITERATURE ANALYSIS

Generally, the main goal of AI is to mimic cognitive functions of humans, and one of the powerful techniques for this is Machine Learning. Consequently, ML could be realized by using one of well-known methods, for example, deep neural networks. As AI devices continuously learn from human input, testing process is persistently improving as well. Development of AI is still in its early-stage despite of appearance number of innovative tools, such as Applitools, Sauce Labs, Testim, TestCraft etc. AI is supposed to change established testing process with use of Machine Learning methods (pattern-recognition technology), Deep Learning.

To gain basic overview of enterprise tools that use AI, it worth to mention at least a couple tools, particularly TestCraft and Testim. On the market exists codeless Selenium test automation platform with revolutionary AI which provides auto-fixing 97, 4 % of flaky tests, namely TestCraft. This tool is designed for functional UI testing. On the one hand, this product has a great range of advantages: building tests with flow builder on the fly, Selenium-based, has integrations with management and CI/CD

tools, etc. But on the other hand, drag and drop function to build flows is not easy-to-use and it is not open source [1].

Unlike TestCraft, Testim is more robust because allows create codeless, coded or partially coded/codeless tests. Testim uses AI to speed-up the authoring, execution, and maintenance of automated tests [2]. Since Testim has more integrations, such as Jira Service Management, TestRail, CircleCI it makes good test management tool.

One of the most critical part in testing process is time for analysis of automated test results, visualization of reports and providing analytics. Solution is provided in open-sourced reporting management tool Report Portal, which among other features gives smart analysis of tests cases based on Machine Learning [3]. Report Portal uses AI in the next features: auto-analysis based on historical data of the test execution; direct submission of issues from the execution result; flagging of tests results after automatic root cause analysis. All features of this tool reduce the time for re-analysis, as well as eliminate the need to create a custom tool for reporting for almost any of software-under-test.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The research object is automated software testing tools.

The research subject is process of automation software testing.

As a research method, this paper uses literature review to synthesize findings and to uncover possible undertaken collection of studies that have capacity to engender new ideas for use of AI in testing.

IV. RESULTS

Stiff competition in the market requires from businesses to deliver software as soon as possible to stay on radar. Consequently, time for testing activities should be reduced. It is well-known problem with lack of time when regression testing is coming [4]. Every time after run execution automation testers spend time to analyze tests failures, to do manual defect triage. As it turned out, AI can reduce the direct involvement of test engineers within reports execution analysis.

With AI, coverage of code by unit tests also could be tracked in the following way: creation of test suites, detection of uncovered code by written test suites, finding out of parameters needed to the test method and creation of test. This approach helps with maintenance unit tests and ascertain testers that features testing is done on unit level.

Apart from that, AI has great potential in generation of API test cases. Recognition of patterns shifts to analysis of users' network traffic. Then based on obtained patterns model is being created, that will be used for generation of test suites that cover limitless user steps.

Validation of UI components already uses ML algorithms to adapt of simple Selenium tests to self-fixing common problems such as dynamic locators.

Gathering of logs from production or from staging environments as a data-source of learning can help with identification of unique test cases that need manual

and automated testing and generate a comprehensive suite of testing scripts that are missing in regression suite, as well as detection and elimination of redundant, unnecessary test cases. Examination concept of AI exposed that forecasting of end-2-end user scenarios can group and identify application areas that require more focus.

Moreover, from business side AI can ensure coverage of testing acceptance criteria by using some ML algorithms for extracting keywords from the Requirements Traceability Matrix. Business risks even outnumber some technical aspects, and it is hypothesized that analytics of defects will be among the most prioritized areas with trial of AI use.

In paper [5], proposed and evaluated testing tool for automation testing of DNN-driven vehicles that can potentially lead to fatal crashes. As it is mentioned, this tool systematically generates test inputs that maximize the numbers of activated neurons by leveraging real-world changes and using domain-specific metamorphic relations.

The focus of present article shifts to development Deep Neural Network [6] for test suites optimization that already have integrations with any test management tool, for example TestRail. Model of network is supposed to be used for optimization of test cases on long-term projects.

Learning of neural network is trained with the supervised learning algorithm that take a set of training data (to learn a desired function) and test data (to validate learning algorithm). The result of this process should be model. As criteria for definition of deviation MSE [6] is supposed to be used. It should be noted that training and testing data is modified from cases in original project.

Block diagram is illustrated in Fig.1

Use of such approach eliminates the need of deep knowledge of project domain specifics to navigate and search for some test cases, not just extending volume of database with new ones.

V. CONCLUSIONS

AI is constantly bringing a new dimension to our lives, and software testing is no exception. AI can improve tests stability and validation, generate end-to-end tests from production user journeys and use them in production to monitor critical parts of systems. Even if users are not aware of AI pervasiveness, application of AI to large volumes data is already used in high-value cases, such as customer engagement [5]. While the benefits of AI in software testing are still in the early development, progress in this direction is natural in the race to fast SDLCs. Number of changes related to growing hybrid cloud use emerging requires AI as never before. Further study of the issue would of interest. Software testing, backed with AI and ML, will only get better with time.

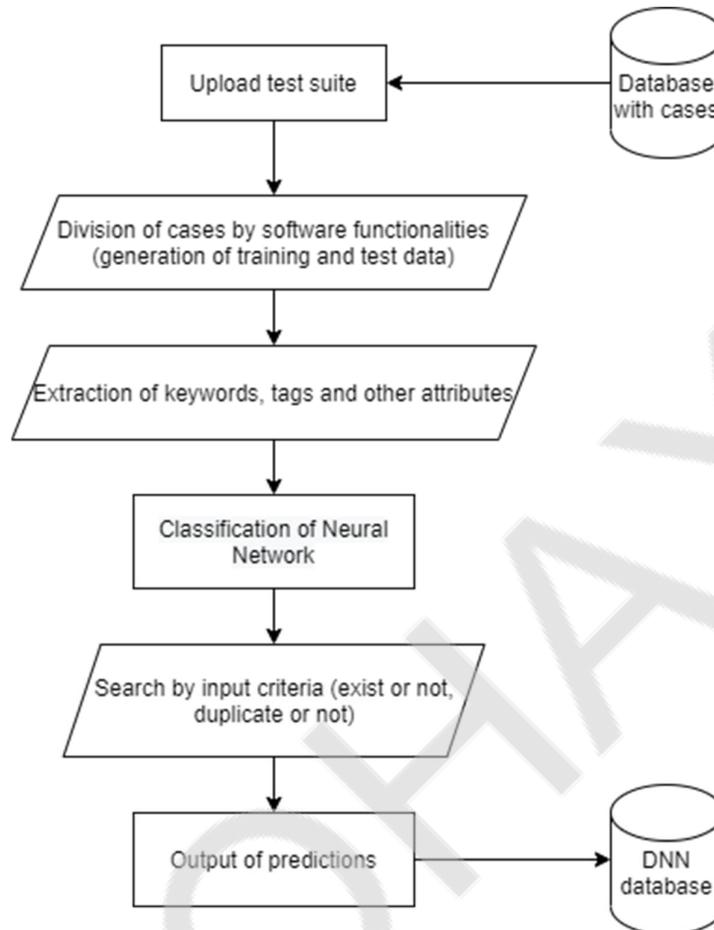


Fig. 1. Diagram of DNN learning process

VI. REFERENCES

1. Codeless Selenium features | TestCraft - URL: <https://www.testcraft.io/product>.
2. Automated - Functional Testing - Software Testing Tool - URL: <https://www.testim.io/test-automation-tool>.
3. Report Portal - URL: <https://github.com/reportportal>.
4. T. M. King, J. Arbon, D. Santiago, D. Adamo, W. Chin and R. Shanmugam, "AI for Testing Today and Tomorrow: Industry Perspectives," 2019 IEEE International Conference On Artificial Intelligence Testing (AITest), Newark, CA, USA, 2019, pp. 81-88. DOI: 10.1109/AITest.2019.000-3
5. AI, machine learning and deep learning: What is the difference? - URL: <https://www.ibm.com/blogs/systems/ai-machine-learning-and-deep-learning-whats-the-difference>.
6. Loss and Loss Functions for Training Deep Learning Neural Networks - URL: <https://machinelearningmastery.com/loss-and-loss-functions-for-training-deep-learning-neural-networks/>

APPLICATION OF IMAGE PROCESSING WITH MULTILEVEL THRESHOLDING FOR MOULD DETECTION ON BLUE CHEESE CUT SURFACE

Authors: *Ivaylo Ivanov, Vladimir Karparov, Magdalena Kutryanska*
Advisors: *Assoc. Prof. PhD Atanaska Bosakova-Ardenska, Assoc. Prof. PhD Peter Panayotov*
University of Food Technologies (Bulgaria)

Abstract. *The techniques used by computer vision are based on signals which carry information about objects and their processing using wide range of methods. There are variety of types of signals according to their frequency or wave length. The visual range of spectrum is defined for wave with length between 380 nm and 750 nm. The waves with such length are registered by humans' receptors and they form sensitivity for colors. The human accepts the biggest portion of information about environment through its vision. Because of this there are developed a lot of methods for storing and processing the visual information. In the last years digital information processing and especially computer based such, is widely used in every area of human activity. By this way the computer vision and especially image processing became to be very important for human life. As a part of quality of human's life, the quality of food is also controlled by methods of computer vision. The subject of this research is one of popular dairy products – blue cheese. The characteristics taste and smell of this cheese are formed thanks to growth of mould *Penicillium roqueforti*. The growth of this moulds is detected by images processing with multilevel thresholding based on Otsu's method. Samples of eight trademarks of blue cheese are used for experiments. The results show that multilevel thresholding with two levels is appropriate for mould detection but multilevel thresholding with four levels support detection of areas with high concentration of moulds *Penicillium roqueforti* and areas with weak growth of moulds. Based on these results, in the future a software which would be helpful in reaching a high-quality control in the dairy industry could be developed.*

Keywords: *image processing, multilevel thresholding, blue cheese, quality, *Penicillium roqueforti**

I. INTRODUCTION

Every living organism needs sustainable energy levels and nutritional support in order to perform daily tasks, be alive and grow and remain healthy. Main source of nourishment is food and its various forms. It contains vital nutrients such as fats, proteins, carbohydrates, which are part of the group of the macronutrients, and minerals and vitamins, classified as micronutrients. Those two categories allow human's body to function properly.

Today's constantly increasing population requires major food supplies, which have been provided by the food industry. It presents a complex system, which is accountable for the food from its production to its distribution including the processes

of supply, processing, consumption and disposal. The food industry main components are: agriculture, food processing and distribution, regulation, financial services, research and development, and marketing [1].

The food quality has been under significant strain due to the ever-increasing requirements for superior standard of living and the consumers' demands for a lower likeability of causing adverse health consequences to them. Consequently, every year the food system is pressured to include modern computerized or digital automation in order to enhance the food health control. With the rapid growth of technology this obstacle could be seamlessly overcome. The pros of implementing software-based gadgets and devices (sensors, programmable logic controllers, microcomputers, etc.) would be beneficial in providing various mediums of control. Without any doubt, computer vision and image processing methods ensure objective food quality evaluation because they could not be manipulated as simple as the human's statements. Moreover, computer (machine) vision systems have tendency to be developed as an inseparable part of the food processing plants for real-time quality evaluation and quality control.

Despite the perceptions of image processing as a tool only for digital image manipulations, it has been proved to be a successful technique applied in the natural sciences and technical disciplines, especially in the observation of food. Studies have stated that the food industry has significantly been using image processing methods and algorithms, which makes it one of the few industries seeking such approaches [2].

The current purpose of this research is to complement information to the science matter of observations through the obtained results by analysing one of the most popular dairy products - blue cheese, with the application of image processing algorithm (*Multi Otsu Threshold*). Cheese in general has vital nutritional value to people because it is rich in protein, fats, calcium, NaCl and low levels of iron [3]. Dairy products naturally are a high-fat and calorie dense food, but low-fat options could also be found. For instance, brands like Cheddar, Gouda and Mozzarella are with low percentage in fats. Cheese could be consumed by people who are sensitive or intolerant to lactose, as well. As a cheese ages, the lactose converts to lactic acid. Lactose-free examples are the soft cheeses such as Cheddar, Swiss, and Parmesan, which makes it the "perfect" food for every well-balanced diet.

Blue cheese's origin is related with the infestation of the mould *Penicillium roqueforti*, which is the reason for its appearance and flavour. In order the cheese to become "blue", oxygen must reach the inside of it. The mould (*P. roqueforti*) is injected into the cheese curd in the early stages of the aging process. In the past, the mould occurred naturally in the milk spontaneously with spores from the environment (from caves, naturally-rotten bread). Then the fungus matures inside the air tunnels of the cheese. The whole process happens from the inside out and it takes about three to six months for the cheese to mature. The ripening temperature is typically 8–15 °C, depending on the variety [4,5].

Today, blue cheese is one of the most preferable foods of all time and its consumption ranges worldwide. Varieties of blue cheeses are French Roquefort,

English Stilton, Spanish Cabrales, Danish Danablu or Italian Gorgonzola.

The appearance of the ripped blue cheese is usually white-off or yellowish, depending on the used animal milk (cow's, goat's, sheep', etc.), with bluish/greenish channels and veins due to the growth of the mould. The produced fresh cheeses have a high amount of moisture, soft texture and a strong flavour. The sharp flavour is due to the free short-chained fatty acids (C4:0±C12:0) and n-methyl ketones, produced by the mould from fatty acids during the lipolysis. Esters and lactones have role in determining the typical flavour of blue cheese, as well [4].

The microenvironment of the blue cheese consists of pronounced gradients of pH and NaCl, salt, water activity, etc, which results in diversity of habitats on the surface and inside of the cheese. During the production and fermentation, when cheese has been dry-salted or brine-salted, salt is added as a preservative. Moreover, the structural differences of blue cheeses determine the level and distribution of O₂ and CO₂. Hence, it influences the growth and biochemical activity of the microorganisms. The quality of the final product is influenced by those parameters [5].

II. LITERATURE ANALYSIS

The potential of image analysis has been noticed by the food industry in recent years due to the importance of maintaining food quality and safety principles. Moreover, the ever-increasing life standard and the high expectations of the consumer pressure manufactories to constantly observe new methods of food evaluation assessments and classifications.

The application of computer vision and image processing covers different product groups such as dairy products, fruit and vegetables, meat, bakery products and more. Its purposes could be classified as defects detection, structure evaluation, size and shape determination, colour recognition, mould detection, feature extraction, etc.

Nevertheless, modern computer vision and image analysis methods have proposed abundance advantages and feasibilities when observing the features of digital images in the urge of achieving higher levels of safety and quality. Moreover, technology is preferred when examine food products because it provides an objective and reliable inspection which could not be simply changed.

2.1. Application of Computer Vision and Image Processing in Cheese Evaluation

Computer vision and image processing have a wide range of applications and offer plenty of algorithms which applied in different ways results in interesting researches. Both of them represents an efficient technique in investigating cheese features and provide information about the composition, the structure and the texture of this dairy product.

Cheese is a kind of food which overgoes multitude inspections from experts before it is offered to the consumers as a result of its dynamically changing quality attributes. When examined, the cheese is determined by its appearance

characteristics, classified as following [6]:

- sensory – taste, smell, texture, appearance, colour;
- physical – size, smoothness of the structure, level of curd fines, hardness, mechanical openings;
- nutritional – macro and micro elements;
- chemical – free fatty acids, free amino acids;
- safety – presence of foreign bodies, absence of pathogens.

For the ordinary consumer most of the quality criteria might be obscure. He relies on his primitive sensory abilities to determine whether the food is good or not. Hence, cheese colour is one of the major indicators, used in image analysis. The colour of the dairy product could vary from white to yellow or even orange due to the affection of different factors. For instance, the kind of milk (from cow, goat, sheep) and its microflora content, preservatives, food additives, presence of mould (especially in blue cheeses) and others. Manufactories could also influence the colour of the final product. For example, a study using image processing and colour diagnosis for determining the presence of diseases in yellow cheese is one excellent application of modern technology [7].

Another quality indicator is the mechanical openings which are often related to defects in the cheese structure. Normally, they are associated with rennet coagulated pressed cheeses, however in some types like Emmental, Gouda, Edam the evenly spaced round openings (eyes) are a desirable characteristic. The potential of computer vision has been noticed in this sphere, as well, as a useful tool for evaluation. X-ray computed tomography and image analysis have been applied in relation to eye formation in cheese and eventually those techniques resulted as a non-destructive medium to monitor the size of every eye hole [8]. Another study also examines the mechanical openings and the structural quality of Swiss-type cheese based on magnetic resonance imaging [9].

Digital image analysis represents a method which could evaluate the texture of the dairy product by detecting the quantity of ingredients added to the food. These are different herbs (parsley, garlic, onion, etc.) and spices (chili, black/red pepper, lavender, etc.) which contributes to the flavor of the cheese. Computer vision method and thresholding algorithm have been implemented in the interest of localizing and distinguishing the additional ingredients in the surface of the food [10]. Therefore, the amount of herbs and spices was successfully determined with 88% (with garlic and parsley) and 81% (with pepper and parsley) accuracy.

An algorithm has been implemented in order to ascertain the length of shreds of Mozzarella cheese which are usually visually determined after the product has been torn into tiny pieces [11]. The X-Y sweep method is applied also to evaluate the cheese shreds [12]. It is based on image segmentation where a visual scene is swept in X- and Y-direction. Therefore, a joint (ambiguous segment) is formed from the intersection of the shared interiors of the two segments. This means that the ambiguous segment consists of pixels which could not be swept through in X-direction or Y-direction. After that, a topology sorting method is applied in order to select the best match. The final results were with 95% accuracy of evaluating the

shred lengths.

Application of image processing and machine vision could be found in analyzing the rest of the quality criteria. Cheese quality indicators are determined by image processing algorithms and techniques which are applied for different kinds of cheese:

- Cheddar, Emmental, Ragusano – cheese meltability, browning and oiling-off [13,14,15,16];
- Mozzarella – cheese meltability [14,15,17];
- White cheese – mould growth on the surface [18] and analysis of cut surface structure [20,21,22,23,24];
- Yellow cheese – mould growth on the surface [18,24];

2.2. Application of Computer Vision and Image Processing in Blue Cheese Evaluation

Despite the various applications of computer vision methods in the food industry and in particular estimating the quality of products, there are a few which provide fast and accurate determination of blue cheese quality parameters. One blue cheese in order to be estimated with excellent expert score, the amount and the distribution of mould on its surface is vital when examining it. There is a study where it is used multispectral digital image processing for a complex analysis and classification of blue cheese [25]. Another one proposes a method for evaluating the blue cheese by the distribution of mould on its surface with image analysis [26]. The images of the samples are divided into nine regions of interest and thereby the ration percent of areas with mould versus the total area size is calculated. The obtained results present information about the statistical distribution of areas with mould by their size. Additionally, a computer vision method for determining the distribution of cavities with presence or lack of mould on the blue cheese surface is implemented [27]. The research establishes a relation between the final conclusions and the experts' evaluation, hence the algorithm could be used for production process optimization and automatic evaluation of the cheese.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH /IBO/

Otsu's method is a means of automatically finding an optimal threshold based on the observed distribution of pixel values [28]. The Otsu's method is named after its inventor Nobuyuki Otsu. The idea of Otsu's method is to find threshold that would maximize the between-class variance of levels and minimize the intraclass variance of the threshold black and white pixels. The Otsu's method can be applied also for the multiple thresholds segmentation [29].

The images which have been used are a 2D (two-dimensional) function of the gray scale intensity and contains N pixels with gray levels $(0, 1, \dots, L - 1)$. Probability of gray level i in an image is denoted p_i :

$$p_i = f_i/N \quad (1)$$

where f_i is the number of pixels with gray level i and N is the number of all pixels in the image.

The pixels of image are divided into two classes: C_1 with gray levels, pixels in $[1, \dots, t]$ and C_2 with gray levels, pixels in $[t + 1, \dots, L]$. Using t as threshold. Therefore the gray level probability distributions for the two classes are:

$$C_1: p_1/\omega_1(t), \dots, p_t/\omega_1(t), \quad (2)$$

$$\text{and } C_2: p_{t+1}/\omega_2(t), p_{t+2}/\omega_2(t), \dots, p_L/\omega_2(t), \quad (3)$$

where means global intensity $\omega_1(t)$ and $\omega_2(t)$ are:

$$\omega_1(t) = \sum_{i=1}^t p_i \quad (4)$$

$$\omega_2(t) = \sum_{i=t+1}^L p_i \quad (5)$$

The means intensity of the pixels in C_1 (μ_1) and C_2 (μ_2) are:

$$\mu_1 = \sum_{i=1}^t i p_i / \omega_1(t) \quad (6)$$

$$\mu_2 = \sum_{i=t+1}^L i p_i / \omega_2(t) \quad (7)$$

The dispersion σ_B are determined as the between-class variance of the thresholded image by formula:

$$\sigma_B^2 = \omega_1(\mu_1 - \mu_T)^2 + \omega_2(\mu_2 - \mu_T)^2 \quad (8)$$

Otsu verified that the optimal threshold t^* is chosen so that the between-class variance σ_B^2 is maximized. The optimal threshold value, t^* is:

$$t^* = \text{Arg Max} \{ \sigma_B^2(t) \} \quad (9)$$

$$1 \leq t < L$$

Multilevel thresholding is a process that segments a gray level image into several distinct regions [30]. Although applying multi-level thresholding to an image is a straightforward operation, computation of the threshold levels with Otsu criterion is a computationally expensive process [31]. Finding a modified between-class variance $\sigma_B^2(t)$ necessarily requires pre-computing the zeroth-order moment $\omega(k)$ and the first-order moment $\mu(k)$ of the k th class [32]. If an image is segmented into K clusters/classes (C_0, C_1, \dots, C_{K-1}), $K-1$ thresholds (t_0, t_1, \dots, t_{K-2}) must be selected [33]. The u - v interval zeroth-order moment $P(u, v)$ and the u - v interval first-order

moment $S(u, v)$ of a class with gray levels from u to v are defined as:

$$P(u, v) = \sum_{i=1}^v P_i, \quad (10)$$

and

$$S(u, v) = \sum_{i=1}^v P_i, \quad (11)$$

The cumulative probability ω_k is computed as

$$\omega_k = \sum_{i \in C_k} p_i = \sum_{t_{k-1}+1}^{t_k} p_i = \sum_1^{t_k} p_i - \sum_1^{t_{k-1}} p_i \quad (12)$$

Therefore ω_k and μ_k are respectively determined by:

$$\omega_k = P(1, t_k) - P(1, t_{k-1}) = P(t_{k-1} + 1, t_k) \quad (13)$$

$$\mu_k = S(1, t_k) - S(1, t_{k-1}) = S(t_{k-1} + 1, t_k) \quad (14)$$

Also, the optimal thresholds can be determined by:

$$\{t_0^*, t_1^*, \dots, t_{k-2}^*\} = \text{Arg Max} \{\sigma_B^2(t_0^*, t_1^*, \dots, t_{k-2}^*)\} \quad (15)$$

A macro has been developed that uses the plugin with the multi-step Otsu threshold algorithm to segment images. This algorithm is used to divide the pixels of an input image into several different classes and allows the selection of the threshold value. Multi Otsu Thresholding for image segmentation is a variant of the basic Otsu's method. Adjustments in the plugin Multi Otsu Threshold have been made. Pixels that have values equal to the threshold values do not enter any of the regions, therefore it has been changed and these values could be included.

Figure 1 presents the steps of launching macro. First step is to launch ImageJ program (step 1). Then it is necessary to open an image for processing (step 2). Next step is to start macro which is located on the "Plugins" menu of ImageJ's menu bar (step 3).

It is presented an algorithm for image segmentation, coded using the ImageJ macro language. Figure 2 presents block diagram for developed macro (MOT_Segmentation). It processes greyscale images. If the original RGB input image is not 8-bit type, the macro will convert it to a matrix with values can be anything from 0 to 255. The output image will be of the same file format as the input. Then the macro calculates the image width and height using methods getWidth() and getHeight(). The multiplication of height and width gives the number of all pixels in the image. After that the macro prompts user to select a numLevels, the possible values for selection are from 2 to 5. Therefore, if the condition $i < \text{numLevel}$ is true, the next step of the algorithm is to run the Multi Otsu Threshold, where the variable i is used as the number of the regions.

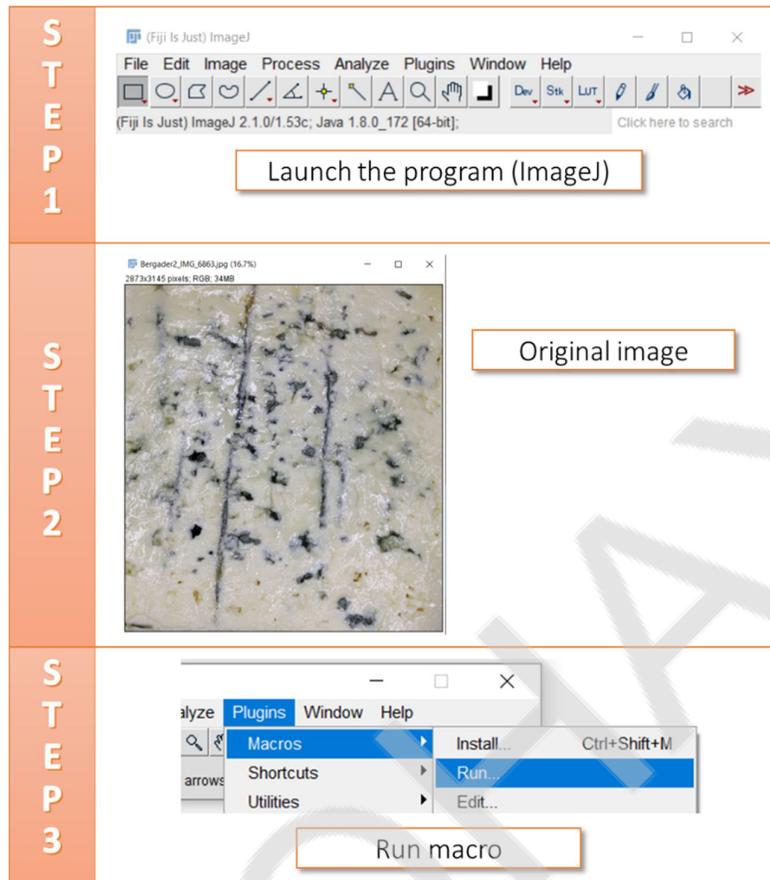


Figure 1. Steps of launching macro

The macro generates a 256 bin histogram for every region and displays the values in the "Results" window. MOT Segmentation counts the pixels with black color of the image. The percentage of pixel for i region is determined by the following formula:

$$C_{ri} = ((N - C_b) / N) * 100\%, \quad (16)$$

where C_b is the number of pixels with black color of the image and N is the number of all pixels in the image. Then the value of C_{ri} will be add to the "Results" window. Then these actions for finding the percentage of pixels will be repeated for the next region. Finally, all calculated C_{ri} values are displayed in the "Results" window.

The research objects which have been analyzed are different trademarks of blue cheese. The tested cheeses were bought from different marketplaces in Bulgaria thanks to financial support of University of Food Technologies. Two pieces of eight trademarks of blue cheese are used for experiments. The selected ones are: Bergader, Steffel Gran Bavarese, DorBlue 50%, DorBlue 55%, Emborg Uhrenholt, Paladin Regina Blue, Ramberter and DorBlue. These cheeses are known for their specific color and taste.

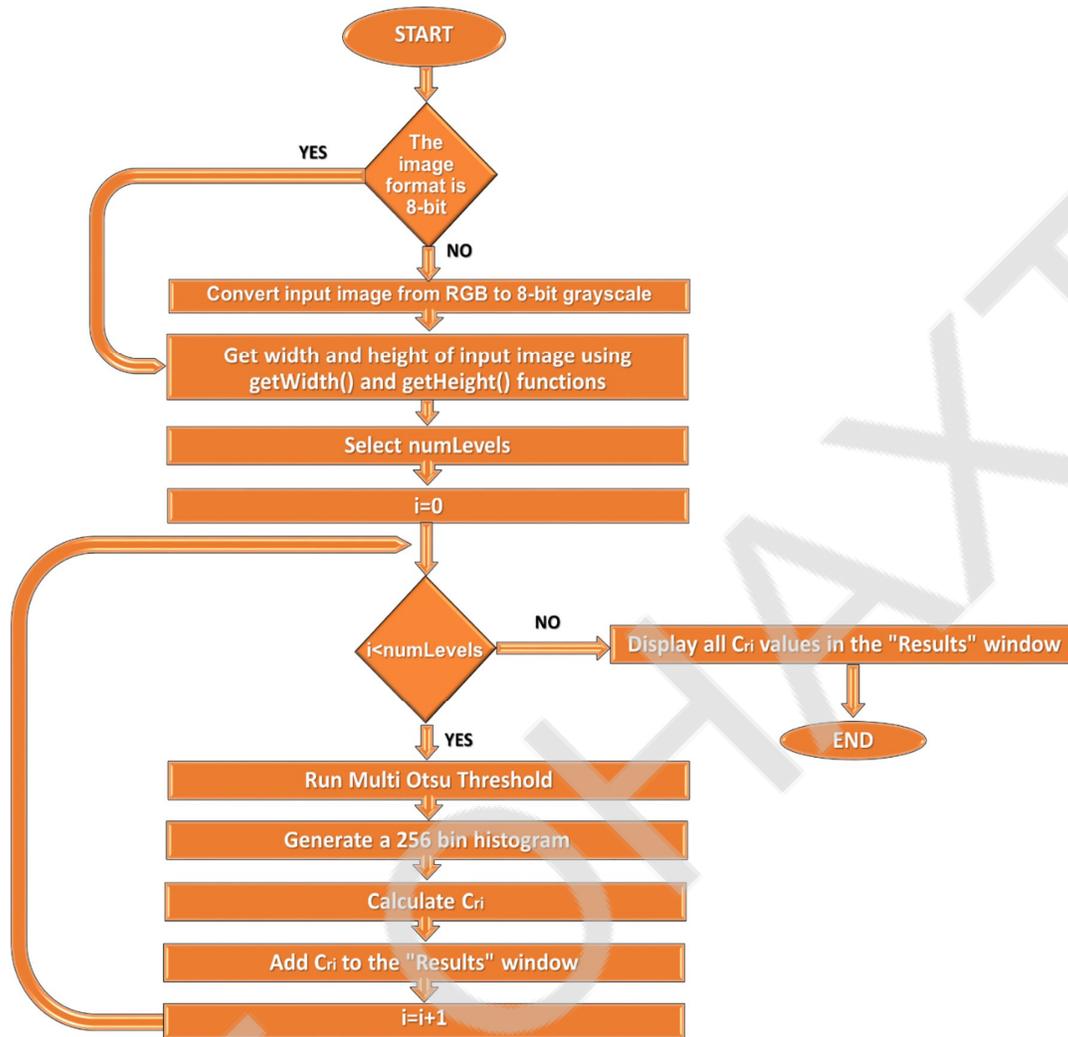


Figure 2. Block diagram for the macro

The system used for images acquisition is located in department of “Computer Systems and Technologies” at University of Food Technologies Plovdiv. The system consists of camera for images capturing, lighting module (ring, 500 lux), tripod and digital camera. The camera was mounted on a tripod so that the distance from the camera to the sample is the same for all experiments. To avoid external light conditions, the camera for images capturing is a cube with sizes 600 mm and it is covered with dark enclosure white-colored inside and the lighting module is positioned in the center of the upper side of camera. The distance between lighting ring and the base of the digital camera is 400 mm. Each of the pieces of blue cheeses were cut with cheese slicer. The all samples of blue cheese cut surfaces are captured by modern Canon EOS 2000D CMOS digital camera with 24.1 megapixel resolution.

Every captured original image is stored in a JPEG format. It is used the rectangular selection tool to select and crop region of interest (ROI) for every image. The ROI images are used for processing with developed macro in ImageJ.

IV. RESULTS /Владимир/

Figure 3 shows the result of using the MOT Segmentation macro for NumLevel3. There are shown Cri values for three regions, where Region 0 represents the pixels of mould.

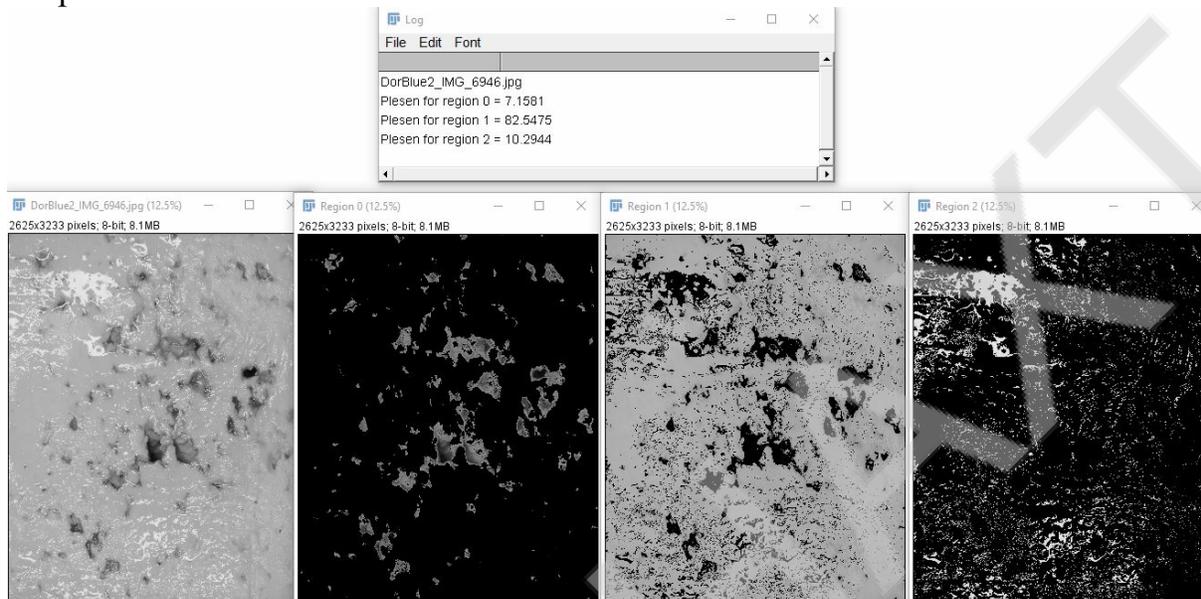


Figure 3. The result of image processing with MOT Segmentation macro

Figure 4 and figure 5 present original ROI images of samples of trademarks Bergader and EmborgUrenholt and segmented images for NumLevel 2. It is observed that Region 0 contains pixels of mould whereas Region 1 – the pixels of cheese. The sample of Bergader has $C_{r0} = 10,3444$ and $C_{r1} = 89,6556$. The sample of EmborgUrenholt has $C_{r0} = 17,4830$ and $C_{r1} = 82,5169$. As it could be seen, the second trademark has more mould on its surface.

Figure 6 and figure 7 present original ROI images of samples of trademarks Bergader and EmborgUrenholt and segmented images for NumLevel 4. It is observed that Region 0 and Region 1 contain pixels of mould, where Region 0 – the pixels of areas with high concentration of mould and Region 1 – the pixels of areas with weak growth of mould. Region 2 and Region 3 contain the pixels of cheese. The sample of Bergader has $C_{r0} = 5,0846$, $C_{r1} = 15,3716$, $C_{r2} = 58,8308$ and $C_{r3} = 20,7130$. The sample of EmborgUrenholt has $C_{r0} = 5,3744$, $C_{r1} = 11,6416$, $C_{r2} = 23,6171$ and $C_{r3} = 59,3669$. The summary of Region 0 and Region 1 provide more quantity of the detected mould in comparison with quantity of mould detected in NumLevel 2.

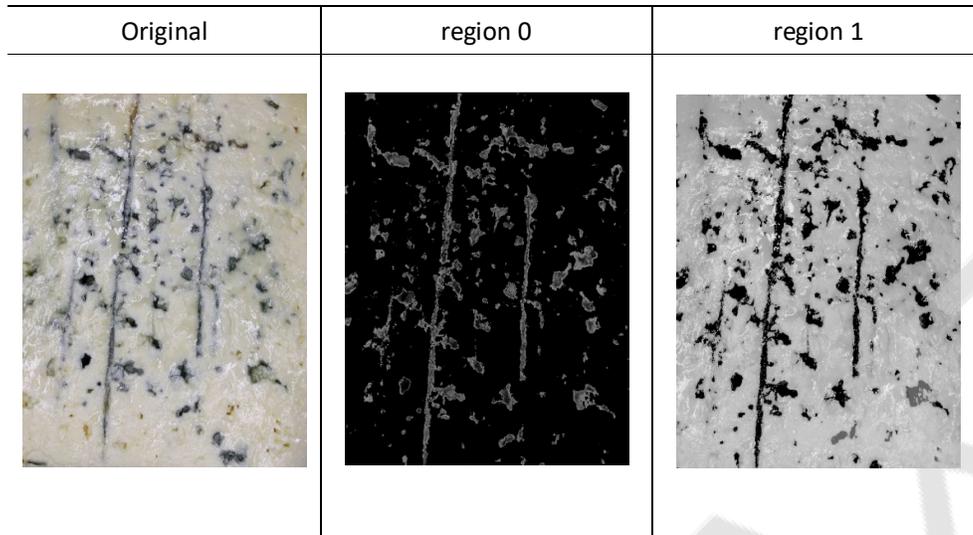


Figure 4. Images of sample of Bergader

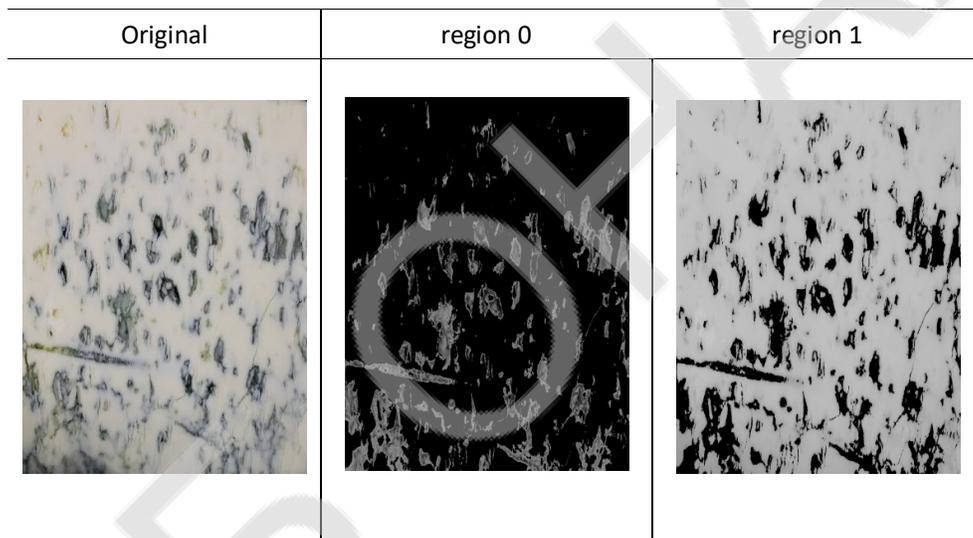


Figure 5. Images of sample of EmborgUrenholt

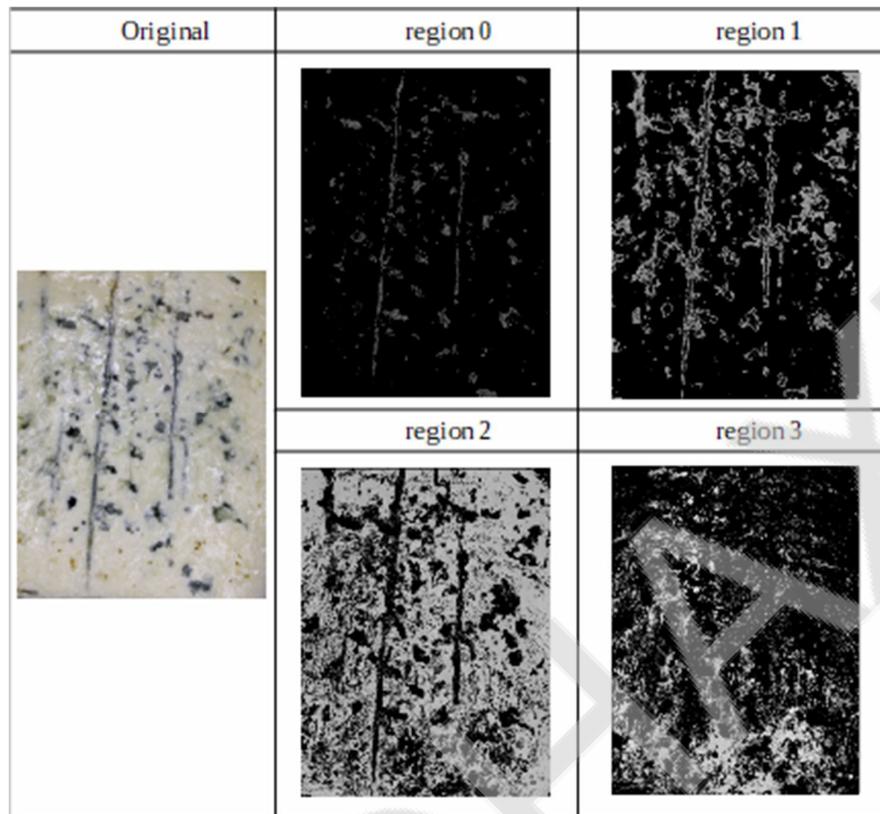


Figure 6. Images of sample of Bergader

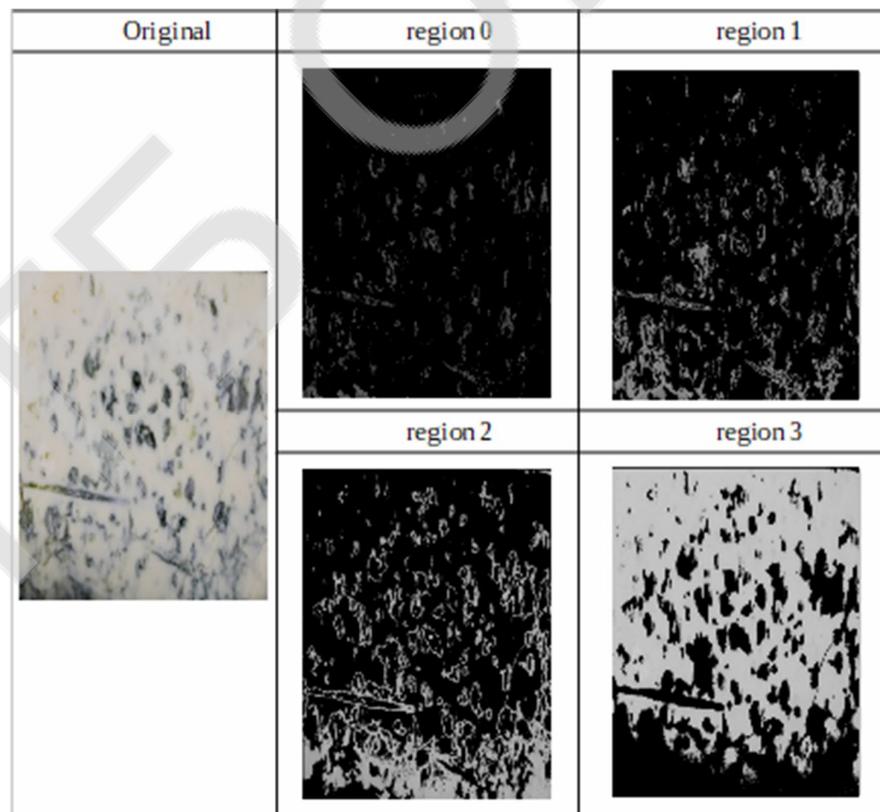


Figure 7. Images of sample of EmborgUrenholt.

Table 1 shows the results of the collected average values for the different NumLevels from 2 to 5 of the examined samples. It is observed that samples of Paladin ReginaBlue have the lowest values for regions with mould.

Table 1. Average values for C_{ri}

	Bergader	Stefel Granbavarese	Dor Blue50%	Dor Blue55%	Emborg Urenholt	Paladin ReginaBlue	Ramberter	Dor Blue
Num Level 2	10,3892	12,4432	11,9790	8,2183	17,5186	6,6220	12,8912	11,6382
	89,6108	87,5653	88,0211	91,7817	82,4814	93,3780	87,1088	88,3618
Num Level 3	5,7883	7,0308	6,1462	4,7073	6,7440	2,8733	7,2868	7,2416
	24,1051	26,3342	26,4947	15,1670	24,3830	21,0053	29,0072	38,7117
	70,1065	66,6349	67,3591	80,1257	68,8728	76,1233	63,7060	56,8001
Num Level 4	4,0580	4,5142	3,1382	2,6825	3,8515	1,4549	4,4141	2,4064
	10,4091	12,0321	9,4648	6,3655	12,2251	6,2892	13,1222	11,9278
	37,9342	43,3369	31,7900	21,8918	26,6360	29,0076	39,7287	43,1751
	47,5988	40,1168	55,6070	69,0603	57,2874	63,2483	42,7352	42,4907
Num Level 5	3,0324	3,1798	2,2047	1,8885	2,7002	0,9637	2,7291	1,7021
	6,0966	7,2862	6,4901	4,6103	7,3730	3,3620	8,4635	6,8753
	16,4198	17,7926	17,5117	10,1401	14,6831	11,8184	19,1943	24,2655
	37,3478	38,4824	32,0568	29,9634	26,4067	32,9528	39,6876	33,4287
	37,1034	33,2590	41,7367	53,3977	48,8369	50,9030	29,9257	33,7285

Figure 8 presents the values of C_{ri} for areas with mould for all samples of trademarks Bergader and Emborg Urenholt. It is observed that samples of trademark Bergader have more areas with high quantity of mould but samples of trademark Emborg Urenholt have more areas with weak growth of mould. It could be seen on figure 8 a) that samples of Emborg Urenholt have more quantity of mould than samples of Bergader thanks to more areas with weak growth of mould (figure 8 b)).

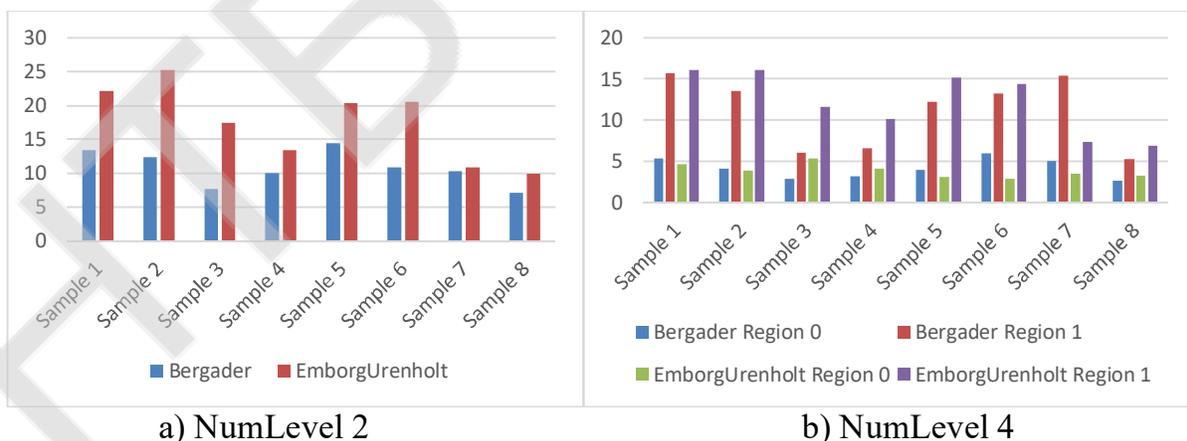


Figure 8. C_{ri} values for areas with mould

V. CONCLUSIONS

The purpose of this research is to present the application of the Multi_Otsu_Threshold by developing a macro (MOT_Segmentation) which could be applied in evaluating the presence of mould on the surface of blue cheese. Depending on the level of segmentation it could be detected mould in different stages of growth. Based on the obtained results, in the future a software could be developed which would be helpful in detecting the mould on the surface of different dairy products. As part of the future work, it could be examined the influence of the quantity of detected mould on the sensory characteristics of the blue cheese (taste, smell, flavour, etc.).

VI. REFERENCES

1. Matthew N., O. Sadiku, Sarhan M. Musa, Tolulope J. Ashaolu, "Food Industry: An Introduction" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3, Issue-4, June 2019, pp.128-130, URL: https://www.researchgate.net/publication/334123694_Food_Industry_An_Introduction
2. Du, C.-J. and Sun, D.-W. (2004) Recent developments in the applications of image processing techniques for food quality evaluation. Trends in Food Science and Technology, 15(5), 230–49.
3. Ropars, Jeanne & Lopez Villavicencio, Manuela & Snirc, Alodie & Lacoste, Sandrine & Giraud, Tatiana. (2017). Blue cheese-making has shaped the population genetic structure of the mould *Penicillium roqueforti*. PLOS ONE. 12. e0171387. 10.1371/journal.pone.0171387.
4. McSweeney, P., 2007. Cheese Problems Solved. Cambridge: Woodhead, pp.152-158, 284 - 288.
5. Cantor, M.D., Van den tempel, T., Hansen, T.K. and Ardoè, Y. (2004). Blue cheese, in Cheese: Chemistry, Physics and Microbiology Volume 2 Major Cheese Groups, 3rd edn, P.F. Fox, P.L.H. McSweeney, T.M. Cogan and T.P. Guinee (eds.), Elsevier Academic Press, Amsterdam, pp. 175-198.
6. Jukić, M. (2018). Application of computer vision and image analysis method in cheese-quality evaluation: a review. Ukrainian Food Journal, 7(2), 192–214. <https://doi.org/10.24263/2304-974X-2018-7-2-4>
7. Savy, S & Dufossé, Laurent. (2002). Final step of carotenoid biosynthesis in *Brevibacterium linens*, a bacteria involved in the coloration of red-smear ripened soft cheeses.
8. Dominik Guggisberg, Marie-Therese Fröhlich-Wyder, Stefan Irmeler, Mark Greco, Daniel Wechsler, et al.. Eye formation in semi-hard cheese: X-ray computed tomography as a non-invasive tool for assessing the influence of adjunct lactic acid bacteria. Dairy Science & Technology, EDP sciences/Springer, 2013, 93 (2), pp.135-149. [ff10.1007/s13594-012-0105-2](https://doi.org/10.1007/s13594-012-0105-2). [ffhal-01201406](https://doi.org/10.1007/s13594-012-0105-2)
9. Moshe Rosenberg, Michael McCarthy, Robert Kauten, Evaluation of Eye

- Formation and Structural Quality of Swiss-Type Cheese by Magnetic Resonance Imaging, *Journal of Dairy Science*, Volume 75, Issue 8, 1992, Pages 2083-2091, ISSN 0022-0302
10. Jelinski T., Dub C.J., Sun D.-W., Fornal J. (2007), Inspection of the distribution and amount of ingredients in pasteurized cheese by computer vision, *Journal of Food Engineering*, 83, pp. 3–9.
 11. Apostopoulos C., Marshall R.J. (1994), A quantitative method for determination of shred quality of cheese, *Journal of Food Quality*, 17, pp. 115–128.
 12. Ni H., Gunasekaran S. (2004), Image processing algorithm for cheese shred evaluation, *Journal of Food Engineering*, 61, pp. 37–45
 13. Everard C.D., O'Donnell C.P., Fagan C.C., Sheehan E.M., Delahunty C.M., O'Callaghan D.J. (2005), Correlation between process cheese meltability determined by sensory analysis, computer vision method and Olson and Price test, *International Journal of Food Properties*, 8, pp. 267–275
 14. Hai-Hong Wang, Da-Wen Sun, Assessment of cheese browning affected by baking conditions using computer vision, *Journal of Food Engineering* 56 (2003) 339–345
 15. Hai-Hong Wang, Da-Wen Sun, Evaluation of the oiling off property of cheese with computer vision: Correlation with fat ring test, *Journal of Food Engineering* 61 (2004) 47–55.
 16. Hai-Hong Wang, Da-Wen Sun, Melting characteristics of cheese: analysis of effect of cheese dimensions using computer vision techniques, *Journal of Food Engineering* 52 (2002) 279–284
 17. Xixiu Ma, Evaluation of Functional Properties and Microstructure of Mozzarella Cheese, and their Correlation, PhD thesis, The University of Auckland, 2013.
 18. Mladenov M., S. Penchev, M. Dejanov, Complex assessment of food products quality using analysis of visual images, spectrophotometric and hyperspectral characteristics, *International Journal of Engineering and Innovative Technology (IJEIT)*, 2015, Vol. 4, Issue 12, pp 23-32
 19. Danev A., A. Bosakova-Ardenska, P. Panayotov, P. Boyanova, H. Andreeva, A research of possibilities for objective evaluation of cut surface of white brined cheese produced with different milk, *Scientific Conference Ecology and Health*, 2018, ISSN 2367- 9530, pp 232-237.
 20. Atanaska Bosakova – Ardenska, Petya Boyanova, Peter Panayotov, Application of Global Thresholding Technique in White Brined Cheese Evaluation, (IJIRSE) *International Journal of Innovative Research in Science & Engineering*, 2014, ISSN 2347-3207
 21. Bosakova-Ardenska A., P. Panayotov, P. Boyanova, Application of „Moment preserving thresholding“ algorithm in white brined cheese cut-surface evaluation, *Scientific works of University of Food Technologies*, 2015, Volume LXII, ISSN: 1314-7102, pp 725-730.
 22. Atanaska Bosakova-Ardenska, Hristina Andreeva, Petya Boyanova, Peter

- Panayotov, CutSurf– a software tool for cut surface evaluation of white cheese, International Conference on Computer Systems and Technologies - CompSysTech'17, ISBN: 978-1-4503-5234-5, pp 241-248.
23. Ganchovska V., P. Boyanova, L. Kostadinova, P. Panayotov, Determination some quality characteristics of cheese on the base of images in the visible range of spectra, Scientific Works of UFT - "Food Science, Engineering and Technologies", 2012, Vol. LIX, ISSN: 1314-7102, pp 123-127.
 24. Vasilev M., Image processing for color diagnosis of diseases in yellow cheese, Innovation and entrepreneurship, 2016, ISSN: 1314-9253, Vol. IV, Issue 1.
 25. A. Kulmyrzaev, D. Bertrand, E. Dufour, (2008), Characterization of different blue cheeses using a custom-design multispectral imager, Dairy Sci. Technol. 88 537–548.
 26. Ganchovska, Vladimira & Bosakova-Ardenska, Atanaska & Panayotov, Peter & Kostadinova-Georgieva, Lena & Danev, Angel & Krasteva, Ivanka. (2019). Blue cheese cut surface evaluation by images analysis: Application of image processing for analysis the mould distribution on cut surface of blue cheese. CompSysTech '19: Proceedings of the 20th International Conference on Computer Systems and Technologies. 169-174. 10.1145/3345252.3345280.
 27. Ganchovska, Vladimira & Bosakova-Ardenska, Atanaska & Panayotov, Peter & Kostadinova-Georgieva, Lena & Boyanova, Petya & Krasteva, Ivanka. (2019). APPLICATION OF COMPUTER VISION FOR EVALUATION DISTRIBUTION OF MOULDS PENICILLIUM ROQUEFORTI ON BLUE CHEESE. 28. 112-116.
 28. Otsu, N., "A Threshold Selection Method from Gray-Level Histograms." IEEE Transactions on Systems, Man, and Cybernetics. Vol. 9, No. 1, 1979, pp. 62–66.
 29. D. M. Tsai and Y. H. Chen, "A fast histogram-clustering approach for multilevel thresholding," Pattern Recognition Letters, Vol. 13, No. 4, 1992, pp. 245-252.
 30. S. Arora, J. Acharya, A. Verma, Prasanta K. Panigrahi, "Multilevel Thresholding for Image Segmentation through a Fast Statistical Recursive Algorithm", Pattern Recognition Letters, 29(2), 2008, pp. 119-125.
 31. Mohamed H. Merzban, M. Elbayoumi, "Efficient solution of Otsu multilevel image thresholding: A comparative study", Expert Systems with Applications Volume 116, 2019, pp. 299-309.
 32. Ping-Sung Liao, Tse-Sheng Chen, and Pau-Choo Chung, "A fast algorithm for multilevel thresholding," J. Inf. Sci. Eng. 17(5), 2001, pp. 713–727.
 33. D.Y. Huang, T.W. Lin, W.H. Hu, "Automatic Multilevel Thresholding Based On Two-Stage Otsu's Method with Cluster Determination by Valley Estimation", International Journal of Innovative Computing, Information and Control, Vol. 7, 2011, pp. 1349-4198.

AUTOMATIC NAIL TRANSFER TO THE IMM ZONE SYSTEM

Authors: *Natallia Unarava, Aleksey Pronchak*

Advisors: *Andrey Tyavlovsky, Alexander Isaev*

Belarusian National Technical University(Republic of Belarus)

Abstract. *The work describes the development stages and automatic nail transfer to the IMM zone system functioning concept.*

Keywords: *molding, thermoplastics, STM32, nails, automatic.*

I. INTRODUCTION

Injection molding machine (IMM) also known as an injection press, is a machine used for the thermoplastics parts manufacturing by injection molding. Currently, more than a third of the world's single-piece products from polymer materials are produced using injection molding machines. The injection molding technology is ideally suited to the mass production of complex shapes, an important requirement for which is exact size matching.

The cycle time in the casting process varies widely - thin-walled products can be produced in a few seconds, castings weighing hundreds of kilograms can be produced in minutes.

Plastics remain one of the most popular materials used in almost any area of technology and medicine. This is one of the most common methods. The main reason for its prevalence is the injection molding machine low cost with the ability to obtain any geometric shape products. Metal, wood or glass are significantly more expensive, so they can compete with polymer materials only in narrow niches. By using IMM you are allowed to automate the manufacturing process as much as possible, to obtain high-precision products at a low cost.

This process automation takes place, since injection molding technology has many advantages over other methods. Let's list the most significant of them:

- minimum waste;
- high performance;
- accelerated technological process;
- the ability to make polymer products with any shape and size [1].

The use of manual labor when using injection molding machines is minimal, all operations are controlled by automation, controlling all casting processes and the amount of material.

Products from polymer raw materials are widespread due to their low cost, high manufacturability of production, and the possibility of recycling.

For many types of manufacturing, it will be beneficial to organize such process on their own, and not buy them on the side.

There is nothing complicated to organize a line for the thermoplastic products manufacturing.

The inner mold contours precisely follow the future product shape, therefore, the complete filling of the tooling with polymer means obtaining geometrically

accurate parts.

II. LITERATURE ANALYSIS

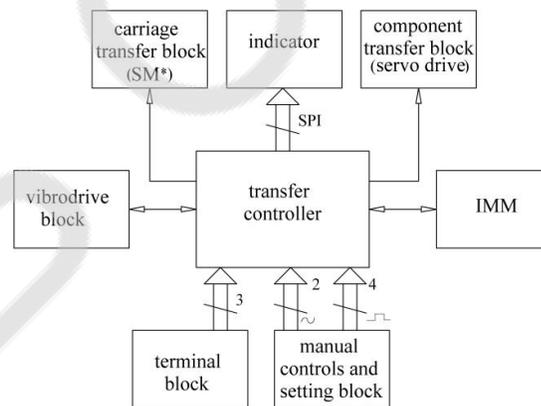
For the manufacturing owner automatic process is the most important, when all operations are controlled by electronics. The IMM elements are usually driven by a pneumatic drive, which is powered by an electric motor.

To avoid destroying the nails head, we cover them tightly with plastic. This way the nail will retain its aesthetic and will last longer as a construction component.

An automation of the transfer nails to the IMM zone process, this will significantly increase the number of processed nails per unit of time. Also we will receive a quality increase, since the transfer process will be fully and completely operated by the controller.

Block-schematic diagram is shown on the Fig. 1. It contains the following blocks:

- transfer controller;
- carriage transfer block;
- indicator;
- component transfer block;
- vibrodrive block;
- IMM;
- terminal block;
- manual controls and setting block.



*SM - stepper motor

Fig. 1. Block-schematic diagram

Transfer controller is responsible for generating an appropriate signals at appropriate times. It analyzes button positions, sets transfer and mounting rate, changes system states and modes. Carriage transfer block is a stepper motor unit. It's responsible for keeping each nail fixed at appropriate place and transferring itself to IMM. Components transfer block inserts each nail to appropriate place. Indicator shows system modes. Terminal block is a device that opens a circuit in a system when moving parts reach their end position. Manual controls and setting block are

used for transfer and mounting rate input. IMM covers each nail tightly with plastic.

General algorithm is shown on the Fig. 2. It contains steps to reach operating mode.

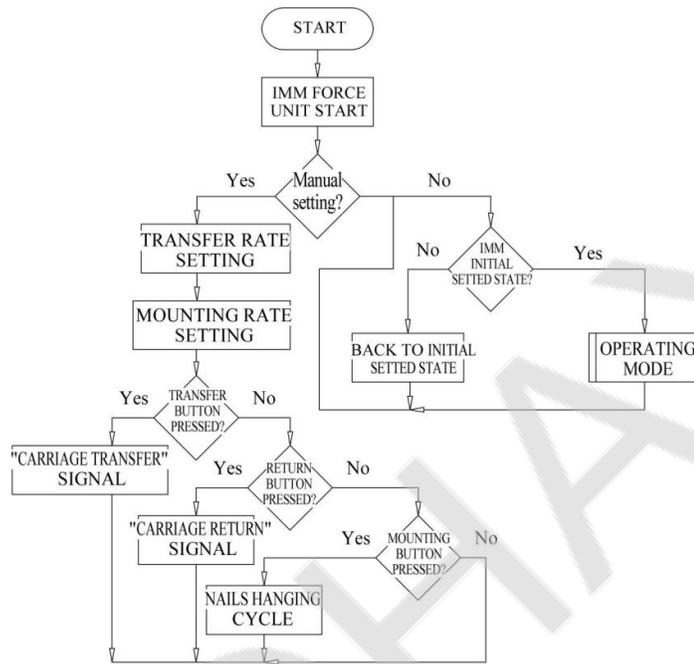


Fig. 2. General algorithm

Originally we launch IMM, we launch IMM force unit too. The controller checks for setting mode occurrence, is it manual. If it's happened, as result we receive transfer rate setting and mounting rate setting polling. These steps we setting the system.

After the controller analyze if the transfer button is pressed. Pressed - a «carriage transfer» signal is generated by the controller. After the system goes for initial state check. Not pressed - the controller analyzes if the carriage return button is pressed. Pressed - a «carriage return» signal is generated. Not pressed - the controller checks for mounting button position. Pressed - the suestem goes to nails hanging cycle. Else - all goes back to setting.

The system is also checking itself for being in the initial setted state before the transfer process. When it's a step checks IMM initial setted state, in positive case, all goes to operating mode. Else the system is getting to initial setted state.

The operating mode includes transfer nails into the IMM zone according settings.

After the operating mode the controller checks for the system being in the initial setted state to continue performing in that mode.

Operating mode exciution algorithm is shown on the Fig. 3. Unlike general algorithm, this one demonstrates operating mode steps only.

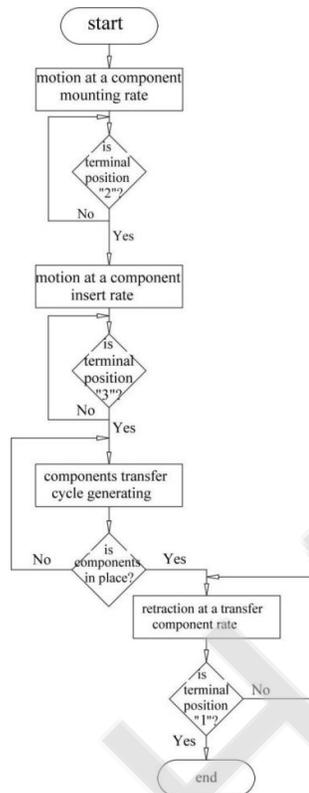


Fig. 3. Operating mode execution algorithm

The controller tells everything to go at a component mounting rate before the terminal switches to position “2”. This is for rate matching. After that, the motion takes a component insert rate value.

If the terminal is switched to “3” position, the controller generates a component transfer cycle. Which means components transfer to the IMM zone.

All components have to be placed into right appropriate places at the zone. When everything is correct, the controller tells the system to start retraction at a transfer component rate. It continues until the terminal position is “1”. It means that every component is in the IMM zone now.

III. ELEMENT BASE DECISION AND REASON

3.1. Microcontroller

To implement the control unit, it is advisable to use the debug board based on the popular and cheap STM32F103C8T6 microcontroller.

The debug board contains the STM32F103C8T6 microcontroller, as well as a voltage regulator, which provides the microcontroller with a stable 3.3 V power supply, which is necessary for a correctly working controller. In addition to the above, the board has an external crystal oscillator, two LEDs, one of which is a power supply indicator, and the other is a test one. Pins of the microcontroller, including pins for programming, are brought out to the edges of the board for easy wiring.

One of the requirements for modern devices is to ensure the safety of the program code from unauthorized access. Read protection through the debug port can be set for STM32 flash memory. While read protection is enabled, flash memory is also write protected to prevent the possibility of incorrect code being placed in the interrupt vector table. STM32 microcontrollers also contain a real time clock and a small amount of battery-powered SRAM. The contents of this area are automatically cleared by an interrupt from the anti-tampering module.

The STM32 requires a single power supply with a voltage ranging from 2.0 V to 3.6 V. The onboard regulator is used to generate 1.8 V for the Cortex core. STM32 can have two additional power supplies. When using an ADC, the VDD power supply voltage must be between 2.4 V and 3.6 V. The 48-pin packages the reference signal is internally connected to the ADC power supply pin. Each voltage source must have stabilizing capacitors.

The STM32 is well equipped with general purpose GPIO I/O ports. They are grouped as five ports, each containing 16 I / O lines. Each digital pin can be configured as a GPIO pin or as an alternative function pin. Each pin can simultaneously operate as one of 16 external interrupt lines.

Ports are designated from A to E latin alphabet and all are 5 V tolerant. Many of the external microcontroller pins can be switched to serve user peripherals such as the USART or I2C instead of performing I/O functions.

The individual pins of each GPIO port can be configured as input or output of various drivers. Ports contain registers into which you can write information in word format or manipulate their bit fields. After making the settings, the registers can be locked.

A port pin can be defined as input or output, and its load characteristic can be selected. If the pin is defined as an input, using the built-in register, you can "pull" the pin to ground or supply voltage. If the pin is defined as an output, it can be configured as push-pull or open-drain. Each output can also be configured to operate at frequencies up to 2 MHz, 10 MHz, or 50 MHz.

In addition to an excellent set of general-purpose peripherals, the STM32 contains five different types of communication peripherals. The STM32 contains SPI and I2C interfaces to exchange information between components on a printed circuit board. There is a CAN bus for communication between different modules of the device, and a USB device interface for communication with a PC. The STM32 also uses the popular USART interface.

For fast data exchange between PCB components, the STM32 contains two SPI modules that provide full duplex data transmission at frequencies up to 18 MHz. It is very important to note that one of the SPI modules is located on the high-speed APB2 peripheral bus, which operates at a clock frequency of up to 72 MHz. The second SPI is located on the low speed APB1 bus, clocked at up to 37 MHz. For each SPI, you can set the clock polarity and phase. Data can be transmitted as 8 or 16-bit words, MSB or LSB. This allows both SPI modules to act as master or slave and communicate with any other SPI device.

To organize high-speed data exchange, each SPI module contains two DMA

channels: one for transmitting data and the other for storing received data into memory. The use of DMA allows high speed data exchange in two directions under hardware control. In addition to the standard functions, the STM32 SPI contains two hardware blocks for calculating the cyclic redundancy code CRC. One CRC block is used for transmitted data, and the other for received data. Both blocks can calculate cyclic redundancy check for 8 and 16-bit data. This function is especially necessary when connecting to SPI MMC/SD memory cards.

STM32 can communicate with other components on the PCB via I2C interface. The I2C interface can operate as a slave or master, and arbitrate in a multi-master system. The SPI interface supports standard data rates up to 100 kHz and fast data rates up to 400 kHz. The I2C module supports 7-bit and 10-bit addressing modes. Essentially, the I2C module simply transmits and receives data over the bus. The I2C module generates two interrupts for the Cortex processor, one to limit error propagation and one to control addresses and data transfers. In addition, two DMA channels are allocated through which you can read from and write data to the I2C transmit buffer. Thus, after coordinating the addresses of devices in the network and data for transmission, the exchange of information can be carried out under STM32 hardware control.

The STM32 contains up to three USARTs, each of which supports several advanced modes to work with modern serial devices. Each of the three USARTs can communicate at speeds up to 4 Mbps. For each USART, you can set the data length (8 or 9 bits), parity stop bit and baud rate. One USART is located on the APB2 bus, which runs at up to 72 MHz, while the rest are on the APB1 bus, which clocks at up to 36 MHz.

Like all other serial communications peripherals, each USART supports two DMA channels for transferring data to and from memory. When the USART is used as a UART, it supports several special communication modes. The USART can transmit data in half duplex mode over a single wire using only the Tx pin. For connecting a modem, as well as for hardware control of data transmission, each USART contains additional control lines CTS and RTS. At the same time, a transmission speed of up to 115200 bit/s is provided, half-duplex NRZ modulation is used, a low power consumption mode is supported when the USART module operates at frequencies from 1.4 MHz to 2.12 MHz.

The STM32 CAN controller is a full-fledged CAN module that supports the CAN 2.0A and 2.0B standards, active and passive data transfer at speeds up to 1 Mbit/s. The CAN controller also has an extension to support fully deterministic data exchange according to the TTCAN protocol. While the TTCAN extension is enabled, automatic message retransmission and message time stamping are supported in the last two bytes of a CAN message packet. The TTCAN extension enables the CAN module to be used by real-time control application software. An important feature of the CAN controller is the filtering of received messages. Since CAN is a broadcast network, every message transmitted is received by all devices on the network. In a CAN network of sufficient complexity, a large number of messages will be transmitted over the CAN bus. The CPU would have to spend all the time processing

these messages. To avoid this, the CAN controller contains a message filter that prevents unnecessary messages from being copied into the receive buffer.

All CAN controllers support two modes of operation: normal mode, for receiving and transmitting message packets, and initialization mode, for setting communication parameters. STM32 can enter "sleep" mode. At such times, the bxCAN clock is disabled, but the mailbox registers may remain available. The bxCAN module will wake up when it detects activity on the CAN bus; it can also be resumed from the application code. In normal mode, there are two sub-modes of operation. The first submode is the silent mode, in which the CAN controller receives but does not transmit messages, and also does not generate an error or message acknowledgment. This mode is intended for passive monitoring of the CAN network. The second submode is the feedback mode, in which all transmitted messages are returned to the receive buffer. This mode is intended for self-testing and is also used when debugging the application code. Both sub-modes can be combined, which is ideal for self-testing a device in a working network.

STM32 contains a full speed (12 Mbps) device USB interface that can be used to connect the device to a PC. The USB module implements the USB physical layer and the data transfer layer with packet error checking and retransmission. The USB interface supports up to eight endpoints, which the user configures as control, interrupt, bulk, and isochronous endpoints. The endpoint buffers are located in a 512 byte SRAM area shared with the CAN controller. During device initialization, the application code splits the SRAM into buffer groups. The SRAM memory area is divided into endpoint buffers using a special table located at the beginning of the SRAM. For each endpoint, the table stores the start address and buffer size. One buffer is allocated for endpoints operating in control mode, interrupts, and large data transfers, while a double buffer is allocated for isochronous endpoints. This allows you to receive data into one buffer and simultaneously process data from another.

3.2. DC motor shaft speed and direction control circuit

To control the DC motor shaft speed and movement direction, we used a circuit coupled with a control unit based on the IRS2186 microcircuit of the 74HCT08 logic gate and the FGH60N60SMD transistor.

The 8-pin SOIC IRS2186 is a high voltage, high speed MOSFET and IGBT driver with independent output channels. Patented anti-latching HVIC and CMOS technologies provide a solid monolithic design.

The logic input is compatible with standard CMOS or LSTTL output, up to 3.3 V logic.

The output drivers have a high surge current buffer stage designed to minimize driver cross-conduction.

The IRS2186 is a 600 V low and high level driver. The driver's output currents are ± 4 A, compatible with 3.3 V and 5 V control logic, undervoltage protection.

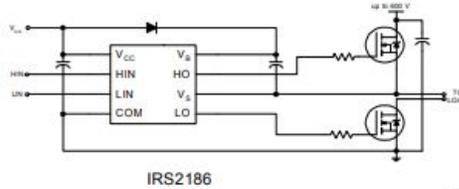


Fig. 7. IRS2186 driver connection diagram

In many cases, it becomes necessary to use field-effect transistors as top-level switches. Also, in many cases, there is a need for field-effect transistors as switches of both the upper and lower levels. For example, in bridge circuits.

In a half-bridge circuit, there is one high-level MOSFET and one low-level MOSFET. In bridge circuits, there are two MOSFETs each of the upper and lower levels. The most common way to drive FETs in such cases is to use a low and high key driver for the MOSFET.

Block diagram, as well the location of the contacts of a common driver IRS2186 for such purposes:

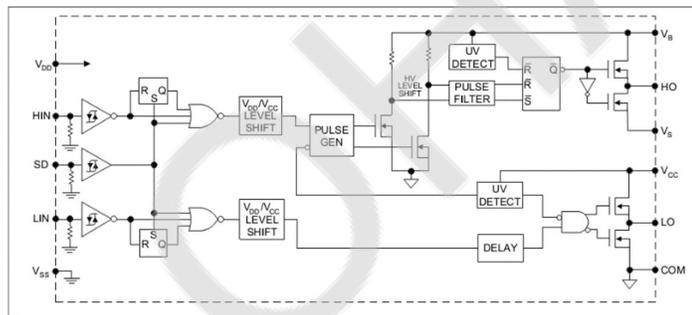


Fig. 8. IRS2186 functional block diagram

It's also worth mentioning that the IRS2186 comes in two packages - a 14-pin PDIP for pin mount and a 16-pin SOIC for surface mount.

V_{CC} is the low level power supply, must be between 10 V and 20 V.

V_{DD} is the logic power for the IR2110, it must be between + 3 V and + 20 V (relative to V_{SS}). The actual voltage you choose to use depends on the voltage level of the input signals. The curve:

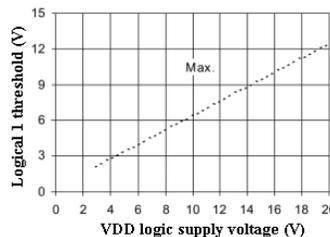


Fig. 9. Logical «1» power curve

Usually a + 5 V V_{DD} is used. At V_{DD} = + 5 V, the input threshold of logic 1

is slightly higher than 3 V. Thus, when $VDD = +5\text{ V}$, the IR2110 can be used to drive a load when the «1» input is higher than 3 (somewhat) volts. This means that the IRS2186 can be used for almost all circuits, as most circuits tend to be powered by about 5 V. When you use microcontrollers, the output voltage will be higher than 4 V (after all, the microcontroller often has $VDD = +5\text{ V}$). When a SG3525 or TL494 or other PWM controller is used, it will probably have to be supplied with a voltage above 10 V, which means that the outputs will be more than 8V with a logical «1». Thus, the IR2110 can be used almost anywhere.

It is also possible to lower VDD to about + 4 V if using a microcontroller or any chip that provides 3.3 V output (for example, dsFig33). In practice, good results are obtained by using the supply voltage + 5 V.

If for some reason in the circuit the level of the logic «1» signal has a voltage less than 3 V, then you need to use a level converter / level translator, it will raise the voltage to acceptable limits. In such, it is recommended to increase to 4 V or 5 V and use the IRS2186 $VDD = +5\text{ V}$.

VSS is the land for logic. COM is «low return» - basically the low ground of the driver.

HIN and LIN are logic inputs. A high signal on HIN means that we want to control the high key, that is, a high level is output to HO.

A low signal on HIN means that it is necessary to turn off the high-level MOSFET, that is, a low-level output is made on the HO. The HO output, high or low, is not considered to ground, but to VS. At a high level, the level at HO is equal to the level at VB, with respect to VS. At a low level, the level at HO is VS, in relation to VS, virtually zero.

A high LIN signal means that it is necessary to drive the lower switch, that is, a high level output is made to LO. A low LIN signal means that it is necessary to turn off the low level MOSFET, that is, a low level output is carried out on LO. The exit to LO is relative to ground. When the signal is high, the level in LO is the same as in VCC, relative to the VSS, effectively ground. When the signal is low, the level in LO is the same as in VSS, relative to VSS, effectively zero.

SD is used as stop control. When the level is low, the IR2110 is enabled - the stop function is disabled. When this pin is high, the outputs are turned off, disabling the IRS2186 control.

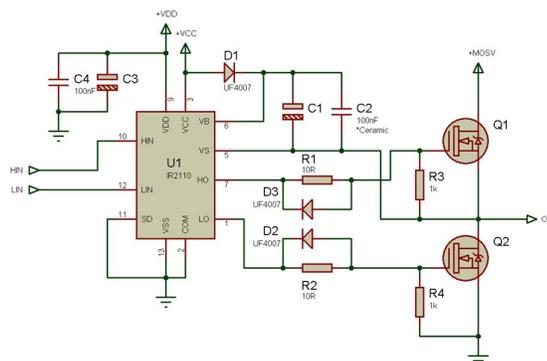


Fig. 10. IRS2186 half-bridge control diagram

D1, C1 and C2 with the IRS2186 form an amplifier circuit. When LIN = 1 and Q2 is on, then C1 and C2 are charged to VB, since one diode is located below + VCC. When LIN = 0 and HIN = 1, the charge on C1 and C2 is used to add additional voltage, VB in this case, above the Q1 source to drive Q1 in the high-key configuration. A large enough capacity must be chosen for C1 in order for it to be sufficient to provide the necessary charge for Q1 to keep Q1 on the entire time. C1 should also not have too much capacity, as the charging process will take a long time and the voltage level will not increase enough to keep the MOSFET on. The longer the time it takes in the on state, the more capacity is required.

Thus, a lower frequency requires a higher C1 capacity. Higher fill factors require higher capacities C1. Of course, there are formulas for calculating the capacity, but for this you need to know many parameters, and some of them we may not know, for example, the leakage current of a capacitor. Therefore, we just estimated the approximate capacity. For low frequencies such as 50Hz, a capacitance of 47 μ F to 68 μ F is used.

For high frequencies, such as 30-50 kHz, I use a capacitance of 4.7 μ F to 22 μ F. Since an electrolytic capacitor is used, a ceramic capacitor must be used in parallel with this capacitor. A ceramic capacitor is optional if the booster capacitor is tantalum.

D2 and D3 discharge the gate of the MOSFETs quickly, bypassing the gate resistors and reducing the turn-off time. R1 and R2 are current limiting gate resistors. + MOSV can be 500V maximum. + VCC should come from a source without interference. Filtering capacitors are also required.

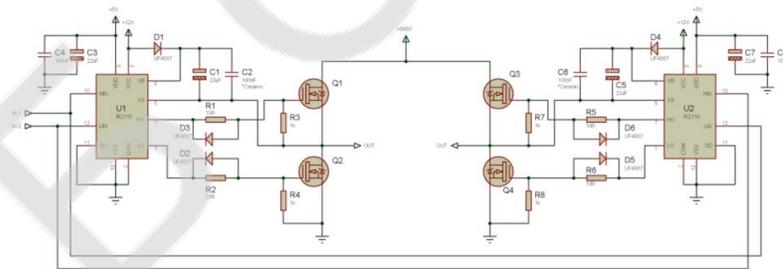


Fig. 11. Applied circuit



Fig. 12. FGH60N60SMD transistor

FGH60N60SMD transistor parameters:

- Maximum voltage – 600 V
- Maximum current at 25°C – 120 A
- Peak transistor collector current – 180 A
- Saturation voltage – 2.5 B

- Power dissipation rating – 600W
- On-delay time at 25°C – 12 ns
- Off-delay time at 25°C – 92 ns

3.3. The switching relay module

The relay switch TR5VL-S-Z is intended for switching the TI unit to the measuring circuit.



Fig. 13. The relay switch TR5VL-S-Z

The switching relay module is a set of miniature telecommunication relays capable of providing reliable contact at low switching currents (from 1 μ A to 2 A). One switch can connect eight two-wire measurement circuits. The switch occupies one «terminal» position and has spring-loaded connectors for connecting switching and control circuits.

3. 4. The matching the signal levels of the control unit and the load circuit

To match the voltage level received from the inductive sensors and the voltage level that the output port of the STM32F103C8T6 microcontroller is used a galvanic isolation scheme based on the PC817 optical pair.

The PC817 is a widely used optocoupler from Sharp. Internally, the optocoupler consists of an LED and a phototransistor, which are not electrically connected in any way, thanks to which, on the basis of PC817, it is possible to realize galvanic isolation of two parts of the circuit - for example, signal and power.

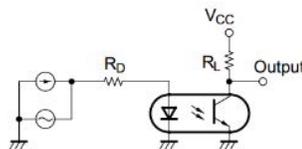


Fig. 14. PC817 connection diagram

PC817 parameters:

- I/O insulation maximum voltage – 5000 V
- Maximum forward current – 50 μ A
- Collector- emitter maximum voltage – 35 V
- Power dissipation rating – 150 mW
- Maximum throughput frequency – 80 kHz

3.5. Transistor switch

Field-effect transistors of the MOSFET family are used as transistor switches in the circuit: IRFR024 and IRLML2060TRPbF.

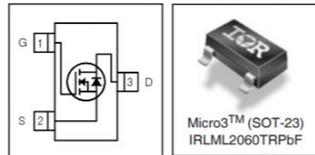


Fig. 15. IRLML2060TRPbF transistor

IRLML2060TRPbF parameters:

- Structure – n-channel
- Source-drain maximum voltage – 60 V
- Source-drain maximum current – 1.2 A
- Gate-source maximum voltage – 16 V
- $R_{DS(on)}$ – 0.48 Ω at 1.2 A, 10 V
- Power dissipation rating – 1.25 W
- Gate threshold voltage – 1...2.5V

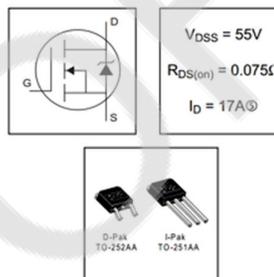


Fig. 16. IRFR024 transistor

IRFR024 parameters:

- Structure – n-channel
- Source-drain maximum voltage – 55 V
- Source-drain maximum current – 17 A
- Gate-source maximum voltage – 20 V
- $R_{DS(on)}$ – 0.075 Ω at 10 A, 10 V
- Power dissipation rating – 45W

IV. RESULTS

To implement the control scheme, the following blocks were designed:

- transfer controller;
- switching relays module;
- DC motor control unit;
- manual controls connection block;
- display unit;

- inductive sensors and optical isolation connecting block.
Control board general view is shown in Fig. 17.

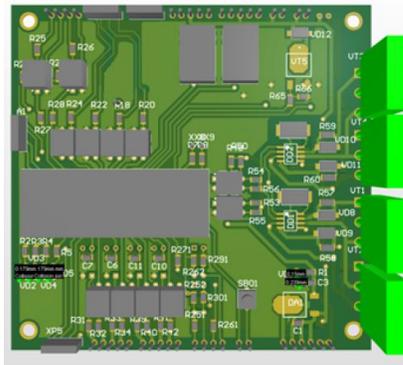


Fig. 17. Control board general view

The device is controlled using a debug board based on the STM32F103C8T6 microcontroller.

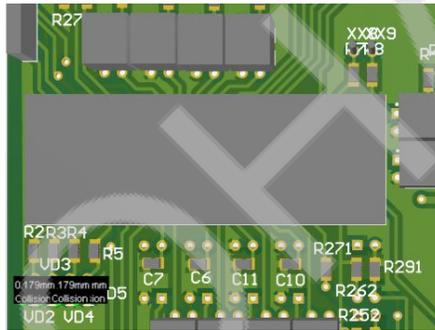


Fig. 18. STM32F103C8T6 debug board location on the control board

The relay switches are controlled by the microcontroller outputs of the control unit. Their placement on the board is shown in Fig. 19.

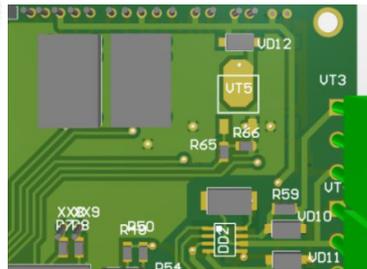


Fig.19. Relay switches location on the control board

The DC motor control unit is implemented using IR2186 high-voltage high-speed drivers and FGH60N60 high-voltage transistors. This circuit is controlled by control unit outputs. The location of the DC motor control unit is shown in Fig.20.

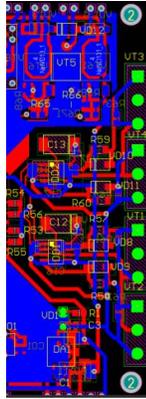


Fig. 20. The DC motor control unit location on the control board Block with detachable interface expander for display connection.

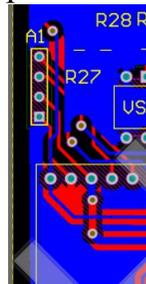


Fig. 21. Display connection

The inductive sensors and optical isolation block is implemented using inductive sensors and PC817 optical pairs. Optical isolation is required to match the level of the signal arriving at the microcontroller input of the control unit and the output signal of inductive sensors. The location of the optically isolated inductive sensor block on the control board is shown in Fig. 22.

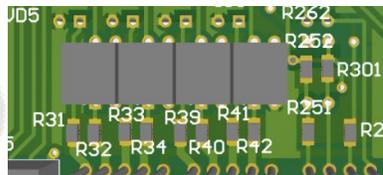


Fig. 22. The inductive sensors and optical isolation block location on the control board

V. CONCLUSIONS

The developed line is installed at the closed stock company "EKT" production association for covering nails with thermoplastic.

VI. REFERENCES

1. Douglas M. Plastic Injection Molding: Manufacturing Process Fundamentals / M. Douglas. – SME, 1996. – P. 11
2. The line for the production of gypsum plasterboard profiles (KNAUF system): <https://meer.group/liniya-dlya-proizvodstva-profilej-dlya-montazha-gipsokartonnyix-plit>

INTERACTIVE ENTERTAINMENT APPLICATION GENERATION SYSTEM

Author: *Dmytro Pesariev*

Advisor: *Maryna Bulaienko*

O. M. Beketov National University of Urban Economy in Kharkiv (Ukraine)

Abstract: *Today, the computer game industry is one of the most promising and important areas of the software development and media entertainment segment. It is based on the creation, promotion and subsequent sale of computer games*

The purpose of this work is to develop an interactive entertainment application - a game - in the genre of "quest" and "visual novel", which will be called "Project AVE". In the process of creating this software product, all the necessary functional components were developed. This application is designed for leisure organization.

The object of research is actually a software product, a computer game, which is designed to organize the leisure of the end users - players.

The subject of research is mathematical models and methods of processing the data received from end users, software modules that organize the interaction of the developed software product with players, as well as information technology related to the organization of leisure of end users.

The software implementation was performed using the methods of RenPy development environment and Python programming language. The program consists of 12 main software modules, the coordinated work of which ensures the correct display of the game and the gameplay. 33 global variables were used for the program code.

Keywords: *computer game, entertainment application, visual novel, leisure organization, gameplay.*

I. INTRODUCTION

The key to the well-being of any country is a strong economy. It has long been considered a full-fledged science [1]. The computer game industry [2] is currently one of the leading sectors of the economy. It is based on the creation, promotion and subsequent sale of computer games, and was the beginning of an entire era of virtual entertainment. This industry originated in 1948 in the United States, but the most noticeable impetus for its further development occurred in the 1970s, and in a very short time this area has become one of the leading industries. In particular, the US profit from the sale of computer games in 2007 amounted to 9.5 billion dollars. The labor market also owes the emergence of a large number of new positions in the field of computer games – from tester to game designer (head of the game creation process), which, in turn, has contributed to the emergence of new niches for employees and employers.

The term "computer game" or "video game" (a noticeable tendency to use the designation "computer game" to address games designed to run on a personal

computer) is used in relation to specialized programs, interactive entertainment applications (app) – games [3]. In turn, the main purpose of the games is to organize the leisure of end users.

Among the notable achievements of the computer game industry is the introduction of new, more powerful components for personal computers (such as more powerful videocards). Modern personal computers owe their power to the development of the virtual entertainment industry and the evolution of approaches and computer game development technology.

The development of computer games is the process of creating them directly (but not implementing and further promoting them to the masses – this is usually done by the publisher). Both a large number of people working in a large firm and a small team of several people can take part in the development. There are also cases when the development of a commercially successful game was mostly done by only one person.

The task of this research is to design and develop an interactive entertainment application (app) – a game – in the genre of "quest" [4] and "visual novel" [5], which will be called "Project AVE". In the process of creating this software product, all the necessary functional components were developed. This application is designed for leisure organization. The object of research is the project product "Project AVE", a computer game designed to organize the leisure of end users – players.

The subject of research is mathematical models and methods of processing the data received from end users – players, software modules that organize the interaction of the developed software product with players, as well as information technology related to the organization of leisure of end users.

II. SUBJECT INDUSTRY ANALYSIS

Video game (computer game) – is an entertainment application (app), a program whose main purpose is to organize the gameplay, to establish interaction between end users - "players" - within the game, as well as between the player and the program. The game process is a component of the game that is responsible for the interactive interaction between the game and the player [6]. It dictates the conditions and rules, within which the player interacts with the game world, how the game world itself will respond to the actions of the end user, determines the relationship between the player and the game.

The basis of the gameplay of video games in the genre of "visual novel" is a demonstration of the story (plot) of the game through text and visual inserts. Interaction between the user and the program is also provided through such actions of the player as the choice of appropriate actions, such as responses in dialogues with non-game characters [7]. One of the prominent representatives of this genre is the computer game "Doki Doki Literature Club!" [8].

The software that is developed – is an interactive entertainment application "Project AVE", a computer game in the genre of "quest" [4] and a "visual novel". The

basis of the game process [6] of video games in the genre of "quest" (or "adventure game") is the solution of certain tasks by the user (player). One of the prominent representatives of this genre is the computer game "Edna & Harvey: The Breakout" [9]. You can see an example of a tyFigital game in the genre of "visual novel" on the figure 1.



Figure 1 – Gameplay of the game in the genre of "visual novel"

Gaming process (or gameplay) of "Project AVE" includes:

- controlling by the player one of the game character thanks to what movement on game space is carried out;
- reading text inserts by the player to understand the plot and to have an idea of the construction of the world in the game;
- the player's choice of certain actions of the game character - first of all, the choice of phrases in the dialogues.

A game character is a specific object of the game that is controlled by the end user or player [10]. It is the control process that separates game characters from non-game characters (NPCs). Non-Player Characters are those game characters that a player cannot control under normal conditions. Usually, they play a background role and can also take part in the scenario of the game itself [7].

Figure 2 shows a UML diagram of the project activity. It describes the basic actions available to the user in "Project AVE". Yes, the player can make settings not only from the main menu, but also from the pause in the main game, as well as save the current process, with its subsequent loading - this will allow him to return to the place in the game where he stopped last time.

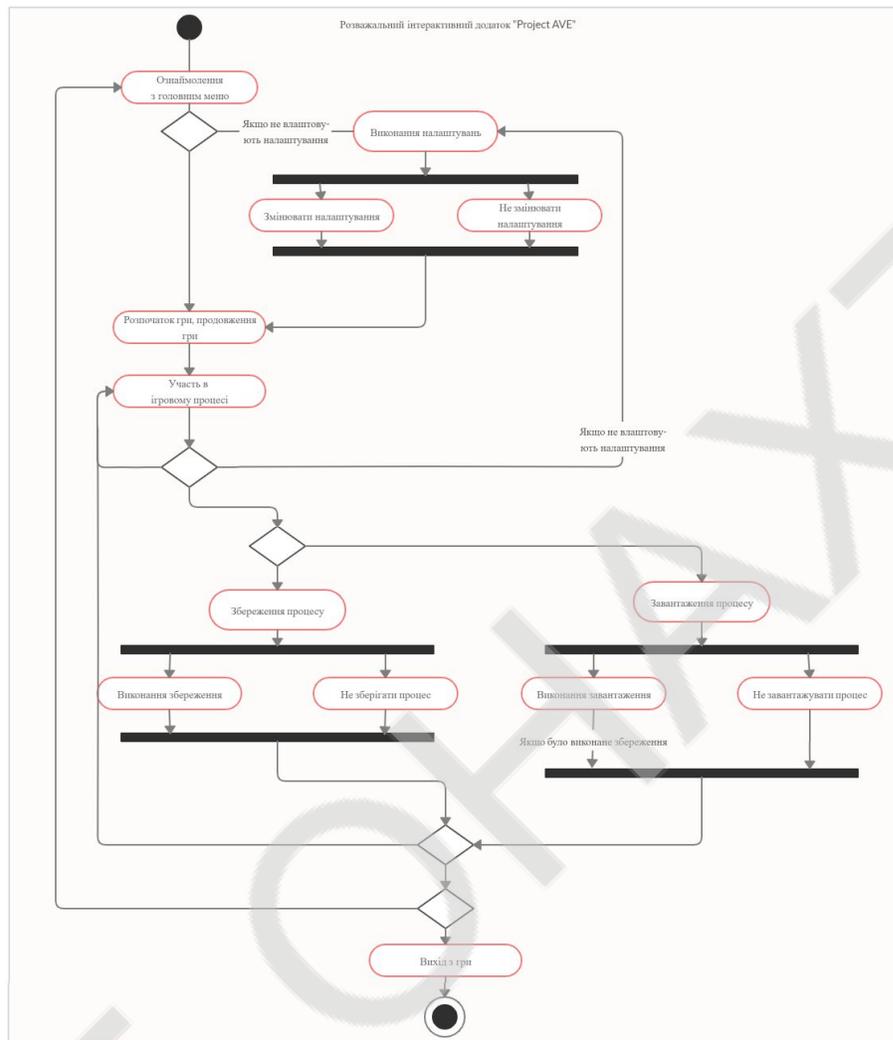


Figure 2 – Diagram of an activity of the end user of the interactive entertainment application "Project AVE"

The actors of the interaction process were identified, as well as what actions are available for each of them within this system.

The end user / player is the target audience of this software product [11]. He can (but is not obliged to) change the settings in the game to his liking, control the game character, explore the game space, but does not have direct access to the source code of the game, ie can not affect it globally, for software security. The interface of an entertaining interactive application is a set of protocols for organizing the interaction of the software product and the end user [12]. Its main purpose is visual and textual interaction, coordination and orientation of the user / player in the game space. Game space (or game process, gameplay [6]) – is a visual representation of the program, the content of the game, in which the main process takes place and realizes the main purpose of any game – the organization of leisure end users. The game space is programmed for appropriate actions, in relation to the user's reactions, and can not act at its discretion or change according to the user's preferences. However,

certain actions of the player affect the state of the playing space. You can see the diagram of use cases on figure 3.

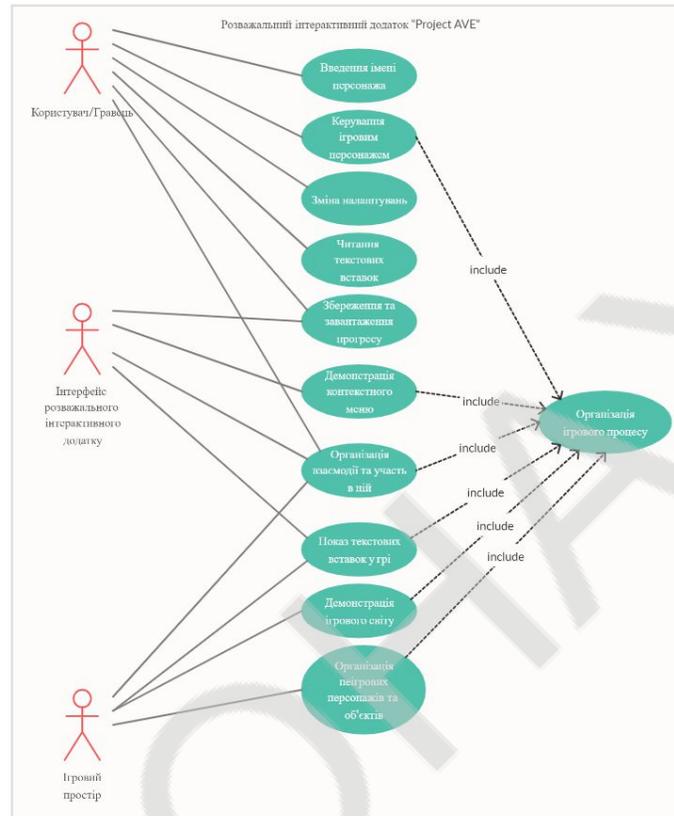


Figure 3 – Diagram of use cases

The organization of the game process is the main purpose of all development and its components; "Leisure organizations of end users".

The main input used by the interactive entertainment application "Project AVE" is the user-entered name of the game character that is used during the game, as well as the player's choices in the game during dialogues with non-game characters or during certain events. The engine used to create Project AVE, Ren'Py [13], uses a system of variables to "remember" the choices made by the player and the data he enters, and outputs the corresponding output data to obtain the necessary information. The main output data demonstrated by "Project AVE" are the fields – text inserts – which through the given text convey to the player the story (plot) [16] of the entertainment application "Project AVE". It should be noted that the user can see all the text outputs of the program only if he selects all available in "Project AVE" options and actions, because the game script does not provide output of all text inserts in order. Another type of such data is graphical. These are images (or "sprites" [15] in the computer games terminology) that show current events in the plot of the game, characters and more.

III. SOFTWARE IMPLEMENTATION

Figure 4 shows a block diagram illustrating the basic algorithm of user interaction and the interactive entertainment application "Project AVE".

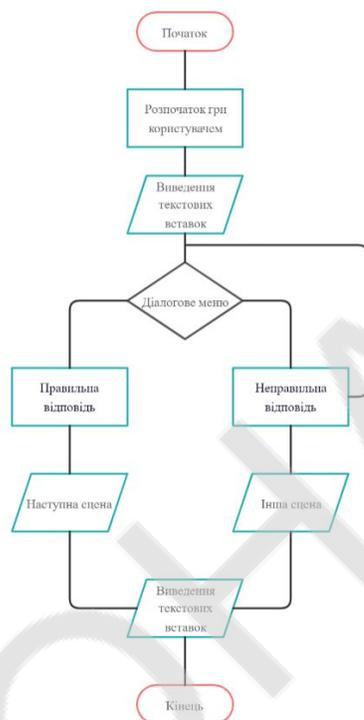


Figure 4 – Block diagram of the gameplay of the application "Project AVE"

Based on the above block diagram of the figure 4, we can draw the following conclusions about the gameplay of "Project AVE". The first thing the user (player) sees after launching the entertainment application is the main menu. After starting the game, the user can see a large number of text fields displayed by the program. At certain points in time, the user will be given the opportunity to influence the further history (plot) of the game, through choices and answers in the dialog menus. Next, according to the script, the player can not go if certain conditions are not met - basically, it is the output of certain text fields by the program, and the user can achieve this if he selects the necessary options in the dialog menus. In case the player has made a wrong action, some events in the game will be inaccessible to him in the subsequent scene of the game space. If everything was done correctly according to the script, the transition to the next scene will take place. The program code provides for the impossibility of the user to go to the next scene, if the necessary conditions have not been met.

Even before writing the program code of the interactive entertainment application "Project AVE", the story (plot) of the game itself was written for further use. There were also pre-specified options for answers and actions of the player and the corresponding various text outputs of the program.

In addition to the text part, sprites [15] – the two-dimensional images – were drawn in advance for further use in an interactive entertainment application, in order to graphically reproduce the events of the story (plot) of the game. These images were created using the graphic editors "Paint.NET" [18] and "Adobe Photoshop CS6" [19].

"Project AVE" was developed by means of the game engine Ren'Py, full name – "Ren'Py Visual Novel Engine" [13]. This engine is a free specialized software environment, the main purpose of which is to create computer games of specific genres - interactive books, visual novels, life simulators or dates [5], in which the display of text and the appropriate response from end users is the central tool program interaction with the player. Ren'Py was developed in 2004 by a programmer with the call sign PyTom, using the Python programming language [20].

A module in programming is a certain functionally complete part of the program. In other words, a module in a program is the part of the general code that is responsible for a particular separate function.

Most of the Project AVE software modules were created using the internal constructions of the Ren'Py engine, while the more complex software functions – initialization and storage of global variables, the use of software (Boolean) logic – are implemented using the Python language.

We can separate the following software modules of the interactive entertainment application "Project AVE":

- main game menu, which can be seen at startup (screen main menu);
- navigation (context) menu that the user can use during the game process (screen navigation);
- parts of the game space in which the plot of the game (label);
- dialog menus, which are the main opportunity for the user to influence the course of the plot in the game (menu);
- information window in which the user can read information about the developer, engine and software version (screen about);
- help window, in which the user can see the configuration of the control keys (screen help);
- this module is responsible for calling the process of loading game progress (screen load);
- this module is responsible for calling the process of saving the game process (screen save);
- history window, which displays all text inserts that the player saw during the game process (screen history);
- creation of non-game characters (Character);
- this module is responsible for displaying text inserts during the game (screen say (who, what));
- styles that are responsible for the appearance of other software modules (style).

The main element of the display of the game space, with images, characters, text and user interface, in games written by the Ren'Py engine are the so-called scenes ("scene"), which, in turn, are a component of more complex objects called "Label". [21]. In general, the purpose of this command is to display a certain image, which will be the general "background" of the scene for a while until the transition to the next scene.

An example of the Ren'Py code for Project AVE, which is designed to create a game space with the label command, is shown in Figure 5.

```
label first_scene:
    show screen mySecondScreen with fade
    scene branch_back_simple with fade:
        size (640, 640), xalign (0.5)
    pause 1.0
    show sprite_hero_back1 with dissolve:
        size (160, 220), xalign (0.35), yalign (0.8), xpos (0.35),
        ypos (0.8), im.Flip("sprite_hero_back1.png", horizontal="True")
    pause 0.5
    show screen mainHeroIdle
```

Figure 5 – Example of using the command "label"

Parts of the program code for creating some game objects using the Ren'Py "label" command to display the game space are shown in Figure 6.

```
label splashscreen:
    scene fill black first with dissolve
    pause 1.0
    return

label start:
    scene fill black first with fade
    pause 0.5
    mainhero "где... где это я?"
    mainhero "кто я?.."

label main_name:
    $ mainhero = renpy.input("Введите имя:")
    if mainhero == "":
        "Меня точно как-то зовут!"
        jump main_name
    else:
        mainhero "так... кажется, меня зовут [mainhero]."
        pause 1.0

label first_scene:
    show screen mySecondScreen with fade
    scene branch_back_simple with fade:
        size (640, 640), xalign (0.5)
    pause 1.0
    show sprite_hero_back1 with dissolve:
        size (160, 220), xalign (0.35), yalign (0.8), xpos (0.35),
        ypos (0.8), im.Flip("sprite_hero_back1.png", horizontal="True")
    pause 0.5
    show screen mainHeroIdle

label inventoryfirstscreen:
    hide screen mainHeroIdle
    scene interface_1 with fade:
        size (640, 640), xalign (0.5)
    pause 1.0

label second_scene:
    show screen mySecondScreen with fade
    scene branch_back_simple with fade:
        size (640, 640), xalign (0.5)
    pause 1.0
    show sprite_hero_back1 with dissolve:
        size (160, 220), xalign (0.35), yalign (0.8), xpos (0.35),
        ypos (0.8), im.Flip("sprite_hero_back1.png", horizontal="True")
    pause 0.5

label bum_scene:
    scene branch_back_garbage with fade:
        size (640, 640), xalign (0.5)
    show sprite_hero_back1 with dissolve:
        size (160, 220), xalign (0.35), yalign (0.8), xpos (0.35),
        ypos (0.8), im.Flip("sprite_hero_back1.png", horizontal="True")
    show sprite_bum_back1 with dissolve:
        xpos (0.51), ypos (0.25)
    pause 0.5

label bum_dialogue1:
    show screen mainHeroIdle
    show screen bumIdle
    menu:
        label option1_1:
        label option1_2:
        label option1_3:
        label option1_4:
        label option1_5:
        label option1_6:
        label option1_7:
    label game_choice1:
        menu:
            "Предложить ему сыграть в загадки":
                $ choice1_5 = "1"
                jump option1_41
            "Предложить ему сыграть в слова":
                $ choice1_5 = "2"
                jump option1_42
            "Предложить ему сыграть в кости":
                $ choice1_5 = "3"
                jump option1_43
            "Отказаться от этой затеи (на три пункта назад)":
                $ choice1_5 = "4"
                jump bum_dialogue2

label cafe_dialogue_start:
    $ naruanwers1 = 0
    $ maffieanswers1 = 0
    $ teidanswers1 = 0
    scene back_inside_door with fade:
        size (640, 640), xalign (0.5)
    show sprite_hero_back1 with dissolve:
        size (160, 220), xalign (0.5), yalign (0.8), xpos (0.5),
        ypos (0.8), im.Flip("sprite_hero_back1.png", horizontal="True")
    pause 0.5
```

Figure 6 – Fragments of software modules using the command "label"

Variables [22] in programming and computer science are objects that have a name and meaning. Common variables are variables that are declared at the beginning of the program code, for further use or change or assignment of value anywhere in the code.

In the Ren'Py engine, there is a "define" command to declare a common variable, which is preferably written before the "scene start" command, which in turn is responsible for the initial scene of the game.

Figure 7 lists the common variables that were used in the following program code.

Most of the common variables use a logical data type, and take the value "True" or "False", depending on the actions and program processes provided by the program code.

```
7 define mainhero = Character("", color = "#66CDA4")
8 define bum = Character("Бездомный", color = "#808000")
9 define naru1 = Character("Официантка", color = "#F08080")
10 define naru2 = Character("Нару", color = "#F08080")
11 define muffie1 = Character("Продавщица", color = "#FF7F50")
12 define muffie2 = Character("Мафи", color = "#FF7F50")
13 define teid1 = Character("Посудомойщик", color = "#20B2AA")
14 define teid2 = Character("Тэйд", color = "#20B2AA")
15 define voice1 = Character("Голос", color = "#FF0000")
16 define knownaru = False
17 define knowmuffie = False
18 define knowteid = False
19 default choicenu1_1 = False
20 default choicenu1_2 = False
21 default choicenu1_3 = False
22 default choicenu1_4 = False
23 default choicenu12_1 = False
24 default choicenu12_2 = False
25 default choicemuffie1_1 = False
26 default choicemuffie1_2 = False
27 default choicemuffie1_3 = False
28 default choicemuffie1_4 = False
29 default choicemuffie12_1 = False
30 default choicemuffie12_2 = False
31 default choiceteid1_1 = False
32 default choiceteid1_2 = False
33 default choiceteid1_3 = False
34 default choiceteid1_4 = False
35 default choiceteid12_1 = False
36 default choiceteid12_2 = False
37 default naru_clear1 = False
38 default muffie_clear1 = False
39 default teid_clear1 = False
40 default lavka1 = False
```

Figure 7 – List of common variables

IV. USER MANUAL

The main task of the user manual is to provide the end users (players in this case) with the necessary information to work independently with a software product or automated system.

For stable launch and subsequent operation of the application, the computer must have the following configuration:

- 1.5 GHz processor for 2 cores (the manufacturer does not matter), preferably better;
- RAM capacity - not less than 1 GB;
- Video memory capacity - not less than 256 MB;
- wide display with a resolution of at least 1280 × 720, with an aspect ratio of 16: 9, for correct display;
- any sound card;
- amount of free hard disk space - not less than 1 GB;
- keyboard;
- computer mouse

The main requirement for the software for the correct launch of the interactive entertainment application "Project AVE" is the Microsoft Windows operating system installed on the computer - preferably Windows 10 × 64.

After installing the interactive entertainment application, you need to start the game using the executable file (with .exe resolution), or the appropriate shortcut (a small icon on the desktop).

The first thing the user (player) will see is the main game menu window. It can be seen on the figure 8.

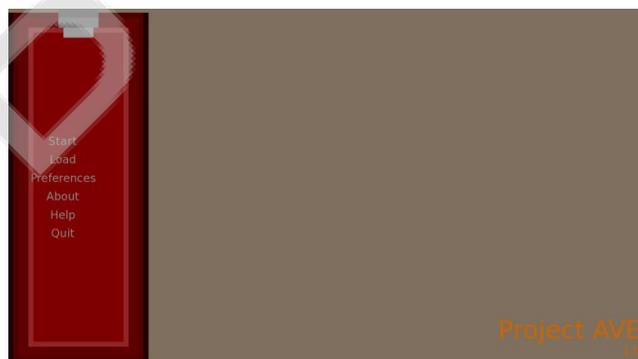


Figure 8 – Window of the main menu of the application

The player can start the game immediately by pressing the left mouse button (or the Enter key on the keyboard) with the "Start" button. In the same way the user chooses all other options in the main menu. Navigate the main menu by using the arrow keys on the keyboard or by moving the computer mouse cursor.

The next option after "Start" is "Load", which will open a window with saves (English "save states" [23]). Here the player can see the previously saved game process and download it to continue the game from the desired location. The "Preferences" button of the main menu is responsible for opening the options window. You can see it on the figure 9.

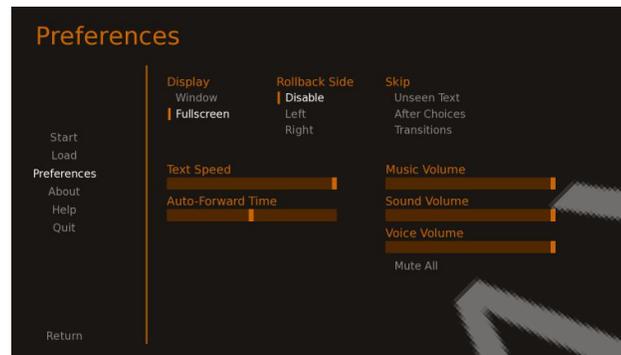


Figure 9 – Options window in the main menu

The "About" option is responsible for displaying the information window – it contains brief information about this game. The "Help" option shows a help window – information on the configuration (assignment) of the keys to perform the appropriate actions in the game. The last button – "Quit" – is responsible for closing the game window, in fact, for exiting the game application "Project AVE".

By pressing the "Start" button, the user will start a new game, regardless of whether he saved his process in the game application before - if so, the player will be able to download it using the "Load" option. The game will start with a black screen and several text boxes. The entire plot of the game will be transmitted to the user through similar text inserts, as well as through changing images and the appearance of new game characters on the screen. After the player reads the text from the output window, you must press the Enter key, Space (space), or the left mouse button to go to the next text insert. At certain points – particularly on the third screen after the start of the game – the player is required to enter a name, which will then be used to identify the game character played by the user. You can enter a name in any language supported by Ren'Py. If the user has left this field blank, the program will warn him that the line with the name must be filled.

In the future, the user needs attention to the text that displays the game, because in this entertainment application it is the main means of acquainting the player with the history (plot) of the game (Figure 10).

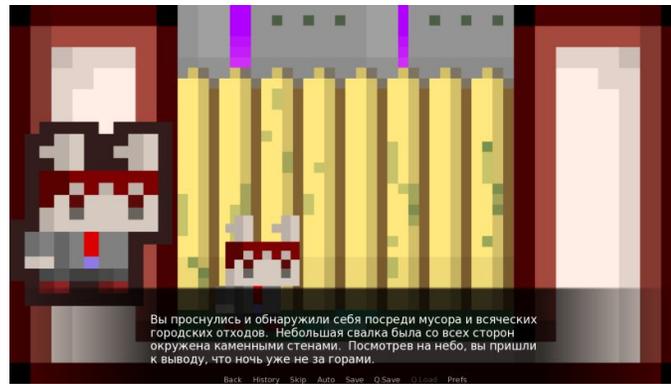


Figure 10 – Demonstration of text output from the game

The basis of the game process (gameplay) of the entertainment application "Project AVE" is the ability of the user to influence the course of the plot in this game, using a menu system with a set of actions and answers in dialogues between the characters of the game. On the figure 11 you can see one of the first such menus.



Figure 11 – Demonstration of the menu during the dialogue in the game

The choice of player in the menu data affects the subsequent story. You can only see some texts and events by selecting a specific option. The interactive application "Project AVE" will respond to any option selected by the player, and if the selected choice was incorrect, the game will return the user to the menu with options to choose another. You can't choose some options if you don't take these steps first. At the bottom of the screen there is a navigation menu, which allows you to download ("Load" button) and save ("Save" button) the gameplay, read history ("History" button), automatically switch dialogs ("Skip" and "Auto"), and open the options menu ("Prefs" button).

V. CONCLUSIONS

As a result of the research, RenPy engine and Python language developed an interactive entertainment application "Project AVE" – a software product, the main purpose of which is to organize the leisure of end users (players), presented in the form of a computer game.

The following issues were also considered:

- the analysis of the subject area is carried out, the main features of the developed software product are marked, the available analogues are given, taking into account their advantages and disadvantages;
- marked input and output data required for the operation of the program;
- the general structure of the interactive entertaining application is developed;
- described the algorithm of the program and the general functions it performs;
- the main program elements - modules - with the description of actions and functions for which they are responsible in the code are allocated;
- were created UML diagrams of activities, uses, classes, sequences, states, with a description of their components;
- a detailed user guide manual, with a description of all the main windows of the program and the features that are available to the user in each of them.

Figure 12 shows the part of the source code of the “Project AVE”:

```

label option2_1:¶
...scene back_inside_2 with fade:¶
...size (640, 640), xalign (0.5)¶
...show_sprite_naru_back1 with dissolve:¶
...size (160, 220), xalign (0.3), yalign (0.75), imFlip("sprite_naru_back1.png", horizontal="True")¶
...pause 0.5¶
...show_sprite_hero_back1 with dissolve:¶
...size (160, 220), xalign (0.7), yalign (0.75)¶
...{size=4} You come to the table, which the waitress is rubbing so hard, and greet her, as if instantly remembering
the correct greeting in these places.¶
...Quickly quitting her job, she straightened up and folded her arms behind her back, turned to you, smiling. size)¶
...She... probably didn't expect to see you here¶
...She smiled absolutely charmingly - naturally and so truly that your soul suddenly felt calmer at once; you almost
forgot that you forgot everything.¶
...{size=5} The girl was about the same height as you, wore the work uniform of the institution (by the way, in your
opinion, quite prestigious for such a not particularly remarkable cafe) - and, for some reason, a man's: a dark red vest
over a white shirt, and strict black trousers: {/size}¶
...naru1 "Oh, hello again, {mainhero}! Is everything I can do for you?"¶
label_naru_dialogue1:¶
...menu:¶
... "Ask if she knows you":¶
... $naruanswers1 += 1¶
... $choicenaru1_1 = True¶
... if knownaru == True:¶
... "You decided to ask the waitress what she knows about you.¶
... It's not for nothing that you have a name badge in your pocket with the name of this establishment."¶
... naru2 "(uncomprehending) What in the world? You are our HR manager, {mainhero}."¶
... "And she added in a whisper, leaning forward a little:¶
... naru2 "Say, are the check came again?"¶
... jump_naru_dialogue1¶
... if knownaru == False:¶
... "You decided to ask the waitress what she knows about you.¶
... It's not for nothing that you have a name badge in your pocket with the name of this establishment."¶
... naru2 "(uncomprehending) What in the world? You are our HR manager, {mainhero}."¶
... "And she added in a whisper, leaning forward a little:¶
... naru2 "Say, are the check came again?"¶
... jump_naru_dialogue1¶
... "You wants to know her name"¶
... $naruanswers1 += 1¶
... $knownaru = True¶
... $choicenaru1_2 = True¶
... "Even when you were so close, you couldn't read the waitress's name badge.¶
... You ask her what her name is."¶
... "The girl's smile did not disappear from her face, but now she began to look strained, and her gaze turned sad."¶
... naru1 "It's nothing... We are here... yes, not all are so easy to remember. You are here, nevertheless, not so
straight for long... My name is Naru."¶
... "The name seemed unfamiliar to you."¶

```

Figure 12 – Part of the source code of the program

VI. REFERENCES

1. Економіка [Електронний ресурс] // Режим доступу <https://uk.wikipedia.org/wiki/Економіка>
2. Индустрия компьютерных игр [Електронний ресурс] // Режим доступу https://ru.wikipedia.org/wiki/Индустрия_компьютерных_игр
3. Відеогра [Електронний ресурс] // Режим доступу <https://uk.wikipedia.org/wiki/Відеогра>
4. Пригодницька відеогра [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Пригодницька_відеогра
5. Візуальна новела [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Візуальна_новела
6. Ігровий процес [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Ігровий_процес
7. Неігровий персонаж [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Неігровий_персонаж
8. Doki Doki Literature Club! [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Doki_Doki_Literature_Club!
9. Edna & Harvey: The Breakout [Електронний ресурс] // Режим доступу https://ru.wikipedia.org/wiki/Edna_%26_Harvey:_The_Breakout
10. Протагоніст [Електронний ресурс] // Режим доступу <https://uk.wikipedia.org/wiki/Протагоніст>
11. Геймер [Електронний ресурс] // Режим доступу <https://uk.wikipedia.org/wiki/Геймер>
12. Інтерфейс користувача [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Інтерфейс_користувача
13. Ren'Py [Електронний ресурс] // Режим доступу <https://en.wikipedia.org/wiki/Ren%27Py>
14. Сценарий [Електронний ресурс] // Режим доступу <https://ru.wikipedia.org/wiki/Сценарий>
15. Спрайт (комп'ютерна графіка) [Електронний ресурс] // Режим доступу [https://uk.wikipedia.org/wiki/Спрайт_\(комп%27ютерна_графіка\)](https://uk.wikipedia.org/wiki/Спрайт_(комп%27ютерна_графіка))
16. Сюжет [Електронний ресурс] // Режим доступу <https://ru.wikipedia.org/wiki/Сюжет>
17. Комп'ютерна графіка [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Комп%27ютерна_графіка
18. Paint.NET [Електронний ресурс] // Режим доступу <https://uk.wikipedia.org/wiki/Paint.NET>
19. Adobe Photoshop [Електронний ресурс] // Режим доступу https://uk.wikipedia.org/wiki/Adobe_Photoshop
20. Python [Електронний ресурс] // Режим доступу <https://ru.wikipedia.org/wiki/Python>

21. Ren'Py Documentation: Displaying images [Електронний ресурс] // Режим доступу
https://www.renpy.org/doc/html/displaying_images.html
22. Змінна (програмування) [Електронний ресурс] // Режим доступу
[https://uk.wikipedia.org/wiki/Змінна_\(програмування\)](https://uk.wikipedia.org/wiki/Змінна_(програмування))
23. Saved game [Електронний ресурс] // Режим доступу
https://en.wikipedia.org/wiki/Saved_game#Save_states

ARTIFICIAL INTELLIGENCE

Author: *Aleksandar Cvetanov*

Faculty of Electrical Engineering and Information Technologies
Ss. Cyril and Methodius University, Skopje, (Republic of North Macedonia)

The toFig of this work is artificial intelligence, what it represents, its development throughout the years, and its use in everyday life. The main purpose is to show the value of artificial intelligence to the world, and to put into perspective the way AI has been developed and utilized with the creation and evolution of intelligent machines. Artificial intelligence has had a substantial influence on people's lives, however many people still believe that AI will one day lead to more bad than it will ever do good to the world. The main goal of this paper, is to learn and explore the world of artificial intelligence, and perhaps help readers dive deeper in order to learn new and exciting things.

Keywords: intelligence, learning, reasoning, problem solving, perception, algorithm, application, development

I. INTRODUCTION

Artificial Intelligence (AI), is intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals, which involves consciousness and emotionality. It is commonly referred to as the simulation of human intelligence in machines that are programmed to think and mimic the actions of humans. The main characteristic of artificial intelligence is its ability to rationalize and take actions which have the highest probability to achieve a certain goal.

There is a specific distinction between two different types of AI. 'Strong AI' usually refers to AGI (Artificial General Intelligence), whereas attempts to emulate 'natural' intelligence are referred to as ABI (Artificial Biological Intelligence). As machines become more and more advanced, many of the tasks linked with thinking and reasoning are no longer associated with artificial intelligence. This is a phenomenon known as the 'AI effect'. Still, despite these advances in machines and

computer processing speed, there are no programs that can match human flexibility over wider domains or in tasks requiring common sense. Modern machine capabilities commonly classified as AI include understanding human speech, competing at the highest level in strategic game systems, autonomously operating vehicles, and military simulations.



Figure 1. Representing Artificial Intelligence

II. LITERATURE ANALYSIS

2.1. Understanding Artificial Intelligence

When people hear the term AI, most associate it with robots. This is mainly due to how AI is portrayed in popular films and novels. However, this is far from the truth. Artificial intelligence is based on the principle that human intelligence can be represented in an easy way in order for machines to try to replicate. A typical AI analyzes its environment and takes actions that maximize its chance of success.

AI work usually revolves around the use of algorithms. Algorithms are sets of unambiguous instructions that a mechanical computer can execute. Many AI algorithms are capable of learning from data, i.e. they can enhance themselves by learning new heuristics, or write new algorithms by themselves.

The goals of artificial intelligence include learning, reasoning, problem solving, and perception. Machine learning, a fundamental concept of AI research since the field's inception, is the study of computer algorithms that improve automatically through experience. There are two types of machine learning, unsupervised and supervised. Unsupervised learning is the ability to find patterns in a stream of input, without the help of humans. Supervised learning includes two

methods, classification and numerical regression, both dependent on a human to input data first. Classification is a method which determines the category of an object. Regression is the attempt to produce a function that describes the relationships between inputs and outputs and predicts how the outputs would change as the inputs change. Reasoning means drawing inferences appropriate for the situation. Inferences are classified into deductive and inductive. Inductive reasoning is usually found in science, where data is collected and tentative models are developed to describe and predict future behavior. Deductive reasoning is common in mathematics and logic, where elaborate structures of irrefutable theorems are built up from a small set of axioms and rules. Problem solving, particularly in AI, can be characterized as systemic search through a range of possible actions in order to reach some predefined goal or solution. Problem solving methods are divided into special purpose and general purpose. A special-purpose method is used only for a specific task or problem, whereas general-purpose methods can be used in a variety of situations. Many diverse problems have been solved by artificial intelligence programs, such as, finding a winning move or a sequence of moves in a board game, devising mathematical proofs, and manipulating virtual objects in a computer-generated world. Machine perception is the ability to use input from sensors (such as cameras, microphones, wireless signals, and radars) in order to deduce and understand different aspects of the world. The scanned environment is then decomposed in various spatial relationships. However, this is difficult to analyze and deduce, as many objects in the world can have a different shape depending on the viewing angle, the direction and intensity of illumination in the scene, and the contrasts with the surrounding field. At present, artificial perception is sufficiently well advanced to enable optical sensors to identify individuals, and autonomous vehicles to drive at moderate speeds on open roads.

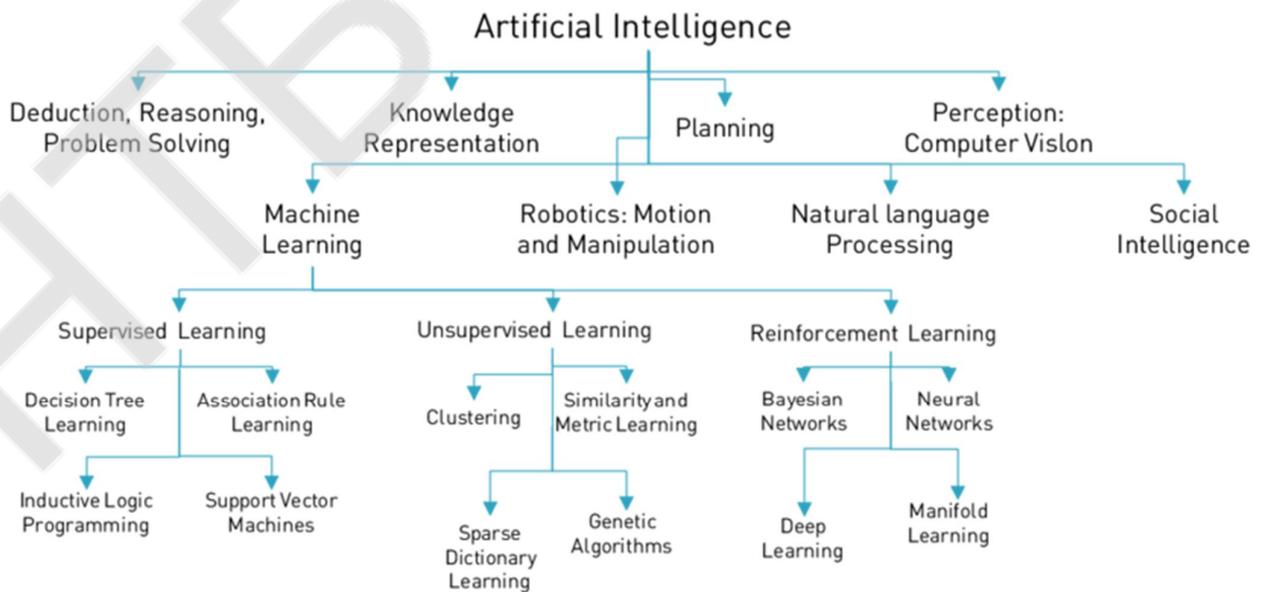


Figure 2. An overview of disciplines used to represent AI

2.2. Methods and Goals in AI

No established unifying theory or paradigm guides AI research. There are multiple approaches to giving the true definition of artificial intelligence and answering the most frequently asked questions regarding the development of AI. There are four main approaches commonly used to describe and define the evolution of artificial intelligence.

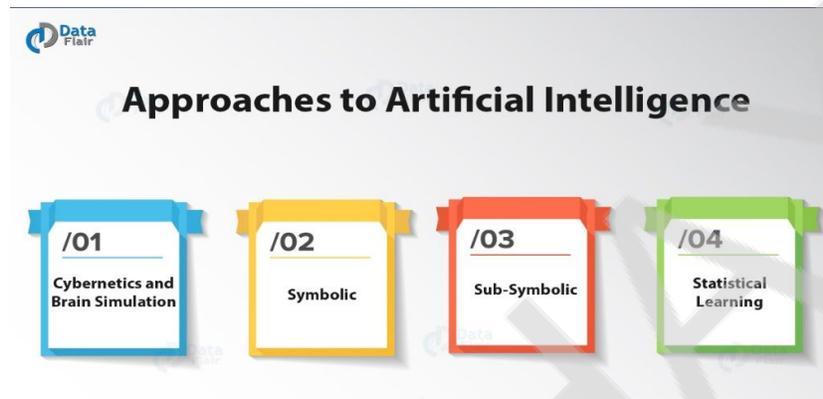


Figure 3. Approaches to artificial intelligence

2.2.1. Cybernetics and Brain Simulation

In the 1940s and 1950s, a number of researchers explored the connection between neurobiology, information theory, and cybernetics. Some of them built machines that used electronic networks to exhibit rudimentary intelligence. However, this method was quickly abandoned and it did not resurface again until the 1980s.

2.2.2. Symbolic Approach

When access to digital computers became possible in the mid-1950s, AI research began to explore the possibility that human intelligence could be reduced to symbol manipulation. During the 1960s, this approach had achieved great success at simulating high-level “thinking” in small demonstration programs. Approaches based on cybernetics or artificial neural networks were abandoned in favor of the symbolic approach. Researchers in the 1960s and 1970s were convinced that symbolic approaches would eventually succeed in creating a machine with artificial general intelligence and considered this the goal of their field. There were four styles that catered to this approach:

a) Cognitive simulation – Economist Herbert Simon and Allen Newell studied human problem-solving skill and attempted to formalize them. Their work laid the foundations of the field of artificial intelligence, as well as cognitive science, operations research and management science. Their team of researchers used the results of psychological experiments to develop programs that simulated the techniques that people used to solve problems.

b) Logic-based – Unlike the approach above, scientist John McCarthy felt that machines did not need to simulate human thought, but should instead find the essence of abstract reasoning and problem-solving, regardless of whether people used

the same algorithms. His laboratory at Stanford focused on using formal logic to solve a wide variety of problems, including knowledge representation, planning and learning.

c) Anti-logic or scruffy - Researchers at MIT discovered that solving difficult problems in vision and natural language processing required ad hoc solutions. They argued that no simple or general principle (like logic) would capture all the aspects of intelligent behavior. The description “scruffy” was given by artificial theorist Roger Schank, who noted that their “anti-logic” approach was not thought of as well as the previous two styles.

d) Knowledge-based – When computers with large memories became available around 1970, researchers from all three traditions above began to build knowledge into AI applications. This revolution in AI development led to the deployment of expert systems, the first truly successful form of AI software. A key component of the system architecture for expert systems is the knowledge base, which stores facts and rules that illustrate AI.

2.2.3. Sub-symbolic Approach

By the 1980s, progress in symbolic AI seemed to have stalled and many believed that the symbolic approach would never be able to satisfy the needs of bigger AI development. A number of researchers began to look into “sub-symbolic” approaches to specific AI problems. There are two main sub-symbolic methods that manage to approach intelligence without specific representations of knowledge.

a) Embodied Intelligence – Researchers from the related field of robotics rejected symbolic AI and focused on the basic engineering problems that would allow robots to move and survive. Their work revived the non-symbolic approach of cybernetics and reintroduced control theory in AI. This coincided with the idea that aspects of the body (such as movement, perception and visualization) are required for higher intelligence.

b) Computational intelligence and soft computing – Interest in neural networks was revived in the mid-1980s. Artificial neural networks are an example of soft computing; they are solutions to problems that cannot be solved with complete logical certainty, where an approximate solution is often sufficient. The application of soft computing to AI is studied collectively by the emerging discipline of computational intelligence.

2.2.4. Statistical learning

Around the 1990s, AI researchers adopted sophisticated mathematical tools, such as hidden Markov models (HMM), information theory, and Bayesian decision theory to compare or unify competing architectures. The shared mathematical language permitted a high level of collaboration with more established fields (such as mathematics, economics or operations research). The development of statistical learning resulted in higher levels of accuracy in many practical domains, such as data mining, without necessarily acquiring a semantic understanding of the datasets. Nowadays, experiment results are often rigorously measurable, and can often lead to amazing new discoveries. Many researchers have said that the shift to statistical learning, while very substantial to the growth of AI development, has shifted the

narrative from explainable AI, i.e. the methods of developing artificial intelligence have become less and less understandable for the layman.

2.3. Applications of Artificial Intelligence

The applications for AI are endless, because the technology can be used in various sectors and industries. Modern artificial intelligence techniques are pervasive and there are so many that it is impossible to list them all. When one of these techniques reaches mainstream use, it is no longer considered artificial intelligence. This phenomenon is called the AI effect. Artificial intelligence has been widely used in the healthcare industry for dosing drugs and different treatments to patients, and for surgical procedures in the operating room. Other examples of machines with artificial intelligence include autonomous vehicles (such as drones and self-driving cars), computers that play games (like Chess or Go), search engines, online assistants, image recognition and many more. Each of these machines weigh the consequences of any action they take, because each action will impact the end result. Artificial intelligence also has applications in the financial industry, where it is used to detect and flag activity in banking such as unusual debit card usage and large account deposits, which help the bank's fraud department. Applications for AI are also being used to help streamline and make trading easier. This is done by making supply, demand, and pricing of securities easier to estimate.

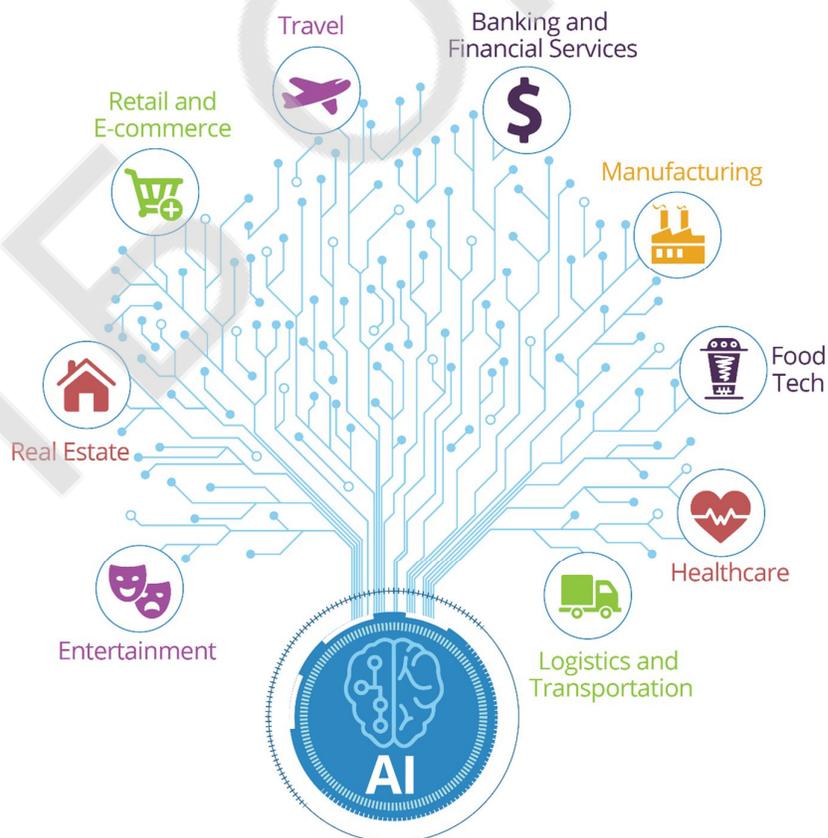


Figure 4. Applications of AI

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Because of the nature of the toFig, the most viable way to gather information is to read already existing articles on AI. The interesting part is that very little is known about the true extent of AI development. Companies are reluctant to reveal the proprietary technologies and approaches to its use in the industries. Its application in everyday life seems to grow by the day, with many companies deciding to pursue machines that use AI in their respective sectors and industries. The subject of this work was not only to show and to present AI to the world, but to encourage readers to dive deeper into the meaning of artificial intelligence and understand its value to the world.

IV. RESULTS

Table 1. Summary of approaches to AI

Approaches to AI			
Cybernetics	Symbolic	Sub-symbolic	Statistical Learning
The first method used to connect artificial intelligence with human intelligence. It was short-lived, but it had its influence on another approach later in the development cycle of AI.	An approach that, at the time of its early stages, was considered to be the breakthrough in the development of artificial intelligence. It helped paint the Figure of what AI should represent.	It brought back cybernetics into the development of AI and introduced the idea that the movement of a body is necessary for reaching higher intelligence.	This method has had the biggest influence on the rise of artificial intelligence. It connected AI to the mainstream world and introduced the technology to companies and industries all around the world.

Table 2. Applications of AI in various sectors and industries

Applications of AI				
Healthcare industry	Travel and Transportation	Financial industry	Online Assistance	Manufacturing
In most recent times, the healthcare industry has been most influenced by AI. It has helped with treatments of patients and surgical operations in the operating room.	Artificial intelligence has been used in the development of autonomous vehicles, mainly self-driving cars. AI has also helped to increase passenger safety, reduce traffic congestion and accidents and lessen carbon emissions.	AI has helped the financial industry in finding and punishing bank fraud (such as large influx of money at a single time, strange deposits and much more). Artificial intelligence has also been used to improve online banking, allowing people to escape long queues and finish their banking activities from home.	Most mobile phones nowadays come out with online assistants, such as iPhone's Siri or Samsung's Bixby. Furthermore, AI has been used in GPS applications in order to ease the way of giving directions to the driver, by using audio and video representations of the directions simultaneously.	Artificial intelligence has played a major role in the manufacturing industry that it even has its own name, industrial AI. It has helped to improve productivity, reduce cost, and optimize the work done in manufacturing as a whole.

V. CONCLUSION

With the development of machines, artificial intelligence has become an essential part to many industries and their usage grows by the day. However, the long-term economic effects of AI are uncertain. Economists are unsure whether the growing amount of use of AI in industries means a higher rate of unemployment, but they generally agree that it could have a net benefit, if productivity gains are

redistributed. A 2017 study showed that the People's Republic of China will have gained the most economically from AI with 26.1% of GDP by 2030. The relationship between artificial intelligence and employment has always been a complicated one. While AI has led to unemployment in some sectors, it has also offered new jobs through micro-economic and macro-economic effects. Economists have pointed out that in the past, technology has usually contributed to the increases in total employment, rather than decrease. However, they acknowledge that we are in uncharted territory with AI, and a little mistake could cost a lot in the long run. Furthermore, there have been multiple concerns that AI could be used by terrorists in order to instigate digital warfare. Things like lethal autonomous weapons should be properly governed, otherwise there is massive potential for misuse. One thing is certain, artificial intelligence has massively helped in every sector and continues to do so every day. Most of the things we have nowadays would not have been possible without the involvement of AI in today's most important industries.

VI. REFERENCES

1. Britannica.com - <https://www.britannica.com/technology/artificial-intelligence>
2. Investopedia.com - <https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp>
3. <https://www.forbes.com/sites/cognitiveworld/2019/07/26/how-ai-can-transform-the-transportation-industry/>
4. <https://www.abbeycode.com/blog/2019/12/13/artificial-intelligence-approaches>

ENVIRONMENT FOR TEACHING CHILDREN THE KAZAKH ALPHABET

Author: *Sagyngaliyev Renat*

Advisors: *Zhakhiena Aizat, Bazarbayeva Ainur*
Zhangir khan University (Kazakhstan)

Abstract. Creating a program for kindergarten and junior school students for learning purposes is an actual toFig of the present time, but it is not sufficiently developed in Kazakhstan. This project is a convenient program for teaching children the Kazakh alphabet with interesting tasks to test the learned material.

Keywords: *teaching children, learning, integrated environment, Kazakh alphabet, C++ Builder.*

I. INTRODUCTION

The aim of the project is creating a environment for teaching the Kazakh alphabet.

The main tasks of the project:

- Analysis of graphical functions in C++;
- Development of a program for teaching the Kazakh alphabet using the graphical capabilities of C++.

Creating a program in C++ is the most interesting and effective way to gain and improve programming skills.

II. LITERATURE ANALYSIS

2.1 Introduction to the C++ Builder environment

C++ Builder is an accumulated high-level language. It allows you to create both high-performance applications and low-level libraries that work with hardware. Millions of programmers around the world work in C++ [1]. It is one of the most popular languages for writing computer programs and the most important language in which large budget computer games are created. C++ Builder integrates a complex library of STL, VCL, CLX, MFC, etc. objects, as well as a compiler, debugger, code editor, and many other components. The development cycle is similar to Delphi. Most of the components created in Delphi can be used in C++ Builder without changes, but not vice versa. Since C++ Builder comes from Delphi. Much of C++ Builder comes directly from Delphi. Thus, code written in Delphi can be converted for use in C++ Builder[2].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Creating projects (programs) in the C++ Builder environment

To create a project in Borland C++ Builder or a similar compiler, go to File -> New and select the project type from there. For example, you can choose VCLForms Application-C++ Builder (Fig. 1.1).

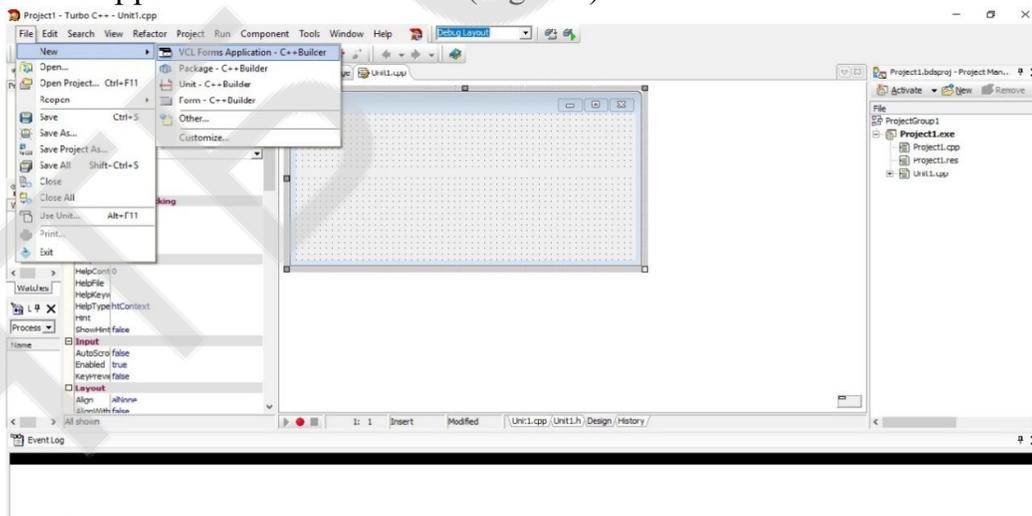


Fig. 1.1 - VCL Forms Application window

The C++ Builder creates main Project.cpp program. The Project that contains the Project.bpr file and WinMain() function. Windows applications use the WinMain () function instead of the Main () function[2]. When adding a new form, C++ Builder updates the project file and creates the following additional files:

- a form file with the .dfm extension containing information about the form;

- extended .cpp module file containing C++code ;
- A toFig file with the .h extension containing a description of the form class.

Select the Compile menu item to create the current project. To compile the project and create an executable file, select Run from the Run menu. As a result, the following form is obtained (Fig. 1.2).



Fig. 1.2 – Form window

Project1.bpr structure. The Project1.bpr file represents an XML Project (C++ Builder XML Project) that contains a description of the program being created. This is a text file, according to which the files must be compiled and linked to the project, and there are also paths that can be applied to directories.Модуль құрылымы. The module includes the implementation of the functional part of the object in C++ and, by condition, this is a Unit1.cpp file. Each such file is compiled into an object file with the .obj extension. When a new form is added to the project, a new module is created.

File structure. File structure (a file with the extension .h, by default Unit1.h) is created when a new module is created and contains a description of the form class. Such descriptions are created automatically and change when new components are added to the form or new event handlers appear. The file structure includes the interface, and the module itself contains the implementation of the method[4].

Form file. The form is one of the most important elements of the C++ Builder application. The form editing process occurs when adding components to it, changing their properties, and creating event handlers. When a new form is added to the project, three separate files are created: 1) the module file (* .cpp) contains code for methods related to the form; 2) header file (* .h) contains a description of the form Class; 3) the form file (* .dfm) contains information about the declared (existing in Inspector objects) properties of components contained in the form.

menu.cpp | menu.h Design

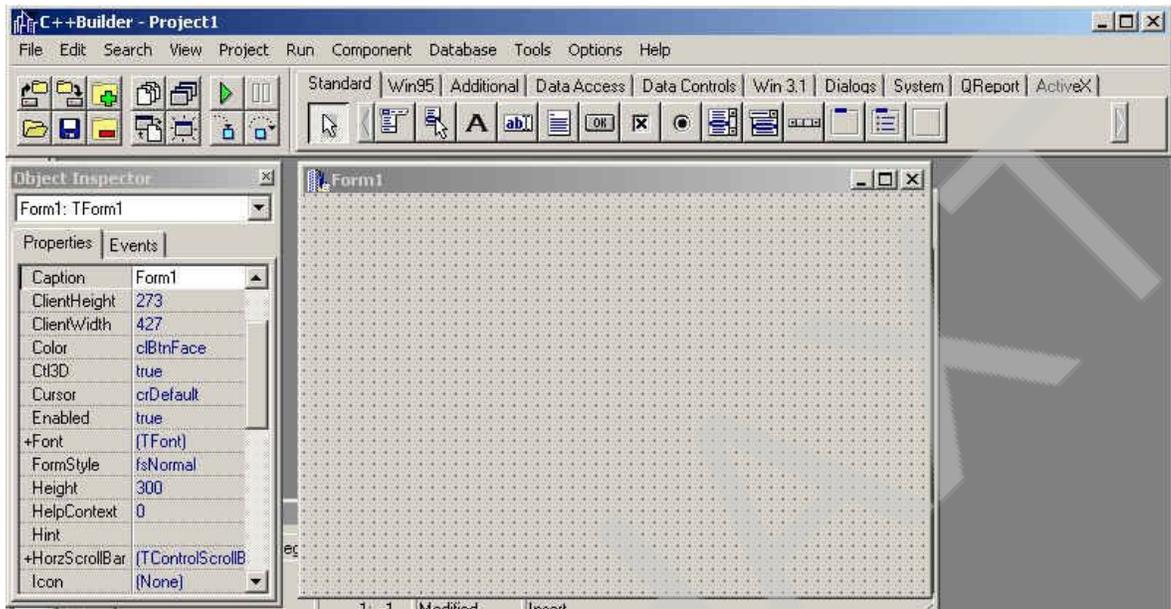


Fig. 1.3 – C++ Builder main window

- main window-C++Builder
- initial form window-Form1;
- properties window — Object Inspector;
- view object lists window-Object
- code writing window — Unit1.cpp. (The code editor window is completely closed by the original form window.) [5].

The main window contains the commands menu, toolbar, and component palette (Fig. 1.4).

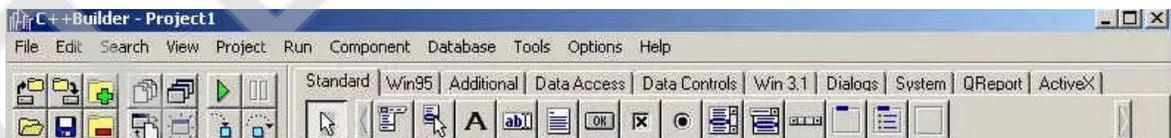


Fig. 1.4 – Components of menu

Initial form window - preparation of the main window of the program (application) in which the Form1 is being developed(Fig. 1.5).

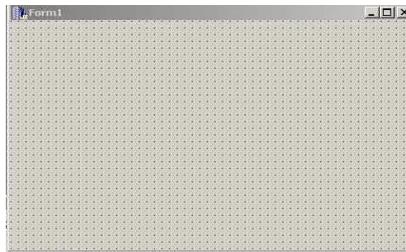


Fig. 1.5 - Form window

The properties window (Object Inspector) is a window in which you can set the values of the properties and events of an object (Properties & Events) when designing a program. The information in the forms inspector varies depending on the component selected in the form. Its appearance and behavior can be changed using the object inspector (Fig.1.6).

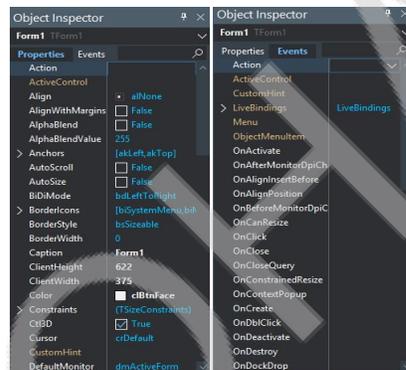


Fig.1.6 - Object Inspector window

IV. RESULTS

Design of the Kazakh alphabet program

The project Form1 contains the following components:

Image – the easiest way to display an illustration in a file with the extension .bmp, .jpg, or .ico can be done using the Image component, whose icon is located on the Advanced tab of the component Palette. The program exists graphically. In the project, two buttons were placed on the home page. This buttons was entered as "Alphabet" and "Game" (Fig. 2.2).



Fig. 2.2 a - Layout of the Image component



Fig. 2.2 b – Home page of the project

Two Button components are installed on the form. Names were entered on each button, i.e. “alphabet”, “game” (Fig.2.3). After installing the buttons, enter their names, as well as colors, font type, and size. The program used 3 Button components.



Fig. 2.3 - “alphabet”, “game” buttons

2.3 “Alphabet” window design

When you click the “Alphabet” button on the Home Page, a window with figure 2.4 opens. 42 letters of the Kazakh alphabet are entered in this window.



Fig. 2.4 a - “Alphabet” window

There OKRightDlg - simple dialog box, the 42 Label is installed. It is mainly used to name other components.



Fig. 2.4 b - “Alphabet” window and labels

On each letter were placed the corresponding Figures. The Image component was used to place these images. The transition from one window to another window (OKRightDlg) has a name and "abc.h" should be written.

```
#include <vol.h>
#pragma hdrstop
#include "abc.h"
#include "menu.h"
#include "game.h"
```

Fig. 2.4 - Example

The Button-component must write the following code: OKRightDlg ->Show(); . When you click on each letter, the corresponding image is pronounced (figure 2.6).



Fig. 2.6 - Placement of images

Figure-loading the image in C++ Builder, LoadFromFile-displaying the path in copmuter, and components were used to output audio(MediaPlayer).The MediaPlayer component provides playback of audio files of various formats (WAV, MID, RMI, MRZ), accompanied by the sound of full, animation and video (AVI) and music CDs.

To the LabelOnClick event:

Image2 -> Figure -> LoadFromFile("1.png"); the code was written i.e. to install the image in the form.

The following code was written for the LabelOnClick event, that is, for creating an audio message.

```
MediaPlayer1->FileName="C:\\avi\\1.mp3";  
MediaPlayer1->Open();  
MediaPlayer1->Play();  
MediaPlayer1->FileName = Show the path  
MediaPlayer1->Open(); - Open Sound  
MediaPlayer1->Play(); - Sound play
```

2.4 Design game window

On the home page, when you click on the game button, a window opens with figure 2.7.

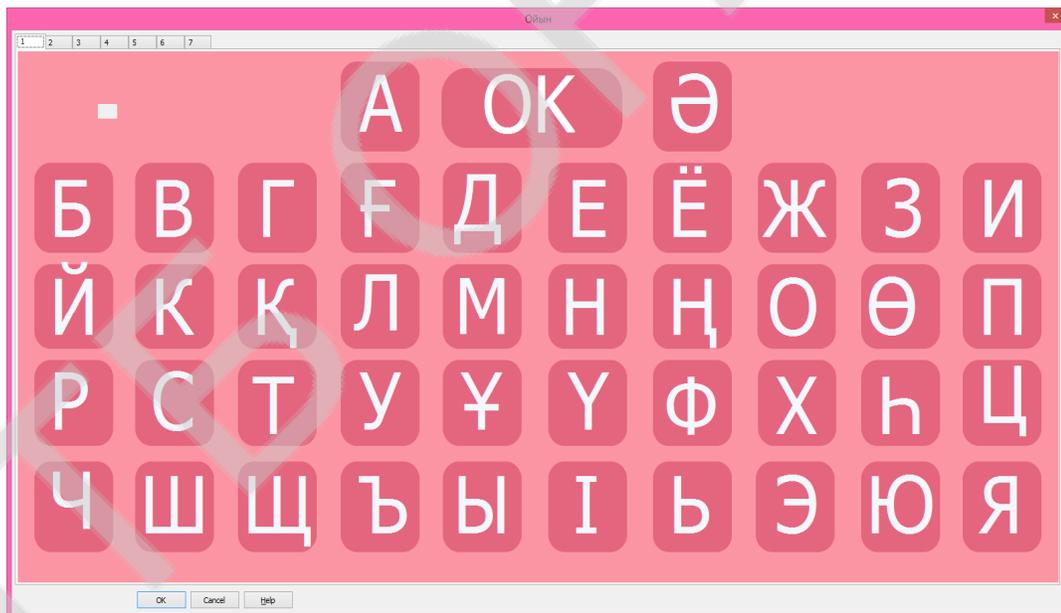


Fig. 2.7 – Game window

To create the game window, the Image and Button components were used. The PageControl component here allows you to combine multiple tabs with different controls into a single form when designing.

In the following figure 2.8 here, when you click on the letter OK, a certain letter is pronounced. You need to find the same letter . If you find a wrong letter, the letter will be painted in red color and will make a sound of error.

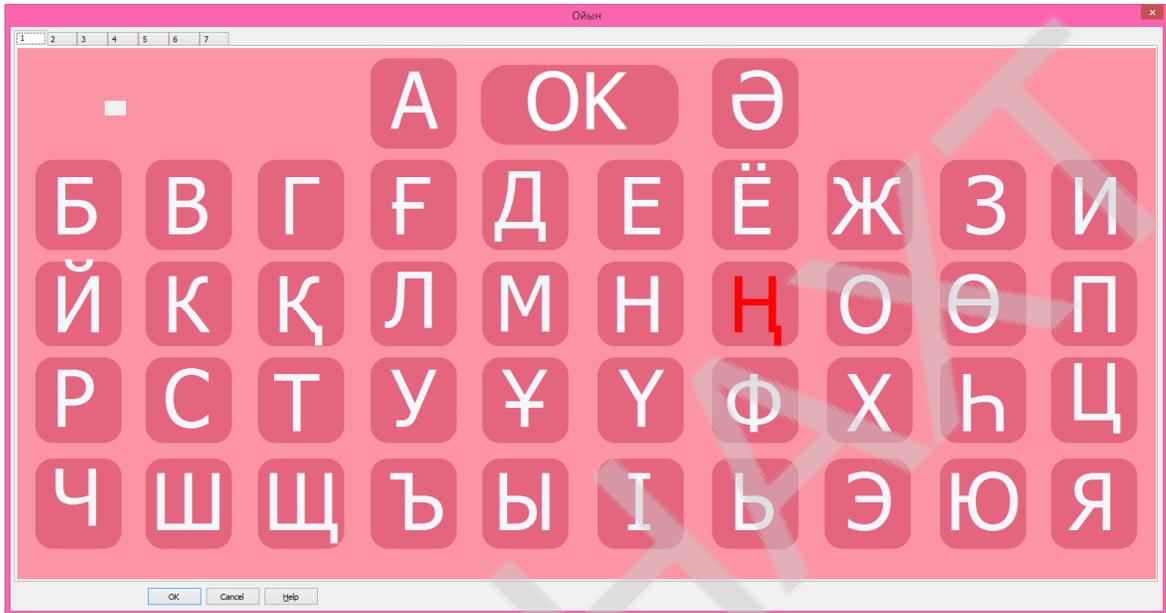


Fig. 2.8 – Error example

If this letter is found correctly, the color of the letter will be colored green and the message correct will appear (figure 2.9).

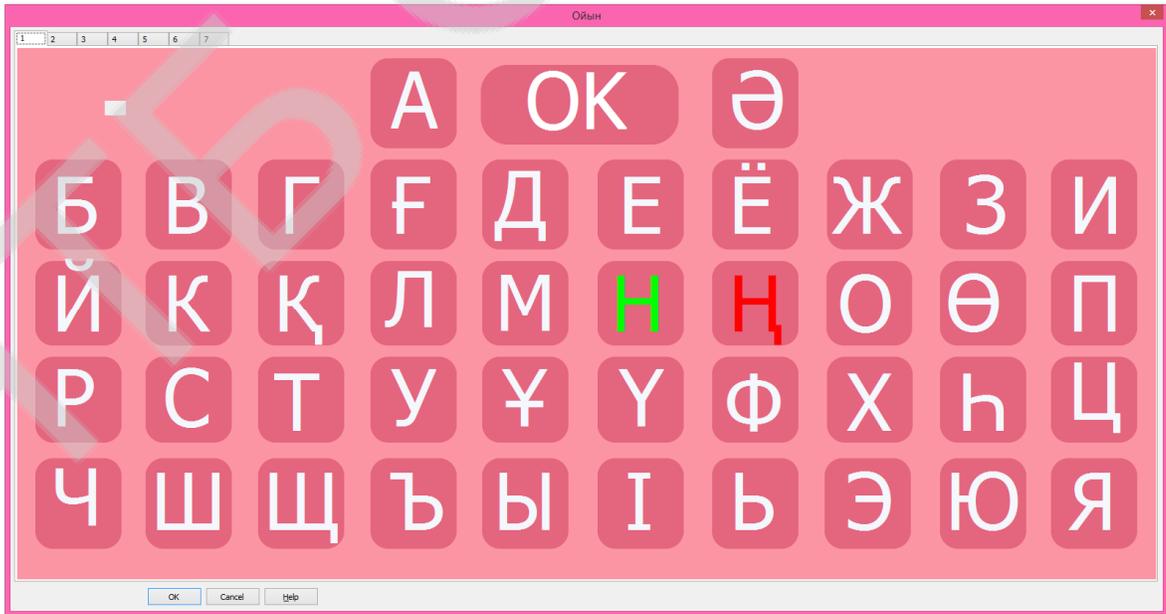


Fig. 2.9 – Right answer example

When you go to the internal pages of the game page window located above, the following window opens (figure 2.10).



Fig. 2.10 – Internal window of the game page

In this window, when you click OK, a certain letter sounds. We need to find 2 words starting with the same letter. In case of an error, the letter X appears in the image (figure 2.11).



Fig. 2.11 – Error example

If you correctly find the image corresponding to the given letter, the letter o will appear in the image (figure 2.12).



Fig. 2.9 – Right answer example

V. CONCLUSIONS

Project result the project was developed in the C++ Builder environment. The program offers to create a project for learning the Kazakh alphabet. In the course of the work, several effective ways to use the mediaplayer component, the transition from one form to another, and the use of the Label component as a button were considered.

During the development of the project, such programs were used:

- C ++ Builder 6;
- Adobe photoshop;
- Adobe illustrator.

The obtained theoretical knowledge was applied in practice. This project is a very interesting program for students of kindergartens and junior classes.

VI. REFERENCES

Currently, much attention is paid to domestic products. Therefore, a project was developed to teach the Kazakh alphabet in the state language for kindergarten children and students of the preparatory school group. It is designed in such a way that the project interface is very user-friendly.

1. Medeshova A.B., Mukhambetova G.G. Programming [Text] : stud. book / - Almaty : "Bastau", 2014.

2. Medeshova A.B., Mukhambetova G.G Object-Oriented Programming [Text] : stud. book / - Almaty : "Bastau", 2016.
3. Pavlovskaya T.A. C/C++. High level programming languages. -Almaty: "Daur", 2012.
4. Boribayev B. Algorithm, data stucture and programming languages: Textbook. – Almaty: Qazaq university, 2012..
5. Boribayev B. C/C++ programming (examples and tasks): Educational and methodical manual. –Almaty: Qazaq university, 2013.
6. Straustup B. Programming. Principles and practice of using C++: 1-2- Volume. Textbook. - Almaty: 2013-2014.
7. Boribayev B. Programming technologies: Textbook. – Almaty: LLP RPBK «Daur», 2011. .
8. Shekerbekova Sh.T., Salgozha I.T. Programming [Text] : Educational manual / - Almaty: Almanah, 2016.
9. Pavlovskaya T. A. Shchupak Yu.A. C/C++. Structural and Object-Oriented programming: Workshop.-SPb.: Piter, 2011.

MONITORING AND MANAGING SYSTEM OF MICROCLIMATE INDICATORS IN EDUCATIONAL FACILITIES

Authors: ***Viesielovskyi Danylo, Ivashchenko Oleksii***

Advisor: ***Ischenko Mykola***

Kryvyi Rih National University (Ukraine)

The algorithm and structure of an automated system for monitoring microclimate indicators in educational facilities are exposed. A model of for monitoring and managing microclimate system based on Phoenix Contact hardware and software has been developed. A user-defined web-interface for remote monitoring and management of the current layout from mobile devices has been developed.

INTRODUCTION

Nowadays, the microclimatic conditions in which the staff of a particular enterprise, institution, or educational institution works are of great importance.

Measuring devices that are offered on the market today have a high cost and will not show the dynamics of changes in microclimate parameters over a long period of time. The process of measuring with separate measuring devices requires personnel who will take the indicators of measuring devices, keep a report in manual mode.

In the modern world, the trend of using alternative energy sources and improving the efficiency of power systems and their automation has long been spreading. One of the most energy-efficient structures is the urban infrastructure of electrical communications for heating educational premises, the modernization of

which cannot be ignored, because it is an integral part of modern technological progress.

Goals and objectives. The aim of the work is to automate the microclimate monitoring system of educational premises with the function of monitoring and managing microclimate indicators.

Relevance. Nowadays, the microclimatic conditions in which the staff of a particular enterprise, institution, or educational institution works are of great importance. The introduction of systems for monitoring the microclimate of Educational Premises is a necessary component for organizing comfortable conditions for all subjects of the educational process and rational use of energy resources.

Problem statement: this system should be easy to use and provide comfort. Be cost-effective compared to other systems.

1. Modern approach to monitoring and managing microclimate indicators and energy efficiency issues in Ukraine

Microclimate is the conditions of the internal environment of premises that affect the heat exchange of employees. Microclimatic conditions in the workplace and industrial premises are the most important sanitary and hygienic factor that determines health and working capacity of a person. Microclimatic conditions are divided into optimal and acceptable.

Optimal conditions are a combination of microclimate parameters that, with prolonged and systematic exposure to humans, ensure the preservation of the normal thermal state of the body, without activating the mechanisms of thermoregulation. They provide a sense of thermal comfort and create prerequisites for a high level of performance.

Acceptable microclimatic conditions—a combination of microclimate parameters that, with prolonged and systematic exposure to a person, can cause changes in the thermal state of the body, which quickly pass and normalize and are accompanied by tension in the mechanisms of thermoregulation within the framework of physiological adaptation.

Due to the unstable supply of energy carriers to power plants in the country, an energy deficit is likely to occur, when the amount of electricity generated will not meet the needs of consumers. Today, the daily load schedule of the United energy system of Ukraine has significant inequality. It is characterized by peak load during the evening maximum hours, failure at night, and almost uniform power consumption in the morning and afternoon.

The fact is that the demand for electricity is always different and varies greatly by time of day. There are two peaks of consumption in a day (the time when the most energy is needed) - in the morning - when the greatest amount of electricity is consumed, because most training sessions are held in the first half of the day. And there is a failure of consumption – evening and night - when a minimum of energy is consumed. In the Ukrainian energy system, the difference between peak and failure is

almost 25%, that is, at the minimum of demand, almost a quarter less energy is consumed than at the maximum.

Having considered the existing problem, the scientific paper proposes an intelligent system for monitoring the microclimate of Educational Premises. This system includes several floor sections, a ventilation system, each of which consists of a heating panel connected to a corresponding relay. As a result, intelligent underfloor heating does not heat the entire area of the classroom, but only the part of it where classes are held. Regardless of the type of heating panels used, even with low power, the total energy consumption is very significant, and such a technical solution provides significant energy savings [1].

2. Software and hardware implementation of the laboratory stand

The proposed automated system for monitoring and managing the microclimate parameters of educational laboratories must meet the following requirements:

- 1) respond in time to individual elements of the system to influence the microclimate indicators such as temperature, humidity, carbon dioxide levels and maintain them during the specified time interval;
- 2) protects the system from overloading and overheating of the equipment;
- 3) organizes a clear sequence of switching on and off installations, receiving and processing data, and clear operation of the web server;
- 4) reports System emergencies and deviations of indicators from the specified operating intervals using mobile and fixed communication channels.

After developing the algorithm of the automated monitoring and management system, it is necessary to develop a software implementation for the training layout .

The entire system consists of the following components:

- 1) Esp8266 Nodemcu V3 controller;
- 2) temperature and humidity sensor;
- 3) CO2 carbon dioxide level sensor;
- 4) high-level relay modules;
- 5) power supply unit;
- 6) underfloor heating modules;
- 7)Phoenix Contact ILC 130 ETH controller [3,4];
- 8) battery for backup power.

The Figure below shows a general Arduino circuit using the components we selected.

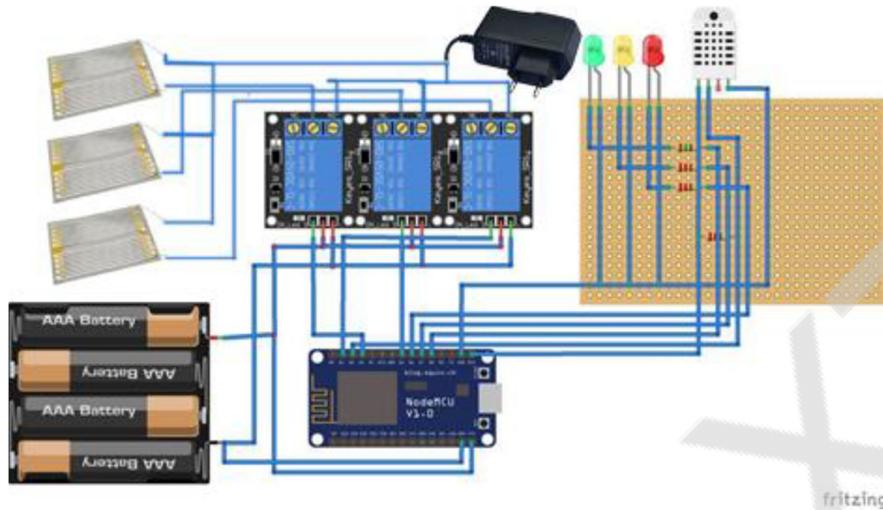


Fig. 2.1 – Arduino scheme

Connecting the Phoenix Contact ILC 130 controller

The ILC 130 controller receives an input signal from NodeMcu and generates a digital signal to control the relay States.

The input signal generation scheme is shown in the figure 2.2

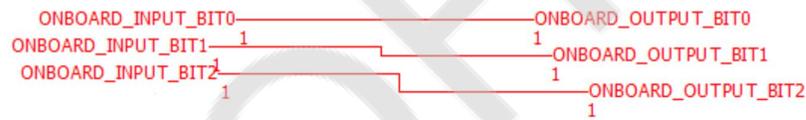


Fig. 2.2 – Input generation scheme

After pointing all the components, we begin to assemble the training stand, first we will mount the NodeMcu ESP8266 controller in a standard model 3s



Fig. 2.3 – Assembling controller

After connecting all the components, we mount them in a standard 3s enclosure.



Fig. 2.4 – 3s enclosure

Next we connect the controllers



Fig. 2.5 – Connecting controllers

After connecting the controllers, we connect temperature sensors, carbon dioxide sensors, underfloor heating plates, and a cooler. The result of developing model is on the Figure 2.6



Fig. 2.6 – Laboratory model

The main goals of creating our system are to achieve optimal microclimate parameters and energy efficiency. To do this, you need to develop a program that will solve these problems.

To solve the problem of energy efficiency, an algorithm for segmented floor heating in educational premises is proposed. This heating model reduces the necessary resources due to the fact that not the entire area of the room will be heated, but only that part of it where people are located. To do this, you need to use several relay modules and underfloor heating modules per audience. There are also several modes of operation of the system – standard and economical. The standard mode will be used when classes are held in classrooms. Economy mode will be used when classes are already over or during weekends and holidays. In Economy mode, the system will not operate at full capacity and will maintain a lower required temperature. This model allows you to save resources when the audience is idle and not heat up when it is not necessary.

The system will also have manual and automatic operating modes. In manual operation mode, the user controls the floor heating devices and segments themselves. In automatic mode, the user sets only the necessary temperature parameters for standard and economical operation. Dali the system controls the states of devices using relays by comparing the current microclimate parameters. The greater the difference in these parameters, the more powerful the system is. Below is a general flowchart of the program's algorithm.

For our project, developing a web server is one of the main tasks. The web server allows you to monitor and manage the system remotely and use a user-friendly web interface.

First, you need to implement the device's access to the internet. This can be done using the `<ESP8266WiFi library.h>`. To connect to the internet, you must specify the username and password from the Wifi hotspot and initialize the internet connection functions.

```
#include <ESP8266WiFi.h>
const char* ssid = "niz";
const char* password = "02121967";

void setup(void){
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.print("Connected to ");
  Serial.println(ssid);
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
}
```

Fig. 2.7 – Connecting to the Internet

The next step is to start the web server. The ESP8266 module will independently perform the function of a web server and draw an html page. To do this, use the previously created sketch and add 2 `<WiFiClient libraries.h >` and `<ESP8266WebServer.h>`. These libraries allow you to send an html page at the user's request.

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
const char* ssid = "niz";
const char* password = "02121967";
void setup(void) {
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
  }
  server.on("/", []() {
    server.send(200, "text/html", webPage());
  });
}
void loop() {
  server.handleClient();
}
String webPage()
{
  String web = "<div>Привет!</div>";
  return web;
}
```

Fig. 2.8 – Creating a web-server

The next step is to connect the Openweathermap web Weather Service and the time web service `pool.ntp.org` from the internet to our web server.

To connect Openweathermap, you need to register on the site to get the API

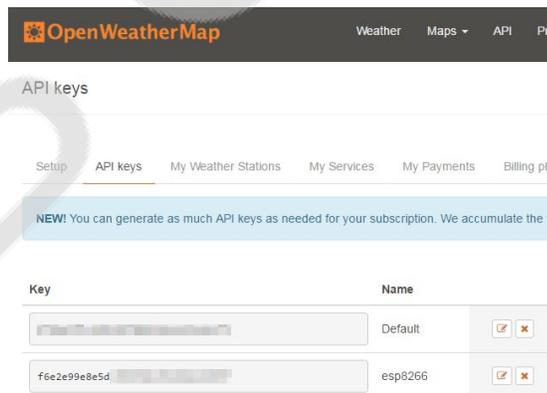


Fig. 2.9 – Receiving API key

These state data obtained allow us to view the temperature outside, use the weather forecast to turn on the heating in advance, since the heating system is inertial, it takes time to set the required temperature.

To get the date and time from the internet, use the `<NTPClient library.h>` which allows you to use the NTP protocol[8]. After initializing a variable that receives time data from the web server `pool.ntp.org` this time is formatted using the

microcontroller's internal clock.

```
#include <NTPClient.h>
WiFiUDP ntpUDP;
NTPClient timeClient(ntpUDP, "pool.ntp.org", 10800, 3600123);
String date_time;
unsigned long times;
void setup() {
  timeClient.begin();
}
void loop() {
  if (millis() - times >= 1000) {
    times = millis();
    while (!timeClient.update()) {
      timeClient.forceUpdate();
    }
    int hh = timeClient.getHours();
    int mm = timeClient.getMinutes();
    int ss = timeClient.getSeconds();
    int dd = timeClient.getDay();
    datxml = String(weekd);
  }
}
```

Fig. 2.10 – Receiving time data

This obtained data on the time state allows us to set the system's operating schedule based on the current time.

The created web interface is uploaded to the web server. Data from sensors is entered in the required fields. Hypertext transitions are implemented for buttons to access the server by the user.

After that, the server responds to the user's requests and sets the necessary system values.

```
server.on("/rele3Off", [](){
  r3 = false;
  server.send(200, "text/html", WebsiteContent());
  delay(100);
});
server.on("/fanOn", [](){
  f = true;
  server.send(200, "text/html", WebsiteContent());
  delay(100);
});
server.on("/fanOff", [](){
  f = false;
  server.send(200, "text/html", WebsiteContent());
  delay(100);
});
server.on("/modeR", [](){
  devmode = 2;
  server.send(200, "text/html", WebsiteContent());
  delay(100);
});
```

Fig. 2.11 – Server response

XML queries and Ajax technology are implemented to dynamically restore data from sensors and web services on the web server without updating the page. The

first step was to create XML to select and generate the necessary data, such as temperature, humidity, time, weather, and CO2 level.

```
void XMLcontent() {
    XML = "<?xml version = '1.0'?>";
    XML += "<Donnees>";
    XML += "<temp>";
    XML += ttemp;
    XML += "</temp>";
    XML += "<time>";
    XML += alltime;
    XML += "</time>";
    XML += "<data>";
    XML += datxml ;
    XML += date;
    XML += "</data>";
    XML += "<hum>";
    XML += hhum;
    XML += "</hum>";
    XML += "<weath>";
    XML += weath;
    XML += "</weath>";
    XML += "</Donnees>";
    server.send(200, "text/xml", XML);
}
```

Fig. 2.12 – XML page

When the user or server accesses an XML page [9], its data is passed to a javascript file. This file selects the fields to which data will be sent and the frequency of data recovery.

```
Javascript += "function response() {\n";
Javascript += "xmlResponse=xmlHttp.responseXML;\n";

Javascript += "xmldoc = xmlResponse.getElementsByTagName('temp');\n";
Javascript += "message = xmldoc[0].firstChild.nodeValue;\n";
Javascript += "document.getElementById('div1').innerHTML=message;\n";

Javascript += "xmldoc = xmlResponse.getElementsByTagName('time');\n";

Javascript += "function process() {\n";
Javascript += "xmlHttp.open('PUT', 'xml', true);\n";
Javascript += "xmlHttp.onreadystatechange=response;\n";
Javascript += "xmlHttp.send(null);\n";
Javascript += "setTimeout('process()', 200);\n";
Javascript += "}\n";
Javascript += "</SCRIPT>\n";
```

Fig. 2.13 –Dynamic updating

To be able to get optimal temperature parameters in automatic operation mode, 2 input fields and a set Send button were created.

```
Javascript += "function set_alert(){\n";  
Javascript += "h = document.getElementById('standart').value;\n";  
Javascript += "m = document.getElementById('eco').value;\n";  
Javascript += "server = \"/modeA?h="+h+"&m="+m+"&Set=Set";\n";  
Javascript += "request = new XMLHttpRequest();\n";  
Javascript += "request.open(\"GET\", server, true);\n";  
Javascript += "request.send();\n";  
Javascript += "alert('Параметры изменены')\n";  
Javascript += "};\n";
```

Fig. 2.14 – Receiving input data

JavaScript reads data from the required fields and passes the value to the controller.

Reliability and fault tolerance are important system criteria. Any sudden malfunction can cause the entire system to fail.

After the development of the software and hardware complex, the entire system was tested for operability and fault tolerance.

Initially, the Esp8266 was programmed with a ready-made sketch of the program. All necessary debugging information is displayed in the port monitor. After downloading the program and enabling the module open the port monitor and see all the necessary information.

```
.....  
Connected to niz  
IP address: 192.168.1.107  
HTTP server started  
0 0 0 0 1 21.50 54 656 23 15  
0 0 0 0 1 21.50 54 656 23 15  
0 0 0 0 1 21.50 54 656 23 15  
0 0 0 0 1 21.50 54 656 23 15  
0 0 0 0 1 21.50 54 656 23 15
```

Fig. 2.15 – Port monitor information

In the figure, you can see data about:

- 1) relay States;
- 2) operating mode of the systems;
- 3) state of the economic regime;
- 4) data from the temperature sensor;
- 5) data from the humidity sensor;
- 6) data from the carbon dioxide sensor;
- 7) optimal temperature parameters in standard mode;
- 8) optimal temperature parameters in standard mode.

Data is read every 100ms.

After starting the system and checking the controller's connection to the internet, go to the site 192.168.1.107 in the browser.

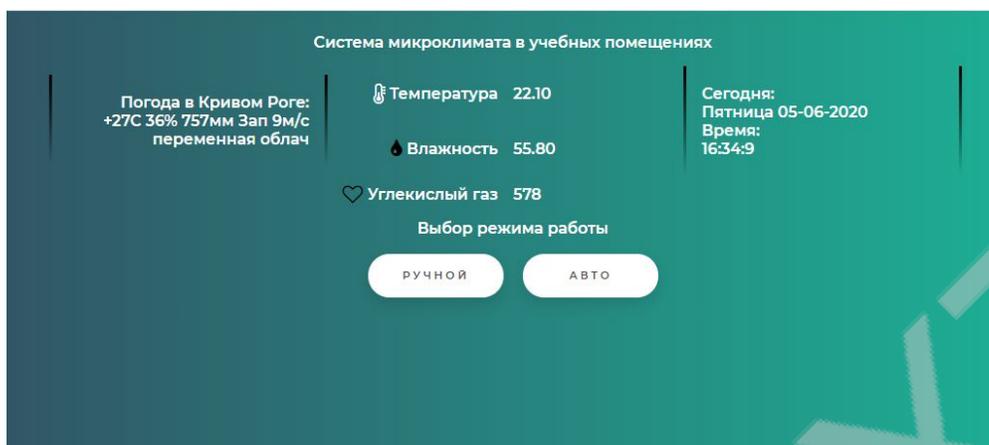


Fig. 2.17 – User web-interface

When switching the robot mode to "Auto", a stand is displayed that is economical to the robot mode, the fields for adjusting the necessary temperature parameters in the new modes, as well as the optimal parameters of the volumetric value and the level of carbon dioxide in the context of the standard norms of the parameters.

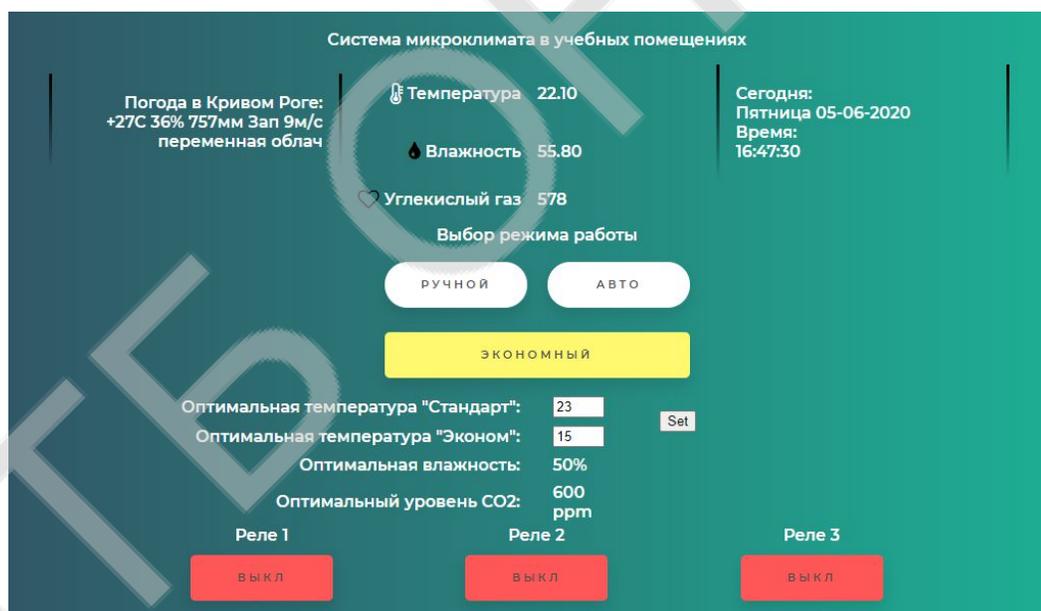


Fig. 2.18 – Economy mode

CONCLUSION

In the course of scientific work, an automated system for monitoring the microclimate in educational premises was introduced. The current state and relevance of the problem were studied, as well as a review of the modern approach to monitoring and managing microclimate indicators in educational premises was conducted. A functional scheme and algorithm of the system operation were developed.

After the developed scheme, the training stand "automated system for monitoring and managing microclimate indicators" was implemented.

After the implementation of the stand, an algorithm for the program was developed, all sensors and libraries were connected and configured. A web interface has been developed and a web server has been implemented. The program was also tested for operability and fault tolerance.

So, let's conclude that all the tasks set by us were successfully implemented and as a result, we have a working system for monitoring and controlling the microclimate in educational premises.

Testing of scientific results is presented at the following scientific and practical conferences: Computer intelligent systems and networks. Materials of the XI all – Ukrainian scientific and practical WEB conference of postgraduates, students and young scientists–Kryvyi Rih: state higher educational institution "Kryvyi Rih National University"2019 and 2020, information technologies and automation-2020:sat. additional information XIII International Conference, Odessa, 22-23 Oct. 2020

REFERENCES

1. Viesielovsky D. Monitoring and managing system of microclimate indicators in educational facilities / D. Viesielovsky, O. Ivaschenko, M. Ishchenko // information technologies and automation–2020 : sat. additional information XIII International Conference. Nauk. - prakt. conf., Odessa, 22-23 Oct. 2020 / Odessa. Nats. ACAD. food. P. M. Platonov Institute of computer systems and technologies "Industry 4.0"; org. com.: B. V. Yegorov (chairman) et al. - Odessa, 2020. - P. 99–101 : fig. – Ref.: 7 tit
2. Viesielovsky D. V., Ivashchenko A. R., Ishchenko M. A. MONITORING and MANAGING SYSTEM of MICROCLIMATE INDICATORS in EDUCATIONAL FACILITIES. Materials of the XI all-Ukrainian scientific and practical WEB conference of postgraduates, students and young scientists (March 22-24, 2020). Kryvyi Rih: Kryvyi Rih National University, 2019, pp. 230-232.
3. ILC 130 ETH-inline controller with Ethernet interface [electronic resource]-access mode: <http://www.denol.ru/phoenix/ilc130eth.php>
4. Phoenix Contact company catalog [electronic resource] - access mode: <http://catalog.phoenixcontact.net/phoenix>
5. DSTU EN 12599:2006 ventilation and air conditioning systems. Test procedures and measurement methods for commissioning ventilation and air conditioning systems. - [Valid from 259 01.07.2006]. - 48 s
6. Viesielovsky D. V., Ivashchenko A. R., Ishchenko M. A. automated energy– efficient heating system for residential premises// materials of the XI all – Ukrainian scientific and practical WEB conference of postgraduates, students and young scientists (March 21-23, 2019) - Kryvyi Rih: state higher educational institution "Kryvyi Rih National University", 2019. - pp. 150-151.
7. Open weather map [electronic resource] // access mode to information: <https://openweathermap.org/>
8. time synchronization NTP protocol [electronic resource] // access mode to information: <http://time.in.ua/ntp.html>
9. XML introduction [electronic resource] // mode of access to information: https://developer.mozilla.org/ru/docs/Web/XML/XML_introduction
10. HTTP requests. Methods of GET and POST [electronic resource] // mode of access to information: <https://guruweba.com/html/metody-get-i-post-ispolzovanie-i-otlichiya/>

DEVELOPMENT OF ELECTRONIC PAYMENT SYSTEMS AND SECURITY OF THEIR FUNCTIONING

Author: *Anna Severenchuk*

Adviser: *Lyudmila Polovenko*

Vinnytsia Trade and Economic Institute KNTEU (Ukraine)

Abstract. The work is devoted to the study of innovations in the market of modern payment systems. A comparative analysis of the security of payment systems using electronic technologies in the implementation of money transfer services in Ukraine. The components of the payment system, information security measures in the electronic payment system are also considered and the criteria for assessing the security of the electronic payment system are determined. The tendencies of development of electronic payment systems in modern conditions and ways of improvement of their activity taking into account the newest information technologies are outlined.

Keywords: electronic payments, electronic payment system, internet banking, vulnerabilities, security of payment systems, non-cash payment instruments, innovations.

I. INTRODUCTION

In today's world, settlements between economic agents are impossible to imagine without the use of payment systems. In the digital economy, ubiquitous access to communication channels, as well as the rapid development of new information technologies, the rapid spread of new payment methods, the emergence of alternative devices used, increasing demands on the development of electronic payment systems. This trend not only forces payment system operators to constantly improve payment services, but also raises questions about the effective security of electronic payment systems.

There are two serious problems - unauthorized debiting of funds from bank cards or accounts of legal entities and the general guarantee of preservation of payments made through non-bank payment transfer systems.

II. ANALYTICAL REVIEW OF LITERATURE

Balakina's work is devoted to the study of the essence and types of payment systems [2].

The problem of information security in the system of electronic payments was studied by Akhramovich, VM Chegrenets [1]. Researchers consider the technology of building an information security management system and features of information security management in banking institutions.

Prospects for the development of the electronic payment system are demonstrated in the work of I.S. Kravchenko, IV Blackbird [3].

The pandemic and quarantine restrictions have accelerated the expansion of the payment infrastructure [4], which in turn raises the issue of security of electronic payment systems.

III. OBJECT, SUBJECT AND METHODS OF RESEARCH

The object of research is the process of functioning of electronic payment systems and the formation of a security system.

The subject of the study are electronic payment systems.

Research methods. During the work were used: system method, which allows to investigate the development of electronic payment systems; methods of analysis and synthesis, induction and deduction (to assess the degree of security of the studied payment systems), systematization, logical approach, grouping and generalization.

IV. RESULTS OF WORK

4.1. Innovations in the market of modern payment systems.

Currently, customers of the payment system mostly switch to the latest technology of Internet banking. The basis for improving customer service technology has become not just a form of i-Banking, but mobile banking. This innovation, thanks to the purchase for private use of smartphones with flexible and secure Microsoft technologies, as well as the iPad is a model of a comprehensive remote service solution, which includes Internet banking, mobile banking and a portal for personal provision of various, including confidential, services with more 200 built-in templates for financial transactions and maintenance of virtual customer accounts.

Mobile applications allow not only to check the balance of personal finances, but also to carry out account replenishment operations, remotely make utility payments and purchases in online stores and other commercial structures.

"Design" technologies in traditional banking structures or other credit institutions, special web portals and mobile device applications create a tendency to abolish commercial banks unnecessarily. Investment borrowing in this case takes the form of contractual and paid crowd funding, ie "public borrowing" to lend to projects that inspire confidence in private creditors.

A trend is formed, expressed by the formula: "banks must go, long live banking", and the agreement on borrowing funds is based on a mobile P2P-platform.

The term "electronic payment system" (EPS) means a system of settlements in which payments are made via Internet channels, the traditional processing of payment orders does not occur [2].

This definition includes::

- bank card payments of traditional Visa, MasterCard, American Express and Diners Club systems. Here, with an absolute guarantee of transaction protection, there is a problem of unauthorized write-offs as a result of intercepting traffic or obtaining card numbers;

- programs of interbank settlements via electronic communication channels, including fast payments made by banks by telephone numbers;
- payments through electronic wallets (GooglePay and others).

The market of electronic payment systems in Ukraine today can be confidently called developing - in this area so far with some success operating about 10 systems.

The first to be mentioned are national payment systems, such as: Electronic Payment System (EPS) and "Ukrainian Payment Space".

Portmone (credit payment scheme provides electronic delivery and payment of bills with Visa, MasterCard), LiqPay (PrivatBank payment system), Wayforpay, Welsend, Telegraf, Google Pay and others can be called successful in the Ukrainian market.

However, the introduction of innovative technologies of modern Internet banking, electronic payment systems is associated with a high risk of data theft. Therefore, it is worth paying attention to the security of electronic payment systems.

4.2. Security of electronic payment systems

If we talk about protection against unauthorized transfers of EPS in general, then regardless of the level of each specific model, they have the same requirements.

Among the most vulnerable places::

- Internet traffic between participants in the exchange of electronic messages about financial transactions (banks, payment wallet operators, ATMs, customers);
- information processing within the bank or operator, when the data may be available to employees;
- constant availability of payment systems for customers, no failures in their work and on the communication line.

The presence of these vulnerabilities forces banks and operators to protect traffic when forwarding in accessible ways (transmission over secure channels, encryption) and to develop authentication models for sender and recipient.

At the same time in the work of the bank or payment operator there are problems:

- determining the mutual authenticity of the participants in the transaction when establishing a connection;
- ensuring the confidentiality and authenticity of payment orders sent via the Internet and other documents;
- protection of the sending process, formation of evidence of sending and receiving documents;
- ensuring the execution of the document (for example, the permanent presence of the balance on the correspondent account of the bank, which allows you to arrange payment)

The Bank and the EPS operator are obliged to implement mechanisms to protect customers from unauthorized write-offs, specific requirements for which are determined by the policies of operators and regulations of the NBU:

- management of access of the client, employees of the operator and the recipient, creation of the authentication mechanism;
- control of reliability and integrity of information in the message;
- ensuring the confidentiality of information in the transmission process;
- inability to refuse the authorship of a power of attorney to send funds or a notice;
- guarantees of access to resources and loss of the message in the course of its delivery;
- inability of the operator or bank to refuse to execute the order for transfer or payment;
- saving data on orders and messages.

On the basis of the national EPS payment system, consider the system of EPS (Fig. 1).

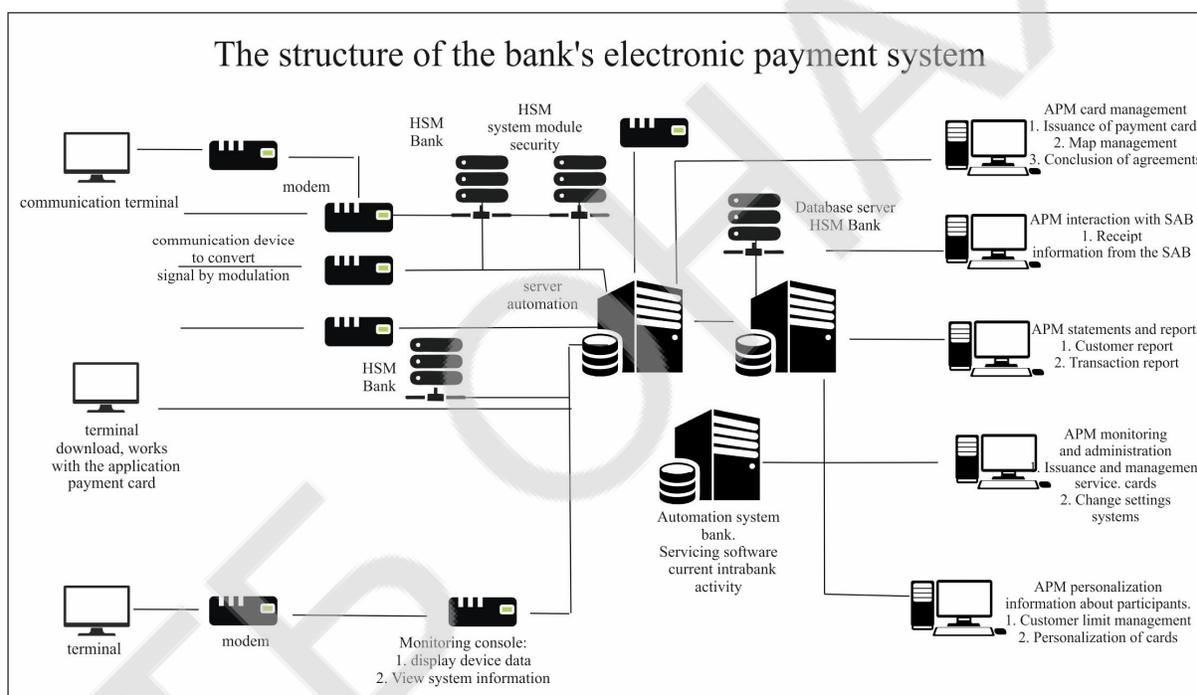


Fig.1. Block diagram of electronic payments

The information security of this system is controlled by the bodies of the Security Department and is performed in accordance with the provisions on the protection of electronic banking documents using the means of information protection of the National Bank of Ukraine.

Technological means of control built into the software and hardware systems of EPS cannot be disabled. In case of detection of an unusual situation, which may indicate a suspicion of unauthorized access to EPS on behalf of a particular EPS participant, COSEP automatically stops accepting initial electronic settlement documents and notifications from this participant. The main means of encrypting files (packages) EPS is AKZI. The work of AKZI is controlled by the software ZZI built in TsOSEP and ARM-SEP and provides hardware encryption (decryption) of

the information according to the algorithm defined in the national standard of Ukraine DSTU GOST 28147: 2009. As a backup means of encryption in EPS the built-in function of software encryption built in TsOSEP and ARM-SEP is used. COSEP and ARM-SEP encryption tools (both AKZI and software encryption) provide strict authentication of the sender and recipient of an electronic banking document, the integrity of each document as a result of the impossibility of forgery or unauthorized modification in encrypted form. Workstation-SEP and COSEP in real time provide additional strict mutual authentication when establishing a communication session. During the work of ARM-SEP creates logs of software and hardware encryption and protected from modification work protocol of ARM-SEP, which records all actions performed by it, indicating the date and time of processing of electronic banking documents. At the end of the banking day, the logs of software and hardware encryption and the protocol of the workstation-EPS are subject to mandatory storage in the archive [1].

The Security Department provides banks (branches) with information services on the accuracy of information on electronic banking documents in the event of disputes based on a copy of the archive of the workstation-workstation for the relevant banking day.

The Security Department decrypts a copy of this archive and identifies:

- 1) the identifier of the bank - EPS participant, which sent (encrypted) the electronic banking document;
- 2) the identifier of the bank - EPS participant to which the electronic banking document is addressed;
- 3) date, hour and minute of encryption of the electronic banking document;
- 4) date, hour and minute of decryption of the electronic banking document;
- 5) compliance of all electronic digital signatures with which the electronic banking document was protected from modification.

When using AKZI, the following are additionally determined:

- 1) AKZI number on which the encryption or decryption of the electronic banking document was performed;
- 2) the number of the IC used during encryption or decryption of the electronic banking document.

The Security Department provides services for decryption of information on electronic banking documents, if there are disputes between EPS participants on issues related to electronic banking documents, in the case of:

- 1) failure to authenticate or decrypt an electronic banking document;
- 2) refusal to receive an electronic banking document;
- 3) waiver of the fact of formation and sending of an electronic banking document;
- 4) a statement that the recipient received an electronic bank document, but in fact it was not sent;
- 5) a statement that the electronic banking document was generated and sent, but it was not formed or another message was sent;

6) the occurrence of a dispute regarding the content of the same electronic banking document, formed and sent by the sender and received and correctly authenticated by the recipient;

7) work with the archive of work of ARM-SEP during audits, etc. [1].

The block diagram of the information protection subsystem in EPS is shown in Fig.2

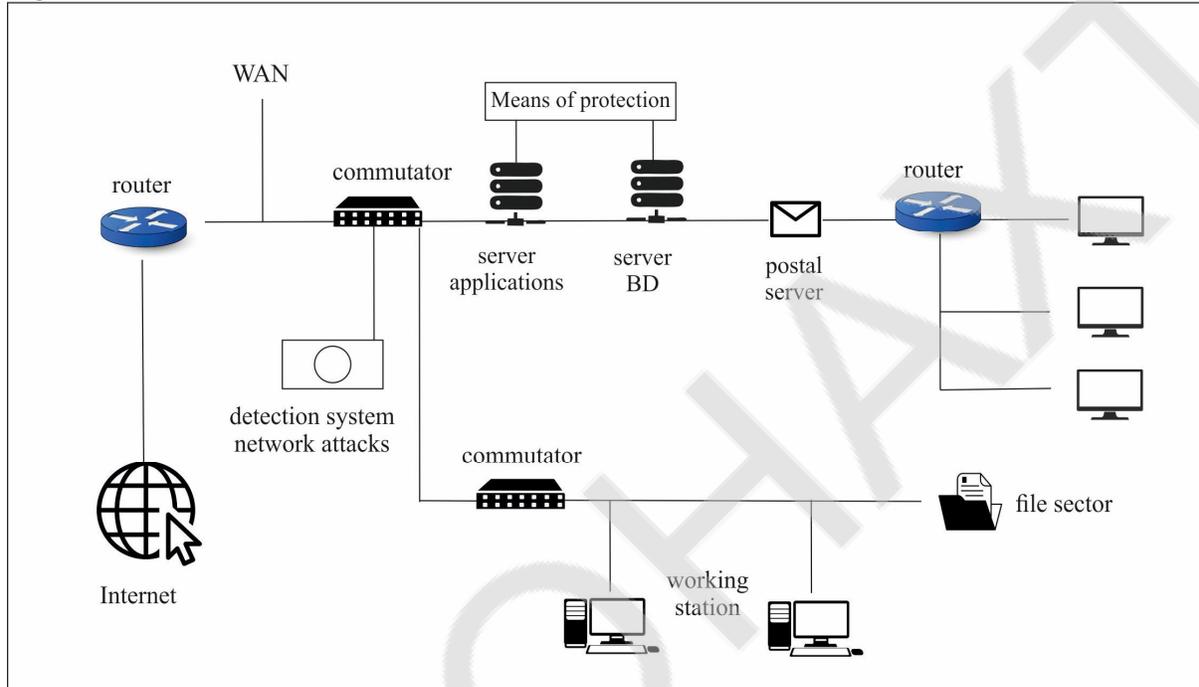


Рис. 2. Структурна схема підсистеми захисту інформації в СЕП

In the course of the work, certain criteria for assessing the protection of the ENP were determined (Table 1).

Table 1. Safety criteria and sub-criteria

Safety criteria and sub-criteria	
1. Primary protection of the EPS account	
Password protect account (criterion 1)	
Presence of account password	
Password strength	Minimum 1 character
	Minimum 5-6 characters
	Minimum 8 characters
	The presence of add. conditions (special. Symbols, uppercase, numbers)
The presence of the password security string	
Limited validity of EPS password	

Using a secure connection to a website (Criterion 2)	
SSL connection security	SSL encryption is not used
	SSL encryption is used, but there is unsecured content, with a serious threat
	SSL encryption is used, but there is unsecured content
	SSL encryption is used
The protocol used	TLS 1.1 protocol
	With TLS 1.2
2. Security at authorization in EPS	
Confirmation of login via mobile phone, E-num or e-mail service (criterion 3)	Mobile phone
	E-num service
	E-mail
3. Authorization using technical settings	
A. Possibility of limited access by IP address (criterion 4)	
B. Issuance of a personal digital certificate for access to the EPS (criterion 5)	
4. Confirmation of operations with a password	
Confirmation of operations (criterion 6)	SMS
	E-num. Google Authenticator
	With an additional payment password
5. Additional methods and techniques that ensure the security of money	
Ability to link mail, phone to EPS (criterion 7)	
Possibility to issue or purchase a virtual card with a short validity period or a limit of funds (criterion 8)	
Presence of identification with confirmation of user documents (criterion 9)	
Use of secret questions or secret word (criterion 10)	
Session limitation - automatic logout (criterion 11)	
6. Information methods of security	
Informing the SMS user about the operations performed (criterion 12)	
Availability of a log of visits by the EPS user (criterion 13)	
Availability of safety instructions and recommendations for EPS users (criterion 14)	
Availability of support service (criterion 15)	By phone
	Via e-mail

If any method or security capability is missing, the security value of this criterion will be equal to 0%. In sum, all criteria give a safety rating of 100%. The security rating of the system depends on the number of collected percentages out of 100. Grade A (excellent) - from 90% (inclusive) and above, grade B (good) - from 80% (inclusive) to 90%, grade C (satisfied) - from 70 % (inclusive) to 80%, grade F (unsatisfactory) - results less than 70%.

A total of 15 safety criteria have been identified, they are divided into 6 groups according to the degree of safety.

For example, in the first subgroup of the first criterion - password protection of the account, where the sub-criteria are the presence of a password, password strength (minimum password starts from 1, 5, 8 characters, or additional characters must be entered), the presence of a password string, password limitation (for example, a few months).

Table. 2. Protection of electronic payment systems

	EPS	Criteria															Evaluation of all indicators			
		Protecting EPS accounts with password		Security when logging in to EPS	Automation with technical settings		Confirmation of operations with password	Additional methods and techniques					Information methods of security							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15				
1	CEPI	2	2	5	5	0	0	3	0	3	3	3	3	3	3	3	6	B	-	82%
2	MASTER CARD	1	2	0	5	5	5	3	3	3	3	3	3	3	3	3	6	B	-	80%
3	GooglePay	2	2	5	5	5	0	0	3	3	0	3	0	3	0	6	C	-	73%	
4	Portmone	1	2	0	0	0	5	3	0	3	0	3	3	3	0	6	C	-	72%	
5	LiqPay	2	1	5	0	0	5	3	0	3	3	3	3	3	0	6	F	-	69%	
6	Telegraf	1	2	0	0	0	5	3	3	3	0	3	3	0	0	6	F	-	56%	

The second criterion in the group is a secure connection of websites, where the sub-criteria are the security of SSL connections (if SSL encryption is used and there is unsecured content on the web page), the second sub-criterion is the protocol used (TLS 1.1 or 1.2, in which does not use dangerous encryption algorithms).

6 electronic system payments were used for the study.

The research results are presented in table 2.

The study showed that only two EPS - EPS and MASTERCARD - have a rating of "good" (B). two EPS (GooglePay, Portmone) were rated "satisfactory" (C). All other EPS were assessed as "unsatisfactory".

4.3. Development of the electronic payment systems market during the pandemic

Over the last year, there have been rapid changes in citizens' payment habits towards non-cash payments, in particular on the Internet. Ukrainians are more actively switching to electronic payments. At the same time, the trend of growing popularity of contactless payment instruments and settlements with them continues.

The total number of transactions made with the help of e-commerce for the nine months of 2020 amounted to 4310.2 million units, and their amount - 2807.9 billion UAH. The number of these transactions increased by 18.0%, and the amount - by 8.7% compared to the same period in 2019. The number of non-cash transactions is even higher - 86 out of 100 payment card transactions were carried out non-cash during the nine months of this year. At the same time, the number of transactions for receiving cash from payment cards decreased by 11.3%, and the amount - by 3.3% compared to the first nine months of 2019. Also during the year, the distribution of non-cash transactions with payment cards by amount changed significantly. Analysis by their types shows that in January-September 2020, the share of Internet transactions increased to almost 30% of the total of all non-cash transactions made with payment cards. For 9 months of 2019, this figure was 27% [4].

V. CONCLUSIONS

As the level of banking transactions through electronic payment systems has increased significantly over the last year, it is necessary to be careful in choosing a system for payment. For electronic payments, it is recommended to use EPS, which received a rating of "satisfactory" and above, but provided that the user will follow the instructions and recommendations of EPS. Every electronic banking system tries to protect its customers from fraud and, unfortunately, many customers do not follow the recommendations, and therefore fall into the hands of fraudsters.

VI. LIST OF REFERENCES

1. Akhramovich, VM, Chegrenets, VM (2019). Information bank risk management of a commercial bank. Modern information protection. №2 (38), 54-59. <http://DOI: 10.31673 / 2409-7292.2019.025459>
2. Б Balakina, Yu.S. (2019). Oversight of payment systems in Ukraine. [abstract of the candidate's dissertation, SHEI "University of Banking"]. URL-http://ubs.edu.ua/images/2017/Avtoreferats/kandidat_balakina.pdf.
3. Kravchenko IS, Drozd, IV (2014). Current state and prospects of development of the National system of mass electronic payments on the market of

bank payment cards in Ukraine. Bulletin of the University of Banking of the National Bank of Ukraine. № 2 (20), 141-148.

4. Національний банк України.(3 листопада 2020).Беззаперечні тренди карткового ринку у 2020 році – розрахунки в Інтернеті та безконтактні платежі. <https://bank.gov.ua/ua/news/all/bezzaperechni-trendi-kartkovogo-rinku-u-2020-rotsi-rozrahunki-v-interneti-ta-bezkontaktni-plateji>.

USE OF K-NEAREST NEIGHBOUR METHOD IN ANALYSIS OF STUDENT DATA FROM SURVEYS

Authors: *Ekaterina Konstantinova, Kamen Kalchev*

Advisor: *Tsankov Tsvetoslav*

Konstantin Preslavsky University of Shumen (Bulgaria)

Abstract. *The purpose of the publication is to analyze the method K-Nearest neighbor and its application in intelligent analysis of student survey data. Examples are given based on student success and satisfaction.*

Keywords: *Educational Data Mining, EDM, K-Nearest neighbor.*

I. INTRODUCTION

Educational Data Mining (EDM) is a new scientific branch with applications in data acquisition education. EDM is “Applying Data Mining techniques to a specific set of data obtained from educational settings to address important educational issues” [5].

The search for dependencies and connections between the data and education will lead to forecasts, evaluation of the factors related to the candidate management method, students’ success ratio, the quality of the learning process, and others [3].

The choice of the “K-Nearest neighbor” method in data analysis for students is dictated by the information of the top 10 algorithms for data extraction identified by the International Conference on Data Mining (ICDM) of the IEEE in December 2006, are C4.5 (Decision Tree), k-Means, SVM, Apriori, EM, PageRank, AdaBoost, kNN, Naive Bayes and CART [6].

II. K-NEAREST NEIGHBORS – KNN

The K-nearest neighbor algorithm is an object classification algorithm that calculates the distance between each pair of objects from the training set by using an appropriate function to measure the distance between the two points. The algorithm uses a majority vote of the k nearest neighbors of the object to classify it [1].

Function for measuring distance:

Euclidean

$$\rho(x_i, x_j) = \sqrt{\sum_{k=1}^m w_k} \quad (1)$$

where:

$x_i = (x_i^{(1)}, x_i^{(2)}, \dots, x_i^{(m)})$ – vector of m-features of the i-th object

$x_j = (x_j^{(1)}, x_j^{(2)}, \dots, x_j^{(m)})$ – vector of m-features of the j-th object

Other known functions for measuring distance between two points are: L_p – metric, L – metric, L_1 – metric, Lance-Williams function.

An important question when using the k-nearest neighbor algorithm is the choice of the number K - this is the number of the nearest neighbors. Heuristic techniques, such as cross-validation, can help with obtaining the appropriate K values.

If the K value is high, the classifier is more precise and more new data sets are correctly classified, but the recognition takes a long time. In the case of a low K value, the algorithm completes fast but produces a great recognition error.

III. STUDENT DATA ANALYSIS SURVEYS

The analytical survey is one source needed for data study. The research results largely depend on it, and it is of great importance to the further stages of the data extraction process.

A variety of rules should be followed when developing surveys. The compilers of the reviews can base the questions on existing methodological research or their practical experience as specialists.

When planning questions [2], it is recommended to use understandable vocabulary, simple syntax, lack of jargon, dialects, and terms. When composing the specific questions, it is necessary to avoid complex grammatical constructions, nested sentences, negations, double negations, etc.

It is important that the inquiry is managed in an acceptable, meaningful, specific, and focused manner. The answers to the closed questions must be mutually exclusive, covering all possibilities.

When compiling a survey, an important decision to make is if the type of questions asked should contain only closed questions, only open questions, or a combination of both.

When developing surveys, compilers usually include mostly closed questions. This type of survey is faster and easier to process, and those who fill it out also prefer it.

The open questions in the surveys often give complete and reliable information. They are preferable to the closed ones when collecting quantitative measurements (number, arithmetic mean, minimum, maximum). Processing such surveys take more time, human resource, and can lead to mistakes.

The issues usually occur when the answers overestimate the information given by some respondents. The completed question with more answers may receive more weight than others who answered with one. Another problem is that respondents may miss these questions or answer "I can't answer" or "I don't know.", which lowers the chances of acquiring the data needed for the analysis.

IV. APPLICATION OF K-NEAREST NEIGHBOR IN STUDENT DATA ANALYSIS

When studying student data, it is crucial to predict the students' success and satisfaction with their studies at the University.

The classification process analyzes the influence of different input variables. They might include: high school success, year of admission, year of graduation from high school type of high school, the profile of the high school, presence or absence of entrance exam, grade from the entrance exam, total score when applying, city of residence, attendance at lectures, attendance at exercises, attendance at lectures, self-

preparation, employment, age, gender, and others [3].

The collected data is divided into a training and a test sample. The training information “trains” the test data. The cross-validation method is used to evaluate the classifier, which equates to the number of participants of each object in the training sample and exactly one participation in the test sample. The essence of the method comprises the following: all sets are divided into k parts, each appearing as a test. Here, it is necessary to choose k . According to researchers in text classification, $k = 5$ or $k = 10$ is preferred [4].

The K-Nearest neighbor method is a technique that makes the classification of new objects based on experience and includes determining the values of a variable (success, satisfaction) based on the values of predictive variables.

The application of the method consists of finding the required K number of the closest objects to the object of the unknown class using a function for measuring the distance between two objects. The definition of the required class is based on the so-called “democratic principle”, i.e. the class received the most votes.

The classification quality can be evaluated through selected assessment measures: accuracy, error, precision, sensitivity, and others.

V. CONCLUSION

The application of intelligent data analysis in the field of higher education in predicting student achievement and satisfaction can help various problems, such as reducing the dropout rate, providing additional help to needy students, predicting enrollment of students in certain specialties, marketing, and management of candidate-student campaigns, improving the functioning of universities and others.

VI. REFERENCES

- [1. Arabadzieva-Kalcheva N. A. Comparative Analysis of Algorithms for Classification of Text in the Bulgarian Language in Machine Learning. // International Conference “Applied Computer Technologies” ACT 2018 – Ohrid, Macedonia, ISBN 978-608-66225-0-3, S. 6-11.](#)
- [2. Fowler F. Jr. Improving Survey Questions: Design and Evaluation. // London: SAGE Publications, 1995, Lyberg.](#)
- [3. Kalchev K., Tsankov Ts. Use of the Decision Tree method in analysis of student data from surveys. // Annual of Konstantin Preslavski University of Shumen, 2020, Vol. X E, Faculty of Technical Sciences, ISSN 1311-834X, S. 72-83.](#)
- [4. Kalcheva N., Karova M., Penev I. Comparison of the accuracy of SVM kernel functions in text classification. // Proceedings of the International Conference on Biomedical Innovations and Applications, BIA 2020, Institute of Electrical and Electronics Engineers Inc., 2020, ISBN 978-172817073-2, S. 141-145.](#)
- [5. Romero C., Ventura S. Educational Data Mining: A Review of the State of the Art. // IEEE Transactions on Systems, Man, and Cybernetics, Part C, Vol. 40, Issue 6, Nov. 2010, S. 601-618.](#)
- [6. Xindong Wu, Vipin Kumar, J. Ross Quinlan, Joydeep Ghosh, Qiang Yang, Hiroshi Motoda, Geoffrey J. McLachlan, Angus Ng, Bing Liu, \[3\] Philip S. Yu, Zhi-Hua Zhou, Michael Steinbach, David J. Hand, and Dan Steinberg. Top 10 algorithms in data mining. // Knowl. Inf. Syst., vol. 14, No. 1, Dec. 2007, S. 1-37.](#)

MOBILE STUDY APPLICATION INFORMATICS OF SCHOOLCHILDREN

Author: *Sofiia Ruslanovna Cherednichenko*

Advisor: *Evgeniy Oleksiyovych Shakurov*
KHNPU named of G.S.Skovoroda (Ukraine)

Abstract. *Along with the development of information technology, their role and use in education is also growing. The introduction of ICT, in particular mobile technologies, provides such advantages as improving the learning process, continuity of education and increased efficiency of education, ensuring quality mastery of software with maximum approximation to modern technical capabilities of the student. The use of mobile technologies is gradually being introduced into the educational process of schoolchildren. The advantage of using mobile applications is that each student has their own mobile device, which instead of carrying a distraction, becomes a full-fledged learning tool that is available at any time. Therefore, the teacher is faced with the task of how to most effectively use the capabilities of mobile applications for a quality learning process during the lesson and the whole learning process.*

Keywords: *Mobile applications, educational programs, lesson organization, educational process organization, computer science lesson.*

I. INTRODUCTION

Today it is important to use such teaching methods that would facilitate and accelerate the transfer of knowledge to students, intensify the process of learning, teach them the techniques of independent work with the material, could also increase the productivity of educational work and teacher work. All these methods can be implemented through the use of information technology.

Modern information technologies include not only the use of computers, interactive whiteboards, electronic libraries, etc. Prospects for the use of mobile technologies are also opening up. The popularity of smart mobile devices is growing rapidly. These digital devices represent a new generation of technological tools, which are equipped with a touch screen, camera, microphone, have Wi-Fi connectivity and, last but not least, high-speed access using 3G technologies to provide Internet access, also support the connection of removable media and long operation without connecting the device to the network. Such tools offer excellent access to content, as well as opportunities for creative use by students of all ages. Learning with mobile devices primarily provides students with the opportunity to learn no matter what time it is and where they are, it also gives people with disabilities the opportunity to learn, and teachers the opportunity to provide maximum flexibility in computer science and diversify learning tools. [1]

The use of mobile technology provides such opportunities as the implementation of joint work of students at any time of the lesson, because now students can quickly move with their device around the classroom; also now students

can present their works on a media projector using the Miracast function; students have the opportunity to use mobile textbooks instead of using a book or computer, which significantly reduces the time to find the information they need; mobile applications, depending on their purpose, can be used to learn new material, consolidate acquired knowledge, when assessing the knowledge and skills of students and others. [2]

Based on the above, it is not difficult to see that even these opportunities are enough for full-fledged work in the learning process using mobile applications.

II. LITERATURE ANALYSIS

2.1. Analysis of the feasibility of using mobile applications in the learning process

Mobile learning is a technology used to increase the productivity and efficiency of learning material, to provide students with information that is always freely available and arrives on time in the context of its immediate priorities.

Scientists (NV Babichev, EN Vodostoeva, ON Maslenikov, N. Sokolova) defined the didactic functions of mobile learning:

- cognitive (satisfaction of intellectual, professional, information needs);
- diagnostic (determination of inclinations and abilities of students, identification of the level of preparedness, level of individual psychological abilities and directions of personal development);
- adaptive (development of information culture, basics of professional management, ability to design an individual learning trajectory);
- propaedeutic (implementation of pedagogical support in the educational process, the choice of the most effective technologies taking into account the individual capabilities of students);
- Orientation (formation of students' inner readiness for conscious and independent construction of professional prospects for their development, practical preparation for professional activity);
- the function of managing educational activities (implementation of flexibility, adaptability and accounting for cognitive abilities of students);
- control (detection of gaps in the preparation, implementation of pedagogical tests);
- prognostic (forecasting the potential capabilities of the student in the development of new material). [3]

The use of mobile applications in the learning process provides great benefits for students, namely:

1. Endless learning - With the help of mobile learning applications, the learning process is not limited to a textbook. Students also have the opportunity to learn at their own pace at any time.

2. Improved interaction - Most mobile applications promote the use of audio-video and media materials that turn learning into an interesting process.

3. Cost savings - Due to the fact that each student has access to mobile learning programs compared to access to computer programs, students can receive materials

on time and improve their learning opportunities.

4. Accessibility 24/7 - Students have access to mobile learning materials around the clock, which speeds up the learning process

5. Personalization of learning, instant feedback and evaluation of learning outcomes, effective use of time in the classroom.

6. Support of situational learning; assistance to students with disabilities and much more

7. Ensuring communication between formal and non-formal learning. [4-5]

2.2. Analysis of developed mobile applications

Unfortunately, the technology of using mobile applications is underdeveloped, so there are also a limited number of developed training programs, but of those that have already been developed, examples that can be used in the educational process in computer science lessons are:

- Mobile application "Algorithms: clear and animated".

- Algorithm City;

- «SoloLearn»

- Google presentations, Microsoft PowerPoint and PhotoAlbum will help in lessons for creating and editing presentations, and others.

All these applications have an interesting interface and help students gain basic knowledge. This type of mobile application is very good for extracurricular learning.

Mobile learning should be easy in content, and it should be used to provide students with access to materials, participation in surveys, conducting or reviewing abstracts, testing the acquired knowledge.

To find the best characteristics of the created information system, consider similar systems, their pros and cons.

1. **SoloLearn** - a guide to different programming languages and a programming simulator. It is offered to study languages at interactive lessons, and to program - in the mobile console;

Advantages of this system:

- Ability to choose a programming language;

- Ability to write run and publish real code directly on the mobile device without any additional settings and preferences.

- Theoretical material and practical tasks

Disadvantages:

- All functions only on a paid basis

- It is not possible to track the progress of students

- Tests for checking the studied material are not presented

2. **“Algorithms: clear and animated”** - a program that can be used to study toFigs such as simple algorithms and animated schemes.

Advantages of this program:

- Interactive learning

- The application has different modes where you can both learn and model your algorithms

Disadvantages:

- The system does not allow access to the publication of information;
- Designed for the user to already have knowledge of algorithms.

3. **“Algorithm City”** - a mobile game for learning the basics of programming. This is an exciting and innovative programming game that teaches the basics of programming and algorithms. He teaches programming through fun games with animals.

Benefits:

- Learning through play;
- Quick understanding of programming principles, basic coding concepts such as sequence of commands, functions and loops

Disadvantages:

- Program in a foreign language;
- The same type of tasks;
- There are no theoretical materials.

After analyzing the existing analogues, their advantages and disadvantages were identified, which serve as a basis for the formation of requirements for the development system necessary to achieve this task. The formulated requirements to the developed system are necessary for construction of functional model of the developed system. [6]

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Purpose: to substantiate the feasibility of using mobile applications as one of the means of teaching students in computer science lessons and implement it.

The object of research is the use of mobile applications as one of the means of teaching students in computer science lessons.

The subject of research is the implementation of its own mobile application that will meet all requirements.

Based on the researched sources, we will identify the requirements for a mobile application that will be used in the process of teaching computer science.

The following theoretical and empirical methods were used in the study:

- Analysis of scientific publications;
- Analysis of the basic concept of mobile learning;
- Method of processing actual data
- Method of secondary analysis of research results;
- Analysis of the results

IV. RESULTS

Based on the study, the requirements for the developed system were identified:

1. The mobile application should provide convenient operation of educational and test materials.
2. The educational system should have an analysis of students' learning outcomes.
3. The mobile application must have a user-friendly interface.
4. The application must perform the following functions: automated input of training and test materials, the ability to edit them; automatic formation of test results; formation of statistics of performance of test tasks by students.

To implement a mobile application that will meet the requirements covered above, was chosen React Native - JS-framework for creating cross-platform applications for iOS and Android, which allows you to develop mobile applications for iOS and Android using only one programming language - JavaScript, and also use in these two applications a significant part of the general code. The Microsoft Visual Studio Code development environment was also used.

The mobile application was designed in such a way that React components wrap around existing proprietary code and interact with proprietary APIs through the paradigm of the declarative React and JavaScript user interface. This allows you to create your own application and allows existing groups to work much faster. [7]

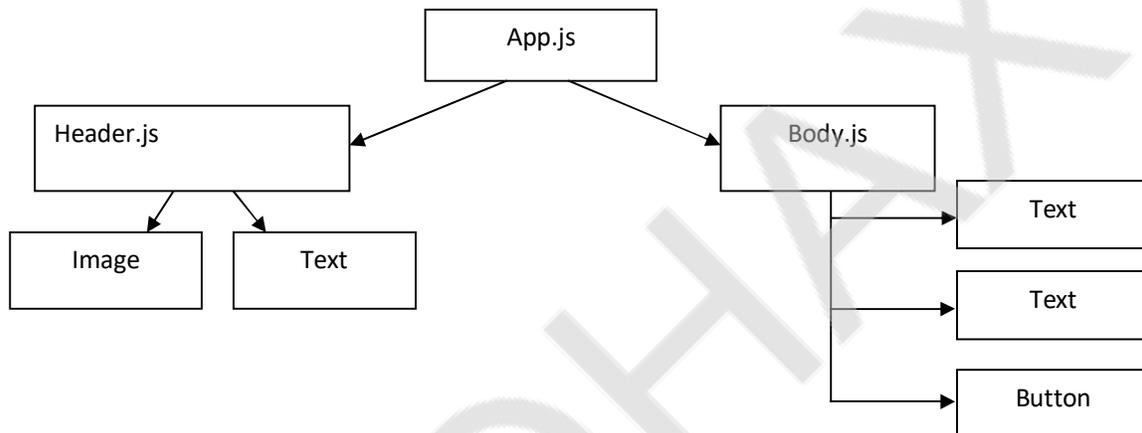


Fig. 1. Diagram of the application implementation using the React native way

The mobile application consists of several screens, the start page presents our program and offers to start learning. The interface of the application is designed to be intuitive, readable and not visually repulsive.



Fig. 2. Application start page

The first page the user enters is the login to the student's account, which has its own id code and password. After entering the student sees his profile and his achievements in the course. Also on the profile page the user has the opportunity to

continue learning after clicking "Continue Learning".

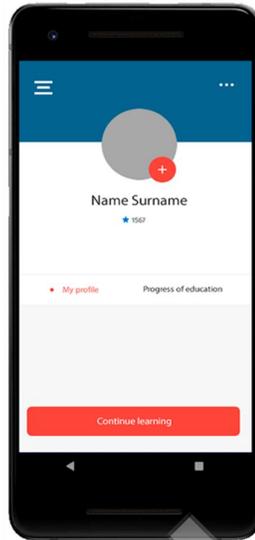


Fig. 3. User page

If you want to view theoretical materials on any toFig or use certain functions, the user can use the menu, which opens after clicking on the "burger menu" in the header of the screen.

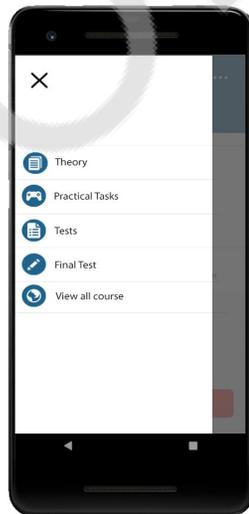


Fig. 4. Menu page

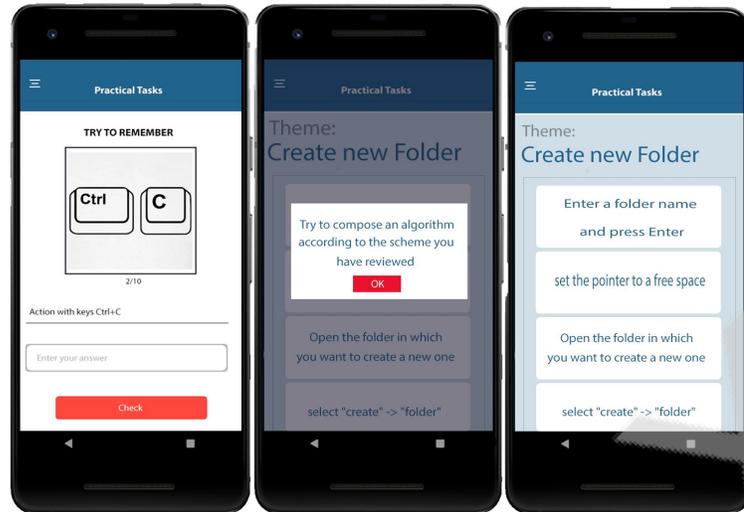


Fig. 5. Practice tasks in application

- a. Learning of Hotkeys, b. explanation of the task, c. task "make an algorithm of actions"

General functions performed by the mobile application "Informatics":

1. Step-by-step training, in which for each toFig theoretical material, interactive tasks and tests to test the acquired knowledge are offered.
2. Review of theoretical material on the selected toFig
3. Passing interactive tasks on the selected toFig at your own pace and an unlimited number of times
4. Passing current tests on the selected toFig
5. Passing the final test, if you have passed previous current tests
6. View the course and progress of user training.

Such functions allow students not only to understand new material, but also to consolidate knowledge with practical skills and check how well new skills have been mastered.

V. CONCLUSIONS

Thus, we can conclude that the use of "mobile learning" technology in the study of many toFigs in the course of computer science secondary school increases the effectiveness of training students in computer science by personifying cognitive interest, increasing the importance of independent work, focus on functions, needs, abilities of each student.

Also, after analyzing the sources, it was found that we currently have a limited number of applications that can be used to teach students.

Our developed application solves a number of problems that teachers face during the learning process and has the following properties:

- Can be used at many stages of the lesson;
- Replaces all the main components of the educational process, including teaching materials, tests, practical tasks;
- Allows you to learn at your own pace;
- Allows you to use the application on devices of different sizes using the

ReactNative framework;

- Allows you to use the application on devices of different operating systems;

In summary, we can say for sure that our mobile application allows to increase the efficiency of the educational process of students in computer science lessons and in extracurricular activities.

VI. REFERENCES

1. Novikov, M. Yu. (2017). Possibilities of application of mobile technologies in a school course of computer science, 6, 98-105.

2. Mardarenko OV Interactive communicative technologies of education: mobile learning as a new technology in improving the language competence of students of non-language universities [Electronic resource] / OV Mardarenko // Informatics and mathematical methods in modeling. - 2013. - Vol. 3, № 3. - P. 288-293. - Access mode: http://nbuv.gov.ua/UJRN/Itmm_2013_3_3_13.

3. Golitsyna IN, Polovnikova NL Mobile learning as a new technology in education. 2011. URL: <http://library.istu.edu/bulletin/>

4. Pogulyaev DV Possibilities of using mobile technologies in the educational process // Applied Informatics, 2006. - № 5, p.80-84.

5. UNESCO Policy Guidelines for Mobile Learning // P. 11-28

6. Google play Android app store. Applications found for "Learning Informatics" [Electronic resource]. - Access mode: <https://play.google.com/store/search?q=%D0%B8%D0%BD%D1%84%D0%BE%D1%80%D0%BC%D0%B0%D1%82%D0%B8%D0%BA%D0%B0%20%D0%BE%D0%B1%D1%83%D1%87%D0%B5%D0%BD%D0%B8%D0%B5> (request date 11.12.2020)

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ORGANIZATION OF INTERNATIONAL CARGO DELIVERY IN A DIGITAL ECONOMY

Author: *Yelyzaveta Arkhanhelska*

Advisor: *Olga Katerna*

National Aviation University (Ukraine)

Abstract. *The study of the domestic market of international transportation was conducted in three steps. Firstly, the state and trends of the international transport services market in Ukraine were analyzed. Secondly, the competitive situation in the Ukrainian market of international cargo delivery was assessed. Thirdly, digital solutions in the organization of international cargo deliveries were characterized, which are already implemented at the macro level, taking into account global trends. Scientific work suggests the ways to develop the transport portal of electronic services; recommends the introduction of an electronic consignment note as a mandatory prerequisite for the digitalization of international cargoes delivery.*

In order to stimulate the transport business to switch to digital technologies, it is necessary to introduce centralized online platforms at the macro level. To this end, Ukraine has taken the first step and launched a transport portal for electronic services, which combines electronic services in all areas of the transport industry into one smart system.

However, the transport business is mostly conservative, so it is necessary to conduct a strong explanatory and educational work among potential users of this system. To this end, the study clearly identified the main benefits and effects for users of the transport portal in terms of individual functions, in particular, the expected effects of obtaining through the transport portal permits for international transport, permits for oversized transport.

The study focused on the analysis of the strategic role of transport exchanges as an online platform for information exchange in the supply chain of transport services to world markets. The characteristics of the main transport exchanges presented on the market of Ukraine and the main IT-solutions that transport exchanges offer to their users are presented.

Keywords: *international delivery, digital economy, electronic commodity-transport invoice, transport portal, effect, transport exchange*

I. INTRODUCTION

The relevance of the study of digital economy problems and related concepts is determined by the following facts. Firstly, the share of industries relying on digital technologies is constantly growing. There are processes of digital technologies penetration into other spheres of human life, in particular, into the international trade and the organization of international deliveries on the digital technologies basis, which radically change their technological structure. Some activities have already been completely transformed under the influence of digital technologies. It is expected that e-commerce will soon dominate at the household level, and approaches

to the trade organization itself will change greatly as well. The study of the socio-economic consequences of such changes is of serious scientific interest.

Urgency of the research is due to the fact that the main task of the system of international freight delivery by road in a digital economy requires a clear definition of strategic directions for the transformation of traditional approaches to the organization of international freight delivery and the introduction of a fundamentally new model of competitiveness.

So, the goal of the work is to develop theoretical and methodological justification of the strategic directions of digitalization of the process of organizing the international delivery of goods.

The main tasks, the solution of which is necessary to achieve the goal of the study are:

- to analyse condition and tendencies of development of the international transport services market in Ukraine;
- to assess the competitive situation of the international cargo delivery organization in the Ukrainian market;
- to propose an improvement of the international cargoes delivery organization through the development of the transport portal of electronic services;
- to recommend the introduction of an electronic consignment note as a mandatory prerequisite for the digitization of international cargoes delivery.

The scientific novelty of the work lies in the theoretical and methodological justification of the peculiarities of the organization of international delivery of goods in a digital economy, in particular, received further development:

- the concept of introduction of the electronic consignment note, in particular, the offered stage of practical realization of this concept is offered;
- directions of improvement of international freight transportation due to the proposal of "using Uber's principles" of freight transportation, divergence (diversity) of IT-products in the transport sphere and creation of "transport IT-platforms".

II. LITERATURE ANALYSIS

The problems of organizing the international delivery of goods have been the subject of research by many scholars. In particular, the works of A.S. Galkin [11], A. Gorbenko [2], K.G. Kozina [8], O.O. Karpenko [5-6], V.P. Levada, Y.A. Davidich, S.V. Smerichevskaya [10, 12], and others are devoted to the organization of international transportation. Peculiarities of the formation of the digital economy are actively considered by many other authors, in particular S.M. Veretyuk [1], V.G. Voronkova, T.P. Romanenko, V.V. Pilinsky [1], and others. But, unfortunately, there is still too little research on the organization of international cargo delivery in a digital economy.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The object of the study is the system of organization of international cargo deliveries in Ukraine.

The subject of the study is conceptual and methodological bases of the organization of the international delivery of cargoes in the conditions of digital economy.

Methodology and methodological foundations of the study based on the basis of a comprehensive and systematic approach, using general scientific and economic research methods, in particular: methods of scientific logic, grouping, comparison and generalization, methods of tabular and graphical analysis, methods of structural-factor and economic-mathematical analysis, project forecasting method.

IV. RESULTS

4.1 Analysis of the condition and tendencies of development of the international transport services market in Ukraine

In accordance with the State Statistics Committee of Ukraine, the number of employees in the field of transport services remained almost at the level of 2010, although it decreased by 6.3% compared to the previous two years (Fig. 4.1). It should be noted that the number of people working in the transport sector is growing in the crisis years for Ukraine after Russia's aggression.

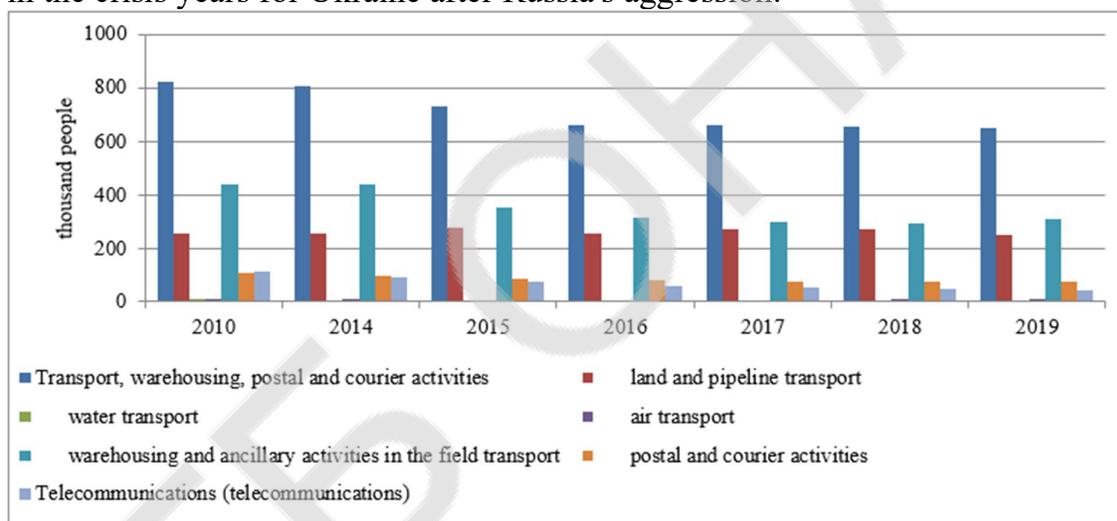


Fig. 4.1.1. Dynamics of the average number of full-time employees of enterprises by type of economic activity "Transport, warehousing, postal and courier activities", thousand people. Source: based on [13]

The total volume of transport services exports in Ukraine amounted to 5851423.3 thousand dollars USA, and imports - 1464807.2 thousand US dollars in 2018.

In 2019, compared to 2018, there was a slight decrease in exports of transport services (by 0.2%), while the volume of imports of transport services increased by 20.8%. Compared to 2010, transport services exports decreased by 25.3%, while imports, on the contrary, increased by 24.3% (Fig. 4.1.2).

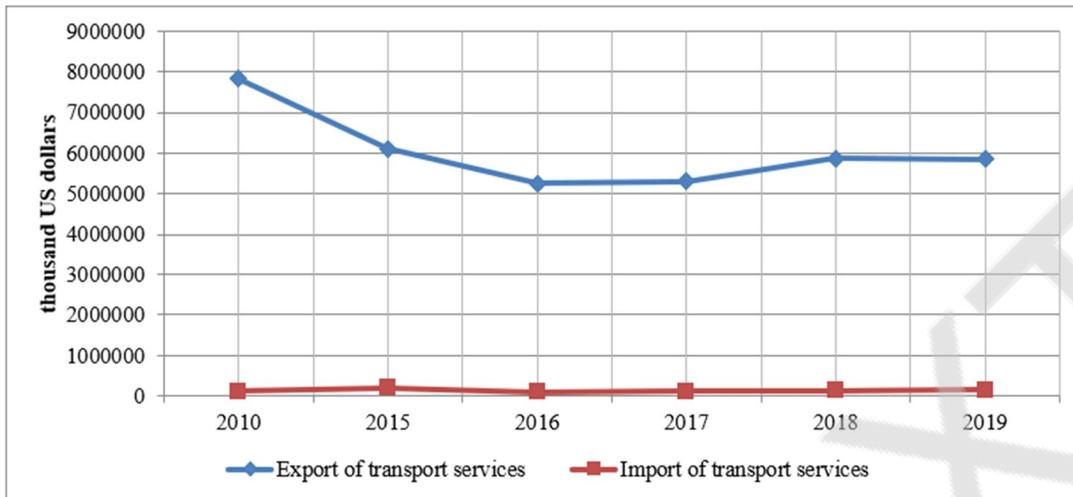


Fig. 4.1.2. Dynamics of exports and imports of transport services in Ukraine, thousand US dollars. Source: compiled by author based on [13]

According to the State Statistics Committee of Ukraine, in the structure of export-import operations, despite the decrease in TS exports, a larger share in the overall structure of export-import TSs belongs to export supplies (80%), which is definitely a positive factor. (Fig.4.1.3).

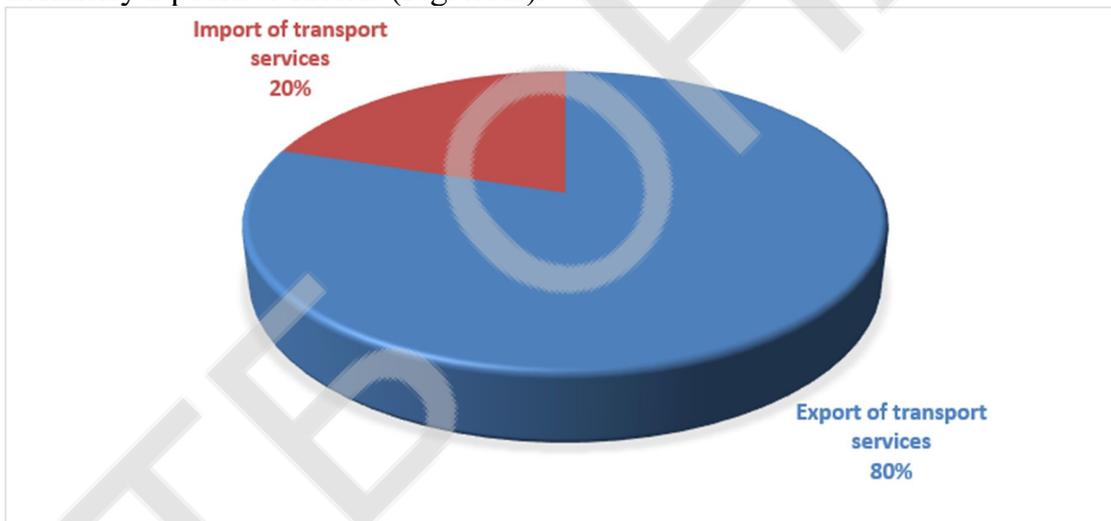


Figure 4.1.3. - Structure of export-import transport services of Ukraine with the countries of the world for 2019. Source: compiled personally based on [13]

The main factors that hinder or slow down the development of competencies for the digitization of business models in the transport and logistics industry, according to surveys of managers of transport and logistics companies conducted by PwC (respondents could choose three answers), are (Fig.4.1.4):

- significant needs for financial investments, 38%;
- unresolved issues related to data security and confidentiality, 38%;
- lack of a clear program for the development of digitalization and support / initiative from senior management, 33%;
- staff shortage, 26%;
- slow spread of basic infrastructure technologies, 23%;

- business partners do not have the opportunity to participate in the joint development of digital solutions, 22%;
- lack of clear understanding of the economic benefits of investing in digitalization, 21%;
- lack of digital standards, norms and certification, 17%;
- concerns about the loss of control over the company's intellectual property, 15%.

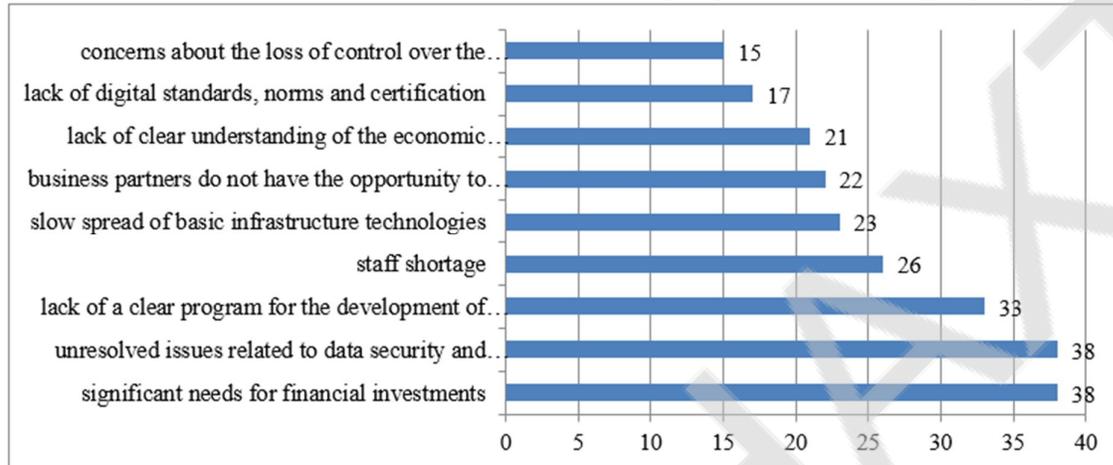


Fig. 4.1.4. Factors that hinder or slow down the development of competencies for digitization of business models in the transport and logistics industry. Source: compiled by author based on [14]

The potential of new technologies for logistics is huge, but now companies in the industry are in no hurry to implement it despite of they also help increase flexibility and scalability, standardize and harmonize processes throughout the organization.

4.2. Assessment of the competitive situation of the international cargo delivery organization in the Ukrainian market

There are many companies on the Ukrainian market that provide international cargo delivery services. The nature and range of their activities are very different. These are powerful international transport and logistics companies (DHL, Kuehne + Nagel), and domestic transport and logistics companies ("Delivery", "Zammler", "Ecole Ukraine"), many ordinary freight forwarding companies and specialized delivery services. Let's try to find out what is the difference and what are the competitive advantages of delivery services that are represented in Ukraine and offer, including services for international delivery of goods.

The study was conducted on the basis of a questionnaire survey of online stores that constantly use different delivery services. The questionnaire, in particular, included questions aimed at finding out which delivery services are used by online stores and to what extent. Delivery services were rated on a ten-point scale. As a result, 120 owners of online stores told about their experience of cooperation with delivery services. In addition, the study assessed the capabilities of services and compared the price of their services.

As was expected, the most popular was the delivery service Nova Poshta. It is used by 97% of respondents, which is almost three times higher than the result of its closest competitor - Ukrposhta (33%). The least popular were Zruchna (3%) and Delfast (0.8%) (Fig. 4.2.1) [15].

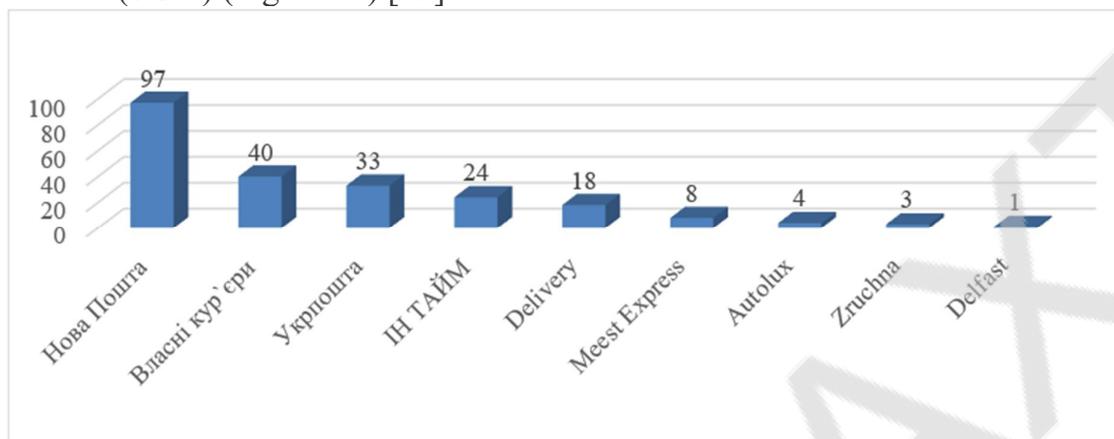


Fig. 2.11. The level of popularity of delivery services in Ukraine among consumers of online stores. Source: based on [15]

In the table 4.2.1 presents the main results of research that highlight the competitive advantages and weaknesses of each of the companies.

Table 4.2.1

The results of surveys of consumers of online stores on the quality of evaluation of services of various delivery services

Company	Number of respondents	Strengths	Weak sides
Nova Poshta	62	-fast delivery (33 answers); -wide network of branches (22 answers); -convenient automation and integration with various services (9 answers) -Fulfillment service	-high cost of services (28 answers)
Ukrposhta	43	-low price (17 answers)	-slow delivery (15 answers); -poor service (9 answers); -inconvenient online office (2 replies)

Intime	23	-low prices (8 answers); -Fulfillment service	-inconvenient location of offices (10 answers); -sloppy cargo delivery (5 replies)
Delivery	9	-one of the lowest prices on the market (3 answers)	-not enough offices (4 answers); -periodic problems with cargo delivery (2 answers)
Autolux	8	-relatively low prices (2 answers)	-small number of offices (6 answers);
Meest Express	7	-relatively low prices (1 answer)	-insufficient number of offices (3 answers); -poor service (3 answers)

Source: based on [15]

4.3. Improving the organization of international cargo delivery through the development of a transport portal for electronic services

The following services can be obtained on the transport portal of electronic services [16] today:

- Booking permits for international transportation.

Previously, nearly 800,000 permits were manually ordered and issued annually.

At the same time there were problems which are easily solved through introduction of a transport portal (fig. 4.3.1):

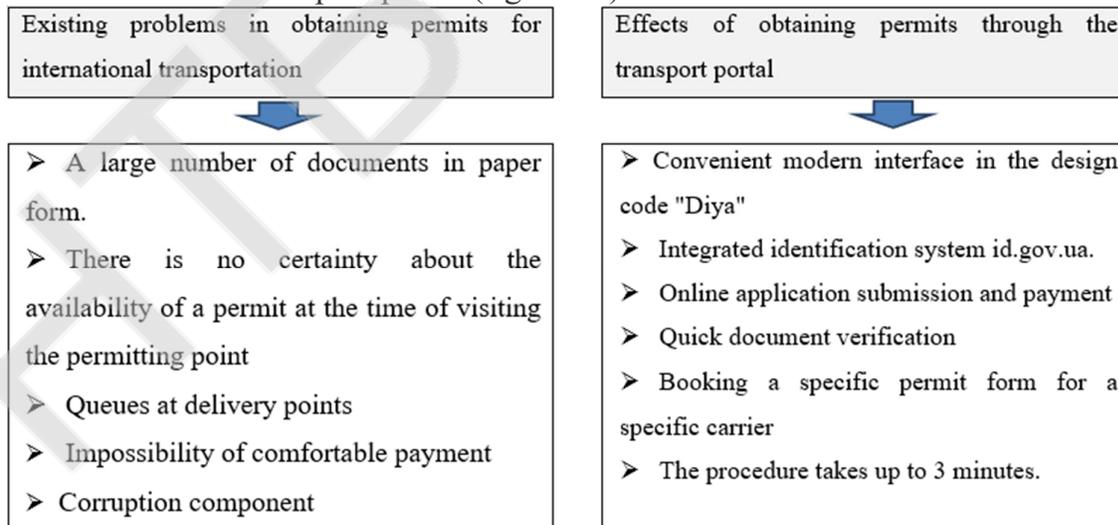


Fig. 4.3.1. Expected effects from the implementation of the system of obtaining permits for international transport through the transport portal. Source: compiled by author based on [16]

- Online post-control at customs.

The portal, which exchanges data with customs, provides an opportunity to actually track intruders who try to forge permits or violate the order of their use. Each registered permit can be traced from the moment of its reservation or printing to the border crossing and return to the permit issuing point.

- Permits for oversized transportation. The effects of this service are presented in Fig.4.3.2.

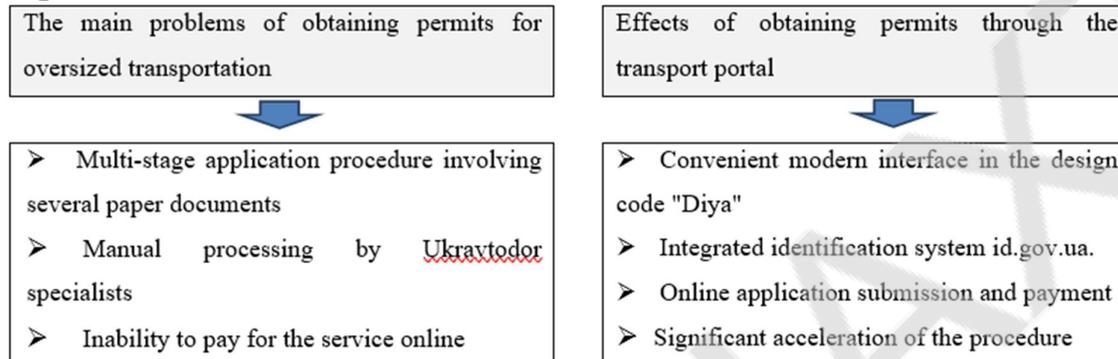


Fig. 4.3.2. Expected effects from the implementation of the system of obtaining permits for oversized transportation through the transport portal. Source: compiled by author based on [16]

- The introduction of E-protocols

It simplifies the accounting and prompt processing of protocol acts issued by Ukrtransbezpeka inspectors. This allows inspectors to promptly, directly from the scene of the accident, to transmit to the Ukrtransbezpeky control department information about violators, which further contributes to the efficiency of handling road accidents.

- Video surveillance in Permitting Points

It allows for public control and increases the transparency of the permitting process. Today there are such video surveillance points in Kovel, Holoby, Lviv, Vinnytsia, Khmelnytsky, Boryspil, Korosten. In the near future it is planned to introduce this service in 7 more important points.

- An e-consignment note, an electronic document certifying the rights to carry out cargo transportation.

E-consignment note is a legally significant document intended for all participants in the transport process, accounting for goods on the way of their movement, payments for transportation of goods and accounting for work performed. Currently, a pilot project has been implemented, a central database of e-consignment notes has been built, and data from commercial document management systems that serve carriers are entered into it [16].

4.4. Introduction of electronic consignment note as a mandatory prerequisite for digitalization of international cargo delivery

The electronic consignment note is an important step towards the digitalization of transport services. Among the post-Soviet countries, Georgia and Belarus already have a positive experience of implementing e-consignment note. For example, in

Belarus, the turnover of electronic consignment note reaches 120 million units per year, and the potential savings from abandoning the paper counterpart is 600 million euros.

The consignment note is a single and obligatory document for all participants of the transport process, which confirms the fact of transportation and delivery of goods, payments for transportation of goods and accounting of work performed.

To understand the scale of the "paper" problem, some figures can be given.

Approximately 500 million invoices and their copies are printed in Ukraine every year. This is more than 120 full 20-ton trucks with 1 million packs of A4 paper, each of which costs an average of 70-80 UAH. Add to this the cost of sending the original by paper invoice - it is still about 20-40 UAH and lost time, not to mention the printing and work of the responsible person. It turns out more than UAH 1 billion of business expenses annually on paper invoices, which are ultimately paid by each of us, paying for the purchased goods.

To solve this problem, the paper invoice should be replaced by an electronic one. That is why the key goal of solving this problem at the macro level should be considered the full digitalization of transport services while ensuring the transition to the highest quality service.

The pilot project on e- consignment note is planned to be implemented in 2 stages; at the 1st stage to introduce e- consignment note for general groups of goods. At the 2nd stage - to digitize consignment note for excisable groups of goods. At the third stage - to introduce the international format of e-CMR electronic consignment note for international freight. On the fourth - to standardize e- consignment note and e-CMR.

The first results of the introduction of e- consignment note indicate a significant reduction in the time for document administration - up to 1-3 days (including transportation time), while with paper consignment note the process sometimes took 21 days. Regarding savings (by courier delivery), the average cost decreased by 5-30 times. The transition to e- consignment note is a prerequisite for the creation of the transport and logistics sector of additional added value and new jobs, which in turn will contribute to the development of all sectors of the economy without exception.

V. CONCLUSIONS

The main factors that hinder or slow down the development of competencies for the digitization of business models in the transport and logistics industry, according to surveys of managers of transport and logistics companies are significant needs for financial investments, unresolved issues related to data security and confidentiality, lack of a clear program for the development of digitalization and support / initiative from senior management. The potential of new technologies for logistics is huge, but now companies in the industry are in no hurry to implement it.

There are many companies on the Ukrainian market that provide international cargo delivery services. The nature and range of their activities are very different. Despite the fact that the market is a competition of two major players - Nova Poshta

and Ukrposhta, alternative services have enough opportunities for development. The market is large and competitive, so large players cannot cover all service segments. Due to this, even new companies appear. For example, the Justin delivery service recently opened. She will work on the bases of Fozzy Group and Autolux.

The priority areas of transport policy in Ukraine today are the development of multimodality of transport and digital transport corridors. To achieve these goals, the Ministry of Infrastructure of Ukraine creates modern electronic services in all areas of the transport sector. However, to stimulate business to switch to digital technologies, it is necessary to introduce centralized online platforms at the macro level. The introduction of electronic services is not just the transfer of old public services online. This is the optimization of services taking into account the urgent market needs and convenience for consumers and users. In addition, in the future all state electronic services will be provided in a single interface.

The following services can be obtained on the transport portal of electronic services today: booking permits for international transportation, post-control at customs, obtaining permits for oversized transportation, transition of Ukrtransbezpeky inspectors to a new format - e-protocol, video surveillance in permitting cities, international consignment note.

It is important to understand that the transition to e- consignment note will create digital transport corridors in the future and will promote the development of multimodal transport in the Europe-Asia-Europe connection, renewal of Ukraine's status as a transit state, construction of a bridge between East and West, Ukraine and investment in infrastructure. The transition to e- consignment note is a prerequisite for the creation of the transport and logistics sector of additional added value and new jobs, which in turn will contribute to the development of all sectors of the economy without exception.

The full-fledged translation of consignment notes into electronic form will have a significant impact on both the freight market and the economy as a whole. Expected results from the implementation of e-consignment note are the following: simplification of interaction between transportation participants, acceleration of business processes of cargoes delivery and inspection of carriers, provides the possibility of accounting for road freight in a single system, which will increase revenue, ensures the coherence of the work of different departments through a single access to all registers that regulate the process of road freight, provides up-to-date information from the necessary registers in real-time.

VI. REFERENCES

1. Веретюк С.М., Пілінський В.В. (2016) *Визначення пріоритетних напрямків розвитку цифрової економіки в Україні*. [Наукові записки Українського науково-дослідного інституту зв'язку № 2.]
2. Горбенко А. *Вантажні автомобільні транспортні біржі в Україні : поточний стан і тенденції*.
ogist.fm/publications/vantazhni-avtomobilni-transportni-birzhi-v-ukrayini-potochniy-stan-i-tendenciyi

3. Дорошук В. О. (2016) *Сучасні підходи до вирішення поставлених задач в економіці транспорту. Ефективна економіка № 11*
<http://www.economy.nayka.com.ua/?op=1&z=5268>
4. Зайцев Е. И. (2016) *Информационные технологии и системы в логистике и управлении цепями поставок: Информационный материал.*
5. Карпенко О.О. (2015) *Логистика с умом: киевская команда создала софт для перевозчиков, способный экономить миллионы*
<https://ain.ua/2015/04/30/logistika-s-umom-kievskaya-komanda-sozdala-soft-dlya-perevozhnikov-sposobnyj-ekonomit-milliony>
6. Карпенко О.О. (2017) *Європейський вектор кластеризації транспортно-логістичних підприємств у площині інформаційно-комунікаційних технологій.*
7. Катерна О.К. (2013) *Інтелектуальні транспортні системи як інструмент економічного зростання країни*
8. Козіна К. Г. (2015) *Аналіз ринку міжнародних автотранспортних вантажних перевезень : сучасний стан та перспективи розвитку.* <http://www.vestnik-econom.mgu.od.ua/journal/2015/10-2015/30.pdf>
9. Коляденко С.В. (2016) *Цифрова економіка: передумови та етапи становлення в Україні і у світі. Економіка. Фінанси. Менеджмент: актуальні питання науки і практики.*
10. Смерічевська С.В. (2019) *Стан та перспективи цифровізації транспортно-логістичної галузі // Проблеми підготовки професійних кадрів по логистике в условиях глобальной конкурентной среды ХУ МНПК 25-26 октября 2019 г.*
11. Galkin A. (2017) *The Role of Consumers in Logistics Systems*
12. Smerichevska S., Martynenko O. (2019) *Improvement of Transport–Logistic Support for Development of Export Potential of Ukraine // Social and Economic Aspects of Education in Modern Society. Proceedings of the XIII International Scientific and Practical Conference*
13. Офіційний сайт Державної служби статистики України.
<http://www.ukrstat.gov.ua/>
14. Смена парадигмы. Будущее транспортно-логистического сектора.
<https://www.pwc.ru/ru/publications/paradigm-shift.html>
15. Обзор украинских служб доставки.
<https://horoshop.ua/blog/obzor-ukrainskikh-sluzhb-dostavki/>
16. Транспортний портал електронних послуг.
<https://e-transport.gov.ua>

**VICTORY MANIPULATOR UNIVERSAL ROBOTS IN THE LINE
SORTING OF FINISHED PRODUCTS OF THE WINE INDUSTRY**

Author: *Igor Kotsur*

Advisor: *Volodymyr Honhalo*

Одеська національна академія харчових технологій (Ukraine)

Annotation

The work considers the introduction of collaborative robots (manipulators) into the line of the technological process for the bottling, drying and packaging of sparkling wines, for safer work of people with manipulators and to reduce accidents at the plant itself.

Key words: collaborative robots, industrial manipulators, production safety, technological process, engine failure.

Introduction

Production safety - to this day they are striving for this. Initially, the human muscle was replaced by mechanical, which simplified the work of man. For example, turning a part on a lathe, a turner - in this case operates with a process, since all the work on rotating the part is performed by an electric motor. But even this work is not completely safe, there are many accidents during such work.

As a result of scientific and technological progress, the mechanical work of man was replaced by automation, that is, the cleansing abilities were performed by program-logic controllers, and not the human mind, where he was in the operator's room and controlled the technological process through a computer.

How many methods are used for the safety of production, for example, at elevators (cereals, sunflower seeds, corn) and flour mills, since a large amount of dispersed dust is released, an explosion occurs when a spark appears. This is avoided by removing dust from the walls of the enterprise. By similar parameters, in chemical plants where vapors can explode, they are also diverted from the process itself. In addition to such productions, use pneumatic or hydraulic actuators, since they do not give a spark.

Most enterprises use conveyors, like other moving elements, they can easily tighten the limbs of a person who, in turn, did not adhere to safety precautions, so that as soon as possible to stop the conveyor, a cable is attached to its base, if it is pulled, it will trigger the end a switch that will operate as a lock and the conveyor will stop.

The use of manipulators in industry is very common, for example, in automobile manufacturing, without them large-scale production of products did not exist. Also, manipulators can be used in the food industry.

Analytical analysis of the literature

We have considered a large number of publications by various authors exploring this issue.

The production line and its sparkling wine champagne process are discussed below[1, 2, 3].

Object, subject and research methods

Field of application of “Universal Robots” collaborative manipulators in the wine industry. Let us single out a section of technological production for the use of collaborative manipulators (robots). By those. The process will be a sparkling wine production site.

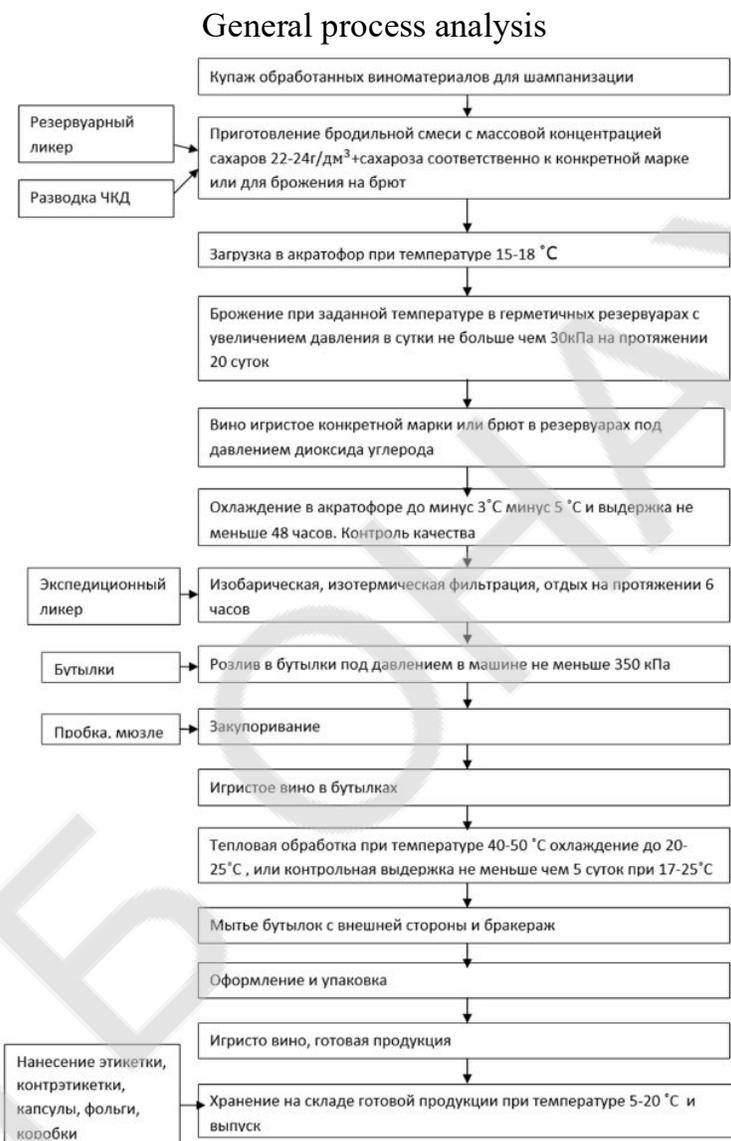


Image 1. The technological process of champagne wine

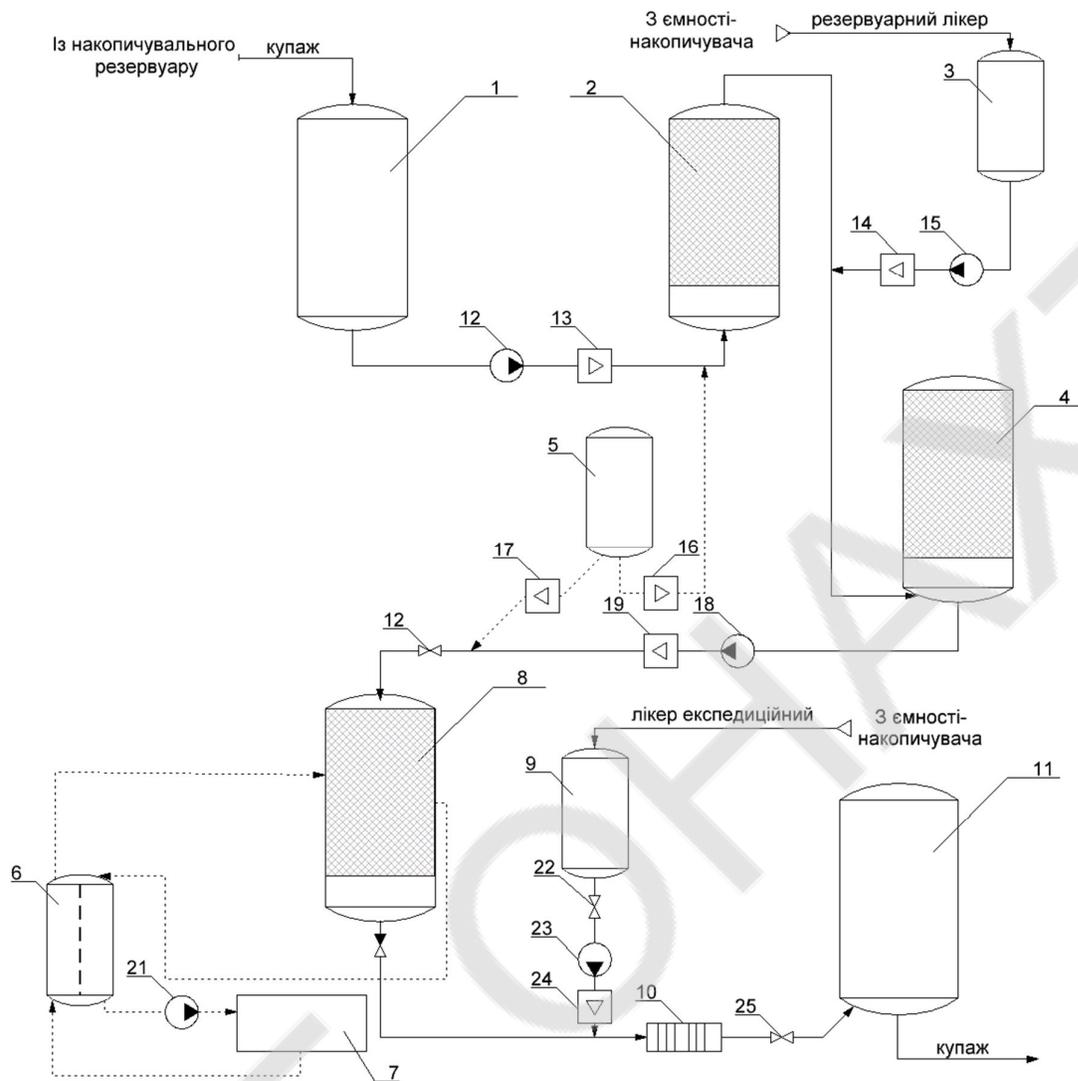


Image 2. Flow diagram of a section of a line for production of sparkling wines

The blending from the reservoir (1) by the pump (12) through the flow meter (13) is supplied to the apparatus (2) with the filler. Simultaneously with the blend, yeast wiring with dispersed mineral and yeast-growing apparatus is injected into the stream (5).

In the apparatus (2), processes of deoxygenation, stabilization and filtration of the blend occur.

Further, the worked blend is fed into the storage tank (4) for preparing the fermentation mixture by supplying the land (3) to the tank liquor stream using a pump (14) through a flow meter (15).

The fermentation mixture is pumped with a batcher (18) through a flow meter (19) and stop valves (20) into the acratophore (8) with a filler for the process of champagne. The fermentation mixture is dosed yeast wiring cultured with dispersed mineral.

At the end of the secondary fermentation, the sparkling wine is cooled, dispensed in the stream by expeditionary liquor from the tank (9), by opening the

shut-off valves (22) of the pump (23) and the flow meter (24). It is filtered on the filter (10), through the stop valves (25) it enters the receiving unit (11) and enters the bottling.

The refrigerant from the tank (6) is pumped to the refrigeration machine (7) by a pump (21). It cools, enters the reservoir (6) and enters the pipe system, which are connected with the acratophore jacket (8), the spent refrigerant returns to the reservoir (6).

The use of cobots "Universal Robots"

After bottling and corking the bottles, they move along the conveyor to the sink and sent to the packaging. On the way to the packaging, filled bottles with sparkling wine are checked for defects, that is, they are illuminated by a laser with a special sensor on the one hand, and on the other hand, the receiving part of the sensor analyzes the density of the signal beam from the laser, if the signal is weak, then the bottle filled with wine, but suddenly the signal turns out to be stronger, then the density is lower, which in turn means that the bottle is empty, maybe the dispenser did not fill it. In any case, it is impossible to pack a defective product with a full one.

It is necessary to eliminate it from the conveyor, for this the manipulator (robot) "Universal Robots" of the UR10e model series is suitable, since they are safe when working with people. Since there is a washing, a marriage check, a label sticker and the packaging itself, which most people can do, is located in the workshop. The use of conventional manipulators can lead to injuries to people at work in cramped workshops, as they do not provide protection.

In cobots "Universal Robots" protection is provided for working with people, for example, when it is working, it accidentally touches a person, the robot instantly stops and will wait for some time according to the algorithm or already an operator's command to continue working, which will give time to a person , which hit, leave this place.

Consider a line of collaborative robots, which consists of four instances (shown below).

A brief description of the line e-series: created with a view to the future, the e-Series line allows you to expand your business, is a springboard to improving quality and increasing productivity, helping you always get ahead of your competitors. With an intuitive programming option, versatile use and an endless list of accessories, the e-Series line fits harmoniously into production regardless of industry, company size or product nature.

Universal Robots “UR3e”



Image 3. Universal Robots UR3e
Specification

- Radius – 500 mm / 19.7 inch
- Payload – 3 kg / 6.6 lbs
- Footprint – \varnothing 128 mm
- Weight – 11.2 kg / 24.7 lbs

Universal Robots “UR5e”



Image 4. Universal Robots UR5e
Specifications

- Radius – 800 mm / 33.5 inch
- Payload – 5 kg / 11 lbs
- Footprint – \varnothing 149 mm
- Weight 20.6 kg / 45.4 lbs

The latest offering in our collaboration robot series, UR5, extends the capabilities of agents ready for future change with collaborative innovation, Human Centric UX, and the ecosystem for each application. Transform ambition into results by changing the way you manufacture using the most flexible automation platform.

Universal Robots “UR10e”



Image 5. Universal Robots UR10e
Specifications

- Radius – 1300 mm / 51.2 inch
- Payload – 10 kg / 22 lbs
- Footprint – \varnothing 190 mm
- Weight 33.5 kg / 73.9 lbs

Universal Robots “UR16e”



Image 6. Universal Robots UR16e

Specifications

- Radius – 900 mm / 35.4 inch
- Payload – 16 kg / 35.3 lbs
- Footprint – \varnothing 190 mm
- Weight 33.1 kg / 73 lbs

Universal Robots “UR16e”, a recently released novelty that expanded the e-series family, one of the main differences from the “UR10e” is the reduced range from 1300 mm to 900 mm, but this is offset by an increase in carrying capacity by 6 kg, for example, “UR10e” - 10 kg vs “UR16e” - 16 kg, also “UR16e” became 400 grams lighter than its predecessor.

Consider an analogue of the Universal Robotics

ROZUM Robotics model 90



Image 7. PULSE 90
Specifications

- Payload – 4 kg
- Radius – 900 mm
- Weight – 13.6 kg
- Footprint – 120 mm
- Non-Stop lifetime cycle – 20000+ hours

In this work, it will be rational to choose a collaborative robot “UR5e”, since the maximum weight of the bottles will reach 3.5 kg, it would also be better to use the kobot “UR10e” in the radius of use, but for the work area, “UR5e” is enough, in addition, a larger radius may be needed only in isolated cases, it will not be necessary to overpay for a more expensive modification if it does not work out at 100 percent.

One of the main differences and arguments for using cobots of the “Universal Robots” from their counterparts is the safety of working with people around, for example, if a person touches him while the robot is working, the cobot will stop and wait for further action or according to the algorithm it will work after a specified time further

Also, the presence of the robot itself is not sufficient to realize its full functionality - grips are additionally used (we will consider below different analogs of grips that have unified mounts for a universal platform of colorative robots).

Manipulator Grip WSG25-CR



Image 8. Grip WSG25-CR

Specifications

- Compliance with safety requirements for human-robot interactions
 - Quick integration
 - Built-in web interface with documentation for configuration and diagnostics
 - Support for textual communication protocols over TCP / IP and UDP, as well as the industrial Modbus / TCP interface
 - Grip control directly by the robot controller via the integrated Modbus / TCP interface

Grip integration without the need for programming. The built-in controller uses the latest capture algorithms, high-speed object detection and capture control.

External position sensors are no longer required since position measurement is carried out using internal sensors. This simplifies the process of integrating a robotic solution into your manufacturing process.

OnRobot RG2 Gripper



Image 9. OnRobot RG2 Gripper Specifications

- Easy installation
- Integrated control board
- Flexible, easy to reconfigure
- Support for two grips simultaneously
- Adjustable force
- Wide working range, work with objects of different sizes
- Fast change of fingers of capture
- Plug & play
- Easy programming
- Retention of gripping force in case of power loss
- Analog Robot Feedback

Adjusting the grip force allows you to hold both light and heavy objects. Standard fingers can be used with many different objects. Installation on capture of third-party fingers is possible. Configure and control capture from Universal Robots software. Technical specifications are shown in the image 10.

Параметр	Мин.	Типичное	Макс.
Полный ход (регулируемый)	0	-	110 мм
Точность позиционирования захвата	-	0,1 мм	-
Повторяемость	-	0,1 мм	0,2 мм
Обратный люфт	0,2 мм	0,4 мм	0,6 мм
Сила захвата (регулируемая)	3 Н	-	40 Н
Точность силы захвата	$\pm 0,05$ Н	± 1 Н	± 2 Н
Скорость захвата	55 мм/с	110 мм/с	184 мм/с
Время захвата	0,04 с	0,07 с	0,11 с
Рабочее напряжение	10 В	24 В	26 В
Потребляемая мощность	1,9 Вт	-	14,4 Вт
Максимальный ток	25 мА	-	600 мА
Рабочая температура окружающей среды	5 °С	-	50 °С
Температура хранения	0 °С	-	60 °С
Вес	-	0,65 кг	-

Image 10. Technical specifications

And the last of the three grip options

GRIPKIT-E1



Image 11. GRIPKIT-E1 Specifications

- 20 million work cycles guaranteed
- Uptime 24/7

- Automatic detection and monitoring of captured objects
- Support for up to 8 captures connected to one robot

A fully integrated solution for Universal Robots. GRIPKIT contains everything you need to realize the task of capturing and moving within a few minutes. It is fully compatible with all Universal Robots models and integrates seamlessly into the Polyscope software environment with the easy-to-use URCaps plug-in.

GRIPKIT is available in various sizes with grip forces from 7.5 to 550 Newtons and is compatible with all robots from Universal Robots, making it the ideal solution for a wide range of applications.

Software was used to work as collaborative robots.

- URsim
- RoboDK
- Programming environment – Python

The software RoboDK is such a description:

Processing robots

Use your robot arm like a 5-axis milling machine (CNC) or a 3D printer. You can simulate and convert NC programs (G-code or APT-CLS files) in the program of the robot itself. RoboDK automatically optimizes the robot path, avoiding features, axis restrictions and collisions.

Offline programming software

Modeling and autonomous programming of industrial robots has never been easier. Create your own virtual environment to simulate your application in minutes.

Easily create robotic programs offline for any robot controller. You no longer need to learn vendor specific programming.

Also, RoboDK has a built-in online library or manually loaded with many different manipulators, robots that you will find on the market, there are also many objects with which these robots work, for example, a grab or drill, or even a welding machine.

One of the conveniences of this program is that the programming of collaborative robots allows you to download program code written in the python language and edit in the program itself each movement in each axis individually for any task.

It can also be noted that robots can be controlled not only by a software algorithm, but also use a real-time control display (shown in the image 12).

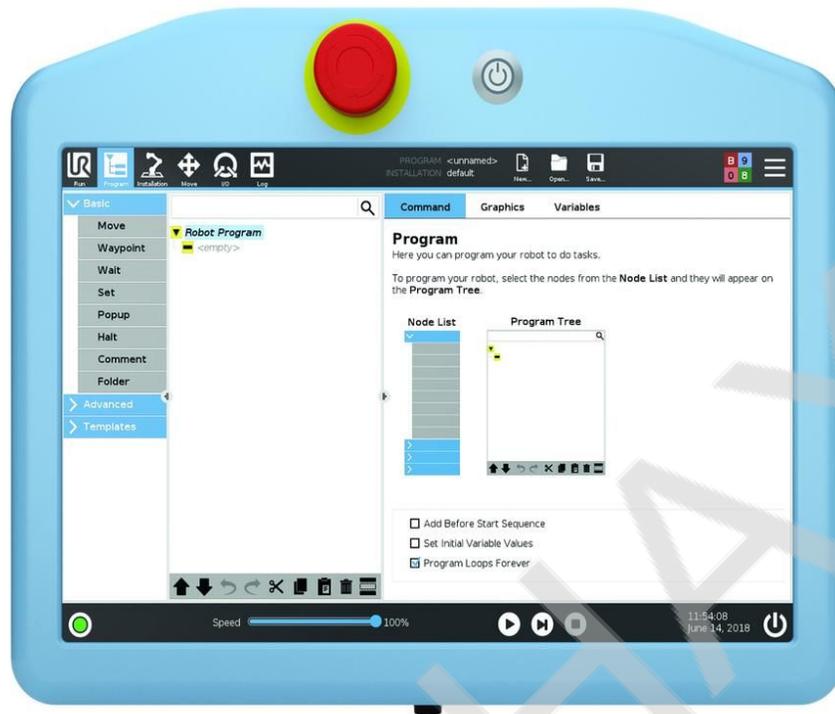


Image 12. Control display
Display features

- Real-time robot control
- Emergency stop
- Monitoring the work of each axis and their degrees of rotation
- Robot calibration

Also, one of the programs for work is yursim software, it allows you to start work in a virtual mode, it is convenient when your robots are busy with work and stopping them can cause the process to stop, therefore testing certain modes of work in virtual mode is a good solution.

Principle of operation

The standard position of this robot above the conveyor belt and products, using transillumination sensors or a vision camera, determines the product itself and its quality. in this case, these are bottles of wine products, if the bottle is very easy to see through, it means that it is empty. (image 12).

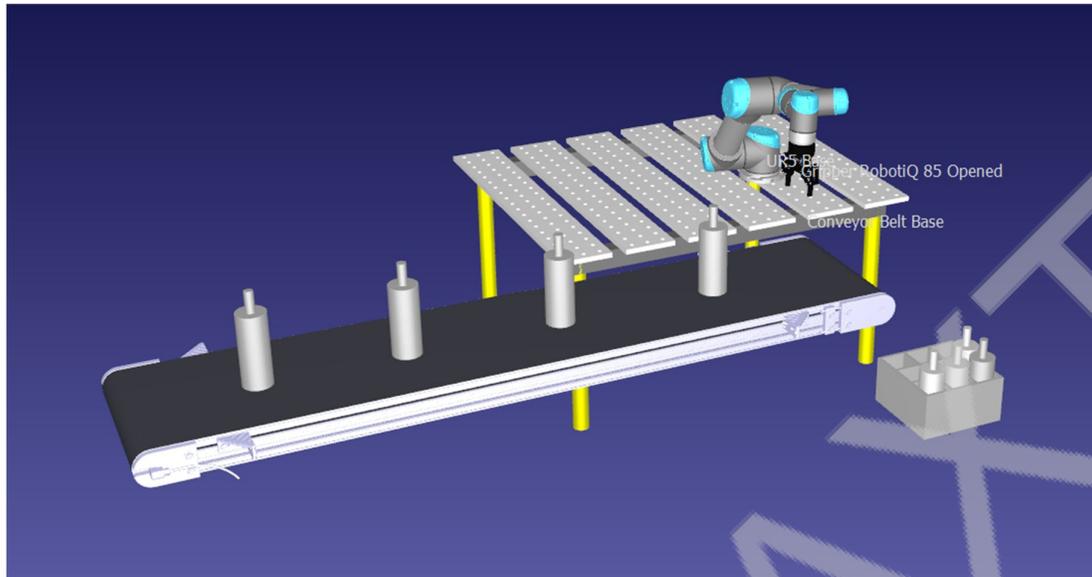


Image 12. Initial position

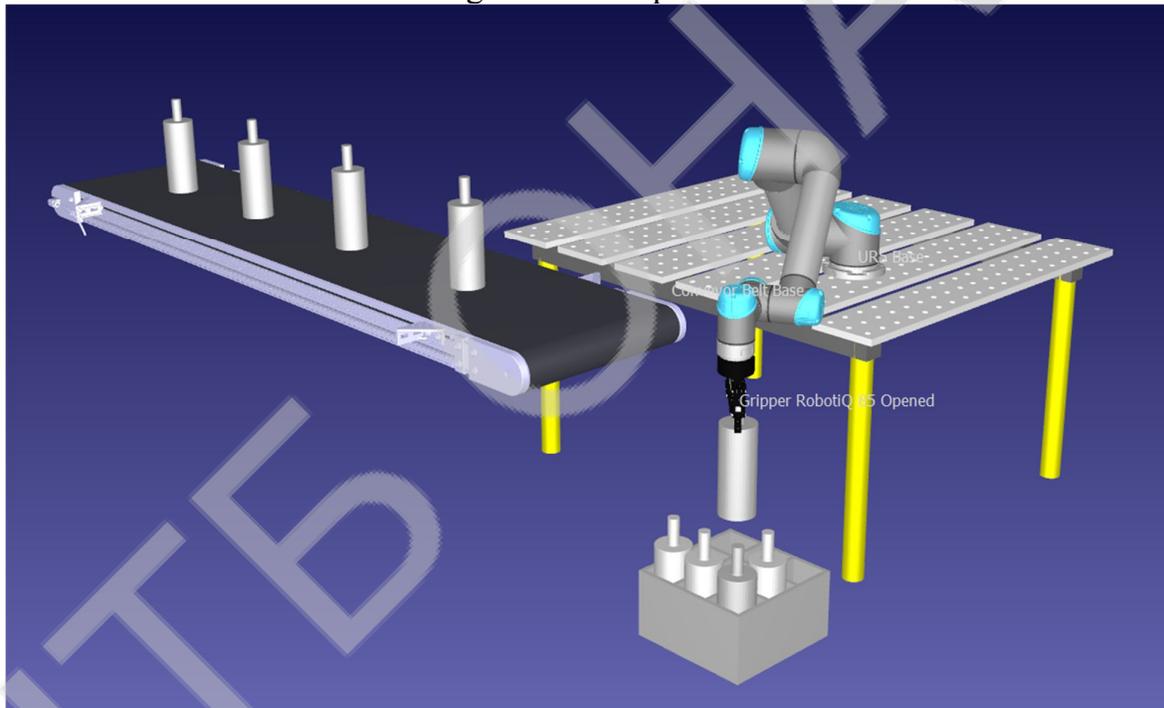


Image 13. Initial position

Image 13 shows the mode of operation when the robot places the gripped product in the container.

When a defective product is identified, the robot places it not in a container, but in a special area. in image 14, a yellow square is displayed. After that, the robot continues to pack the products as usual.

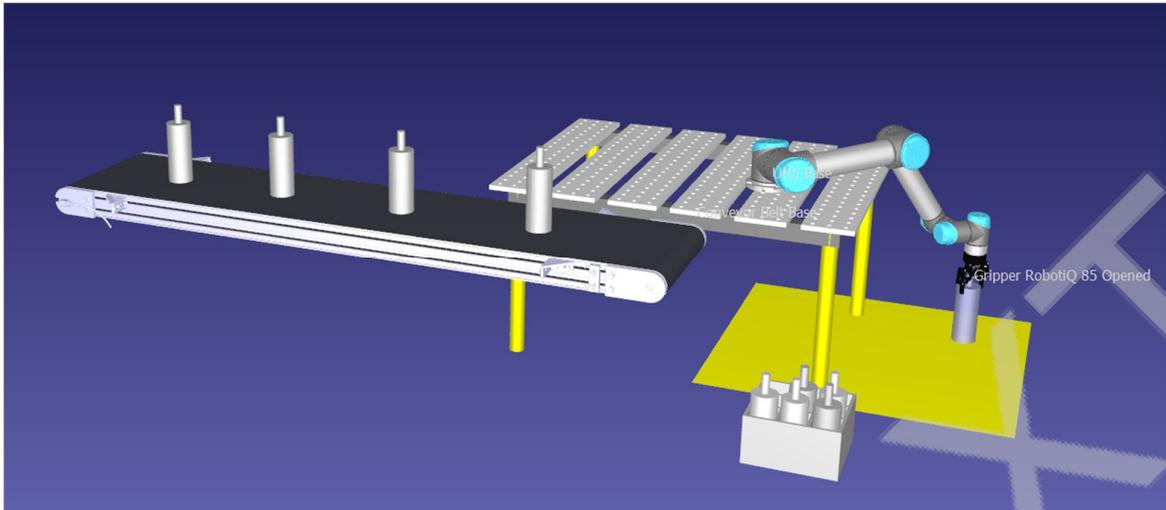


Image 14
Laboratory tests

Laboratory tests were carried out on a laboratory bench (image 15) in the laboratory of robotics and mechatronics fab lab. Also, to control the conveyor, a programmatic controller of the Phoenix Contact company was used, where the regulating body was a frequency converter to control the speed of a three-phase motor. In order to properly maintain the variable conveyor speed, PID control was used. In order to select the tuning parameters of the controller parameters, an identification of the control object was made, namely the conveyor. We managed to get the data of the transient process from the SCADA system (Image 16). After that, according to the data of the control object, the parameters of the PID controller were calculated, after which the process was simulated (Image 17) and the parameters of the PID controller were optimized - Image 18.



Image 15

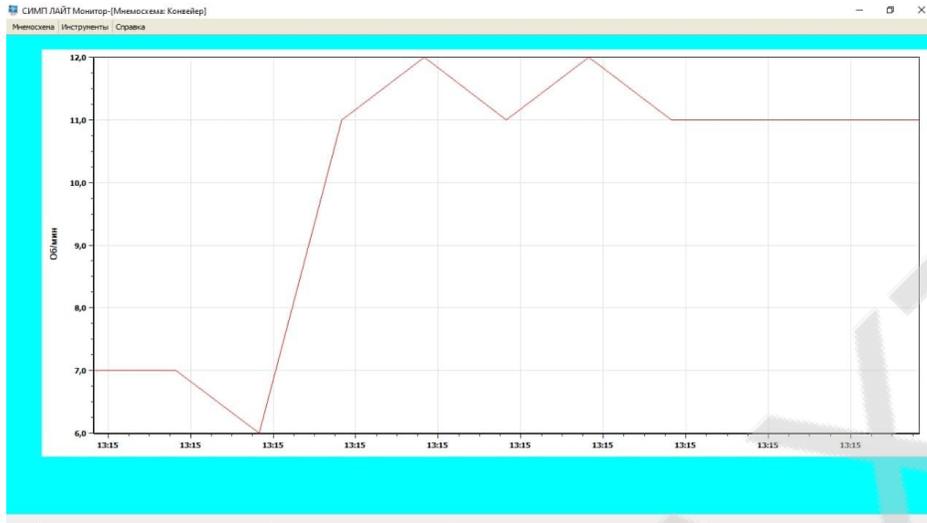


Image 16

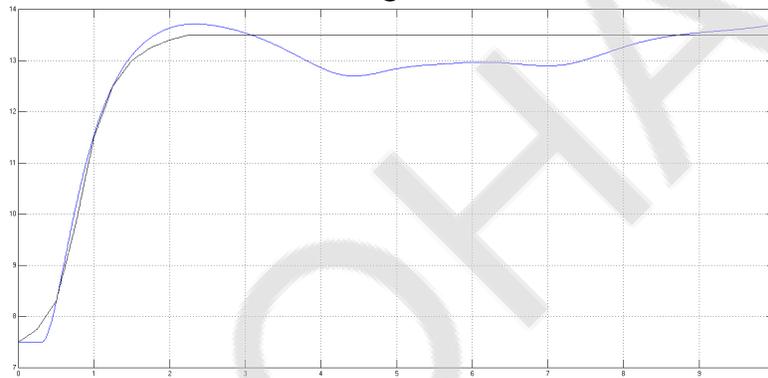


Image 17

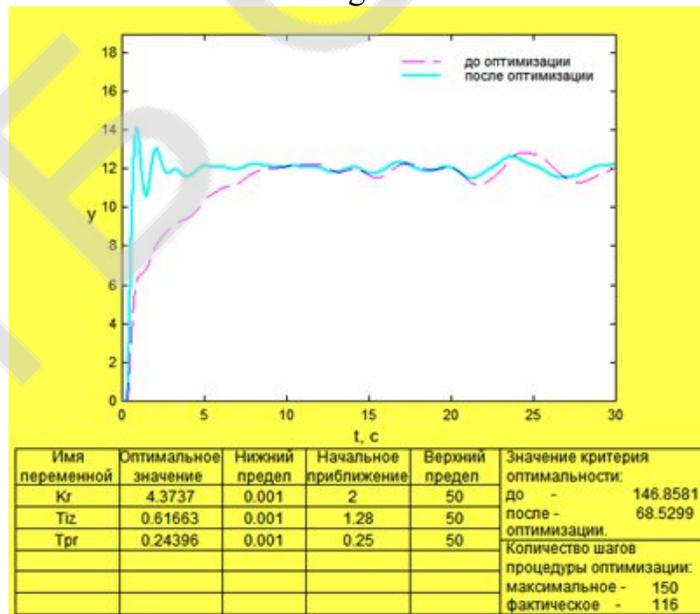


Image 18

The smaller the optimality criterion, the closer the system is to the real

Conclusions

PID control	Direct quality indicators		optimality criterion
	$\Delta T_r^{\text{МАКС}}$	t_{per}	
before optimization	0,2	10	146,9
after optimization	2	5	68,52

The paper considers the task of production safety in the wine industry, namely, the safe contact of people with collaborative robots in the packaging section of the wine champagne technological process.

Literature

1. Jean-Riberto Guyon. Theory and practice of winemaking. T. 3. Methods of winemaking wines. Remaking in wines - M.: Kharchova promislovist, 1980 - 480 p.
2. Sarishvili N.G., Reyblat B.B. Microbiological fundamentals of technological champagne wine - Moscow: Kharchova promislovist, 2000 - 364 p.
3. Makarov A.S. Virobnitstvo champagne. - Simferopol: "Tauris", 2008 - 416 p.
4. <https://www.universal-robots.com/products/ur10-robot/>
5. <https://sovtest-ate.com/equipment/wsg25-cr/>
6. <https://sovtest-ate.com/equipment/gripkit-e1/>
7. <https://sovtest-ate.com/equipment/onrobot-rg2-gripper/>
8. <https://rozum.com/robotic-arm/#available>

AUTOMATION OF POSITIONING OF PNEUMATIC ACTUATORS BY MEANS OF INTRODUCTION OF THE PHOENIX CONTACT CONTROLLER

Author: **Dmytro Makletsky**

Advisor: **Serhii Kovtun**

Одеська національна академія харчових технологій (Ukraine)

Abstract

Abstract Object of research or development - Automation of control of process of positioning of piston executive mechanisms

The purpose of the work is to develop a system of automatic control of the process of positioning of piston actuators, which would support adjustable variables in the regulatory zones both in steady and transient modes of operation.

Research methods and tools - when identifying the properties of the object of control, the methods of imaginary active and passive experiment were used with further processing of their results; control object models and control systems were developed in Simulink / Matlab environment; parametric synthesis of the control system is carried out by the method of optimization of the quality indicator of its functioning; the development of the advanced system was carried out analytically

using the apparatus of transfer functions. The obtained results - the received system of the increased dynamic accuracy which supports adjustable variables in regulatory zones both in steady, and in transient operating modes. Significance of work and conclusions - the developed system has advantages in comparison with traditional SAR which are used in practice.

Keywords: Control object, automatic control system, zone of insignificant deviations, mathematical model, system of increased dynamic accuracy, pneumatic actuator, distributor, controller, PC Worx, Visu +.

Introduction

The level of development of modern technology is largely determined by the efficiency of drive systems that ensure the movement of target mechanisms in the process equipment and, as a consequence, the required productivity and accuracy of work processes. Therefore, the improvement of existing and the creation of new machines and mechanisms requires the development of driveconstruction and the creation of new drive systems that can compete with known circuit design solutions.

In these conditions, the creation of automated positional drives is an important scientific and technical task. With the known advantages (ease of energy transfer, high speed, good mass and size characteristics, the possibility of stepless speed control, etc.), pneumatic actuators are a promising direction to solve this problem. They are widely used in positioning mechanisms, especially in combined pneumomechanical and pneumoelectric drive systems, which in certain solutions form mechatronic systems. This allows to expand the possibilities of structural and parametric synthesis of software and hardware implementations of algorithms.

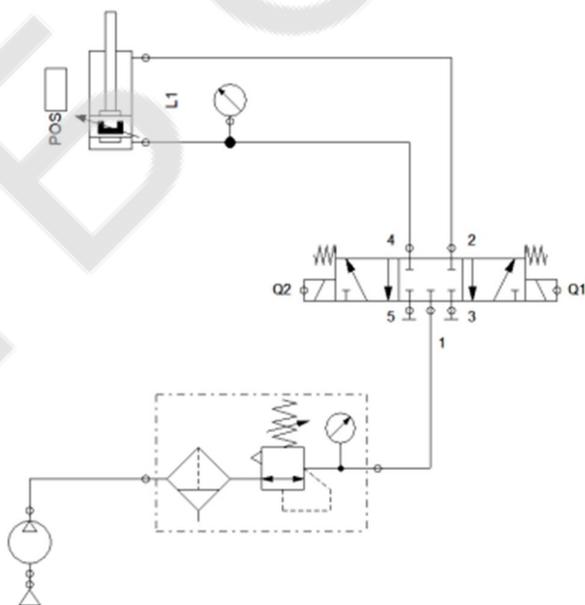


Рис 1.1.

Analytical analysis of the literature

We have reviewed a large number of publications by various authors who study this issue.

Object, subject and research methods

Analysis of the physical essence, possible ranges of change and frequency properties of input actions and their consequences.

Development of schemes for modeling the dynamics of action transformation channels, obtaining transient characteristics of models and comparing them with experimental transient characteristics.

First you need to get a mathematical model of management.

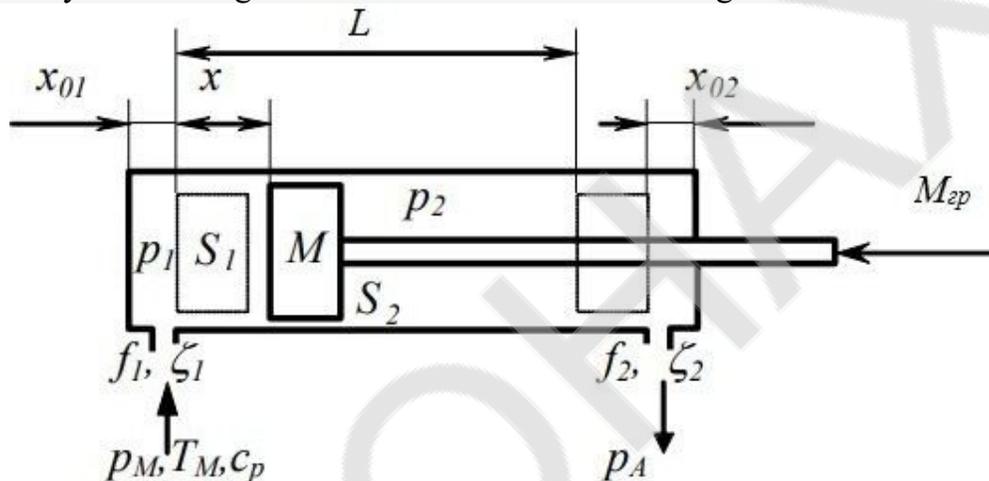


Figure 2.2 model of a pneumatic cylinder

Basic symbols:

p - pressure, Pa;

p_A - outlet pressure, Pa;

p_M - supply pressure, Pa;

x is the coordinate of the position of the piston, m;

x_0 - the given coordinate characterizing volume of harmful space, m;

f is the cross-sectional area of the pipeline, m^2 ;;

M_{zp} - weight of cargo, kg;

M - mass of moving parts, kg;

S_1 S_2 -area of the piston and rod cavity, m^2 ; L is the maximum stroke of the piston, m;

Numerical values of parameters for air at temperature $T = 2930K$ (200C) and pressure $p = 101,3$ kPa (1 atm.): $K = 1,4$; $R = 287$ J / (kg * K): $\rho = 1.204$ kg / m^3 ; $c = 344$ m / s.

1. The equation of motion of the drive has the form:

$$M \frac{d^2 x}{dt^2} = p_1 F_1 - p_2 F_2 - p_A (F_1 - F_2) - N. \quad (2.2)$$

Mathematical model of air is expressed by adiabata:

$$p^K \cdot V = const \quad (2.3)$$

where p is the pressure in the cylinder, MPa; V is the volume of the cylinder, m³.

$$p^K \cdot V = k \cdot m \quad (2.4)$$

To solve k we take 1 cubic meter of air at atmospheric pressure then

$$0,1^{1,4} \cdot 1 = k \cdot 1,29 \quad (2.5)$$

$$k = \frac{0,1^{1,4}}{1,29} = 0,03086 \quad (2.6)$$

To develop a mathematical model, it is necessary to consider the state of the air in the left and right cavities

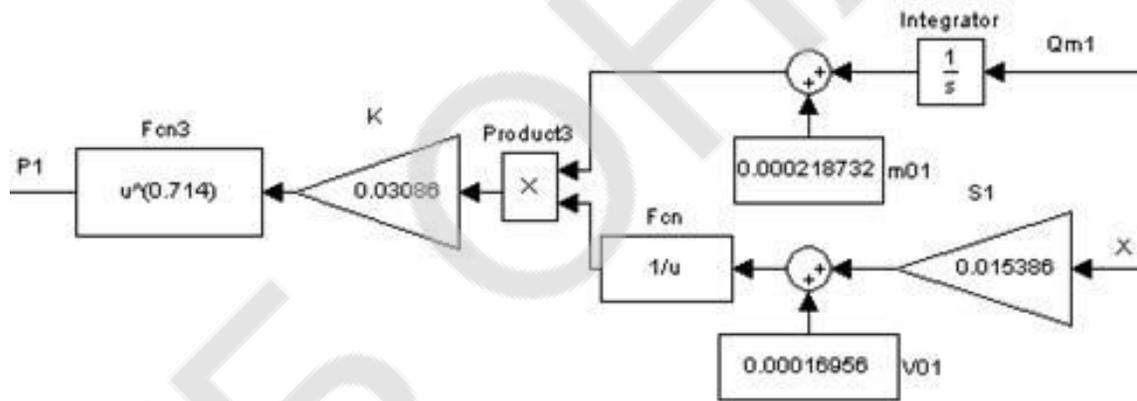


Figure 2.3 - S-model of the state of the air in the left cavity

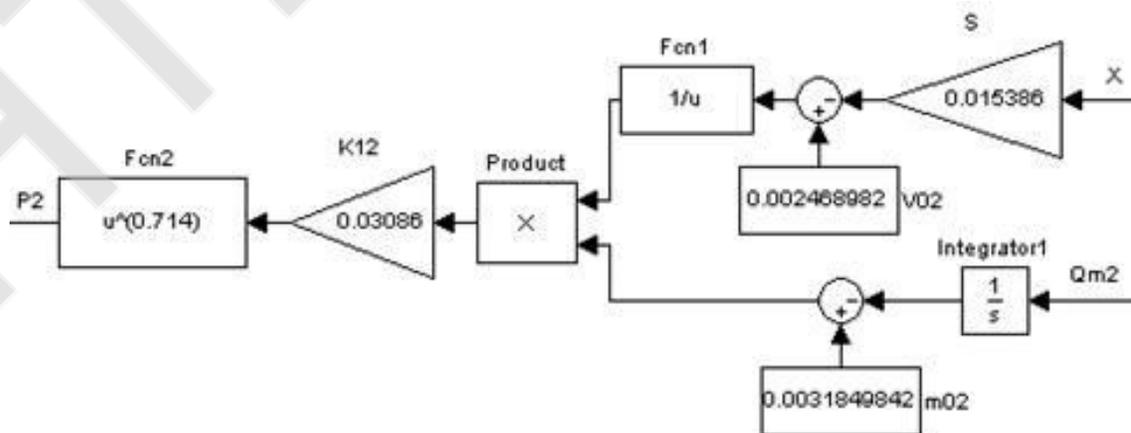


Figure 2.4 - S-model of the state of the air in the right cavity

Development of a mathematical model of air drive aeromechanics The mathematical model of air drive aeromechanics is expressed by equations

hydrodynamics for two cavities. The expression determines the mass flow rate Q_{m1} of air in the left cavity, the expression - the mass flow rate Q_{m2} in the right cavity

$$Q_{m1} = \sqrt{2\rho \cdot \mu \cdot S_{dp}} \cdot \sqrt{(P_{max} - P_1) \cdot P_1} \quad (2.7)$$

$$Q_{m2} = \sqrt{2\rho \cdot \mu \cdot S_{dp}} \cdot \sqrt{(P_2 - P_{min}) \cdot P_{min}} \quad (2.8)$$

It is seen from the expressions that the input value for the models of air aeromechanics in the cavities of the pneumatic cylinder is the pressure in the respective areas, and the output is the mass flow rate in the respective areas.

Figures 2.5 2.6 show S-models of aeromechanics for the left and right cavities, respectively.

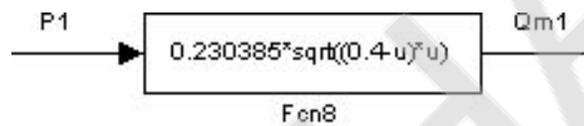


Figure 2.5 - S-model of aeromechanics in the left cavity of the pneumatic actuator

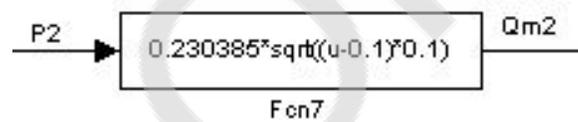


Figure 2.6 – S-model of aeromechanics in the right cavity of the pneumatic actuator

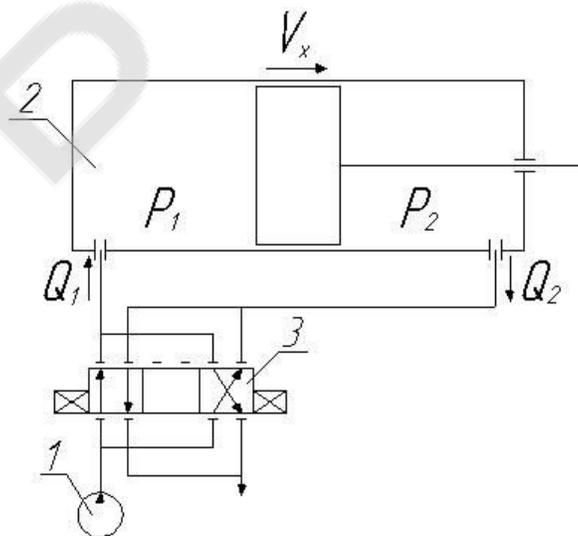


Fig.2.7 mathematical model of a pneumatic cylinder

- Schematic diagram of the control of the pneumatic cylinder GM air consumption from an unlimited volume (highway) is most often determined by the formula of Saint-Venant and Wenzel

$$G_M = \mu_1 \cdot f_1 \cdot P_M \cdot \sqrt{\frac{2k}{k-1} \cdot \frac{1}{R \cdot T_M} \cdot \left[\left(\frac{P_1}{P_M} \right)^{2/k} - \left(\frac{P_1}{P_M} \right)^{\frac{k+1}{k}} \right]} \quad (2.9)$$

The volume V1 of the working cavity is equal to the product of the area of the piston F1 to move the piston x (taking into account its initial coordinate X01), we obtain

$$\frac{dP_1}{dt} = \frac{k \cdot \mu_1 \cdot f_1 \cdot K \cdot P_M \cdot \sqrt{R \cdot T_M}}{F_1 \cdot (x_{01} + x_1)} \cdot \varphi(\sigma_1) - \frac{k \cdot P_1}{(x_{01} + x_1)} \frac{dx}{dt} \quad (2.10)$$

The flow of air from a limited volume of V2 in the highway is also described by the formula of Saint-Venant and Wenzel, but it should put $T_M = T_2$, $P_m = P_2$ bearing in mind that all these values are variable

$$\frac{dP_2}{dt} = - \frac{k \cdot \mu_2 \cdot f_2 \cdot K \cdot P_2 \cdot \sqrt{R \cdot T_2}}{F_2 \cdot (s + x_{02} - x)} \cdot \varphi\left(\frac{1}{\sigma_2}\right) + \frac{k \cdot P_2}{s + x_{02} - x} \frac{dx}{dt} \quad (2.11)$$

Dynamic calculation of a differential drive

The equation of motion of the piston of the differential drive has the form

$$m \frac{d^2x}{dt^2} = P_1 \cdot F_1 - P_2 \cdot F_2 - P$$

where m is the mass of the piston;

P1 - force of harmful resistance (friction); P2 is the force of useful resistance

P is the result of all the forces applied to the piston

$$m\ddot{x} = P_1 \cdot F_1 - P_2 \cdot F_2 - (P_{avon} + F_{mp});$$

$$m\ddot{x} = P_1 \cdot F_1 - P_2 \cdot F_2 - P_{avon} - \mu \cdot \dot{x};$$

$$\ddot{x} = \frac{P_1 \cdot F_1}{m} - \frac{P_2 \cdot F_2}{m} - \frac{P_{avon}}{m} - \frac{\mu}{m} \cdot \dot{x};$$

$$\ddot{x} = \frac{P_1}{m} - \frac{P_2}{m} - \frac{P_{avon}}{m} - \frac{\mu}{m} \cdot \dot{x} \quad (2.13)$$

Consider the reverse stroke of the piston. The equation of its motion in reverse when the piston cavity 2 connects to the atmosphere has the form:

$$P = P_1 + P_2 + P_3 + P_a \quad (P_1 - P_2) \quad (2.14)$$

If the pneumatic cylinder is in the extreme left position, then the program must immediately after calculating the acceleration artificially set the acceleration, speed and coordinate equal to zero, ie to the obtained equations of the mathematical model

of the pneumatic actuator must add a condition:

$$\text{если } x \leq 0, \text{ то } \frac{d^2x}{dt^2} = \frac{dx}{dt} = x = 0. \quad (2.16)$$

Similarly, for the case when the piston reaches the end in the extreme right position, it is necessary to write a condition that limits the coordinate x the length of the drive S

$$\text{если } x \geq S, \text{ то } \frac{d^2x}{dt^2} = \frac{dx}{dt} = x = 0. \quad (2.17)$$

$$\left. \begin{aligned} M \frac{d^2x}{dt^2} &= p_1 F_1 - p_2 F_2 - p_A (F_1 - F_2) - N, \\ \frac{dp_1}{dt} &= \frac{k f_1 \sqrt{RT_M}}{F_1 (x + x_{01}) \sqrt{\zeta_1}} \sqrt{p_M^2 - p_1^2} - \frac{k p_1}{x + x_{01}} \frac{dx}{dt}, \\ \frac{dp_2}{dt} &= - \frac{k f_2 \sqrt{RT_M}}{F_2 (S - x - x_{02}) \sqrt{\zeta_2}} \left(\frac{p_2}{p_M} \right)^{\frac{k-1}{2k}} \sqrt{p_2^2 - p_A^2} + \frac{k p_2}{(S - x - x_{02})} \frac{dx}{dt}, \\ \text{если } x \leq 0, \text{ то } \frac{d^2x}{dt^2} &= \frac{dx}{dt} = x = 0, \\ \text{если } x \geq S, \text{ то } \frac{d^2x}{dt^2} &= \frac{dx}{dt} = x = 0. \end{aligned} \right\} (2.18)$$

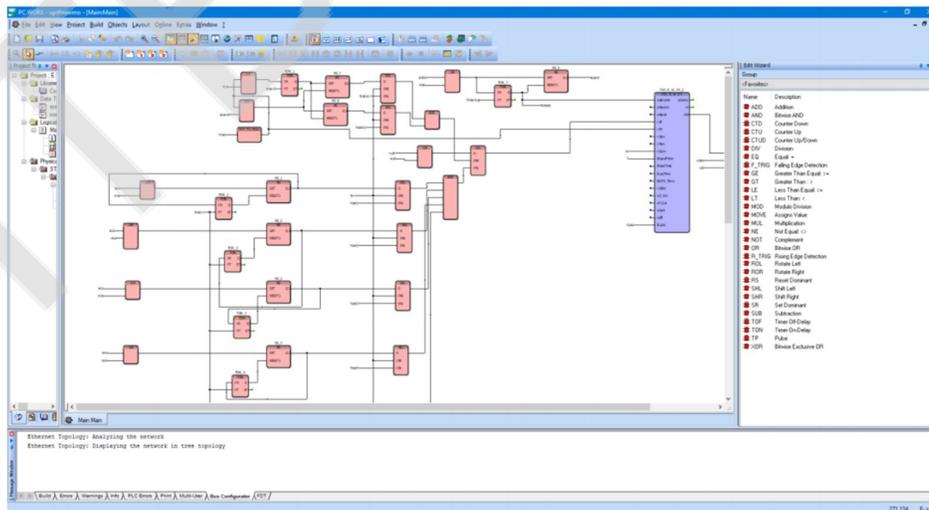


FIGURE 2.8 Screenshot of the logical control program findings

The Phoenix Contact Axiocontrol AXC 1050 controller was selected for the Office and software was developed to perform the task.

The paper deals with the task of Automating the positioning of pneumatic actuators behind the help of the Phoenix Contact controller

List of references

1. Catalog ST70 "SIMATIC - Components for Complex Automation". - Siemens AG, 2007.-- 862 p.
2. Catalog IK PI "Industrial communication for automation systems and drives". - Siemens AG, 2005.-- 666 p.
3. Hans Berger. Automation with Step 7 LAD and FBD programs - Revised 2nd edition, order number 6ES7 810-4CA05-8AR0, Siemens AG, 2001. - 605 p.

KINEMATIC ANALYSIS OF THE HINGE-LEVER MECHANISM OF THE GRIPPING DEVICE ANTHROPOMORPHIC ROBOT

Author: *Vladyslav Borysov*

Advisors: *Yevgen Mykhaylov, Oleksandr Kniukh*
department of lifting-transport equipment and robotteknologi,
Odessa national Polytechnic University (Ukraine)

Abstract. *The analysis of forearm prostheses presented on the modern market has been carried out. Their features, advantages and disadvantages are characterized.*

The relevance of this research work is shown.

A prototype of the prosthesis was selected. Selected drive type with justification of the choice. A method for controlling the prosthesis has been developed. The kinematic diagram of the brush has been compiled. The analysis of the functionality of the modular hand prosthesis was carried out. Calculated brush drive. Corresponding drive selected Hand force factors calculated.

Keywords: *PROSTHESIS OF FOREAR, Four-bar Linkage, Kinematic diagram of fingers, Hand Mechanism Design, 3D Printing, DC motor.*

INTRODUCTION

Prosthetics is the restoration of lost forms and functions of individual organs or parts of the body. Prosthetic construction is engaged in development and production of artificial technical means of restoration.

Currently, 42,000 people with disabilities in the Odessa region are in need of prosthetic and orthopedic care.

The largest number of amputations on the upper extremity - amputation at the level of the forearm (50.5%). Disabled people who have undergone such an amputation are primarily deprived of the opportunity for self-care, and in most cases

even lose their profession. Therefore, the purpose of prosthetics of the upper extremities: the return of the disabled to the possibility of self-care and employment.

The main task of prosthetic construction is to create a technical device that can maximally fill the lost functions, ie return the disabled person the opportunity to perform basic household movements. Such movements are: grasping and manipulating the object. At amputation at the level of a forearm the full-fledged movement in shoulder and elbow joints remains that is sufficient for very exact positioning of an artificial hand in space without need of compensation of mobility of a radial wrist joint.

To implement the same grip requires a special technical device, a very simple design solution which is now widely used and is a mechanical prosthesis. The most common control methods are: traction mechanical, cosmetic and bioelectrical methods.

The purpose of my work is to develop a domestic prototype of a bionic prosthesis, which in modernization will not yield to European counterparts

II. ANALYSIS OF THE CURRENT PROSTETIC MARKET

By the principle of work prostheses on:

1. Traction (active, mechanical);
2. Mioelectric (bioelectric, bionic);
3. Cosmetic (Workers);

2.1. Cosmetic prostheses

The first, currently existing type of prosthesis, the main task of which, as the name implies, is to maximize the exact reproduction of the appearance of a lost limb (Fig.1).



Fig.1 Cosmetic prostheses

The cost of manufacturing a cosmetic forearm prosthesis in Ukraine is about 4-5 thousand hryvnias. Warranty period not more than a year.

2.2 Bioelectric prostheses

Bioelectric, also called myoelectric or bionic prostheses - these are some of the most modern and advanced hand prostheses. Management in myoelectric prostheses is carried out due to the signals arising from the contraction of muscles that read EMG sensors.

Myosensors are integrated in the stump receptacle, which capture the change in electric potential. This information is transmitted to the brush microprocessor, and as a result, the prosthesis performs a certain gesture or grip. (Fig.2)

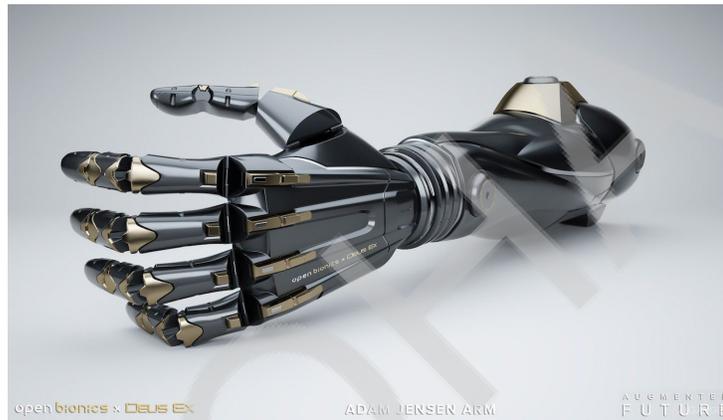


Fig.2 Bioelectric prosthesis

2.3 Traction prostheses of the upper extremities.

These are active manipulators controlled by the physical forces of their own body. The motor function of the prosthesis is carried out by means of a traction bandage. The advantages of this type are simple mechanics, the possibility of prolonged contact with water and low prices for prostheses of the lower limbs and upper.

Active (traction or mechanical) prostheses of the hand and forearm

The active prosthesis is controlled by rods and is completely controlled by the efforts of the person himself without any electronics.

The principle of operation of a mechanical prosthesis is very simple, therefore, such prostheses are installed from a very early age. Modern active prostheses are made even for children from 2 years old with injuries at the level of the hand and forearm.

The strength of this mechanism is the ability to control the force. When performing a grip, the user himself determines the compression force, its speed and can feel resistance when the brush rests on the subject. Pic.3



Fig.3 Active traction prosthesis

III. PROTOTYPE DEVELOPMENT

3.1. Drive types

For full recovery of the functions of the lost hand, it is necessary that the created prosthesis could repeat all kinds of grips. So the management of the prosthesis should be a simple, intuitive control system, which the patient can be taught in a short time. It is also important that the prosthesis has sufficient grip strength to hold the objects, as well as a sufficient reaction rate so that the objects can be manipulated. And on top of that, the battery life of the prosthesis should be enough for the whole day.

Currently, there are a huge number of different actuators: electric motors (Fig 4),

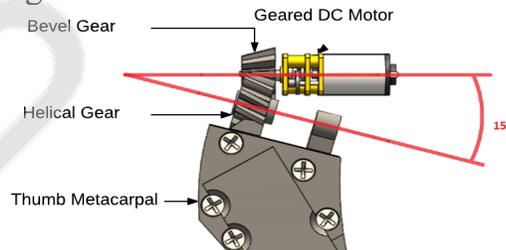


Fig.4. DC motor

hydraulic drive (Figure 6), pneumatic muscles (Figure 7), silicone muscles, materials with shape memory and others.

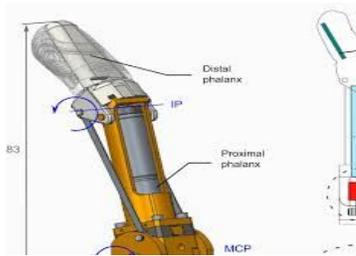


Fig.5 Hydraulic drive



Fig.6 Pneumomuscle

The actuator installed in the prosthesis must be compact, powerful enough, with great stroke and speed. Generally speaking, the closest to the muscle in terms of mass and dimensions. From all variety of actuators existing at present the most suitable on the listed parameters are electric motors. In this work, a DC motor with a built-in reducer is selected. It is more compact compared to stepper and collectorless motors and much cheaper. But, it is worth noting, it creates more noise at work and has a finite number of duty cycles.

Among the main advantages of this engine are its size, power, metal gears of the gearbox, can withstand heavy loads, and ease of mounting, both the engine and the pulley on the shaft, due to the presence of coffin.

A helical transmission is used as a transmission. (Screw nut)

The kinematic scheme shown in Fig 7 (c) was used to transmit the force from the motor to the finger. In this scheme, the finger consists of two movable joints and one fixed (the last 2 phalanges are a single part). This scheme allows you to move all 3 phalanges on a unique trajectory, using only one engine. Also at such design of a finger there is a possibility of creation of a modular brush that gives a number of the following useful properties: fast and easy replacement of fingers at breakage; quick adjustment of the prosthesis to the degree amputation of the arm.

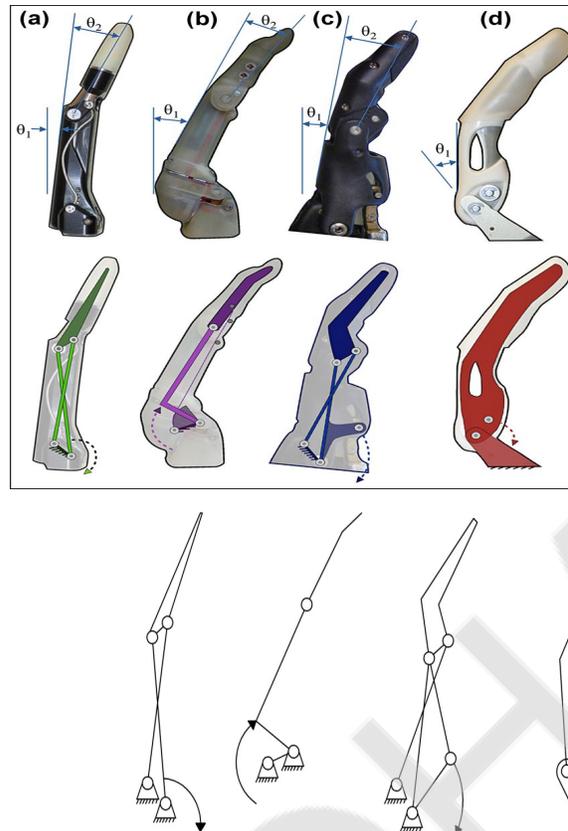


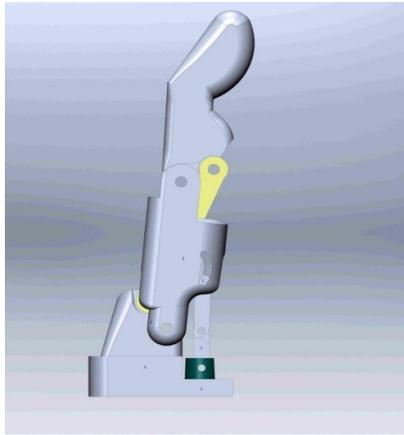
Fig.7. The kinematic scheme

3.2. Drive Type Selection

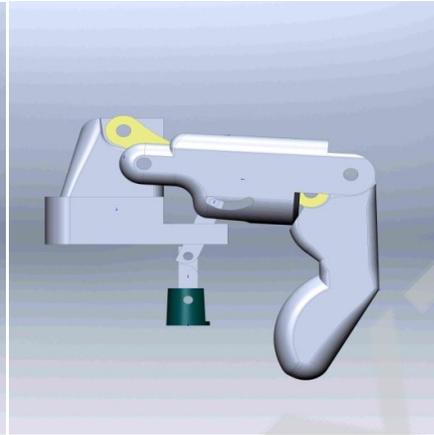
Based on the general requirements for portable (wearable) equipment, it was decided to use DC electric motors with a low-noise metal gearbox and high torque as a drive, since they have considerable traction power with small dimensions and light weight, they are represented by a wide model range and have an affordable price

3.3. Mechanics and construction

The selected device diagram is five-finger. Each finger consists of two phalanges that are interconnected on one axis, also a spring is fixed on this axis, which provides the finger with reverse movement (fixes it in the upper position 1).(Pic.5)



Pic.8 Position 1



Pic.9 Position 2

The lower phalanx (2) is attached directly to the base of the prosthesis (10). It also has a slot for the shaft of the stem (5), which is the pulling mechanism of the structure. The rod is connected to the part (3), which transmits the translational motion to the stem from the motor shaft. from rotation of the motor shaft is carried out by transmitting the screw nut (in my case it is a brass sleeve soldered into the part (3)).

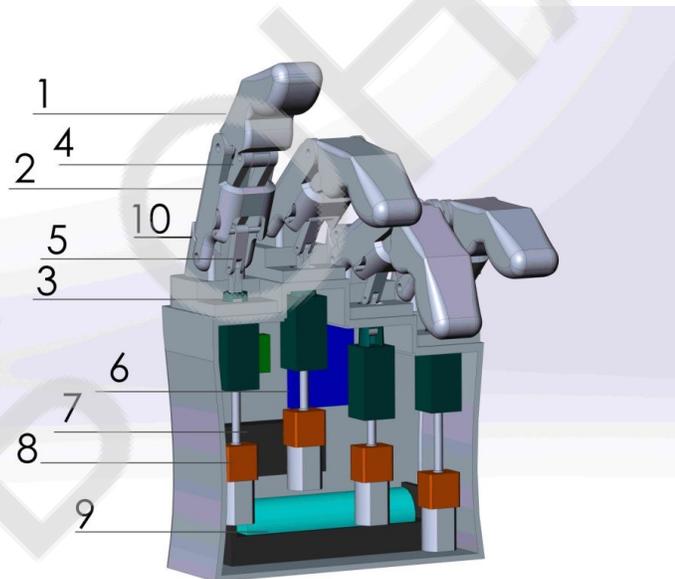
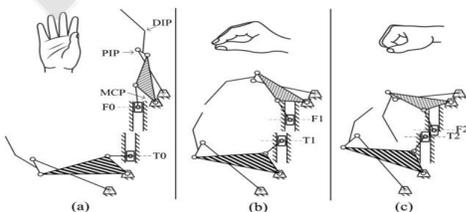


Fig. 10 General assembly

A guide (4) is fixed on one of the axes of the upper phalanx, which is part of the four-beam communication system of the so-called four-bar linkage. Bionic hand uses four-bar linkage with a linear motion plastic rod connected to distal link.

Kinematic diagram of fingers and thumb mechanism. (a) Open hand position, (b) Precision grip position, (c) Power grip position.



The main controller will be the Arduino Nano 328 controller One of the major

advantages of choosing this card is its small size and the convenient mini USB output for programming, which greatly facilitates device setup, eliminating the need to use additional devices or attach a large number of wires each time.

IV Analysis of the functionality of a modular arm prosthesis

4.1 Kinematics of modular hand prosthesis

For the correct repetition of all kinds of hobbies, it is necessary to correctly set the kinematics of the fingers and hands. It is necessary to determine on what trajectories each phalanx of a finger moves. To this end, this section calculates the kinematics of the fingers and hands.

Figure 11 schematically shows the kinematic diagram of the finger. Also in Figure 11 presents the introduced notation: lengths and angles. To determine the kinematics, it is necessary to calculate the dependence of the angles α and γ on the position of the nut. It is believed that the finger is first unbent and the nut is in the extreme right position

Using the theorems of cosines and sines, we obtain:

$$\gamma = \arccos\left(\frac{b_1^2 + B_1 C_1^2 - b_3^2}{2b_1 B_1 C_1}\right) - \arcsin\left(\frac{b_4 \sin\beta}{B_1 C_1}\right)$$

$$\alpha = \arctg\left(\frac{a_4}{a_1 + \Delta l}\right) + \arccos\left(\frac{a_2^2 + (a_1 + \Delta l)^2 + a_4^2 - a_3^2}{2a_2 \sqrt{((a_1 + \Delta l)^2 + a_4^2)}}\right).$$

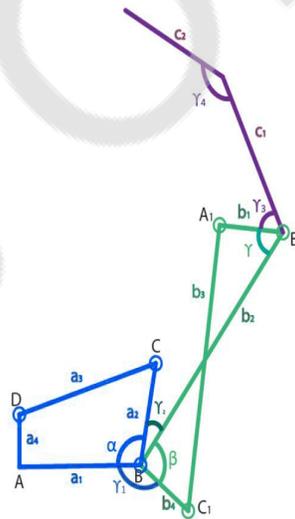


Fig.11 Kinematics of modular hand prosthesis

4.2 Knowing the dependence of the angles α and γ on the position of the nut is not difficult to restore the trajectory of each joint and each of the points of the phalanges

$$\begin{cases} x_3 = x_2 + \cos(3\pi - \alpha - \gamma - \gamma_2 - \gamma_3 - \gamma_4)c_2 \\ y_3 = y_2 + \sin(3\pi - \alpha - \gamma - \gamma_2 - \gamma_3 - \gamma_4)c_2 \end{cases}$$

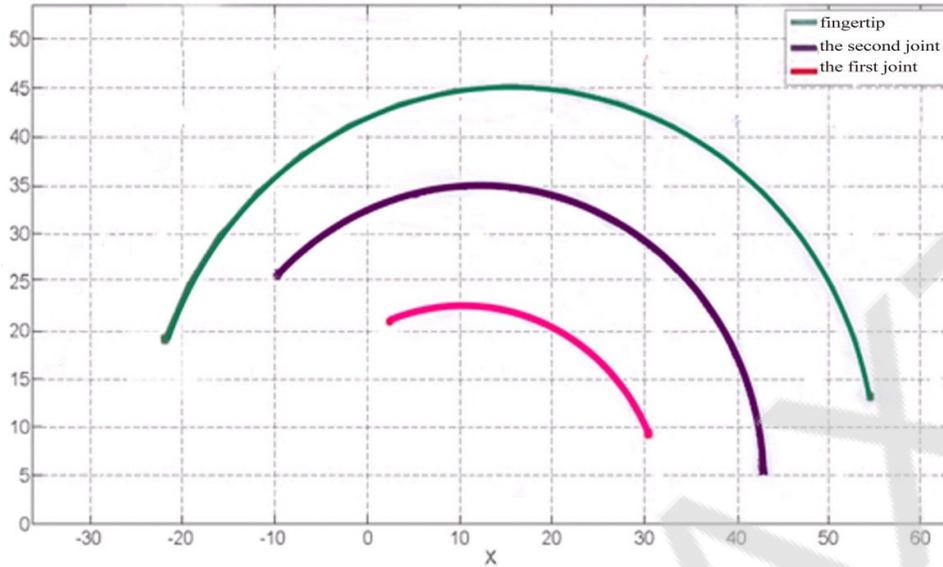


Fig. 12 The trajectory of the joints and fingertips

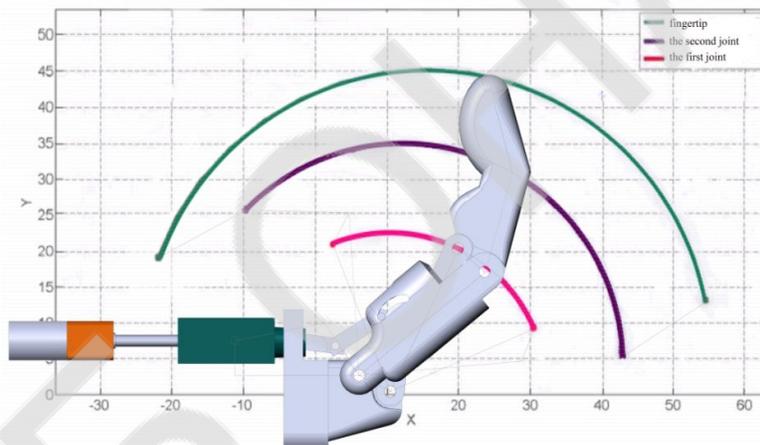


Fig.13 The trajectories of the joints and the fingertip are combined with the movement of the finger

a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	c_1	c_2	γ_1	γ_2	γ_3	γ_4
M	M	MM	MM	MM	MM	M	MM	M	MM	рад	рад	рад	рад
M	M					M		M					
11,3	16,7	24,6	8,95	9,1	42	40,7	9,7	26,7	25,7	2,67	0,52	1,12	2,61

V Dynamics of modular hand prosthesis.

5.1 One of the most important characteristics of the prosthesis is the strength of its shawl. In this section, the calculation of the dynamics of the finger of the prosthesis. Determines the forces created by different types of grip.

Suppose that the moment created on the motor shaft is equal to M_{motor} (in this work, motors with $M_{motor} = 2.4 \text{ kg} \cdot \text{cm} = 0.24 \text{ N} \cdot \text{m}$ were used). Determine the

force that will develop the nut when it moves along the screw. The moment created at point B is equal to:

$$M_B = F_{mot} a_1 \sin \left(\alpha + \angle ACD - \frac{\pi}{2} \right) \cos \left(\angle ACD - \frac{\pi}{2} \right)$$

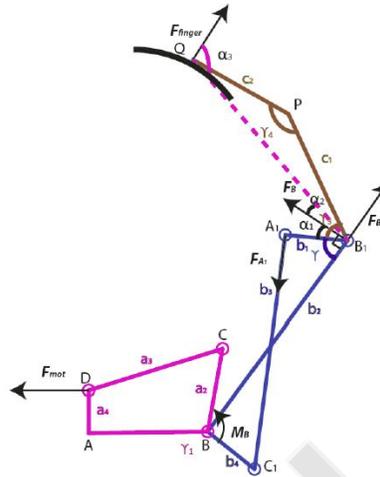


Fig.14 Notation of lengths and angles.

Introduced notation of moments and forces 5.2 Using the theorem of cosines and moment balances with respect to points A1 and B1, we obtain

$$F_{finger} = \frac{F_B b_1 \sin \angle C_1 A_1 B_1}{c_1 \cos(\angle C_1 A_1 B_1 - \alpha_1) \sin \alpha_3 + \cos(\alpha_3 - \alpha_2) b_1 \sin \angle C_1 A_1 B_1}$$

Figure 18 shows a graph of the dependence of forces F_B (red) and F_{finger} (blue) depending on the position of the nut (for the case when F_{finger} is directed normally to QP).

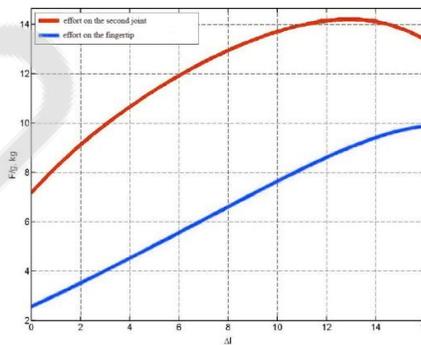


Fig.15 The graph of the dependence of the forces on the fingertip on the position of the nut is combined with the movement of the finger

The graph shows that as the finger bends, the forces increase. Approaching the extreme position there is a slight decrease F_B

CONCLUSIONS

- The analysis of anatomy and principles of work of a human hand is carried out. Determine the main parameters that must meet the prosthesis. The main types of gestures that the prosthesis should reproduce are determined.

- A model of a functional prosthesis of the arm on the Thread rod was developed and assembled. 3D prototyping technology is used for manufacturing.
- A model of a modular hand prosthesis has been developed and assembled.
- The analysis of kinematics of a modular prosthesis of a hand is carried out. The equations of trajectories of phalanges and beams are received. The analysis of the basic types of captures which the prosthesis can carry out is carried out.
- The analysis of dynamics of a modular prosthesis of a hand is carried out. The expression for the forces developing on a fingertip is received. These efforts are enough to make the prosthesis can take and hold most of the items used in the home. The obtained results are aimed at creating a functional prosthesis, and will further create a device as similar as possible to the human hand in appearance and functionality (taking into account the achievements of modern science and technology).

List of reference

1. Joseph T. Belter, Jacob L. Segil, Aaron M. Dollar, Richard F. Weir. Mechanical design and performance specifications of anthropomorphic prosthetic hands: A review. // Journal of Rehabilitation Research & Development. 2013. P. 599-618.
2. Butterfass, J., Hirzinger, G., Knoch, S. and Liu H., "DLR's Multisensory Articulated Hand Part1: Hard- and Software Architecture", IEEE Conference of Robotics and Automation, Belgium, vol.3, Leuven, Belgium, May 1998, pp. 2081-2086.
3. Butterfass, J., Grbenstein, M., Liu, H. and Hirzinger G., "DLR-Hand II: Next Generation of a Dexterous Robot Hand", Proc. of the IEEE International Conference of Robotics & Automation, vol. 1, Seoul, Korea, May 2001, pp. 109-114.
4. Lovchik, C.S. and Diftler, M.A., "The Robonaut Hand: A Dexterous Robot Hand For Space", Proc. of the IEEE International Conference on Robotics & Automation, vol. 2, Michigan, USA, May 1999, pp. 907-912
5. <http://www.youbionic.com/>
6. <http://bebionic.com/>
7. <http://www.prensilia.com/>
8. <http://schunk-microsite.com/>
9. Selection and calculation of gripping devices for industrial robots / Ya. N. Oteniy, PV Olshtynsky - Volgograd: Polytechnic, 2000 - 65 p.
10. ChNPP: Robot and Robotics in Accident Elimination [Electronic resource] // Vikipediya - Access mode: <http://chornobyl.in.ua/robot.html>
11. Trusov A.N. Adaptive gripping devices for industrial robots / Trusov A.N., Kalinin V.I. - Kemerevo. 2015.
12. Gripping devices and tools for industrial robots: Textbook / Yu.G. Kozyrev. - M.: KNORUS, 2010. -- 312 p. : ill.
13. Design of springs / R.S. Kurendash K.-M. : Mashgiz, 1958., 108

ROBOTIC PACKAGING SYSTEM PRODUCTS FROM PRIMARY TO SECONDARY PACKAGING

Author: *Vlad Sydorov*

Advisor: *Serhii Kovtun*

Odessa National Academy of Food Technologies (Ukraine)

Annotation

The paper considers the problematics of production lines of modern confectionery factories, discusses the issues of existing analogues and options for solving problems on the packaging lines, the advantages of implementing collaborative robotic complex in the ecosystem of the plant.

The main purpose of the work is to identify the problematics of production lines for packing products in secondary packaging in confectionery factories, to optimize the production area by introducing collaborative robot Universal Robots, to analyze the production of confectionery products, to develop a rational solution to the problem and calculate the ROI.

Key words: *confectionery factories, secondary packaging, robotic complex, collaborative robot, ROI.*

I. INTRODUCTION

According to 2020 data, nearly 3 million robots are used in industry worldwide, including collaborative robots. Collaborative robots are robots that are designed to work together with an operator.

The use of robots in modern industrial production and construction is due to the need to replace humans in the technological process to intensify production and create new technologies.

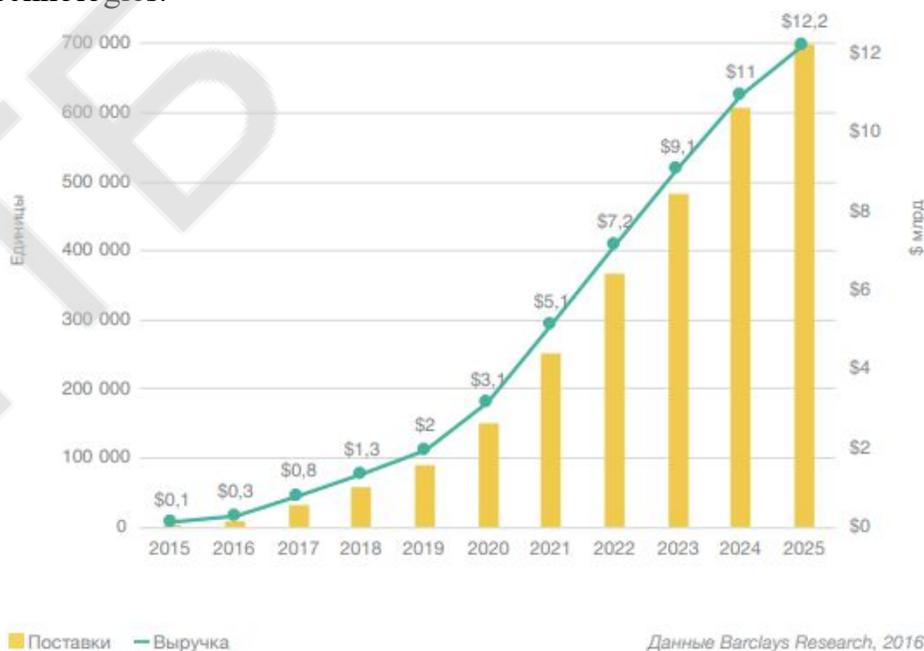


Image 1 - the dependence of end-user revenue on the supply of robots

The first cobot was invented in 1999 by Edward Colgate and Michael Peshkin, engineers at Northwestern University. But the breakthrough in the history of collaborative robotics came from the Danish company Universal Robots.

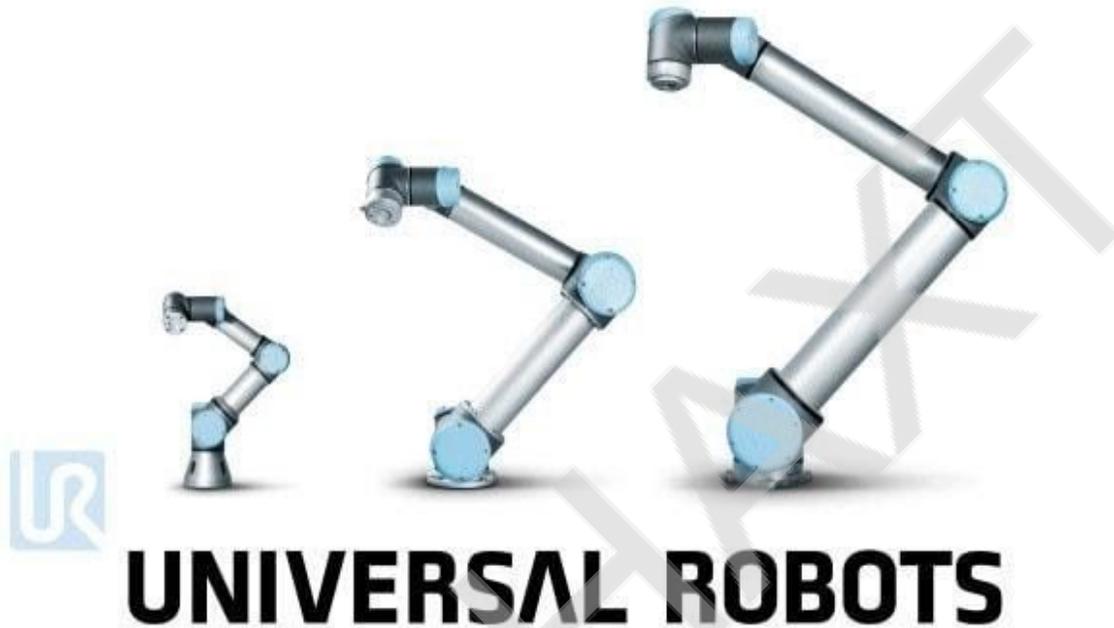


Image 2 - A series of collaborative robots from Universal Robots

One of the advantages of cobots is a wide range of applications, robots can be used in object relocation, injection molding, CNC machining, packaging and product stacking, quality control, assembly, polishing, for machine maintenance, laboratory testing, welding metal structures and others.

The payback period of such a robot (from 2 to 6 years) in the Ukrainian market and (from 12 to 36 months) in the European market.

By installing a robot you can remove the human factor in production, namely:

- a human can work for a limited time;
- a person can make a mistake;
- a person may fall ill;
- the person may quit.

II. LITERATURE ANALYSIS

The analogues in the field of industrial and collaborative robotics applications were analyzed. The theory of programming a modern collaborative robot Universal Robots was studied. Possible options for site automation in the confectionery production were studied.

The analogues of automation of a site on the basis of industrial robot KUKA AGILUS, with load-carrying capacity 6kg, but this robot is not suitable as the confectionery manufacture demands flexible application to production, hence the bias on the collaborative robot was made.



Image 3 - Picture of the KUKA AGILUS robot

The analogues of the gripper for this task are considered, considering the adaptability and mobility of the system, as well as the usability of the device itself. Of the existing analogs, one can consider the gripper from Robotiq, Schmalz, and OnRobot.



Image 4 - Photo of the analogues of the gripper device from the campaigns Robotiq, Schmalz, OnRobot

Object, subject and research methods

The subject of the study in this paper is the packaging process and its optimization in real production.

The following input data were used during the site analysis phase:

- 30 packs per minute enter the packing area;

- the product gripping mechanism should be adaptive;
- packaging options should be adaptable to any crate size;
- the product should be packaged without damaging the product.

The object of the study in this paper is the design of a robotic complex for packing confectionery products in secondary packaging based on collaborative robot Universal Robots.

This robotic complex consists of several areas:

1. Conveyor with products;
Conveyor on which 30 packs per minute are moved, the speed is limited due to a human standing in the packaging area
2. an automated shelf to collect the layer of packs;
Automated shelf based on electric axles and pneumatic cylinder
3. Primary product packaging areas;
Adaptable zones for crates (in 2 rows of 5 units and height of 6 units) and boxes (in 1 row of 3 units and height of 3 units/ in 1 row of 3 units and height of 1 unit/ in 2 rows of 2 units and height of 5 units/ in 1 row of 1 unit and height of 5 units)
4. Pylon with robot;
A mobile system that can be moved and disassembled as needed.
5. Rack with panel to control the robot and HMI panel to control the whole system.

System to control the robot and the mechanical shelf separately in order to select the "product packaging recipe", adjust the system to new products, calibrate the robot, etc.

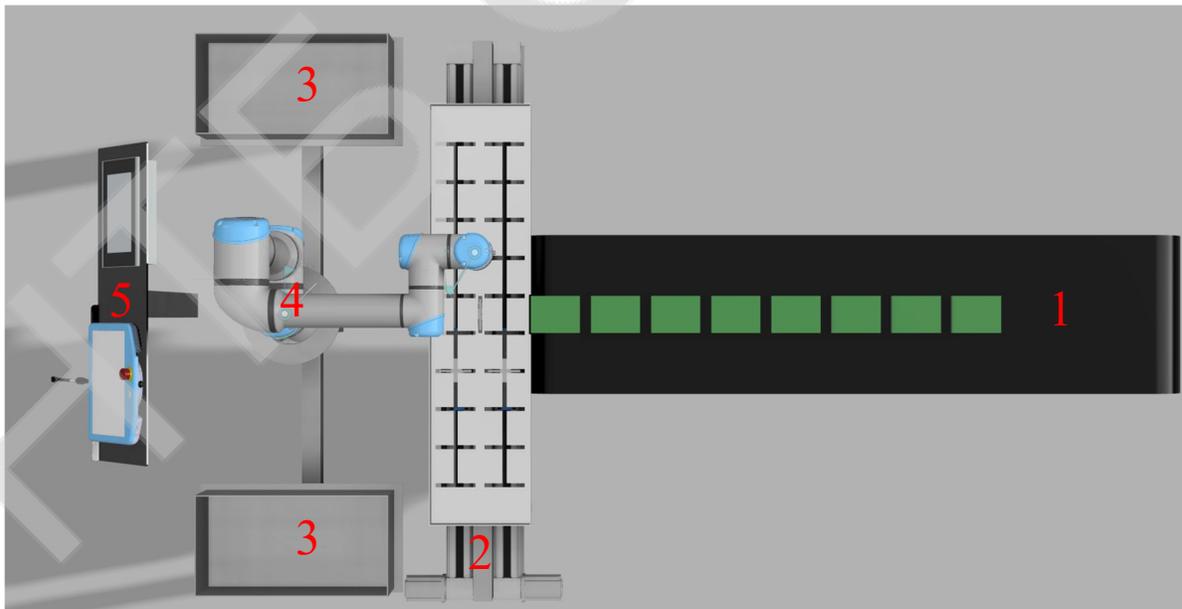


Image 5 - Schematic diagram of the developed robotic complex

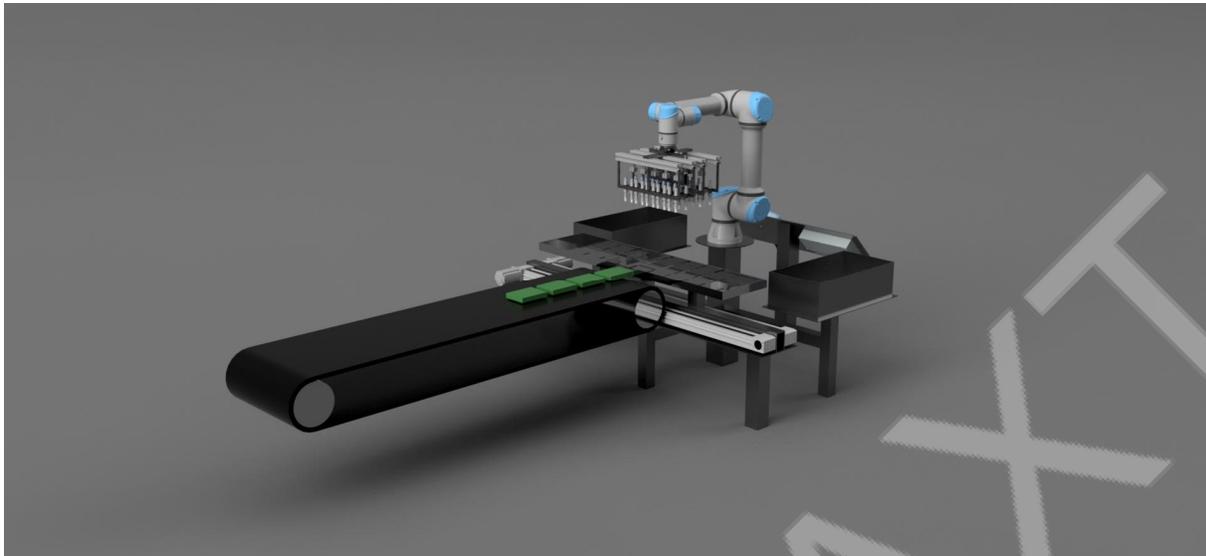


Image 6- Side view of the robotic complex

Cycle tests for approximate analysis were conducted at the Mironaft Mechatronics and Robotics Research Laboratory at the Odessa National Academy of Food Technology. The tests were conducted with the UR5 collaborative robot. The robot showed itself positively and managed to perform the necessary operations in precise cycles.

Baselines	Your Application	Potential Scenario	Your Application
Employee on a Shift [Unit]	4	Employee on a Shift [Unit]	0,5
Hours per Shift [Unit]	8	Shift per day [Unit]	3
Shifts per day [Unit]	1	Employee Yearly Salary [\$]	4 280 \$
Employee Yearly Salary and Benefits [\$]	4 280 \$	Downtime Cost	3 210 \$
Downtime Cost	3 210 \$	Scrap Part Cost	1 000 \$
Scrap Part Cost	1 000 \$	Jig and Process Enhancement Cost [\$]	1 000 \$
Jig and Process Enhancement Cost [\$]	1 000 \$	Weeks Worked per Year [Unit]	50

Table 1 - Scheme of site optimization in production

Below is a payback period in Ukraine and Europe, given that the robot has a stable wage of 13.82 \$ / hour.

Ukraine

Time of Reimbursement [Years]:	4,86	(Return on Investment)
Time of Reimbursement [Months]:	58,28	(Return on Investment)
Robot Cell Hourly Rate [\$ / hr]:	13,82 \$	(Total robotic cell cost / total robot working time)
Total Savings [\$]:	69 338 \$	(Cummulative savings after 5 years)

Table 2 - ROI on the Ukrainian market

Europe

Time of Reimbursement [Years]:	0,41	(Return on Investment)
Time of Reimbursement [Months]:	4,94	(Return on Investment)
Robot Cell Hourly Rate [\$ / hr]:	13,82 \$	(Total robotic cell cost / total robot working time)
Total Savings [\$]:	1 416 044 \$	(Cummulative savings after 5 years)

Table 3 - ROI on the European market

Approximately \$10,000 a year will save production by replacing 4 employees with 1 complex and 1 operator, and therefore the production of the product becomes cheaper. There is a possibility of 3 working shifts, which will increase the number of manufactured products by about 6 times.

Below are the charts, where the blue color indicates the cost of purchasing a robotic system, followed by the annual production savings.

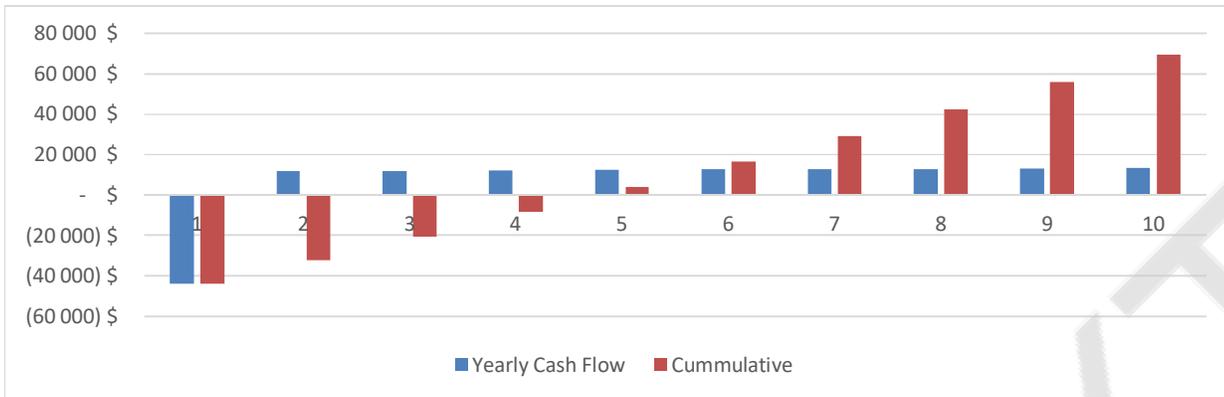


Diagram 1 - The payback period of this complex on the Ukrainian market

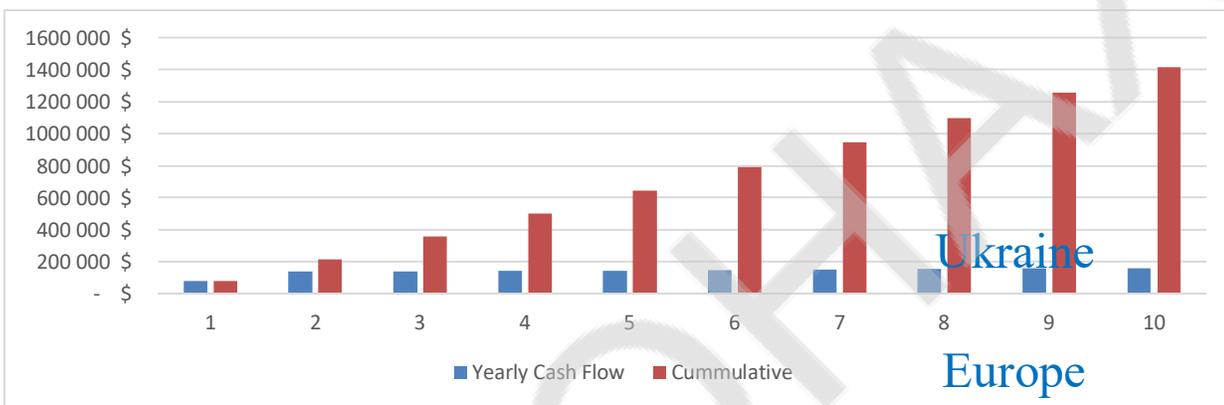


Diagram 2 - Payback on this complex in the European market

Conclusions

So, the problem of production lines for secondary packaging in confectionery factories was identified.

The optimization of the production area was carried out by introducing the collaborative robot Universal Robots, as well as the development of an automated system for the formation of a layer of products for packaging.

Production for the production of confectionery products on the Ukrainian market was analyzed, and an approximate analysis of similar production in the European market was conducted.

A rational solution, which allows increasing the speed of packaging of products in 2 times, was developed, and the RIO for the Ukrainian and European markets was calculated.

The analysis of gripper devices, presented on the market, for work with similar type of production was conducted, after what the decision was made to develop an adaptive analogue for convenient work with confectionery products.

The positive and negative qualities of collaborative robots and industrial robots were studied, after which it was decided to use cobots because they are more adaptive to changes in the packaging area.

I believe that this complex is relevant for the majority of confectionery factories, and the complex is one of the best solutions that are presented in the Ukrainian and European markets.

Literature

1. Woodhead Publishing Series in Food Science, Technology and Nutrition
2. 2013, Pages 401-419.
3. Human + Machine: Reimagining work in the age of AI, by Paul R. Daughtery & H. James Wilson, Harvard Business Review Press, 2018, 249 p.
4. Robotics in meat, fish and poultry processing: edited by K. Khodabandehloo, Blackie, 1993. 214 p.
5. <https://www.roboticstomorrow.com/article/2019/12/packaging-the-future/14515>
6. https://www.robotics.org/userAssets/riaUploads/Robotic_Packaging_Automation_Considerations_09-28-06.pdf
7. <https://www.tthk.ee/inlearcs/5-robot-cell-design-principles/>

MODERN SSDS: A HIGH-TECH SOLUTION TO THE OBSOLETE HDD SYSTEMS

Author: *Ekaterina Konstantinova*

Advisor: *Tsvetoslav Tsankov*

Konstantin Preslavsky University of Shumen (Bulgaria)

***Abstract.** Throughout the years, many innovations have been made to all computer components, except memory organization units. The transition from obsolete HDD systems to modern, ultra-fast SSDs has only been initiated in the last ten years. This paper researches basic similarities and differences between both configurations.*

***Keywords:** Data transfer, Error-correcting code, Hard disk drive, High-speed interfaces, NAND, Solid state drive.*

I. INTRODUCTION

HDD hard drive technology is relatively old (in terms of computer history). Computer hard-drive format was standardized at 5.25 inches in the early 1980s, and shortly after that came 3.5-inch desktop and 2.5-inch laptop drives. Nowadays, 2.5-inch and 3.5-inch devices use mostly SATA interfaces. Capacity has grown from a few megabytes to a few terabytes, an increase of a million times.

SSD has a much shorter history. From the invention of personal computers, there was a need for non-mechanical hard drives. Current flash memory is a logical extension of the idea, as it does not require constant power to store the data. The first SSDs were introduced during the rise of netbooks in the late 2000s. With the mass implementation of laptops, the capacity of SSDs has increased and standardized to

the 2.5-inch form factor. Other form factors have emerged, such as the M.2 SSD in SATA, PCIe options, and DIMM-like SS Flash Storage in the Apple MacBook Air and MacBook Pro. The commercial 2.5-inch SSD capacity currently reaches 4 *TB*.

II. HDD

HDD (Hard Disk Drive) – the traditional rotating hard disk drive is non-volatile computer memory. The information is stored on plates covered with magnetic layers. The storage device uses one or more disk plates (disks) around a common axis in the so-called disk package. Each metal plate is comprised of many concentric circles called tracks, which are divided into logical units called sectors, each of which has a unique address (Fig.1).

Main parameters:

- Capacity has always been the main thing to consider. For desktop systems, it varies from 500 *GB* to 10 *TB*. Currently, the most popular hard drives have a capacity of 1 *TB*.
- The shape factor is determined by the size of the rotating plates and defines the size of the whole device. Notebooks typically use 2.5-inch smaller hard drives, desktops – 3.5-inch ones.
- The speed of rotation (*rpm*) of the spindle usually varies from 5400 *rpm* – for 2.5-inch hard drives to 7200 *rpm* – for 3.5-inch ones.



Fig. 1. Generic Hard Disk Drive 160GB SATA 3.5"

It is mechanical, which means that the information on it does not 'disappear' when turning off the system. HDDs are the slowest type of storage devices in modern computers. In an age of fast processors and large memory sizes, a hard drive is often an obstacle to high-performing systems.

III. SSD

An SSD (Solid State Drive) does everything that a hard drive does, but the data is stored on interconnected flash memory chips. They do not contain moving mechanical parts, thus eliminating the reading delay and significantly increasing the operating speeds, preserving the data even when there is no power supply. Although they can replace traditional 2.5-inch or 3.5-inch hard drive slots, they can be installed

in a PCIe slot or even mounted directly on the motherboard, a commonly used configuration in high-class laptops.

The key components of every SSD are the controller and the storage memory. The main element of the memory is the DRAM, mostly replaced by the improved NAND memory.

3.1. Controller

Each SSD includes a controller that manages the electronics connecting the NAND memory components to the host computer. The controller is a built-in microprocessor that executes code at the Firmware level, making it one of the most significant disk performance factors. Some of the functions are:

- Error-correcting code (ECC).
- Marking bad sectors.
- Cache memory.
- Garbage collection.
- Encryption.

The SSD performance is proportional to the used number of parallel NAND chips in the device. The single NAND chip is relatively slow due to the narrow (8/16 *bit*) asynchronous I/O interface, and additional high latency in basic I/O operations. When multiple NAND devices run in parallel on a single disk, the frequency is scaled, and high latency can be hidden as long as there are enough pending operations and the load is evenly distributed between the different devices.

3.2. Memory

3.2.1. Based on flash memory

Most static drive manufacturers use non-volatile NAND flash memory because of its lower cost compared to dynamic and its ability to store its data even without a constant power source.

3.2.2. Based on dynamic memory

Static drives based on variable memory such as DRAM are characterized by ultra-fast data access, most often below 10 μ s, which are used to accelerate applications that would otherwise suffer from the latency of flash-based static or traditional hard drives. Dynamic memory-based SSDs typically include either an internal battery or an external AC/DC adapter and archive storage systems to ensure data security from external sources. If the power goes out, the battery will provide it while all the information is copied with random access to backup storage. When power is restored, the information is copied back to RAM from the backup, and the solid-state drive resumes operation (similar to hibernation in modern operating systems) [3], [7].

3.3. Advantages of using an SSD over an HDD

The advantages of using an SSD instead of an HDD outweigh the disadvantages, explaining the rapid implementation of this technology.

- SSDs provide much faster reading and writing data speeds than hard drives. As

a result, the operating system installed on the SSD loads in seconds, and searching for files takes less time.

- They are more economical and more compact. This advantage makes it preferred by laptop manufacturers.
- It allows a wide range of used interfaces for connection.
- A lack of data 'fragmentation', typical of hard drives.
- They are more resistant to vibrations and other mechanical disturbances.

3.4. Disadvantages of SSD technology:

- SSDs have a limited number of overwrite cycles. That is the reason why they are not preferred for storing multimedia – movies, videos, music, etc.
- The cost of SSD modules is significantly higher than the price of hard drives per unit of memory.

IV. Types of SSDs

4.1. Form factors

Solid-state drives (SSDs) are commonly used in client, hyper-scale, and enterprise compute environments. The most popular ones are NVMe, SAS, and SATA. Since SSDs are made from flash memory, they can be built in many different form factors (Fig. 2).

EDSFF – a form-factor used in data centers. It is based on Intel's former Ruler SSD standard.

M.2/mSATA – the mSATA form factor uses the physical parameters of the PCI Express Mini Card. It is electrically compatible with its interface specification while requiring an additional connection to a SATA host controller via the same connector.

The M.2 form factor, formerly known as the Next Generation Form Factor (NGFF), is a natural transition from mSATA, using its physical layout, becoming a more advanced form factor. When created, mSATA started operating a similar form factor and connector, and M.2 was designed to maximize the use of space. The M.2 standard allows both SATA and PCIe SSDs to be mounted on M.2 modules.

2.5-inch (U.2) – formerly known as SFF-8639, is an interface standard for connecting SSDs to a computer. It manages the physical connector, electrical characteristics, and communication protocols. It can be used with PCI Express drives along with SAS and SATA drives. It uses up to four PCIe lanes and two SATA lanes.

Add-in Cards – add-on cards, similar to graphics and sound cards. They only work with desktops with additional PCIe 3.0 x4, x8, or x16 slot. However, because they are larger than other form factors, they have room for more chips and better cooling, making them the fastest drives on the market.

	SATA 2.5"	U.2	M.2 SATA	M.2 NVMe	NVMe PCIe
Types of SSD					
Physical Connector	SATA	U.2	M.2		PCIe
Connection Protocol	SATA	PCIe	SATA	PCIe	
Technology	SATA	NVMe	SATA	NVMe	
Form Factor	2.5"		M.2		PCIe AIC (Add-in-Card, like GPUs)

Fig. 2. Most common types of commercial SSDs

4.2. Interfaces

4.2.1. SATA/mSATA SSDs

SATA (or S-ATA) stands for Serial Advanced Technology Attachment and is the most regularly used interface for data transfer between hard drives and storage devices. Almost all SATA SSDs have a 2.5-inch format (approx. $10 \times 7 \times 0.7$ cm), which is practical because it matches the size of notebook hard drives [1], [5].

The smaller version of the SATA SSD is mSATA, short for mini-SATA. Performance-wise, mSATA drives also deliver a maximum throughput of 6 Gbps. The only difference is in size and the associated application areas: mSATA SSDs are about eight times smaller than 2.5-inch SATA drives. Due to the identical interface specification, SATA ports can be converted to mSATA ports via a simple adapter.

4.2.2. SAS

A SAS SSD (Serial-Attached SCSI solid-state drive) is a NAND flash-based storage or caching device meant to fit in the same slot as an HDD, using the SAS interface to connect to the host computer.

The most common drive form factors for a SAS SSD are 2.5-inch and 3.5-inch. SAS SSD bandwidth options include 3 Gbps, 6 Gbps, and 12 Gbps.

SAS SSDs are primarily used in enterprise servers and storage arrays with application workloads requiring high availability (HA), high input/output (I/O), and low latency. Use cases for SAS SSDs include server virtualization, online transaction processing, high-performance computing, and data analytics.

Drive manufacturers sometimes offer SAS SSDs with different write endurance options. A high-capacity SAS SSD intended for read-intensive workloads might guarantee only one drive write per day (DWPD), while a lower-capacity SAS SSD intended for write-intensive workloads might support up to 25 DWPDs.

4.2.3. NVMe

Non-Volatile Memory Express (NVMe) is a communications interface and driver that defines a command set and feature set for PCIe-based SSDs with the goals of efficient performance and interoperability on a broad range of devices.

NVMe was designed for SSD. It communicates between the storage interface and the CPU using high-speed PCIe sockets, independent of the storage form factor. Input/Output tasks performed using NVMe drivers begin faster, transfer more data, and finish faster than older storage models. Because it was designed specifically for SSDs, NVMe is becoming the standard for both servers in the data center and client devices like laptops, desktop PCs, and gaming consoles.

NVMe technology comes in many form factors such as the PCIe card slot, M.2, and U.2. While there are SSDs that use the SATA, PCIe slot, and M.2, U.2 is a form factor that exclusively uses the NVMe protocol (Fig. 3 & 4).

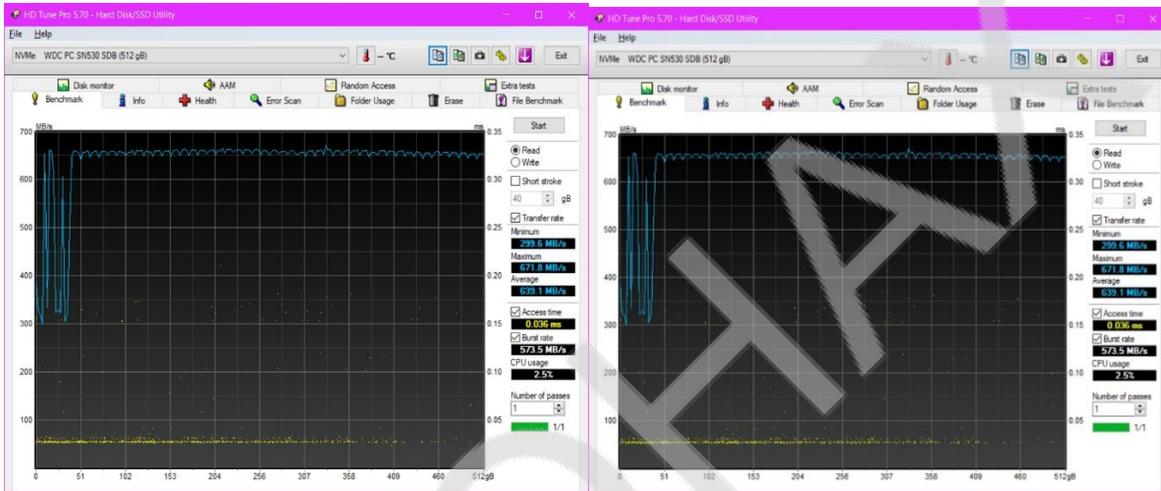


Fig. 3. Benchmark on a NVMe WDC PC SN530 SDB (512 Gb)

4.2.4. PCIe

Peripheral Component Interconnect Express (PCIe) is a standard type of connection for internal devices in a computer [2], [4].

Because of SATA 3.0 600MB/s ceiling, PCIe is starting to supersede SATA as the latest high-bandwidth interface. A PCIe connection consists of one or more data-transmission lanes connected serially. Each lane consists of two pairs of wires, one for receiving and one for transmitting. There can be one, four, eight, or sixteen lanes in a single PCIe slot, denoted as x1, x4, x8, or x16 (Fig. 5).

PCIe technology enables interface speeds of up to 1 GB/s per client lane (PCIe 3.0), versus SATA technology speeds of up to 0.6 GB/s. More lanes from SATA require more SATA devices, but PCIe bandwidth can be scaled up to 16 lanes on a single device.

While computers may contain various types of expansion slots, PCIe is considered the standard internal interface. Many computer motherboards today are manufactured only with PCIe slots [1], [6].

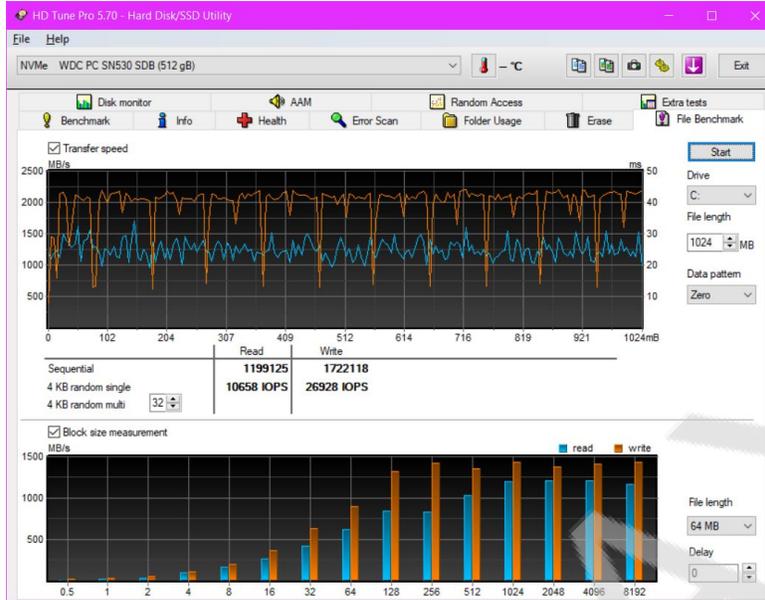


Fig. 4. File benchmark on a NVMe WDC PC SN530 SDB (512 Gb)

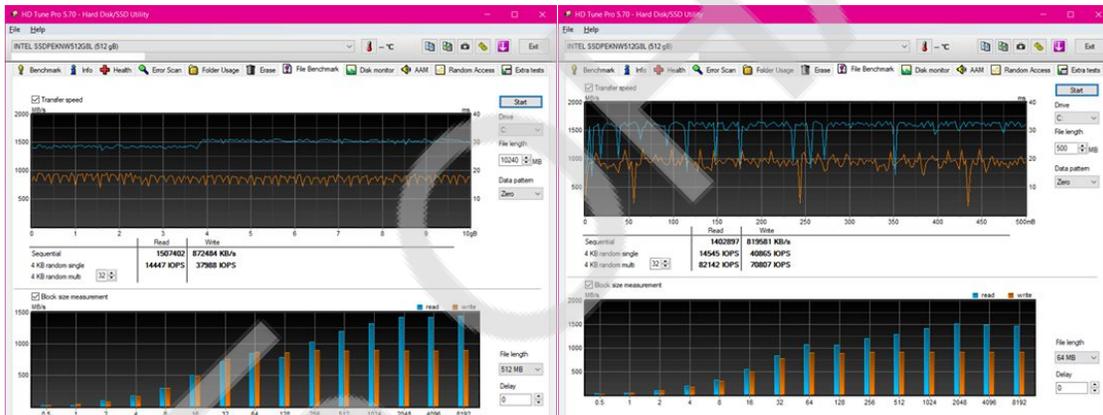


Fig. 5. Tests performed on Intel SSD PEKNW512G8L

V. Conclusion

Given the advantages we have highlighted in favor of SSDs, in mid-range and high-end configurations, the presence of SSDs today is a must. It is unclear whether the SSD will completely replace traditional HDD, especially in increasingly accessible cloud space. SSDs are falling in price, but they are still too expensive to completely replace terabytes with data that some users have.

VI. References

1. [Trifonov T. Performance analysis of a mobile computer equipped with solid state disk. Annual of Konstantin Preslavski University of Shumen, 2014, ISSN 1311-834X, S. 27-42.](#)
2. [Vasilev V., Yankova-Yordanova Y. Gradation from HDD to SSD. Scientific conference MATTEH 2016, Shumen., 2016, ISSN 1314-3921.](#)
3. [HD Tune Pro manual version 5.70, EFD Software, 2017.](#)
4. <https://www.harddrivebenchmark.net/>
5. https://pcguide.bg/hdd-ili-ssd-predimstva-i-nedostatuci/?fbclid=IwAR2_WLfZw7yPA0UKG856TUFZvEFbKNpJ-y3C1iBk7Atd-kYpzIzZq3RNyKA
6. <https://tehnologichno.bg/article/hdd-ili-ssd-diskovo-prostranstvo?fbclid=IwAR3SMIGHo-t-IQOIOzDt3Op0EJzZcYx65WZvr8KRZKgxzjT-MALHOJNom30>
7. https://www.techradar.com/news/best-solid-state-drives-ssds?fbclid=IwAR2_WLfZw7yPA0UKG856TUFZvEFbKNpJ-y3C1iBk7Atd-kYpzIzZq3RNyKA

COMPLEX SYSTEM OF AI INTERACTIONS IN SOCIAL SIMULATION OF A CITY INFRASTRUCTURE

Author: **Ildar Sabirov**

Supervisor: **Olga Olshevska**

Odessa National Academy of Food Technologies (Ukraine)

Abstract. *Goal of this project is the research and development of an artificial intelligence for city infrastructure and social interactions in simulator game for deeper immersion and analysis of mental states of players. It composes of complex interactions of mental states, personality traits, fields of activity of characters and events in which the characters may be involved. This system will bring the activity of AI closer to human. This opens up many possibilities for using this system, namely:*

1. *For a deeper immersion and flow in the game world;*
2. *To analyze human actions in certain situations;*
3. *To analyze the mental state of the player during the game through his choices.*

Keywords: *Artificial Intelligence, personality, social engineering, social interaction, mental state, psychology*

I. INTRODUCTION

Nowadays a great evolution of used technologies in game industry that continues to improve graphics and in-game mechanics shows that game development is important for modern society. Generations of gamers making a lot of various subcultures. These interests significantly influenced their perception and life in general, and, consequently, the life of future generations. This influence, which has been criticized many times for brutality, is not a strong argument in favor of critics because it is not the cause of an aggressive or depressed state of people.

This system can be a solution to this problem by assessing the player's gaming experience to check his psychological state. This process will require a thorough analysis of the player's choice in different situations. In addition, the difficulty of the assessment increases, as does its effectiveness, due to deep immersion in the gameplay. This immersion is provided by a complex system of character mental states and interactions with environment.

II. LITERATURE ANALYSIS

Efforts by cities around the world to engage artificial intelligence (AI) and robotics for their betterment aim generally to support or extend the “social infrastructure” of the city. Ideas about how the life of each city’s resident ought to be constituted, supported, and improved through AI and robotics technologies guide these activities. At the same time, the new visions of AI-and robotics-enhanced cities expose changing social values and norms that we must examine to understand how their enactment may affect urban life [5-8].

The meaning of “social infrastructure” can be categorized in three iterations. Traditionally, social infrastructure referred to the subset of infrastructure assets that accommodate social services, for example: medical facilities, schools, community and sport facilities, local government facilities, water treatment, bus stations, parks, prisons and court houses. The term itself is curious because it applies “social,” a term we usually associate with human interaction, to infrastructure, which is about physical organization as a means to provide a service. Thus, the services provided by social infrastructure (clean water, education, correction) in this original meaning of the word can be seen as material and institutional supports for a particular way of life. As social media companies became popular, the term “social infrastructure” took on a second and parallel meaning to describe internet services supporting integration of “social functionality” with their products and user interfaces [5-8].

Agent-based modelling and simulation (ABMS) is a relatively new approach to modelling complex systems composed of interacting, autonomous ‘agents’. Agents have behaviours, often described by simple rules, and interactions with other agents, which in turn influence their behaviours. By modelling agents individually, the full effects of the diversity that exists among agents in their attributes and behaviours can be observed as it gives rise to the behaviour of the system as a whole. By modelling systems from the ‘ground up’—agent-by-agent and interaction-by-interaction—self-organization can often be observed in such models. Patterns, structures, and

behaviours emerge that were not explicitly programmed into the models, but arise through the agent interactions. The emphasis on modelling the heterogeneity of agents across a population and the emergence of self-organization are two of the distinguishing features of agent-based simulation as compared to other simulation techniques such as discrete-event simulation and system dynamics. Agent-based modelling offers a way to model social systems that are composed of agents who interact with and influence each other, learn from their experiences, and adapt their behaviours so they are better suited to their environment [5-8].

Agents may also have other useful characteristics [5-8]:

An agent may be adaptive, for example, by having rules or more abstract mechanisms that modify its behaviours. An agent may have the ability to learn and adapt its behaviours based on its accumulated experiences. Learning requires some form of memory. In addition to adaptation at the individual level, populations of agents may be adaptive through the process of selection, as individuals better suited to the environment proportionately increase in numbers.

An agent may be goal-directed, having goals to achieve (not necessarily objectives to maximize) with respect to its behaviours. This allows an agent to compare the outcome of its behaviours relative to its goals and adjust its responses and behaviours in future interactions.

Agents may be heterogeneous. Unlike particle simulation that considers relatively homogeneous particles, such as idealized gas particles, or molecular dynamics simulations that model individual molecules and their interactions, agent simulations often consider the full range of agent diversity across a population. Agent characteristics and behaviours may vary in their extent and sophistication, how much information is considered in the agent's decisions, the agent's internal models of the external world, the agent's view of the possible reactions of other agents in response to its actions, and the extent of memory of past events the agent retains and uses in making its decisions. Agents may also be endowed with different amounts of resources or accumulate different levels of resources as a result of agent interactions, further differentiating agents.

In an agent-based model, everything associated with an agent is either an agent attribute or an agent method that operates on the agent. Agent attributes can be static, not changeable during the simulation, or dynamic, changeable as the simulation progresses. For example, a static attribute is an agent's name; a dynamic attribute is an agent's memory of past interactions. Agent methods include behaviours, such as rules or more abstract representations such as neural networks, which link the agent's situation with its action or set of potential actions. An example is the method that an agent uses to identify its neighbours [5-8].

One tool that has been increasingly used to examine urban health issues is agent-based modeling (ABM). Agents are given traits and initial behavior rules that organize their actions and interactions. Stochasticity can be included in the assignment of agent characteristics and in determining which agents interact and how agents obtain information and make decisions. The model is run over time and repeated numerous times, to obtain a distribution of possible outcomes for the

specified system. The micro-entities, referred to as “agents”, are anything that alters its behavior in response to input from other agents and the environment [5-8].

ABM is able to accommodate high heterogeneity in agent characteristics and interactions between agents and environments, as well as features like dynamics, feedbacks and adaptation, which are impossible to represent in traditional statistical models. Agents can be defined at multiple levels, including individuals or group of individuals (e.g., families, institutions, policy-making bodies etc.). Research questions that require significant heterogeneity within and between agents and diverse spatial and relational elements are well-suited to ABM. In urban health research, simulations can be used to explore dynamic scenarios involving diverse entities and settings such as the built and social environment, city agencies, legislative bodies, health services, individual residents and families. Some agent-based models include detailed data and strive for high realism⁴ while others are abstract [5-8].

Despite the ABM suitability to research complex problems in urban health, it is a new tool to many researchers. One important barrier to foster ABM adoption among researchers is their unfamiliarity with steps needed to carry out the modeling. Therefore, the purpose of this paper is to provide a very brief introductory guide to carrying out a simple agent-based model. We then use a previously constructed model to illustrate the steps one can take when building a simple model. This is only a brief guide; before starting a computational model, it is recommended that readers refer to comprehensive guides [5-8].

All basic processes of ecological populations involve decisions; when and where to move, when and what to eat, and whether to fight or flee. Yet decisions and the underlying principles of decision-making have been difficult to integrate into the classical population-level models of ecology. Certainly, there is a long history of modeling individuals' searching behavior, diet selection, or conflict dynamics within social interactions. When all the individuals are given certain simple rules to govern their decision-making processes, the resultant population-level models have yielded important generalizations and theory. But it is also recognized that such models do not represent the way real individuals decide on actions. Factors that influence a decision include the organism's environment with its dynamic rewards and risks, the complex internal state of the organism, and its imperfect knowledge of the environment. In the case of animals, it may also involve complex social factors, and experience and learning, which vary among individuals. The way that all factors are weighed and processed to lead to decisions is a major area of behavioral theory [5-8].

While classic population-level modeling is limited in its ability to integrate decision-making in its actual complexity, the development of individual- or agent-based models (IBM/ABMs) (we use ABM throughout to designate both “agent-based modeling” and an “agent-based model”) has opened the possibility of describing the way that decisions are made, and their effects, in minute detail. Over the years, these models have increased in size and complexity. Current ABMs can simulate thousands of individuals in realistic environments, and with highly detailed internal physiology, perception and ability to process the perceptions and make decisions based on those

and their internal states. The implementation of decision-making in ABMs ranges from fairly simple to highly complex; the process of an individual deciding on an action can occur through the use of logical and simple (if-then) rules to more sophisticated neural networks and genetic algorithms. The purpose of this paper is to give an overview of the ways in which decisions are integrated into a variety of ABMs and to give a prospectus on the future of modeling of decisions in ABMs [5-8].

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Complex AI system

Research into the possibilities of artificial intelligence in the gaming industry is yielding amazing results. The search for better action through a comprehensive set of tools and the freedom of AI comes to "creative" solutions. It also allows a player to feel deeper immersion, flow and presence with a human-like NPC intelligence and complex system of interactions. Applying this system of complex interactions to a city infrastructure simulator, we get random interactions of characters with / without the participation of a player, which in one way or another affect the world, and therefore the player himself.

Structure of complex interactions system

First of all, in this system, it is worth developing a scheme of social interactions between the fields of activity of the city infrastructure and the properties of the corresponding type of activity that are characteristic of them (Fig. 1).

Fields of activity, like characters in this system, have a number of characteristics, such as:

- Dependence (on other fields of activity);
- Recruitment capability;
- Necessary staffing requirements;
- Possibility and ways of interacting with other fields of activity;
- Reasons and methods of staff reduction (complicate due to the personal qualities of the characters and the player);
- Ways and opportunities for career growth;
- The ability to change the field of activity;
- The level of conflict between fields of activity;
- Influence on other fields of activity;
- Influence on subordinates during career growth in their field of activity.

All these characteristics of fields of activity are independent but can influence each other through complex interactions between characters, taking into account their personality traits.

In addition to fields of activity, actions themselves also have characteristics, such as:

- The number of characters participating in the action for each field of activity;
- Possibility of interaction between fields of activity;

- The ability to perform new actions based on this action;
- The ability to perform new actions based on several actions interconnected through complex interactions between characters according to their personality traits;
- The possibility of random participation of characters that have no connection with the fields of activity performing the action;
- The ability to influence other fields of activity through action;
- The ability to change the level of conflict between fields of activity;
- The ability of participating characters to change the field of activity;
- Career opportunities for characters involved in the action.
- Location of the action;
- The ability to change the level of conflict between characters according to their personal traits.

The location of the action isn't less important and also has a number of characteristics, such as:

- Open or closed space (introduces a number of restrictions on the actions of characters and can influence their decisions);
- Location belonging to the field of activity;
- Possibility of better or worse interaction of fields of activity;
- The ability to interact with characters from conflicting fields of activity due to personal traits;
- Possibility of a random event due to environmental elements or/and personal traits of characters;
- The possibility of action;
- Ability to change the level of conflict between fields of activity.
- Ability to change the level of conflict between characters and player;
- Content of sublocations with their own set of characteristics out of all possible.

All this system creates an opportunity of wide range of complex activities between fields and involved characters, making immersion deeper.

The personal traits and mental state of the characters is the main factor in the choice of subsequent actions of the characters.

A complex set of character characteristics allows to most accurately convey human-like AI interaction with other characters and player in different actions with fields of activity at locations or sublocations.

Personal character traits and his state of mind as a whole constitute a large decision-making system, taking into account the number of factors, such as:

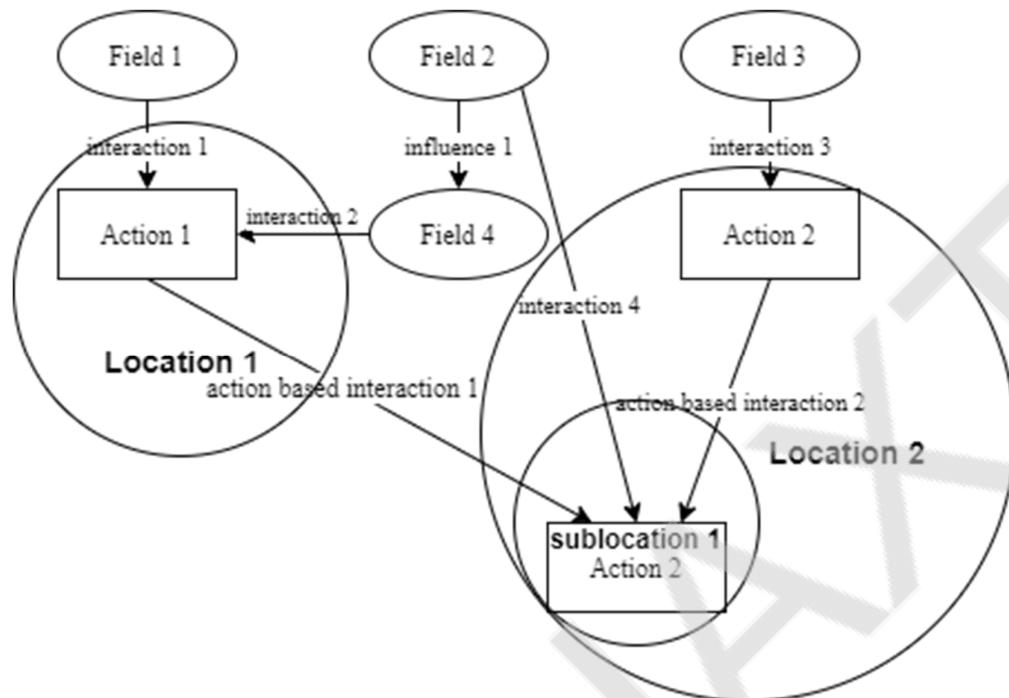


Figure 1. Basic interactions between fields of activities and actions at the certain locations (without influence of personal traits of characters)

- Temperament (sanguine, choleric, phlegmatic, melancholic);
These types of temperament have a difference of interaction between each other.
- Character (contains 4 groups of traits expressing the attitude to different aspects of life: attitude to work; attitude towards other characters; attitude towards oneself; attitude to things);
Each of group has a positive and negative trait types.
- Abilities (to do something);
- Emotions (preferences and fears);
Abilities and emotions can depend on the environment and physical, mental state, which can change in the course of action and are interrelated.
- Personality orientation (The focus is on the task, on communication, on oneself);
- The ability to adapt and accommodate (the ability to change personal traits later on participating in activities);
- Moods (the ability to change the mood after the actions taken);
- Self-assessment (attitude towards oneself, assessment of one's abilities);
- Ability to generate ideas (from the list of possible, taking into account the field of activity and nature) and search for possible performers;

In accordance with this system of interaction of characters with all the influence of the environment, the player, through his choice, will compose his psychological portrait, according to which it is possible to diagnose the player with psychological problems.

IV. RESULTS

Due to this work a complex system of city infrastructure interaction has generally been developed up to the personal characteristics of the characters, namely:

- Interactions between fields of activity through actions in certain locations, taking into account complex interactions between characters;
- Actions and their characteristics, possible consequences affecting the fields of activity (including their members individually) and locations;
- Locations that can influence the relationship between fields of activity through the actions that take place and the possible environment;
- A complex set of characteristics that, through the individuality of each character, influences the decisions made and the state of affairs in the game world;
- An analysis of concepts such as immersion in the game world, flow state and a sense of presence, which include physical and emotional immersion in the game, loss of self-awareness and constant attention;
- The concepts of Personality and behavior;
- Analysis of AI in video games.

V. CONCLUSIONS

This system of interactions creates wide range of possibilities in video game industry to provide great idea of immersive game world and helping people with psychological problems to prevent irreversible.

With all the possible actions that can happen in the game, according to the player's choice, building a psychological portrait does not cause problems. According to research by psychologists, playful tests allow you to make a choice sincerely, without hesitation. It is impossible to obtain a psychological state in an absolutely exact measure. It is possible to get only a snapshot of the current state of consciousness and subconsciousness. But you can understand some controversial points worth paying attention to and taking them into account in the future.

I will develop this system in more detail to get more immersion in the gameplay and for a more accurate analysis of the psychological state of the player.

VI. REFERENCES

1. Michailidis, L., Balaguer-Ballester, E., & He, X. (2018). Flow and immersion in video games: The aftermath of a conceptual challenge. *Frontiers in Psychology*, 9, 1682.
2. 11.1 *Personality and Behavior: Approaches and Measurement*. Introduction to Psychology. <https://open.lib.umn.edu/intropsyc/chapter/11-1-personality-and-behavior-approaches-and-measurement/>.
3. Bandura, A., & National Inst of Mental Health. (1986). *Prentice-Hall series in social learning theory. Social foundations of thought and action: A social cognitive theory*. Prentice-Hall, Inc.

4. Hadnagy, C. (2010). *Social engineering: The art of human hacking*. John Wiley & Sons.
5. Boenig-Liptsin, M. (2017). AI and robotics for the city: Imagining and transforming social infrastructure in San Francisco, Yokohama, and Lviv. *Field Actions Science Reports. The journal of field actions*, (Special Issue 17), 16-21.
6. Macal, C., North, M. Tutorial on agent-based modelling and simulation. *J Simulation* 4, 151–162 (2010). <https://doi.org/10.1057/jos.2010.3>
7. Auchincloss, A. H., & Garcia, L. M. T. (2015). Brief introductory guide to agent-based modeling and an illustration from urban health research. *Cadernos de saude publica*, 31, 65-78.
8. DeAngelis, D. L., & Diaz, S. G. (2019). Decision-making in agent-based modeling: A current review and future prospectus. *Frontiers in Ecology and Evolution*, 6, 237.

SYSTEM OF AUTOMATED DETECTION OF CERAMIC DISC SURFACE DEFECTS

Author: **Bohdan Konechnyi**

Advisors: **Maksym Semchenko, Roman Velgan**
Lviv Polytechnic National University (Ukraine)

Abstract. *A handheld USB digital microscope is considered as an instrument for ceramic disk inspection automatization in the production cycle. It provides the opportunity for surface defect detection in the needed range from 50 to 500 μm . Such a device providing 15 fps with the standard VGA resolution of 640x480 pixels enables one track scan for 18 seconds. As a decision unit, a system based on the artificial neural network was used. The basic system software has been developed. A study of the object illumination and the size of the database influence on artificial neural network training results (probability of defect detection) have been carried out. The use of digital filtration, adaptive histogram equalization, threshold function, and feature detection as a classical approach showed a good result. Deep learning has proven its effectiveness, selecting features of the defect and presenting more stable results in defect detection.*

Keywords: *artificial neural network, image recognition system, digital microscope, ceramic discs.*

I. INTRODUCTION

Technical ceramic parts have increased use in textile machinery. For example, ceramic discs used for texturing yarns as guide discs, working discs, and knife discs. Ceramic components offer significant performance enhancement in textile machinery due to optimized grip and eliminated snow, as a result of special surface engineered features.

The studied ceramic disks Rapaltex [1] (Fig. 1) are used in the equipment of thread weaving of the textile industry.



Fig. 1. General expected discs view

Special fibers are intertwined with each other on a certain trajectory, which is set by their passage through the cassette with a certain location of such disks. Contact from disks with fibers occurs on working surfaces. The nominal disk parameters [1] are as follows (Table 1).

Table 1. Disk nominal parameters

Working Discs - STANDARD

Article-No.	OD	ID	H	R	Shape	Surface Ra
90747-1	52	14,45	9	5,5	C	0,85
90750-1	52	12	9	5,5	C	0,85
90749-1	49,62	12	6	3,5	C	0,85
90748-1	45	12	6	3,5	C	0,85

The presence of defects on these surfaces leads to damage to the fibers and rupture of the thread, which is unacceptable. As examples (Fig.2) are shown images of typical defects taken with the help of a digital microscope Qscope QS.20200-P [2].

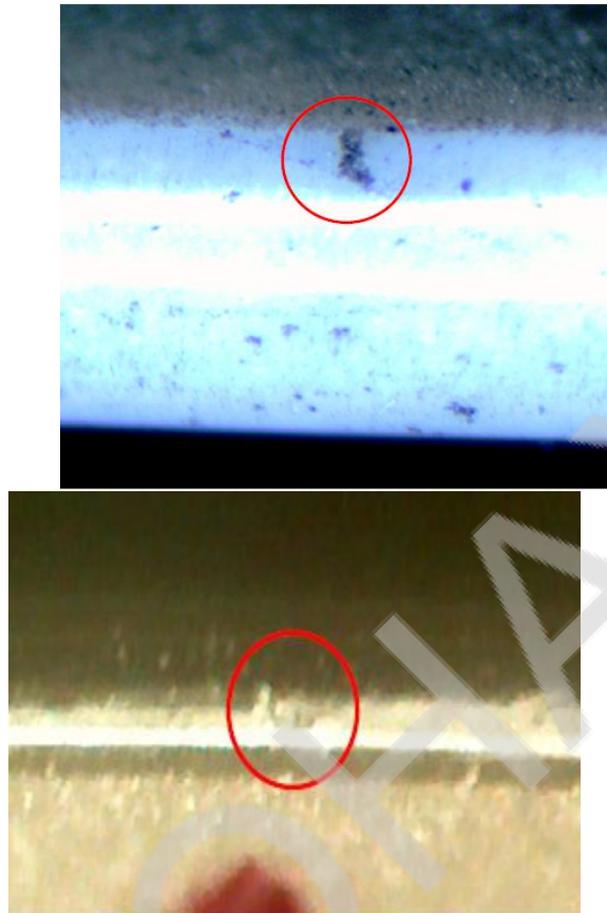


Fig. 2. Typical disk defect examples

There were also some pictures available from manufacturer (Fig. 3).

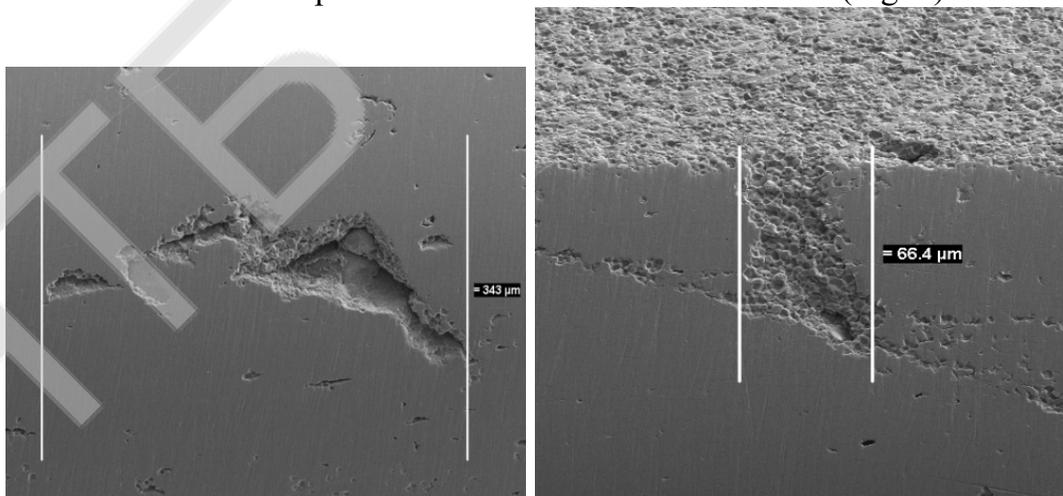


Fig. 3. Disk defect examples

Preferably, these are crater-like depressions with a surface area of $50 \mu\text{m}$ or more, but there may be chips, scratches and dark spots, which are also defects (Fig. 4, a - b).

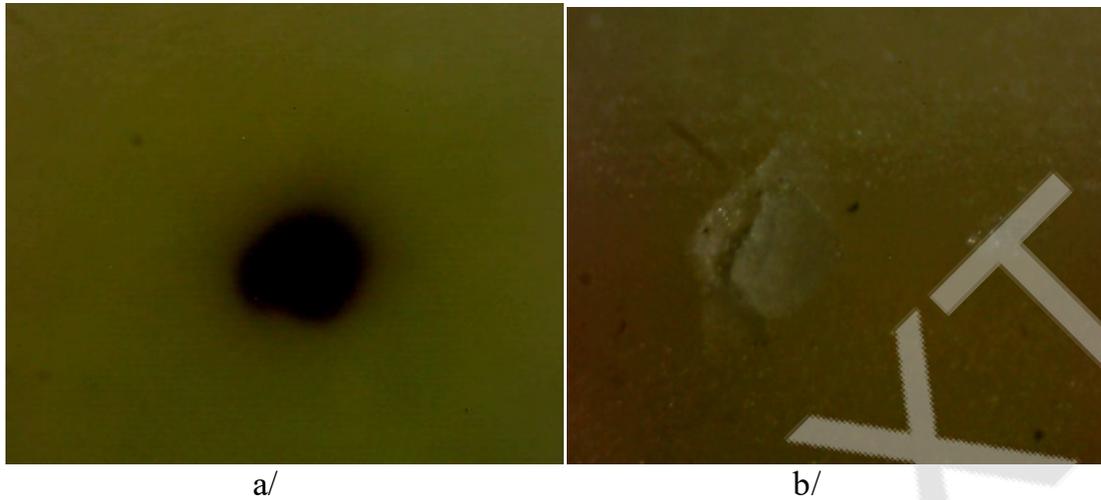


Fig. 4. Typical disk defect examples

The depth of these defects can vary, preferably up to 0.5 mm maximum, but there are cases of defects that are not actually deep, which creates obstacles to their identification by classical sensors scanning the surface of the object.

The working surface of the disk is checked for defects. As you can see, this is the edge of the disk with the radius set for each type of rounding radius. This part of the rotating disk is in contact with the thread. Defects described above damage the thread, it leads to its rupture, as a consequence - lack of production, damage.

The problem is that nowadays surface quality check of such parts is performed visually by highly qualified personnel with extensive experience. The reason for this is the complexity of the inspection and therefore difficulty to automate the quality control of ceramic products.

II. LITERATURE ANALYSIS

Areas with defects were studied using a digital microscope Qscope QS.20200-P [2]. It was found that the defects are up to 100 μm in size as well as the possible methods of ceramic disks defects detection are analyzed. For inspection of ceramic surface different types of instruments can be used: ultrasonic sensors [3], laser profile scanners [4], microscopes with image processing algorithms [5]. It was defined that inspection equipment hardware should provide the necessary resolution and defect detection ability and at the same time, it should be cheap and easily accessible. The problem is that ultrasonic instruments are designed for an in-deep view of the material, and our object of interest is located on the surface. The existing laser profile scanners [6] are relatively costly and can not fully solve the problem, because certain defects can be identified only visually. Laser scanners do not allow to identify all the necessary types of defects, which will lead to product shortages, and secondly have a very high price, which makes it impossible to conduct even the experimental part. However, with the development of technology, more and more tasks of automation, even such complexity can be solved. Against this background, we continued to work with the available USB digital microscope. It was decided that it will be

economically feasible to use a digital microscope from Qscope that does not lose in accuracy, and the system is much cheaper than commercially available scanners.

The next question was which algorithms can be used. Classical edge detection methods from the image processing toolbox are problematic to adapt to a wide range of defect shapes. The choice of a defect detection system using a digital microscope and an artificial neural network [7-9] was substantiated. There is one of the top and free image processing library [10]. It enables us to build systems with self-contained Deep Learning and Computer Vision capabilities using simple code. As an analogue, the Python image object recognition system, in particular based on the ImageAI library, was chosen for the study. To work with ImageAI, you need to install Python 3.6.-version, as well as some other libraries and Python frameworks. ImageAI provides very powerful yet easy-to-use classes and functions for detecting image objects, allowing you to perform all these actions using state-of-the-art deep learning algorithms such as, and. With ImageAI, you can run detection tasks and analyze images. Such a system has advantages in the relative simplicity of design, price, and ease of operation.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The *object of the study* is image recognition with a deep neural network system for detecting defects in the images of ceramic discs.

The *subject of the study* is the ability of the system to detect defects and its sensitivity to external factors.

The aim of this work is to provide reliable detection of ceramic disks defects using a low-cost system, based on a digital USB - microscope. The system should perform a visual inspection of surface quality.

The training of the artificial neural network is carried out on the same type of photographs, containing and accordingly marked defects of different types and nature. In such conditions, as for the requirement of more correct operation of the network, after its training, for research, it would be necessary to give photos of the object with approximately the same lighting as in the photos on which the network was trained. There were used in the work 300 photos (although about 5000 photos are recommended for the correct operation of the network) owing to the limited defect examples number at hand. They were divided into two parts for training and test folders as 80% / 20%, i.e., 264 photos for neural network teaching, and 66 photos – for testing. The basic software of the system was developed. It was enough to defect detection with the probability more then 90%. It is experimentally established that if the probability of finding a defect is lower than 70%, the system begins to work incorrectly. That is, it finds objects - defects that are not really defects, or does not detect real defects. A study of the influence of object illumination change factor during system operation and the size of the database for training an artificial neural network on the probability of defect finding was performed.

Usually, the neural network is trained to find typical objects that have clear common external features (cars, people, specific objects, etc.), here the image is the same type (always the same background), when the image appears strange object, the

system must identify it as a defect. Therefore, the training of an artificial neural network is carried out on the same type of images containing and accordingly marked defects of different types and nature. In such conditions, in order for the network to work as correctly as possible, after its training, for research, it would be necessary to take photos of the object with nearly the same lighting as in the photos on which the network was trained.

IV. RESULTS

2.1. Object illumination influence experiment

Thus, when the system works (search for a defect in a photograph) with photographs in which the illumination of the object is the same as in the training photographs, were obtained the following results (examples in Fig. 4).

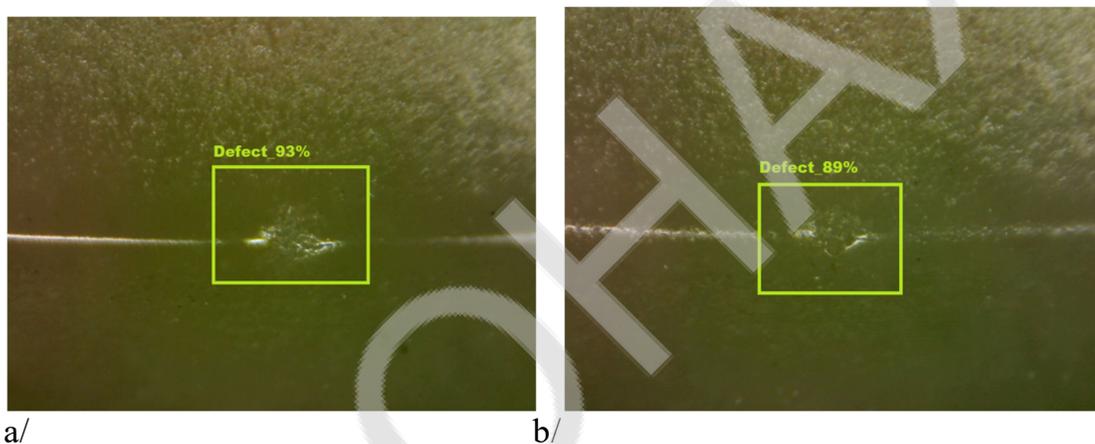


Fig. 4. Disk defect discovering examples

To study the effect of lighting influence a series of twenty shots with same lighting level was taken for four known defects. The graph of the result is given below (fig. 7 - "blue line"). It can be seen that the probability that the found object is checked as defect ranges from $94\% \pm 5\%$. Because the surface of objects is almost uniform in terms of the reflection coefficient, the image histogram (graph of statistical distribution of brightness values for image pixels) is relatively narrow (30-40% of the range of values) and remains approximately the same at different intensity values. Therefore, it was decided to determine the light intensity by the peak of the image histogram. Now, let's take photos of these same defects in the worst light and check them by our created system (fig. 5).

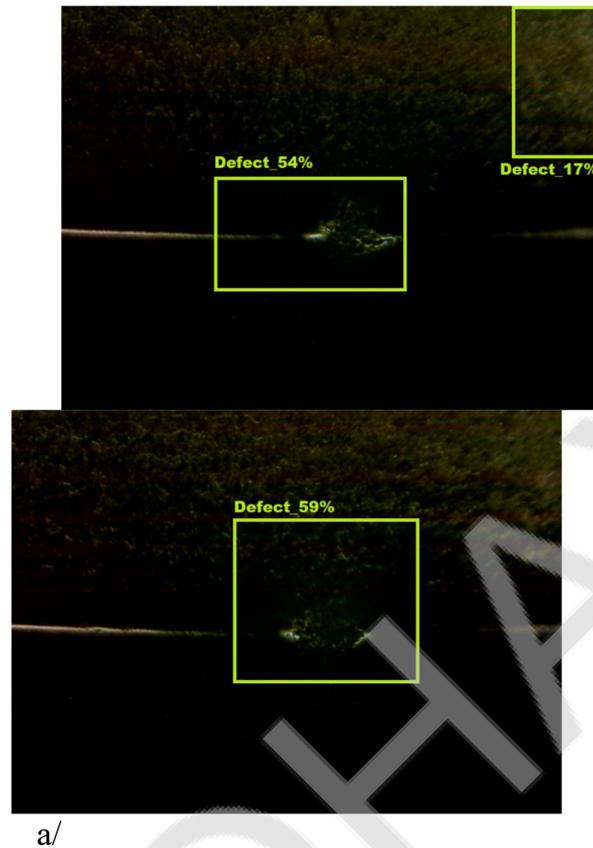
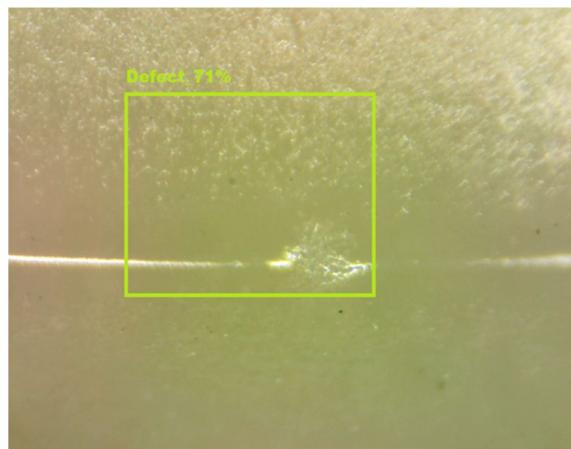


Fig. 5. Disk defect discovering in the worst light examples

For reliable statistics, there was checked the result also on 20 photos, the graph of the result is given below (fig. 7 - "red line graph"). As you can see, the probability that the found object is checked as defect ranges from $55\% \pm 10\%$. Experience has shown that a result with a probability of less than 70% is unacceptable, because in most cases the object is not a defect. So, the system started to work incorrectly. Therefore, such a change in lighting is not permissible.

Now, let's take a photo of these same defects in the brighter light and check them by the system (fig.6).



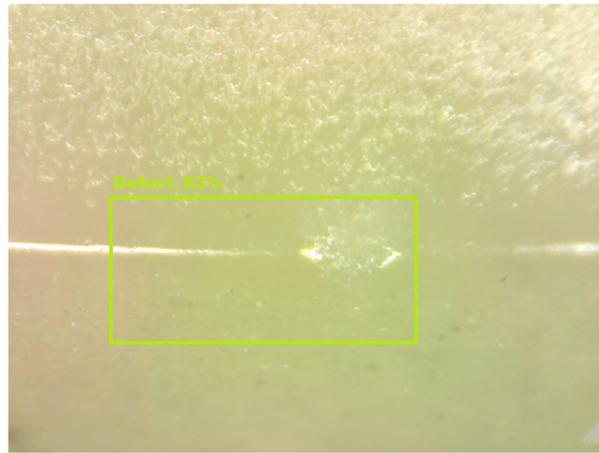


Fig. 6. Disk defect discovering in the brighter light examples

For reliable statistics, check the result on 20 photos, the graph of the result is given below (fig. 7 - "grey line graph"). The following results were obtained - the average probability that the object found is a defect range from $35\% \pm 10\%$. In some cases, the system either did not find as defect at all or gave a false result. It is obtained the clear conclusion: such a change of lighting is extremely unacceptable!

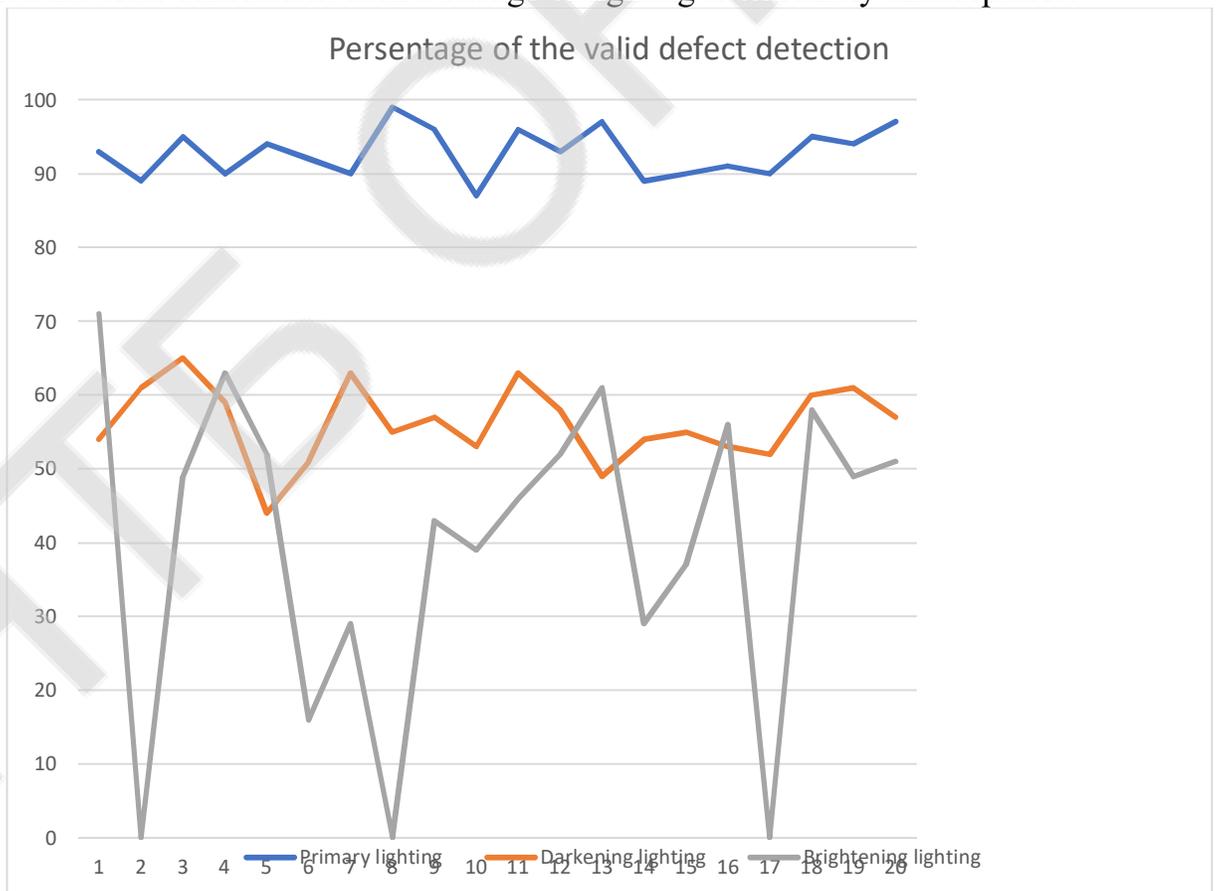


Fig. 7. Experimental results of defect detecting probability vs the experiment number for different lighting conditions

It has been experimentally established that the optimal results (the best image contrast) are achieved at the histogram peak in the range of 25% - 35% of the intensity range. With decreasing intensity (approaching the histogram peak to 10%), the probability of detection decreases to 70%. With the subsequent decrease of the peak of intensity (up to 5%) the probability decreases to (20 - 50)%, which is unacceptable. A similar pattern is observed with increasing intensity, ie the shift of the histogram peak in the range of more than 50%. The probability of detecting a defect in this case also falls below 70%.

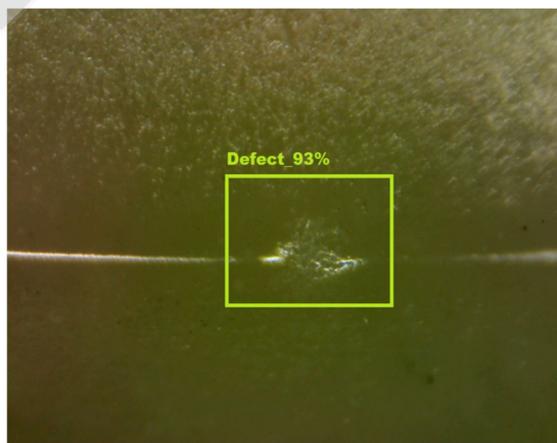
2.2. Training image number influence

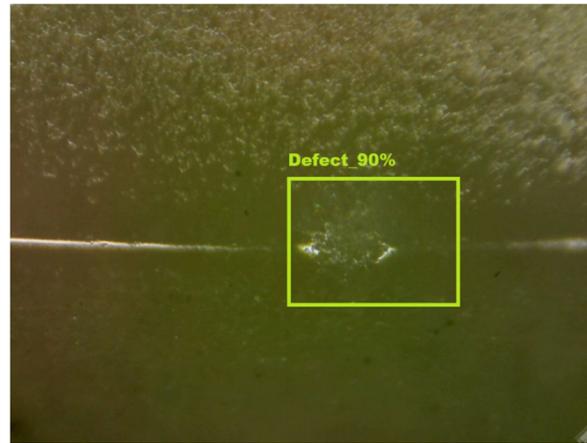
The accuracy and correctness of the artificial neural network depends on many factors. The most important stage of creating such a system for a specific task is the stage of training an artificial neural network. During the training of an artificial neural network, several factors are considered, one of the most important is the training database. In our case, this is a certain number of photos with defects. According to advanced neural network developers, the systems used in object recognition in the image require a recommended minimum number of training images in the amount of 5,000 images (files). It was recognized how this factor affect the operation of the system. Similar to the previous study, there were conducted three experiments.

For the first experiment it was used the initial data from the previous study, namely: for a minimal demonstration of the system, 100 photographs and 2,000 training cycles of an artificial neural network were used in the training of the network.

It was kept the number of training cycles and other parameters unchanged but was changed the number of photos to larger and smaller sides, respectively. So, let's move on to the first experiment.

As was mentioned above the number of photos for training was equal to 100 examples. Training cycles of artificial neural network was equal to 2000. The results can be observed below (Fig.8).





a/

b/

Fig. 8. Disk defect discovering examples with 100 samples

To create statistics, check the result on 20 photos, the resulting "blue line graph" is given below (fig. 11). As you can see, the result is satisfactory, the system works correctly, the probability that the found object is a defect is higher than 85%, which is an excellent indicator.

Now let's increase our training database from 100 to 200 photos. After training and checking the system, the following results were obtained (Fig. 9).

To create statistics, check the result on 20 photos, the "red line graph" of the result is given below (Fig.11). As you can see, the result is satisfactory, the system works correctly, the probability that the found object is a defect is higher than 85%, which is an excellent indicator. Comparing this result with the previous one, we can see that the system has become more accurate, the percentage of the found object is a defect has increased to an average of 97%, the highlighted area of the defect has become more accurately positioned. Therefore, we can conclude that the increase in the training database is a positive indicator for improving the accuracy and correctness of the system.



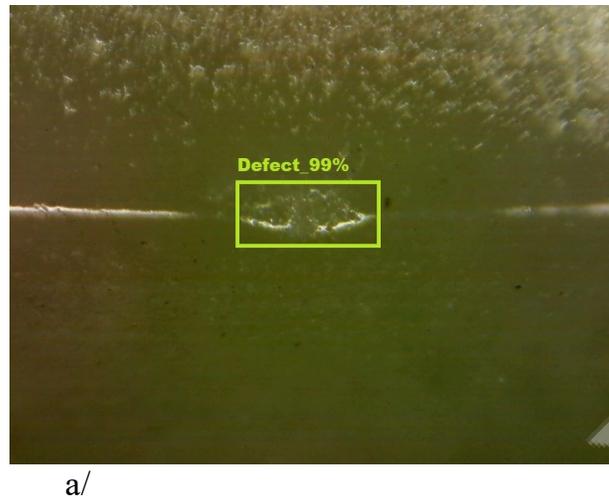


Fig. 9. Disk defect discovering examples with 200 samples

Also was conducted the third experiment, reducing the training database from 100 to 50 photos. The following results were obtained (Fig. 10)

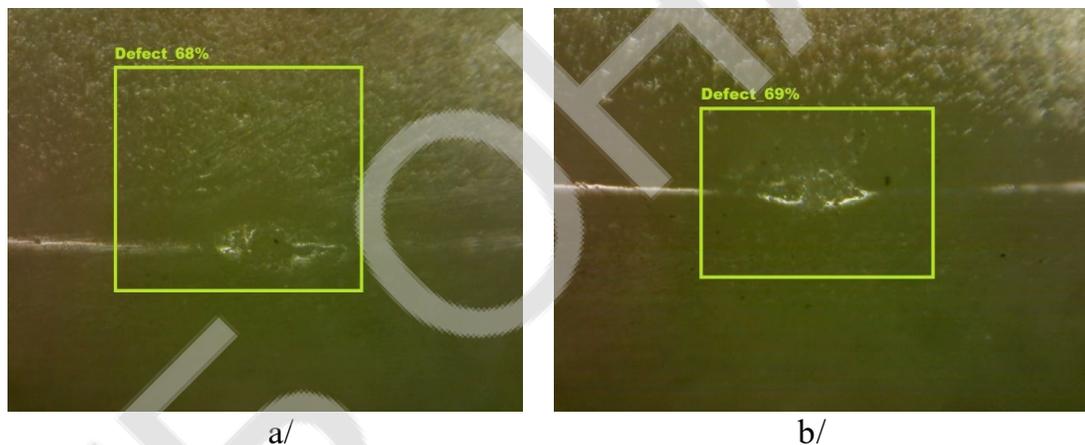


Fig. 10. Disk defect discovering examples with 50 samples

To create statistics, check the result on 20 photos, the "grey line graph" of the result is given below (Fig. 11). It can be seen that the result is unsatisfactory, the system sometimes does not work properly, the probability that the found object is a defect is less than 85%, which is an unacceptable indicator. Comparing this result with the first and previous, we can see that the system has become less accurate, the percentage of the found object is a defect decreased to an average of 67%, the highlighted defect area became less accurately positioned, false signals appear. Thus, it may be concluded that the reduction of the training database is a negative indicator for the accuracy and correctness of the system.

Down (Fig. 11) is put a common graph to demonstrate the results of the experiments. Thus, it noticed that increasing the size of the training database increases the accuracy and correctness of this system and reducing on contrary - lowers and leads to unsatisfactory results.

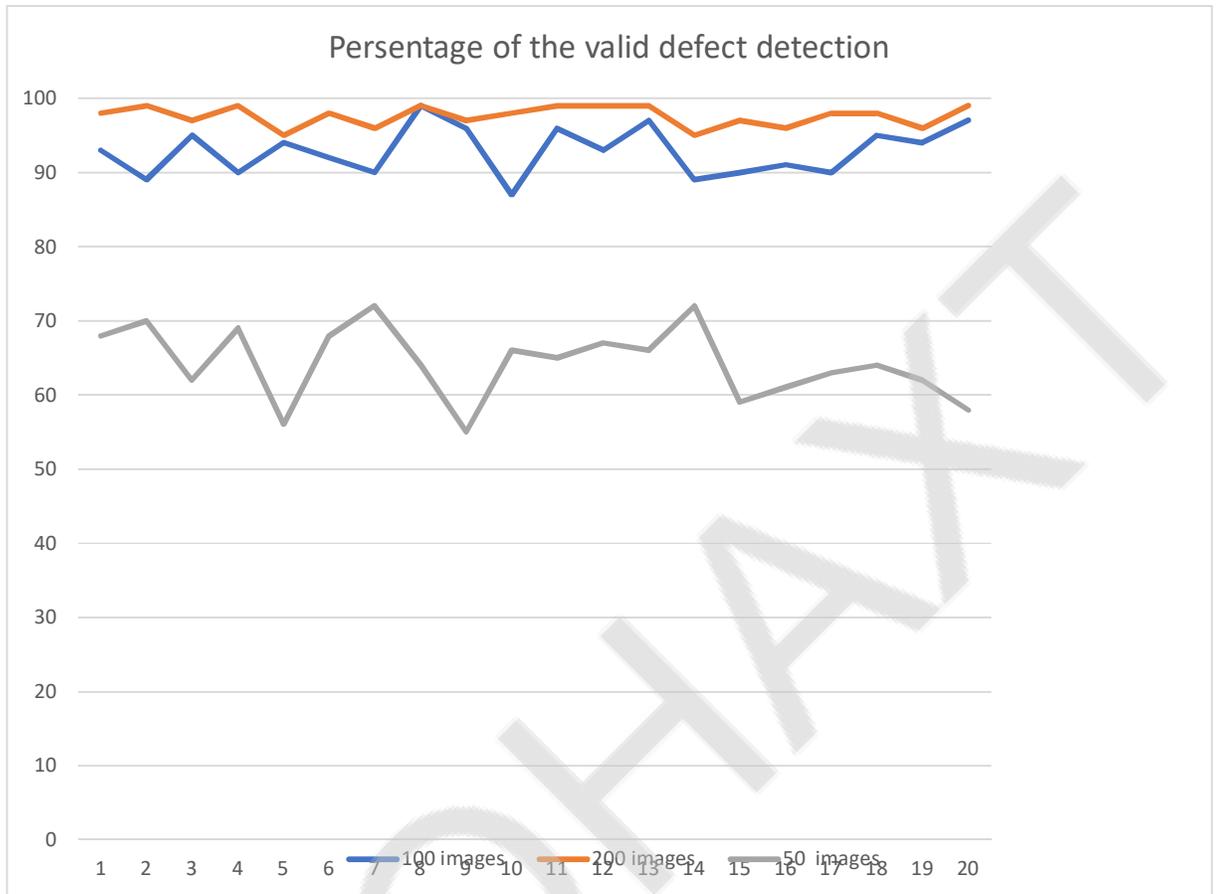


Fig. 11. Experimental results of defect detecting vs the experiment number for the different training samples number

V. CONCLUSIONS

Possible methods of detecting defects of ceramic disks were analyzed and it was decided that it is economically feasible to use a digital microscope from Qscope that responds to the requirements of accuracy, and the system hardware is much cheaper than the scanners available on the market.

The areas with defects were investigated using the handheld USB digital microscope Qscope QS 20200-P. It was experimentally found that the defects have sizes up to 100 μm with the different shape and size of the defects.

The choice of a defect detection system using a USB digital microscope and an artificial neural network was substantiated. Such a system has advantages in the relative simplicity of design, price, and ease of operation.

Features of use of the chosen software were developed, as well as specifics of the training process of an artificial neural network. Also, there was investigated the system operation at the different object illumination levels, and the different number of images for training. The practical implementation of the system has proven its functionality and efficiency, so it can be concluded that the main purpose of this work has been achieved.

VI. REFERENCES

- [1]. RAUSCHERT GmbH. (2015, May). Rauschert. Ceramic Friction and Guide Discs. http://www.leclairmeert.be/files/6714/5769/8812/PB_Ceramic_Discs_GB.pdf
- [2]. Euromex Microscopen bv. (2021, January 29). QS.20200-P - Q-scope. <https://www.q-scope.com/products/usb-products/qs20200-p/>
- [3]. Stockman, A., Lam, M., & Nicholson, P. S. (1990). Ultrasonic Characterization of Surface and Sub-Surface Defects in Ceramic Materials. In *Review of Progress in Quantitative Nondestructive Evaluation* (pp. 1115-1121). Springer, Boston, MA.
- [4]. Sioma, A. (2020). Automated control of surface defects on ceramic tiles using 3D image analysis. *Materials*, 13(5), 1250.
- [5]. Karimi, M. H., & Asemani, D. (2014). Surface defect detection in tiling Industries using digital image processing methods: Analysis and evaluation. *ISA transactions*, 53(3), 834-844.
- [6]. Micro-Epsilon Messtechnik GmbH & Co. KG. (2020, February 3). Blue Laser Technology for demanding measurement tasks. https://www.micro-epsilon.com/press/release/PR463_BlueLaser-Patent/?sr=7&sc=26&st=ceramic
- [7]. Su, J., Nakonechnyi, M., Ivakhiv, O., & Sachenko, A. (2015). Developing the Automatic Control System Based on Neural Controller. *Information Technology and Control*, 44(3), 262-270.
- [8]. Sachenko, A., Ivakhiv, O., Vyshnia, V., Grzeszczyk, K., Osolinskyi, O., Novosad, S., ... & Kopania, L. (2020, October). The Method of Neural Network Control over the Process of Manufacturing Foil Solar Panels. In *2020 IEEE 2nd International Conference on System Analysis & Intelligent Computing (SAIC)* (pp. 1-6). IEEE.
- [9]. Nakonechnyi, M., Ivakhiv, O., Viter, O., & Nakonechnyi, Y. (2020). Neurocontrolled object parameters adjustment by Ackermann's formula usage. *Measuring equipment and metrology*, 1 (81), 2020, (1), 22-29.
- [10]. Vladimirov L. (2020, December 4). Installation - TensorFlow Object Detection API tutorial documentation. <https://tensorflow-object-detection-api-tutorial.readthedocs.io/en/tensorflow-1.14/install.html>

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