

**International Scientific – Practical Conference
« INFORMATION INNOVATIVE
TECHNOLOGIES»**



The conference is held in the Year of Science and Technology and is dedicated to the 60th anniversary of the first manned flight into space.

**Prague – 2021
April 26-30**

International Scientific – Practical Conference
«INFORMATION INNOVATIVE TECHNOLOGIES», 2021

UDC 681.3 + 681.5
I 64

I 64 Information Innovative Technologies: Materials of the International scientific – practical conference. /Ed. Uvaysov S. U., Ivanov I.A. – M.: Association of graduates and employees of AFEA named after prof. Zhukovsky, 2021, 344 p.

ISSN 2542-1824

The materials of The International Scientific – Practical Conference is presented below. The Conference reflects the modern state of innovation in education, science, industry and social-economic sphere, from the standpoint of introducing new information technologies.

It is interesting for a wide range of researchers, teachers, graduate students and professionals in the field of innovation and information technologies.

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Proceedings of the conference contains

- information about the organizers;
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Results of fundamental researches in different scientific and practical activities are considered

Form of the report: plenary

Time-limit of the speech – up to 30 minutes

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Time-limit of the speech – up to 10 minutes



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Form of the report – section

Time-limit of the speech – up to 10 minutes

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Science and culture determine the level of civilization development. The last century has been characterized by rapid development of science and technology. On the basis of scientific knowledge, essentially all aspects of social life are being reformed. Science has become the direct productive force of society. Innovative information and computer technologies fundamentally change the material civilization and our way of life.

In modern conditions, an important factor in the development of science and technology is the relationship between scientists and research teams. The exchange of views and information is facilitated by specially organized international scientific seminars and conferences.

The Russian Center for Science and Culture in Prague sees one of its main tasks as promoting the achievements popularization of the domestic science and wishes the participants of the annual international scientific and practical conference "Information Innovative Technologies" (I2T) productive work and new discoveries.

Yours sincerely,
Director of Russian Centre for Science and
Culture in Prague

A.P.Tkachev

Dear participants of the conference «Information Innovation Technologies» - I2T!



Congratulate you on the beginning of the conference and sincerely thank you for responding to our call and taking part in the annual scientific and practical conference.

On your behalf, I express my gratitude to the staff of the Russian Center for Science and Culture in Prague for their support and invaluable assistance in organizing and holding the conference. I thank all the co-organizers of the event and express my hope for further productive and effective cooperation in promoting innovative scientific achievements in all spheres of human activity: in enlightenment and education, in fundamental and applied science, or in socio-economic sphere, healthcare or industry.

This conference, like last year, is held online, due to a difficult circumstance for the whole world - the Covid-19 pandemic. Despite this, the conference is held as an annual one with a large number and vast geography of participants and a wide range of organizational profiles: from educational and scientific to industrial, medical and socio-economic.

This instills confidence that under conditions that are more favorable the popularity of the conference will increase even more.

Within the framework of the conference, a specialized scientific and practical seminar SED-2021 - International seminar on Electron Devices Design and Production is traditionally held, dedicated to the issues of design automation and production of electronic means, as the basis for the development of the absolute majority of all modern information and telecommunication technologies. The collection of the seminar proceedings is published separately from the electronic and printed collection of the conference proceedings and is indexed in the Scopus and WoS databases, which is very important today for those working in the field of science and education.

Finally, it is important to note that this year's Information Innovation Technologies - I2T conference is dedicated to the 60th anniversary of the first manned space flight. We are proud of the fact that this person was our compatriot - Yuri Alekseevich Gagarin! This flight became possible not only thanks to the selfless labor of our people, but also thanks to the achievements of science and technology. The year 2021 was declared the year of science and technology.

I wish all the conference participants effective work, creative inspiration and vivid impressions!

Yours sincerely,
Chairman of the Organizing Committee

Saygid Uvaysov

Section 1
INFORMATION TECHNOLOGIES IN EDUCATION

SOFTWARE SYSTEM FOR STUDENT KNOWLEDGE CONTROL

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Abstract – The article describes the results of the development of a software knowledge control system for local computer testing. The functionality of the system allows you to create tests, conduct tests and give the resulting statistical information to the teacher.

Keywords: knowledge control, computer testing, test shell, test designer.

INTRODUCTION

One of the applications of digital systems in e-learning is automated knowledge control - automated testing [5]. Test tasks are now an important part of the educational process. In the practice of using new educational technologies, computer testing has become the most popular [1, 5]. In this subject area, as a rule, there are two types of users: the compiler of tests and the tester. Test writers are usually teachers, instructors, staff managers or specialists in a particular field. Test software packages must have a special application that allows compilers to conveniently design tests. Testing, as a rule, is carried out about the help of a separate application. A number of systems provide the ability to use the web interface for Internet testing [9].

Knowledge testing systems have the following basic requirements [2, 4]: availability of test creation and testing tools; convenient user interface; convenient format of information presentation when creating a test and storing it; maximum possible number of different types of test questions created; generate a report and statistics on test results.

The developed software test system has the following characteristics:

- the system is platform-oriented Win32/64; easy installation of the program using the created installer
- consists of two independent modules: test creation program and testing program; both programs are graphical window applications
- both programs of the complex have a built-in assistance system that facilitates the work of an inexperienced teacher

Microsoft Visual C++ [3.8] was used to implement the complex applications. The graphical interface is designed using the MFC framework library in the Windows API. For debugging and testing IBM development tools Rational Purify and Rational Pure Coverage were used [6, 7]. The Microsoft GDI graphics library was used in the implementation of work with drawings.

TEST DEVELOPMENT AND TEST PROCESS

To create a test, the software system provides the following options for implementing it:

- the test may consist of any number of questions
- the question may have no more than eight proposed answers
- the text of the question may include text information and pictures (images)
- for any provided response, the test originator can specify its "weight" as an integer in the range from one to one hundred; thus, you can consider the importance of the question or rank points for a particular answer

The test process can be configured:

- setting the number of test questions for the test subject and the question selection method: sequential or random question generation
- to allow or prohibit the subject from returning to previously specified questions
- testing with or without time spent
- to allow or prohibit viewing response statistics during testing and analysis of test results

Before starting testing, the teacher must select the questions that will be asked to the subject. The selection can be made sequentially or randomly. Then the test program starts. The answerer must answer the questions by choosing one or more of the proposed answers. You can answer questions in an arbitrary order. By default, the response time is not limited.

The teacher has the opportunity to limit the maximum time to answer any question, if desired. If the responder fails to meet the response time, the response will be considered incorrect. Next, the student will be given the following question. Thus, it is possible to organize testing taking into account the time spent on answers.

SYSTEM OPERATION

The software system consists of two independent applications. To create a test, the program EasyTest Creator is designed, for the test process itself - the application EasyTester.

The test files you create on the system will have the .tst extension. After the complex is installed in the Windows system environment, this extension will be registered in the system registry. Later test files will be associated with this software system. After running Installer.msi, the Setup Wizard will guide you through the normal steps of installing any program, such as selecting the installation path, installing mode, creating icons in the program menu, desktop shortcuts, etc. (Fig. 1).



Fig. 1 Installation Wizard Window

CREATE A TEST

The process of creating a test in EasyTest Creator consists of three events: the actual preparation of questions, the setting of test parameters and the setting of test results logging. Figure 2 shows the main window for creating a test, which consists of two forms.

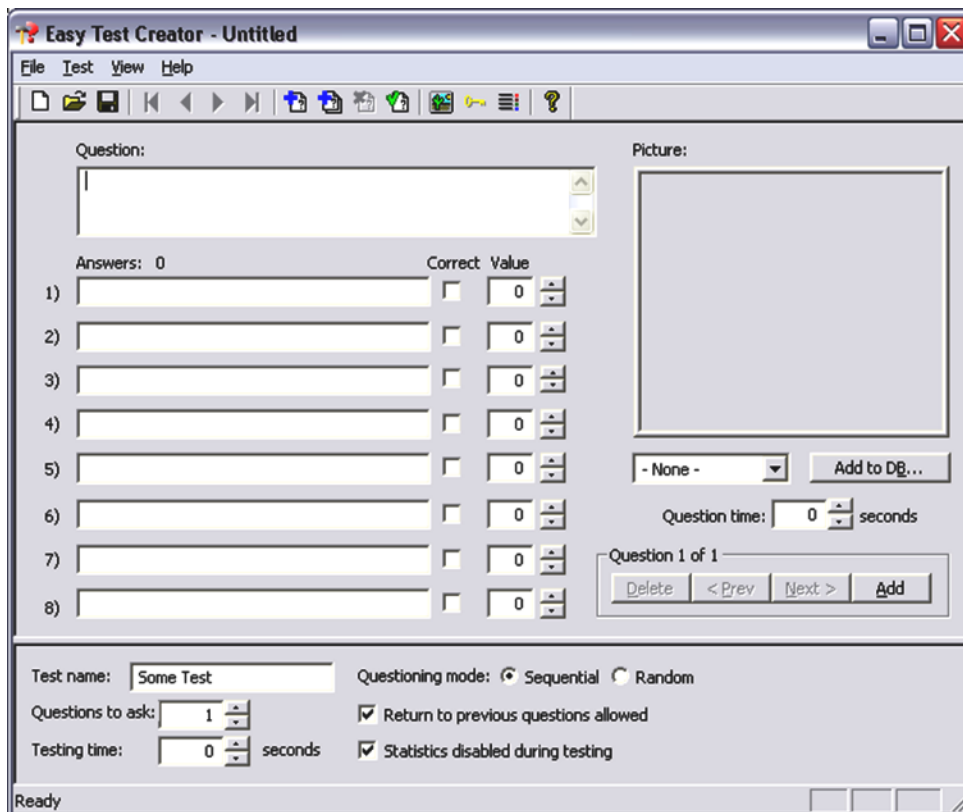


Fig. 2 Test Creation Start Window

The upper part of the window contains elements for preparing the current question:

- question field
- answer fields for entering up to 8 correct answers and points from 1 to 100 for correct answers (Value) if you want to rank the "weight" of questions and answers (for incorrect answers, the score should be 0)
- adding an image from the file to the question (Picture)
- question time limit if you want to consider the response time when testing

At the bottom of the window, the instructor specifies:

- the name of the test
- number of questions to ask
- questioning mode - sequential or random
- whether to allow the subject to return to previous questions (check box)
- prevent viewing of statistics of the current test (check box)

You can see an example of a prepared question with a picture in Figure 3. When creating the question, 4 answers were provided, two correct answers were noted and points other than 0 were indicated for them.

Question:

Picture:

Answers: 4 Correct Value

Answer	Correct	Value
1) 1	☒	15
2) 2	☐	0
3) 16	☐	0
4) Затрудняюсь ответить	☒	3
5)	☐	0
6)	☐	0
7)	☐	0
8)	☐	0

Krolik

Question time: 30 seconds

Question 1 of 1

Fig. 3 Picture Question Creation Example

You can attach graphics up to 540x400 pixels in the test system image base to any question. You can load pictures of any graphic formats (Add to DB) into the database.

An example of the configured test parameters is shown in Figure 4. The test is given the name "Test about rabbits," the test subject will be given 10 questions from the test by random sampling, the response time during testing will not be taken into account, the test subject will be allowed to return to previously answered questions again, current testing statistics will not be available to him.

Test name:

Questioning mode: ☐ Sequential ☒ Random

Questions to ask:

Testing time: seconds

☒ Return to previous questions allowed

☒ Statistics disabled during testing

Fig. 4 Test Setup Example

The top line of the main EasyTest Creator window contains user interface controls such as a drop-down menu, toolbar, and status bar (in Figure 5).

File

- New Ctrl+N
- Open... Ctrl+O
- Save Ctrl+S
- Save As...
- Export
- 1 Sample - C++ test
- 2 Sample - Animals test
- Exit

Test

- Add question F2
- Duplicate question Shift+F2
- Delete question
- Add picture to DB... F3
- Edit picture database... F4
- Previous question F6
- Next question F7
- First question Shift+F6
- Last question Shift+F7
- Validate question F5
- Set password... F8
- Edit response messages... F9

View

- ☒ Toolbar
- ☒ Status Bar

Help

- About EasyTestCreator.

Fig. 5 EasyTest Creator Menu

Through the Test → Edit response messages menu, you can configure test program messages based on the test results. These are the points scored intervals (min, max) and their corresponding text messages.

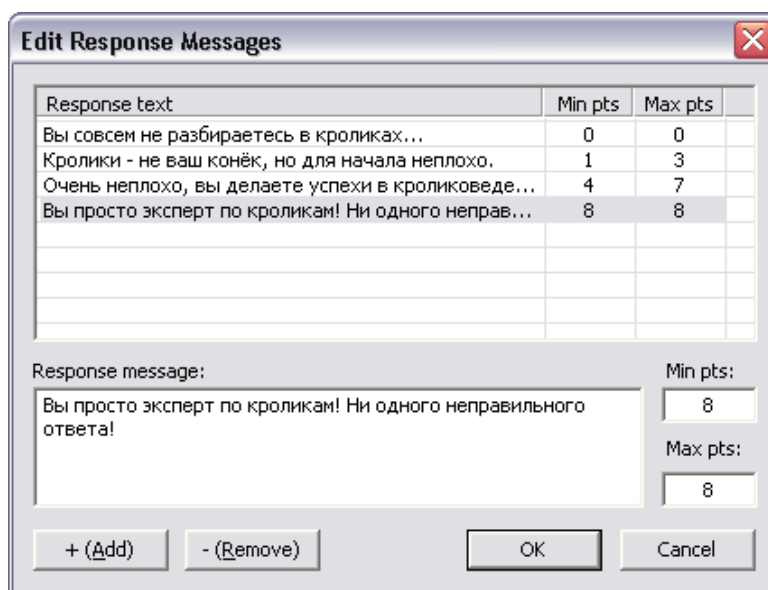


Fig. 6 Configuring Test Results Messages

The Edit Response Messages dialog box (Fig. 6) shows the reactions that have already been created to four ranges of test results. Through the Add/Remove buttons you can add/remove scheduled messages, in the Min and Max fields you can set the values of the score range.

Create a new test, open an existing test, and save the test to a file from the top File menu. The generated test file can be password protected if desired.

TESTING

Similar to the test creation program, the test program window EasyTester contains similar context controls for the user interface: menu, toolbar, and status bar. After running the test program, you must load the test file created using EasyTest Creator and initialize the test.

During testing, the EasyTester provides the test window to the test subject, what is divided into two areas: the question area and the answer option area (Fig. 7). The question area shows the question, its current number, and the total number of questions in the test. The question containing the picture will display the button (Show picture) that you click to display the picture.

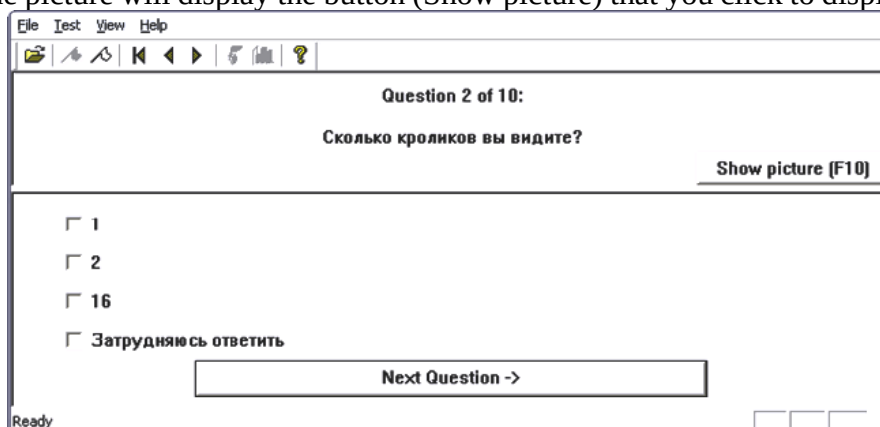


Fig. 7 Test Program Main Window

After selecting the correct/correct answers, the tester proceeds to the next question of the test by pressing the button (Next Question). If the test parameters have been adjusted for time, the button will show the remaining time to answer the question. If the return to previous questions in the test settings was allowed, then you can move on the test questions in any direction.

Testing will automatically end after answering the last test question. You can force the test through the testing program menu. After the test is completed, a dialog box (Fig. 8) will be automatically displayed with the test results: the number of correct answers, points scored and text messages. If the test settings were enabled, the statistics window can be displayed during the test (Fig.8).

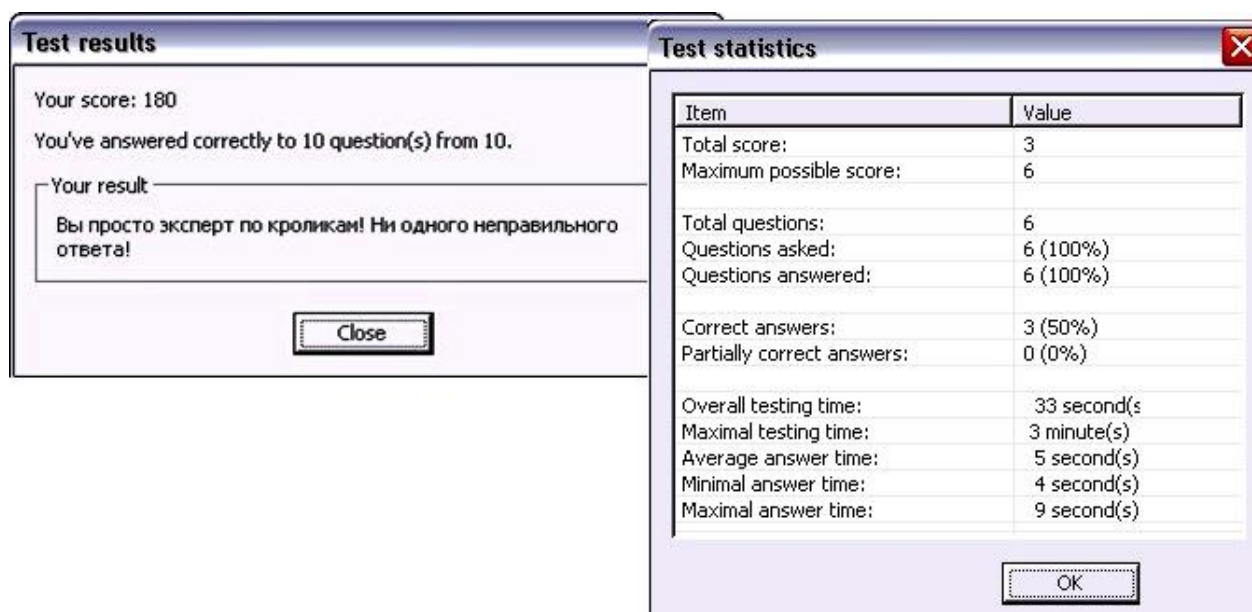


Fig. 8 Test Results and Test Statistics windows

CONCLUSIONS

The developed testing system allows automated testing of students on a personal computer. The system is distinguished by the ease of test preparation, which does not require special tools and skills from the teacher; it is simple and easy to use. The system has the necessary level of functionality for such programs and avoids the financial costs associated with purchasing corporate assets. The developed electronic resource is used in the educational process of the department "Computing Systems, Networks and Information Security."

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DEVELOPMENT AND ANALYSIS OF A METHOD FOR INCREASING THE SECURITY OF HARDWARE AND SOFTWARE OF INDUSTRIAL FACILITIES OPERATING ON THE BASIS OF LANS OF VARIOUS HIERARCHICAL STRUCTURES

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Abstract — This paper presents a method developed and used to protect a local area network (LAN) from unauthorized access. The essence of the method is to control the hardware of PCs, that are part of the local network by means of a specialized server that performs a network survey and stores information in a specialized database. The General principle of operation of SOFTWARE based on this method is considered, and flowcharts are provided.

Keywords: Information protection, software, local area networks.

INTRODUCTION

The relevance of this work lies in increasing the security of the hardware and software of local networks of various objects, as well as prompt response to cases of unauthorized changes in hardware configurations, both downward (for example, when unauthorized replacement of components), and upward (for example, when unauthorized connecting third-party devices to try to organize a channel of confidential information leakage). The objects can be various enterprises and organizations with both conventional and geographically distributed LANs based on structures from a dedicated server to a centralized cluster of servers [1].

PROBLEM STATEMENT

The object of the research is the level of protection of expensive hardware and software of local area networks of objects, which has unique or specialized properties from unauthorized intrusions and changes.

The purpose of the research is to improve the efficiency of protecting local area networks (LANs) from unauthorized access when keeping records of hardware, and to develop tools that allow you to instantly notify about unauthorized changes.

SOLUTION OF THE PROBLEM

Currently, two methods are used to try to solve this problem:

- in terms of combating attempts to connect unauthorized devices - by mechanically blocking the casing of the processor units, as well as sealing external interfaces, and daily

monitoring the integrity of the seal. This method, with its high reliability, has a significant drawback - the daily presence of a controlling person is required;

- in terms of combating attempts to steal or substitute components - by using specialized software systems (for example, AIDA64 by FinalWire Ltd, or "Inventory of computers" by the domestic manufacturer 10-Strike).

These software systems allow you to obtain information about the hardware configuration of any network node from any point in the network. However, this method does not allow you to automatically check the current state of the hardware configuration of the host with its state in the previous time. The principle of operation of this and similar software is shown in Figure 1.

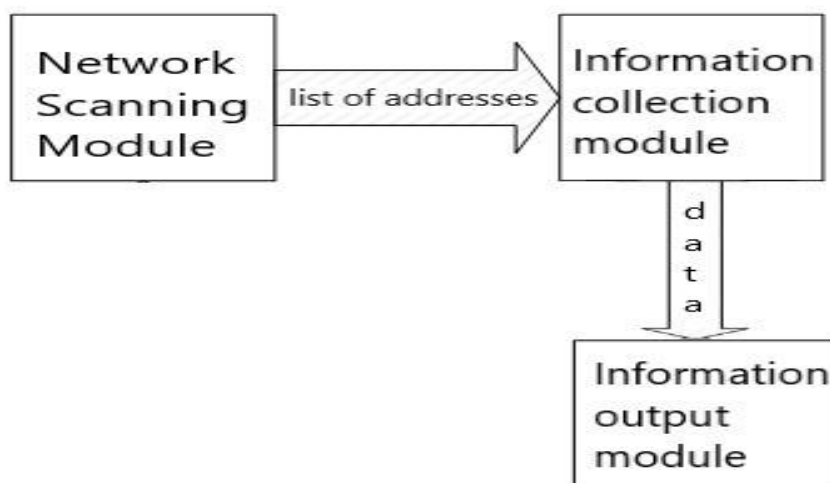


Fig.1 How the AIDA64 software works

To achieve the goal set in the work, it is necessary to solve the following subordinate tasks, namely:

- saving information about the reference state of the hardware of the network nodes;
- determination of the status of network nodes in parallel;
- periodic collection of information about the current state of the hardware of the network nodes [2].

In this work, it is proposed to use the following original method. Its structural diagram is shown in Figure 2. The local area network of the facility is subject to round-the-clock monitoring from the central server of the facility's network, which has a sufficient degree of protection against outside interference. The very structure of the method excludes the possibility of the above disadvantages. There is no need to perform "sealing" and "sealing" of interfaces and processor units, as well as to perform manual logging of hardware configuration states - these operations are performed automatically at a specified frequency. Reducing this time interval increases the response time to tampering, but increases the load on the network.

Network scanning module (its block diagram, which is the principle of the network scanning module functioning, is shown in Figure 3) This principle calculates the valid address range of computers in the network, based on the subnet identifier and mask. Further, it checks the connection with these computers, and excludes those addresses for which it was not possible to establish a connection. Then, using the received list of addresses, a check is carried out for the possibility of collecting the necessary data using WMI, using a short WMI query, thus excluding all devices that do not support it, or for some reason there is no access to them at the moment. The resulting list of available addresses is passed to the next modules.

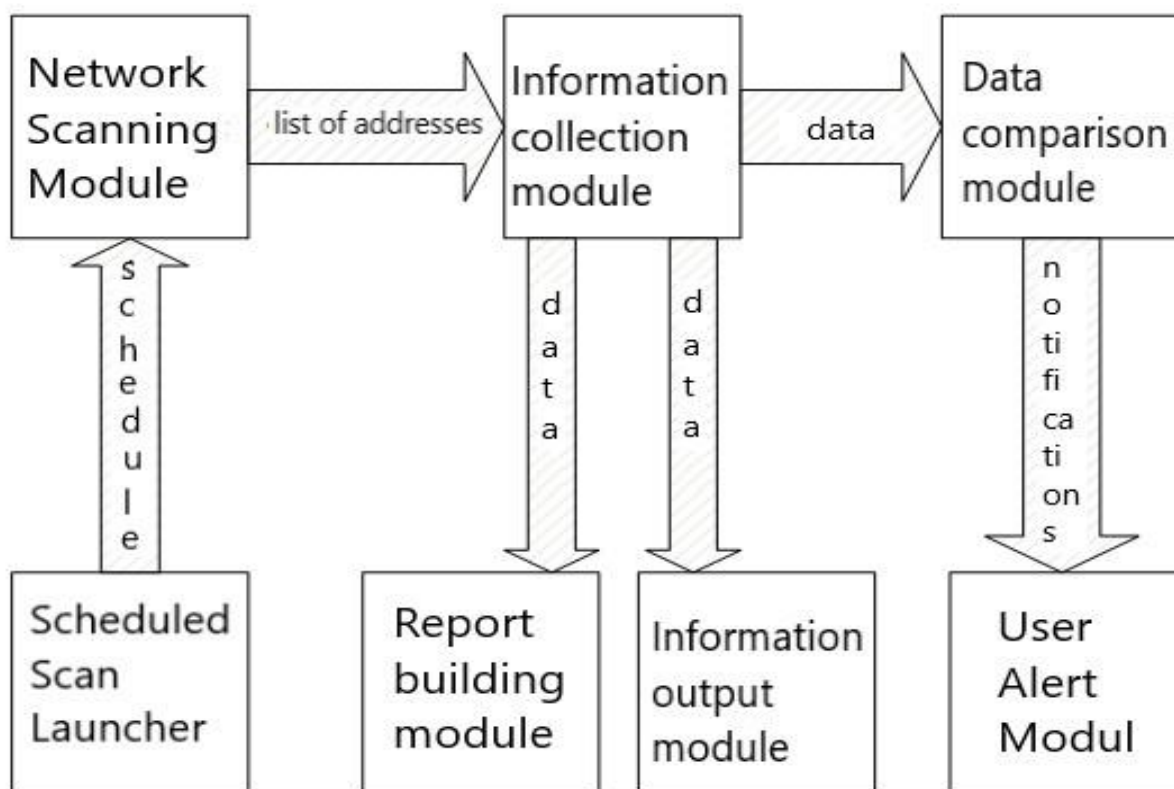


Fig. 2 Block diagram of the implementation of the method proposed in this work

At the first stage, the subnet mask is converted to a binary number system, then the number 2 is raised to the power of the total number of bits in the mask, which take the value "1", which allows you to get the number of possible computer addresses. At the second stage, a list of possible host addresses is generated by incrementing the address by the number of possible addresses. At the third stage, all addresses in the list are scanned. If there is an address in the list that has not yet been verified, then an echo request is performed on it, as a result of which the presence or absence of access to the address is determined. If you have access to the address, it is checked using a short WMI query, thanks to which the address is either written to the list of available addresses, or excluded from the list, and then the next address is passed. If there is no access to the address, it is excluded from the list and a transition to the next address occurs.

If all addresses in the list have passed the check, then the module passes the list of available addresses to the next modules.

The information gathering module polls computers according to the list of addresses, for the properties and parameters of their internal components. Then it converts the received information to the object model, creating a conditional object for each computer, which contains objects of its component parts, which, in turn, are assigned the properties of real components. Bringing information to this form is due to the need to unify the processing of all computers. The resulting array of objects is passed to the next modules.

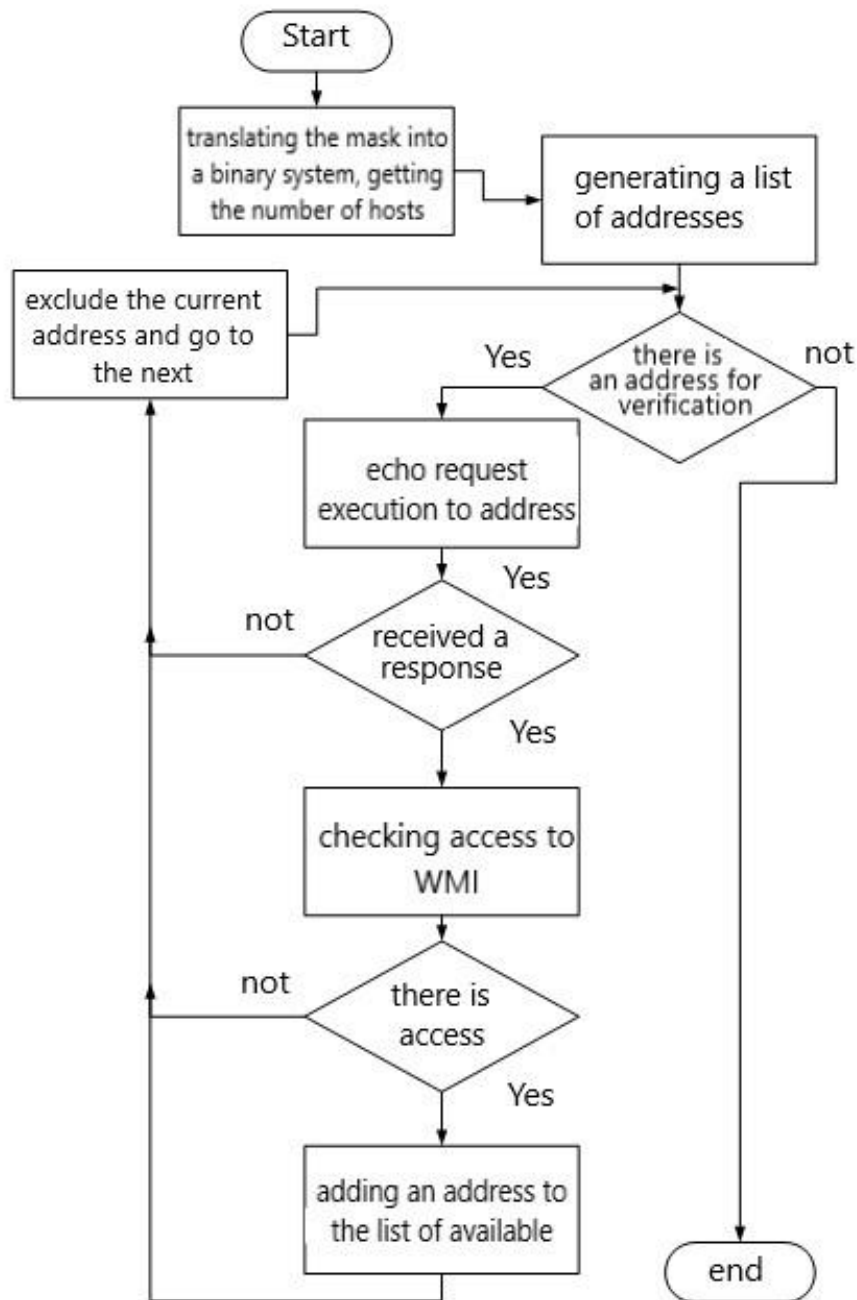


Fig. 3 Block diagram of the network scanning module

Let us describe the algorithm presented by the block diagram (see Fig. 4). At the first stage, according to the list of addresses received from the network scanning module, information is collected from computers [3].

At the second stage, an abstract object is created for each computer, as a collection of a number of devices. At the third stage, for each detected component, an abstract object is created as a set of properties of the component. The properties of this object are filled with information about the characteristics of a real component. At the fourth stage, there is a logical combination of computer objects with component objects, in accordance with the real equipment. At the fifth stage, each computer object is assigned service properties: name, address, and scanning time, which are necessary for processing this structure by subsequent modules.

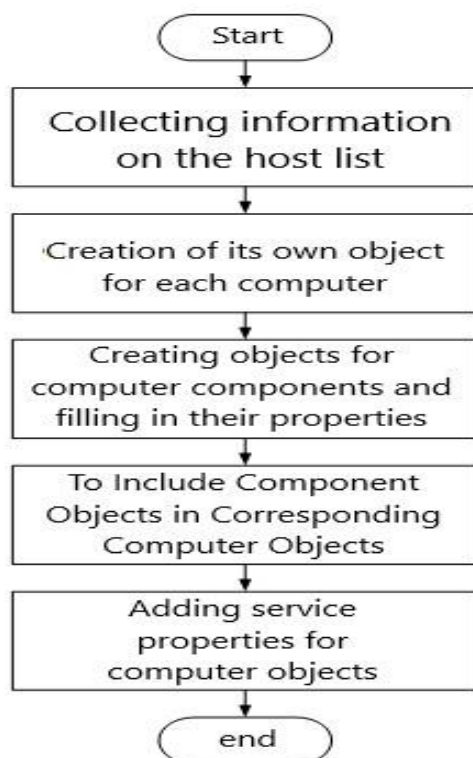


Fig. 4 Block diagram of the information collection module

The data comparison module compares the so-called "archived data" of the previous scan and the "new data" obtained during the last scan. If there is no archived data, then the new data will automatically become archived. This happens the very first time you start the program.

Let us describe the algorithm presented by the block diagram (see Fig. 4). At the first stage, there is a pairwise comparison of each property, each component in each computer. At the second stage, when changes are found, then there is a check for the presence of archival information about the mismatching property. If information about this parameter was previously present in the archive, the module will conclude that the device is probably missing and will move on to the next parameter. If no information about a mismatched parameter is found, the module will conclude that this parameter belongs to a new device and will move on to the next parameter. If there are no changes, the module simply terminates its work [4].

CONCLUSION

Thus, the developed method increases the security of the hardware and software of local networks of various objects from unauthorized access and makes it possible to promptly respond to unauthorized changes. These capabilities differ from the currently existing methods due to the absence of the need for physical control of the hardware and also due to the possibility of performing a reconciliation of the current state of the hardware configuration of a network node with its state some time ago.

A software tool created on the basis of the developed method allows you to refuse to purchase expensive software packages (the cost of an AIDA64 license for 1 workstation is about 14 thousand rubles, and if the office of an organization contains about 20 computers, then the license will cost them 280 thousand rubles, and when the fleet is updated PC or motherboard change, the license will have to be purchased again) to monitor the state of the LAN hardware based on Windows OS.

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TEXT RECOGNITION FROM VIDEO RECORDINGS

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Abstract — This work is devoted to solving the problem of creating a tag cloud for video recordings of lectures held at the Moscow Institute of Electronics and Mathematics. The work is focused on the development of a program for recognizing and searching for keywords in video recordings. Different solutions to the problem of text recognition and keyword extraction have been considered in the research.

Keywords: optical character recognition, keyword extraction.

INTRODUCTION

The task of text recognition in computer vision is one of the most important tasks in machine learning. Over a long period of time, a lot of research has been done on this topic, which has subsequently had a strong influence not only on text recognition, but also on text analysis in general.

Optical Character Recognition (OCR) is a technology that allows you to translate documents in a variety of formats, such as PDF files and photo documents, into electronic form. The first methods for text recognition appeared in 1929, and over the decades more and more advanced systems have been created and used in various fields. But such systems were narrowly focused, they could only recognize a few special fonts or formats, which is why more documents were never digitized.

The use of models based on deep neural networks solved this problem. Modern character recognition systems are now quite robust against various interference, noise in images. Also, the achievement of high recognition quality is due to the fact that by now there are more datasets. At the same time, thanks to the generation of synthetic data, such as the creation of bad lighting, additional noise in the image, the stability of the models increases.

Intelligent text analysis consists of many tasks, one of which is keyword extraction. The idea is this: the algorithm produces a ranked list of words (keywords) that most accurately describe the source text. There are two ways to highlight keywords, namely keyword assignment and keyword extraction. The first method is characterized by the allocation of only those words that were presented in the dictionary selected for analysis, the other method selects keywords from the text for analysis.

The Moscow Institute of Electronics and Mathematics (MIEM) has developed and launched a service that allows you to record and archive video recordings of lectures held in some auditoriums equipped with cameras for automatic video recording. The service also saves lectures that were held on the JITSY video conferencing platform. Before the implementation of the proposed solution, in order to find the right video among all of them, it was necessary to open

each one and view it. And to simplify the search task, it was decided to create a module for tagging keywords from the videos for this service. The module should highlight keywords or phrases for each video and store them in the archive in the bundle of keyword and time of appearance of this word on the video. The task I'm considering consists of a number of basic steps, such as recognizing all the text on the frame, searching for keywords and phrases.

This paper focuses on solving the problem of indexing the content of video presentations. Inspired by [1-2], an algorithm using TesseractOCR for text recognition and KeyBERT for keyword extraction was proposed.

LITERATURE REVIEW

In machine learning, the task of text recognition is a classification problem, which can be solved by different approaches. One such method is solver trees, as proposed in [3]. However, this method has difficulties when classifying objects that have a large number of parameters.

In [4] an attempt was made to compare different methods of machine learning. The most interesting among the compared methods are the nearest neighbor method and artificial neural network. The results show that both methods show good results, but the nearest neighbor method also has some difficulties in classifying objects with a large number of attributes, which is especially important for image classification.

To compare the performance of the neural network and the nearest neighbor method in [5] we used a data set consisting of images of digits. The number of training objects was eleven thousand. As a result, it was shown experimentally that the neural network is better suited for image classification tasks. Also, the work proposed a slightly improved method that improved the recognition accuracy.

Since the listed methods could partially cope with the task of classification, it was still not enough. With the discovery of convolutional neural networks, the task of image classification gained new development.

At present, one of the popular solutions for this task is TesseractOCR [1]. This method supports more than 100 language models and gives high recognition accuracy. Tesseract is based on a recurrent neural network LSTM [6]. Recurrent neural networks are a type of neural networks, where the connections between the elements form a directed sequence. This makes it possible to process a series of events in time or sequential spatial chains. But the problem of such neural networks is the vanishing gradient, and the fact that they cannot handle long sequences. LSTM solves the problem of the vanishing gradient.

LSTM is well suited for classifying, processing, and predicting time series with time delays of unknown duration. It trains the model using back propagation.

The OCRopus document analysis toolkit was presented in [7]. This tool processes only those pages that are oriented directly, also the input image must be high resolution.

In [8] the authors presented a system of optical text recognition EasyOCR, which supports more than 40 languages. The machine learning algorithm CRAFT is used for text detection [9]. This paper describes the architecture of the used neural network and the learning process. The testing was done on 6 datasets including TotalText and CTW-1500. These datasets contain strongly curved texts on natural images. A CRNN neural network is used to recognize character sequences [10]. The paper also presents the architecture, the learning process, and various comparisons with other counterparts. The CTC algorithm, which is presented in [11], is used to decode the output data of the neural network into text.

The following works have been considered for the task of keyword extraction.

An unsupervised graph-based TopicRank keyword extraction method was presented in [12]. Keyphrase extraction from a document consists of the following steps. Initially, the document is pre-processed (sentence segmentation, word tokenization and part-of-speech tagging), and the candidate keyphrases are grouped into topics (the candidate phrases are used as

vertices in the complete graph). Topics are then ranked according to their importance in the document, and keyphrases are extracted by selecting one candidate keyphrase for each of the most important topics.

Another interesting method for keyword extraction is presented in [2]. KeyBERT is a keyword extractor developed based on the bi-directional pre-trained BERT language model. First, the words of the input text are converted into vectors using the BERT model, and then cosine similarity is used for keyword extraction.

METHODS

The process of the developed module can be divided into 3 main steps. Initially, the program divides the input video into frames. Then the text on the image is recognized, and then the keywords are determined. The algorithm then writes the keywords together with their related timecodes to the Google Table and sends this table to the archive for further work with it.

Currently, many systems have been developed that allow the recognition of text on images. Among the systems considered (OCRopus, TesseractOCR, EasyOCR) it was decided to use TesseractOCR. This is a popular solution that supports many languages and there is a library for the Python language PyTesseract, which is very important for us, because the development was conducted in this programming language. The other system OCRopus does not support Russian, which is very important for the module we are developing, since the lectures are mostly in Russian. Another open system for text recognition is EasyOCR. It supports 40 languages, including Russian.

TABLE 1: COMPARISON OF TESSERACTOCR AND EASYOCR SOLUTIONS [13]

Model	Error rate on numbers	Error rate on alphabets
TesseractOCR	5.50%	0.70%
EasyOCR	1.90%	4.30%

EasyOCR recognizes text worse than TesseractOCR as opposed to numeric data. But the tag cloud is character data, so EasyOCR is not suitable for the task of text recognition in the module we are developing.

Solutions such as TopicRank graph-based method and KeyBERT based on neural networks were considered for keyword selection. The TopicRank method and KeyBERT have been described in Literature Review. For our task, we used KeyBERT because this model is easily customizable, accurate, as demonstrated in Table 2, and contains many pre-trained dictionaries.

TABLE 2: KEYBERT RESULT ON INSPEC [14] AND DUC [15] DATASETS.

	Precisio n	Recall	F1
Keyword	0.90	0.86	0.88
Non-keyword	0.76	0.82	0.79

RESULTS

The result is a module for the lecture videorecording service that recognizes text and extracts keywords and writes the recognized data to the archive. The module is activated when a video is received at the input and queues up the videos for processing.

The module makes it easy to find videos in the archive. Also, other developed services at the university can use the recognized data.

CONCLUSION

Neural network approaches have now advanced significantly in solving the OCR problem. Therefore, neural network-based methods were used to solve the task, as they show

greater accuracy and performance. The module recognizes text quite accurately, which is very important for more accurate video indexing.

In the future, you can create a system that recognizes the voice accompanying a presentation and converts it into text for more accurate identification of content.

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DEVELOPMENT OF A SOFTWARE PROTOTYPE OF THE PROFESSIONAL SKILLS
TESTING FOR ENGINEERING STUDENTS

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Abstract – With the introduction of the competence-based approach, the vector of education development has become more focused on the acquisition of professional skills of graduated specialists. The main task is to graduate a competent specialist who has successfully mastered the curriculum of a vocational educational institution. Such a competent specialist will be in demand on the labor market and, accordingly, employers are highly interested in accepting such an employee. A competent specialist can be called only when the student has successfully mastered all the professional and general educational competencies provided for in the curriculum of the specialty. The article discusses the need to develop a program for testing students' professional competencies, and also describes a prototype of such a program developed by a team of authors.

Keywords: professional skills, program development, skill's testing, higher education.

At the current level of development of information systems and technologies for the exchange and manipulation of information, testing is increasingly used in training, which acts as a tool for professional monitoring and forecasting. Monitoring in the role of a controlling and diagnostic system provides the teacher with fairly objective and timely information about the level of mastering by students of competencies, and the administration about the effectiveness of management of an educational organization. The computer testing system is a universal tool for determining the level of formation of various competencies provided for in the work programs of academic disciplines.

The development of test items at a high methodological level sets the teacher the task of developing a clear conceptual and terminological structure of the discipline, i.e. tables of definitions and concepts checked in tests, structured by sections and topics of the work program of the academic discipline.

In the content of education, within the framework of the competence-based approach, the practical, interdisciplinary, applied aspects of education are strengthened. This is achieved not by introducing new subjects, increasing the volume of the content of the studied disciplines, but by reorienting their content to the activity type of training content (from “declarative” knowledge to procedural and value-semantic knowledge). This presupposes the inclusion of problem situations and tasks in the content of education, the methods and technologies for resolving which correspond to the future professional activities of students. When implementing a competency-based approach in teaching methods and technologies, it is necessary to focus on developing technologies based on active, reflective-active forms and methods of teaching. To include in the learning process problem-modular learning systems, design and research methods, through which the independent work of students is expanded and activated. In the professional field, there are several types of competencies:

- special (subject), determining the ownership of the actual professional activity;
- general professional (general subject), related to several subject areas or types of professional activity that a graduate must master within the framework of his profession;
- key (basic, universal), contributing to the effective solution of various tasks from many areas and the implementation of social and professional roles and functions based on the unity of generalized knowledge and skills, universal abilities.

Competencies are most effectively formed in the educational process of the university through technologies that contribute to the involvement of students in the search and application of knowledge, the acquisition of experience in independently solving various problems. Designing the educational process with a competence-based approach puts forward the task of testing the productive and creative, creative levels of application of knowledge, abilities, skills in the future professional activity of the student.

The computer as a tool for testing knowledge has a number of advantages and disadvantages. However, in objectivity and accuracy of assessment, he has no equal. Namely, this factor contributes to the expansion of the scope of computer testing.

The use of information technologies in the computer assessment of students' knowledge has a huge number of different advantages over the forms, methods and methods of knowledge assessment usually used in the course of the educational process. After characterizing the aforementioned tests, an analysis was made comparing computerized testing with conventional written testing and the following several advantages were found:

1 Performing a test using a computer takes significantly less time than the process of writing a standard written test, when it is necessary to invent written answers.

2 It is very simple and quick to calculate and finalize the level of knowledge, since all this should be automated (without human intervention), with the option of choosing a ten-point system or a percentage value, the computer program gives the results immediately after the end of the test.

3 Automated scoring is performed when one correct answer, and when a different number of points is assumed for each available answer option, and when at the same time it is possible to mark the range of correct answers. Since computer testing takes place with direct use of a computer, it is not necessary for all students to distribute worksheets, which means there are no expenses for purchasing paper.

4 Students improve their computer skills.

5 Ability to supplement the test question with a high-quality illustration, which is located on the monitor screen.

6 After the end of the test, files are formed in the computer memory, which are the final table of the test performed.

7 Testing students' knowledge using information technology makes the educational process more interesting, as it differs from the usual methods, at least in that everything happens in an interactive multi-environment [1].

At the same time, the set of methods of testing complexes is rather limited:

Typically, tests can use the following five types of questions:

- choice of the only correct answer;
- selection of several possible correct answers;
- setting a sequence of correct answers;
- setting correspondences of answers;
- entering the answer manually from the keyboard.

Taking into account a small number of different testing methods, it is advisable to create a universal software product that will allow teachers of various disciplines to develop their databases and receive control tasks for their discipline in a short time. There are several such applications, but none of the programs implements testing of the formation of students' competencies. In accordance with [2], there are competences that are the result of mastering the entire educational program, and, directly, learning outcomes in a specific discipline. The result of training is the mastery of a particular part of the work program and some intermediate and current assessment will correspond to it. The correlation between the learning outcome and the result of mastering the competence is as follows: in order to form a student's professional competence, it is necessary to achieve certain learning outcomes in a number of studied

disciplines (practices). Thus, competence is a category that is understandable to the employer, and the learning outcome is a category that is understandable to the teaching community.

In other words, it can be stated that competence is decomposed into results that work as important and necessary criteria for the formation of competence. In addition, the consequences of teaching in individual disciplines are checked in the course of certification - current, intermediate, final. This check is performed using tests, control cases, oral sample surveys, term papers, etc.

In the course of the educational process and during the current and intermediate certification, not the competencies themselves are checked, but the learning outcomes correlated with them, which are formed in the course of studying a number of academic disciplines.

The creation and execution of a test task for testing competencies is a very complex process. Each developer should look for a specific and most adequate design for their test. Let us consider in more detail the possible options for tasks that can be used when testing students' competencies.

The first thing to start with is to define a concept that can be used in professional activities. The subject needs to make the choice of the correct definition for a particular professional concept, using the list of definitions attached for testing. It is necessary that the versions of the definitions in the answer options differ slightly from one another, but the correct one must be the most accurate and complete.

It is very important to include conceptual competence in almost every competency testing system. It will reflect the level of mastery of the basic concepts used in this specialty competence.

The next step is the analysis of information tables. This is the most common form for test items. Developers can use different kinds of such tables.

Tables can be used to check how well the tested person understands the purpose of certain professional actions, devices, devices. These tasks are quite effective when the actions of a specialist are clearly regulated, obey clearly defined rules [3]. When solving such tasks, the professional competence of the subjects is manifested.

The type of test tasks "algorithmicization of professional actions" is aimed at checking the level of practical readiness of the student. For this purpose, the subject needs to choose the correct sequence of actions when performing a specific professional task.

In this case, there is an initial list in which the work steps are listed in random order.

This type of task very adequately simulates the implementation of a real production task.

Using such a scheme, one can check not only the knowledge of the correct algorithm for professional actions, but also the understanding of the students of what materials, tools, auxiliary devices, software should be used in this case.

It is also possible to suggest several correct options for working steps.

The difference between the correct algorithm of actions and the wrong order should not be conspicuous; it should only touch on the nuances (albeit essential).

This type of test tasks allows you to correctly assess how well the specialist is familiar with this equipment, devices, to what extent he is prepared to work with them.

The next stage is the analysis of diagrams and graphs.

As a rule, a specialist of any profile and specialty has to deal quite often with various graphs, diagrams that carry important visual professional information. This circumstance can be successfully used in the formation of test items.

The proposed diagrams have the ability to reflect real processes by simulating various typical production situations. The subject needs to give an answer according to one or another diagram, in another case - to choose a diagram that meets the specified conditions, mode, phase of the process, etc. [4].

Those test tasks are considered effective if they offer graphs and diagrams for analysis, differing in subtleties, requiring the test subject to demonstrate his competence as a specialist.

Analysis of the proposed graphs can be associated with identifying the best parameters, as well as unacceptable deviations from technological requirements, detecting non-standard situations, etc. The use of photographs, slides, drawings opens up great methodological possibilities for the creators of test tasks, and are also useful in that they relieve inevitable psychological stress students taking part in testing.

Completion of professional texts: This technique is quite typical for testing use. The person being tested needs to insert the missing words-terms into the proposed professional definitions, judgments, conclusions, demonstrating their competence in this matter.

Within the framework of the competence-based approach and the accepted limitations, the assessment of the quality of the formation of competencies is associated with the diagnosis of the measure of appropriation of cultural means or methods of action. This formulation of the problem is combined with the traditional one and recalls a long series of attempts to develop methods for assessing the level of assimilation of knowledge, skills, and abilities.

Thus, the development of the foundations and tools for assessing the quality of competencies should be considered as another attempt at rethinking and modernizing the existing system of pedagogical diagnostics.

When developing a program for testing students' professional competencies, the following sequence of actions is required.

1 Creation of a model of a system for assessing the levels of competence formation and learning outcomes. In this model, the initial, basic and advanced levels of the formation of learning outcomes and competencies are distinguished.

2 Creation of a mechanism for assessing the level of competence formation.

3 For each specific level of learning the development of competence, highlight the categories "to know", "be able to", "own", in which the following meaning is embedded:

- "to know" - to reproduce and explain educational material with the required degree of scientific accuracy and completeness.

- "be able to" - to solve typical problems based on the reproduction of standard solution algorithms;

- "own" - to solve complicated problems on the basis of acquired knowledge, skills and abilities, with their application in atypical situations, is formed in the process of gaining experience of activity and be able to convey this experience. For each of these categories, 5 criteria for assessing learning outcomes (descriptors) are distinguished, corresponding to the degree of formation of this category. The allocation of descriptors is based on the completeness of mastering the learning outcome.

Descriptors are some general formulations that describe the characteristics and context of student learning expected at each level of competency assessment. They form a rating scale that makes it easier for educators to form expectations of learners and help ensure equivalence and consistency of standards across subject areas [5].

4 Associate the formation of competence with learning outcomes through a system of descriptors.

5 Develop a system for monitoring the formation of competence.

Thus, the introduction of testing at each of the stages of assessing the quality of mastering educational programs simplifies the process of checking the mastering of competencies. The testing program should contain tasks for assessing the level of formation of competencies and learning outcomes. The test results should be visual, formed for the convenience of processing and improving the teacher's activities, reflect the lack of knowledge in a particular section of the discipline. With the help of tests on the quality of mastering competencies, the student will show the degree of his readiness to solve practical problems of varying degrees of complexity. You can visually analyze how students apply theoretical knowledge and skills in their professional activities.

All of the above necessitates the development of a competency development testing software. We have developed a prototype of a software for testing the professional skills of students studying in the direction of "Information systems and technologies". The generalized algorithm of the program is shown in Figure 1.

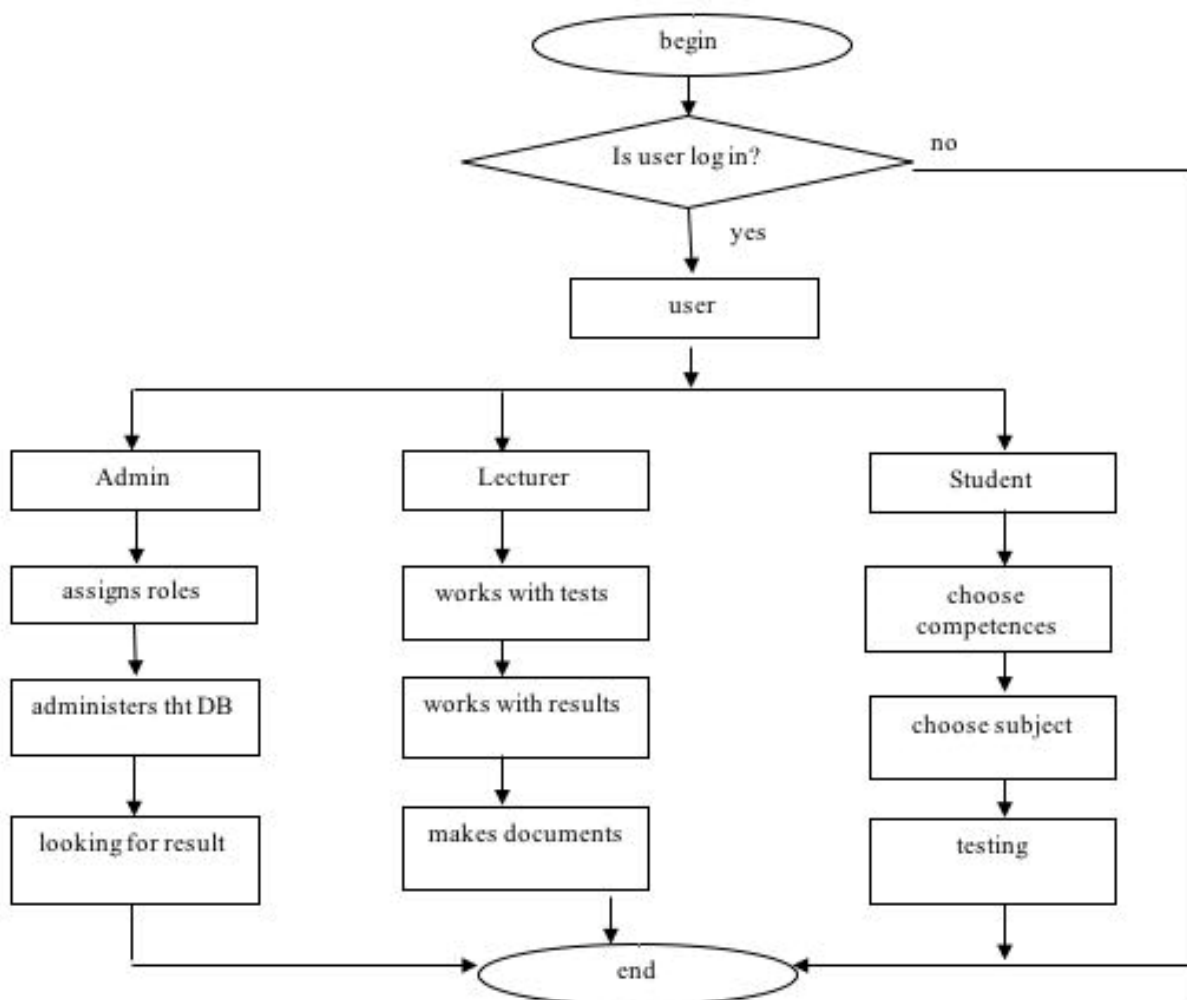


Fig. 1 Generalized algorithm of the competency testing program

Users of this software are divided into three types:

- administrator;
- student;
- lecturer.

For each of the users, a certain range of tasks and functions that he can use are separated. For example, after receiving a username and password for the program, a student can choose the discipline and competence for which he will be tested. The administrator provides password generation, loading tests into the program. The lecturer enables access to testing and checks the test results. Then he can generate a report on the development of the competence.

The prototype of the software is developed in the object-oriented language C # and can work with the Microsoft Windows operating system version 7 and later.

In the most general case, the testing program allows teachers to test the formation of competencies during the educational process at various stages of control: input, current, intermediate. An important advantage of the developed software product is the ample opportunities available to the teacher when working with the test results of students. It is

convenient to track the dynamics of learning, generate reports on the development of certain competencies, which makes it possible to speed up the work of teachers when submitting reports. At the moment, the possibility of implementing a remote access module for testing using the Internet is being considered.

Thus, the testing system using computer technologies is the main component for the successful, promising development of distance learning.

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ANALYSIS OF SOFTWARE FOR THE DEVELOPMENT OF SITES OF SCIENTIFIC AGRARIAN ORGANIZATIONS

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Abstract— The paper discusses the software used for the development of sites for scientific agrarian organizations, in order to analyze the possibility of forming a single Internet space of scientific and educational resources within the digital economy, the required integration of both information resources and standardization of software in terms of compatibility. A formalized rationale is given for the transition to methods of integration and typification in the development of sites for agricultural research institutes. It is shown that these sites use mostly free software. This indicates the low level and quality of sites, which, together with a wide variety of software, makes it impossible to form a single digital platform for scientific resources.

Keywords: integration methods; scientific and educational resources; information security of sites; website software; Agriculture.

INTRODUCTION

Research institutions, due to their innovative mission, are simply obliged to test on themselves all modern trends in the digitalization of the economy. So, at this stage, one of the main general principles of digital transformation of world social development is the formation of an information management system based on the integration of disparate data into a single system, which requires the development of digital standards for all three main axes of the project

space of information systems, which are the basis of such a transformation: information resources (IR), the axis of applications (control tasks) and the instrumental component representing the system-wide software and electronic equipment [1]. The standards for the development of their sites are their uniform ontological models of their content, applications, as well as their software. Only in this case information technologies can fulfill their functions of stimulating the country's digitalization.

For this purpose, science has presented the implementation of an integrated three-dimensional space of scientific and educational resources based on digital standards in the form of a single information Internet space for scientific and educational resources (SISSER), which, in addition to the function of supporting scientific research, increasing the level of education for all segments of the population, should become an effective tool for introducing scientific achievements into the economy [2, 3, 4]. Such a space should bring together science and business, currently living independently of each other. This paper considers the possibility of its formation, based on the state and comparative characteristics of software for the development of sites for scientific agrarian organizations.

PROBLEM STATEMENT

The need for SISSER is due to another factor that undermines trust in science - a sharp increase in distorted, inaccurate information on the Internet. For example, this manifests itself in the discussion of the coronavirus problem not only on Internet forums, but also at scientific conferences and scientific sites. The publication activity in the field of the digital economy of researchers who are very far from informatization has grown especially sharply in the last three years, which is explained by the requirements for an increase in scientometric indicators from the Ministry of Education, attention to the problem on the part of the country's leadership, as well as the outflow of specialists in this area from science and education into business. This also led to the growth of distorted, unreliable information. As an example, we can cite the promising forecasts of the Analytical Center of the Ministry of Agriculture, based on GoldmanSachs estimates for developed countries, by 2024 an increase in labor productivity at agricultural enterprises by 2 times per employee; reduction in the share of material costs in the unit cost by 20% or more as a result of the digitalization of the industry with a total economic effect of 4.8 trillion. rub. per year or 5.6% of Russia's GDP growth [5].

Such forecasts, not supported by mathematical models and the realities of our economy [6], are simply explained by the desire to receive some preferences, investments for domestic forecasters, to seize the sales market - by Western companies, which is facilitated by the promise of a fundamental possibility of obtaining a significant economic effect from digitalization. However, this information was reflected in scientific publications. Another example: on the RAS website (http://www.ras.ru/win/db/show_org.asp?P=.oi-3017.ln-ru.dl-.pr-org.uk-10) by the Department of Agricultural Sciences information on subordinate organizations is provided. And although in recent years there has been a reorganization of scientific organizations, the latest updates on the site are dated 2016-2017. with the old list of them. There are no scientific centers. The search for organizations, their subjects and persons does not work. It is possible to understand about the unreliability of information only by knowing the situation from the inside, while an uninitiated user will take the available information as true.

One more example. In [7], on the basis of mathematical modeling of digital platforms, the calculation of the potentially required number of IT specialists for the DE in the agro-industrial complex in the amount of 90,000 people is given. At the same time, at the moment they need only 17% of the calculated value due to the unpreparedness of most enterprises for digital transformation, obtained on the basis of a mathematical model of scenarios of possible options for informatization [6]. However, the Ministry of Agriculture has voiced 90,000 people as a need at the present time without correcting for the simulation results. And this value spreads

on the Internet, migrating from publication to publication. And the director of the All-Russian Institute of Agrarian Problems and Informatics (VIAPI) named after A.A. Nikonova, academician A. Petrikov, who considers the Internet the main means of digitalization of the agro-industrial complex. For this reason, he achieved the exclusion of research topics on the digital economy at his own institute. The Internet is dealt with by specialized organizations in other industries, respectively, and IT departments in agricultural universities must be closed. As a result, there is not a single scientific organization in the agro-industrial complex that is comprehensively engaged in research in the field of the digital economy. Although specialists understand that technologies such as centralized storage and data processing centers, broadband Internet access and others, which many companies and experts focus on, have very little impact on the development of the digital economy [8]. And there are many such examples.

Hence, it is clear that without solving the problem of ensuring information security of the websites of scientific organizations from distorted, inaccurate data, these incidents will only discredit the whole science in the eyes of the community of IT specialists and other users who want to get reliable information from the hands of scientists.

SOLUTION OF THE PROBLEM

From the experience of designing and developing information systems (IS) it is known that IS can be formed in three ways: individual, standard and automated. In the digitalization of agricultural scientific organizations, so far only disintegration processes are observed on the basis of individual design and development of their websites.

In such a situation, with the increasing problems of their lagging behind the global trends in the digitalization of society, there is a need for an integrated, systematic approach to the problem of creating and implementing sites, i.e. in an industrial approach to the design, development and implementation of them in the form of SISSER with the simultaneous solution of information security problems. This will reduce the cost of digitalization tens, hundreds of times, as well as radically change the approach to solving the problem of information security of the content of scientific organizations, in particular, due to the possibility of attracting qualified personnel to the development and maintenance of SISSER, which most of them are deprived of due to leaching IT specialists from science.

To formalize the justification for the transition to methods of integration and typing in the development of sites, we introduce the notation: $S = \{S_m\}$ – considered many sites and $S_m = \{S_{rmp}\}$; $r = \overline{1, R}$; $m = \overline{1, M}$; $p \in P$; S_{rmp} – r-th subsystem of the m-th site for organizing p. $P = \{P_{oj}\}$, where o is an index characterizing industry differences, j – organizational, economic, technological, information security requirements, etc. features of agro-industrial production.

The way $I_{sm}(i, U_{l \in L_i} K_l)$ – project of the m-th site at the i-th stage of design using a set of development tools K_l , $K_l \subset K$; $l = \overline{1, L}$; $i = \overline{1, I}$.

Thus, we represent the design process in the form

$I_{sm}(i, U_{l \in L_i} K_l) \xrightarrow{PR(i, i+1)} I_{sm}(i+1, U_{l \in L_{i+1}} K_l)$, where $PR(i, i+1)$ design operator, reflecting the creation of the site project in terms of the corresponding methods and development tools. Moreover, the efficiency criterion $F(PR, P, K, S, T)$ design procedures should take optimal value.

If projects $I_{sm}(i, U_{l \in L_i} K_l)$, $I_{sm}(i+1, U_{l \in L_{i+1}} K_l)$ can be formulated in the form of information resources and development tools and, at the same time, many design operators PR applicable for one organization $P = P_0$, then design is called individual, if design statements are applicable to a group of organizations $P_1 \subset P$, then the design is called typical, but if PR does not depend on

specific p and $PR(i,i+1)$ presented in the form of software tools - automated, the urgent need for the transition to which is dictated by the digital economy.

In general $PR(i,i+1)$ depends besides K_l from the resources allocated for design R_{II} ; system structure G_{sm} , in particular, site management structures; system resources R_{sm} , for example, funds allocated for the purchase of computing equipment; system parameters B_{sm} , for example, timing, cost characteristics and other restrictions imposed on the system. K_l includes, among other things, at certain stages, information about data structures (canonical, logical, physical). For the sites of scientific agricultural organizations and universities with a large number of homogeneous information resources, it is of great importance to solve the following problem: by choosing appropriate design tools C_{II} during the design operation, achieve the specified values of the characteristics of the sites, including the requirements for information security, $D_{sm} \subset D_o$. In practice, this requirement is more often represented in the form:

$W_{sm}^3(\Pi_o) \leq \sum_{p \in C_{II}} \min W_{sm}^1$, $W_{sm}^3(\Pi_o) \leq \sum_{q \in C_{II}} \min W_{sm}^2$, where W_{sm}^n - site costs: for individual design ($n = 1$), site costs for standard design ($n = 2$) and automated ($n = 3$); Q - many classes of typical sites.

In accordance with the above, we will analyze the software used by the websites of agricultural scientific organizations for the fundamental possibility of integrating these sites without switching to some standard set (digital standard), for which a free plugin called Wappalyzer (<https://wappalyzer.com/>). This plugin is installed as an extension to almost all types of popular browsers, and allows, when you go to a specific site, immediately see which software in the form of a web application (VA) is used on this particular site.

In total, 954 different cases of use of 86 types of VA were found on 185 websites of agricultural scientific organizations. According to VA types, all 954 detected cases of their use are divided into 25 software classes, a list of which with a description of their use is given in tab. 1.

TABLE I. DESIGNATION AND BRIEF DESCRIPTION OF THE FUNCTIONS OF SOFTWARE CLASSES

Cod e	Software class designation	Brief description of software classes functions	Numbe r
1	JavaScript frameworks	Website page design (client technology)	183
2	Web server	Server on which the site is launched	180
3	Analytics	Website visit tracking systems	145
4	Programming language	Language used in the site	128
5	CMS	Automated content management systems (technology server)	92
6	Font set	Additional page generation fonts	61
7	Web frameworks	Similar to item 1, but only for the Internet	45
8	operating system	Operating system the site is running on	40
9	Blog	Special kind of CMS for diaries	21
10	Widgets	Display of small program inserts on the site	12
11	Creation program	Website creation VP (technology server)	7
12	wappalyzer_title_web	Built-in Wappalyzer	6
13	Hosting panel	VA for managing site content	6
14	Video	Video for display on the site	5
15	Advertising network	VA for displaying ads on the site	4

16	Marketing	Automation tools on the site	3
17	Map	Means of displaying maps on the site	3
18	Photo gallery	VA for displaying images and / or photos on the site	3
19	Internet shop	Online sales management	2
20	Kesh	VA for caching site pages	2
21	miscellanea	VA not included in any group	2
22	CDN	VA for fast delivery of page content	1
23	Javascript graphics	Same as item 1, but graphics (technology client)	1
24	Database	Database used on the site	1
25	Mobile framework	VA for creating a mobile version of the site	1

As follows from tab. 1, two software classes are leading by a wide margin: "Java-script frameworks" and "Web servers" (183 and 180 use cases, or 19.2 and 18.9 %% of the total). Classes "Statistics" and "Programming languages" are also quite widely represented on the websites of scientific organizations (145 and 128 use cases, or 15.2% and 13.4% of the total number on software sites). For a comparative analysis of the found software with the software of universities, we will give a detailed composition of the most important classes of universities. Those interested in a more complete analysis of all software are referred to work [9].

TABLE 2. PRESENTATION OF SOFTWARE IN THE "CMS" CLASS

No	Name	Number	% of the total number of sites
1	Joomla	40	43,5
2	WordPress	21	22,8
3	1C-Bitrix	9	9,8
4	uCoz	6	6,5
5	Drupal	5	5,4
6	TYPO3 CMS	3	3,3
7	MODX	2	2,2
8	Amiro.CMS	1	1,1
9	Concrete5	1	1,1
10	DataLife Engine	1	1,1
11	MaxSite CMS	1	1,1
12	October CMS	1	1,1
13	Orchard CMS	1	1,1
TOTAL		92	100,0

Taking into account the fact that only the third and last CMS are commercial, we can state the fact that the websites of agricultural scientific organizations work in the vast majority under the control of free CMS. This, of course, speaks of the low level and quality of these sites more than eloquently.

TABLE 3. PRESENTATION OF SOFTWARE IN THE CLASS "WEB FRAMEWORKS"

No	Name	Number	% of the total number of sites
1	Twitter Bootstrap	29	64,4
2	Microsoft ASP.NET	7	15,6

3	UIKit	3	6,7
4	CodeIgniter	2	4,4
5	Django	1	2,2
6	Django#ZURB Foundation	1	2,2
7	Laravel	1	2,2
8	ZURB Foundation	1	2,2
TOTAL		45	100,0

As follows from the table, the almost exclusive use of the first software in the list (2/3 of sites) is explained by the high popularity of this software in the world, as well as its free.

TABLE 4. PRESENTATION OF SOFTWARE IN THE CLASSROOM "ANALYTICS"

No	Name	Number	% of the total number of sites
1	Yandex.Metrika	77	53,1
2	Liveinternet	43	29,7
3	Google Analytics	25	17,2
TOTAL		145	100,0

The analysis showed that out of 185 sites on 77 sites (41.6% of the total) this class of software is not used. This means that either these 77 sites use very rare statistics accounting systems, that they are simply unknown to the Wappalyzer system, or the owners of these sites simply do not need statistical information about their sites and / or are not interested.

CONCLUSION

Analysis of the software of the sites of agricultural scientific organizations showed that none of them uses database management systems when creating sites, which, along with the absence of certain standards for software for developing sites and too great a variety of it, postpones the prospect of creating a single information Internet space for scientific research. - educational resources.

ACKNOWLEDGMEN

This work was supported by RFBR (grant № 20-07-00836)

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INFLUENCE OF THE SOFTWARE FOR THE DEVELOPMENT OF SITES OF AGRARIAN UNIVERSITIES ON THE INTEGRATION PROCESSES OF FORMING A UNIFIED EDUCATIONAL ENVIRONMENT

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Abstract— This paper analyzes the software used by the websites of agricultural universities for the requirements of the digitalization of education, both for the integration of information resources and systems, and for the compatibility of software to form a single digital platform. It is shown that such a single digital platform is due to the need for scientific and educational resources not only for traditional users, such as researchers, students and teachers, but also for future applicants and employers, government agencies, commodity producers, business, management, and other categories of the population. It is shown that the absence of digital standards for this software, leading to a wide variety of it, makes it impossible to form a single digital platform for scientific and educational resources.

Keywords: website software; scientific and educational resources; education, agriculture.

INTRODUCTION

The need to form a unified information Internet space of scientific and educational resources (EIIPNOR) in connection with the coronavirus epidemic, which forced students to transfer to distance learning, and employees of organizations to work remotely, led to the transformation of this problem from a purely theoretical format at conferences and in scientific journals into a practical plane. At the same time, the ever-increasing pace of the introduction of digital technologies into the economy and public life requires a significant number of highly qualified workers, retraining of many specialists, a radical renewal of both production and management, and a transition to digital management methods. In this situation, science, together with education, should offer scientifically grounded advanced digital technologies that are ahead, both in time and in efficiency, spontaneous, chaotic, non-complex technologies offered by the

market. Otherwise, we will soon hear many critical comments about the unfulfilled hopes for the digital economy.

This paper discusses the possibility of forming an EIIPNOR on the example of agriculture, based on the state and comparative characteristics of the software for the development of websites of universities that make a significant contribution to this space, since scientists of educational organizations are actively involved in scientific research. So, the analysis of publication activity in agricultural research institutes and universities showed an almost equal number of works among them.

PROBLEM STATEMENT

Recent events related to the pandemic have become a serious reason for rethinking the need for transformation of the world and Russian educational process. The crisis prompts the discussion of a new strategy for the development of digitalization of Russian education and science, which are closely related to each other, as it is fashionable to say now, which are in complementary relations. To bring these important areas in line with new challenges, it is required to carry out their systemic transformation towards the creation of a modern competitive scientific and educational environment. Of all the basic general principles of digital transformation of all sectors of the world economy [1] for education and science, the most important is: the creation of an information management system, i.e. collection, processing, storage and distribution of the necessary data in a form adapted to the daily activities of organizations, based on the widespread integration of disparate data into a single system. EIIPNOR perfectly satisfies this principle.

In addition to solving the immediate problems of universities that have arisen due to the pandemic, in the form of joining efforts to invest in new distance educational technologies, organizing their remote functioning as management objects, creating fundamentally new content, retraining teaching and administrative and managerial personnel associated with a narrowing of the financial base (income) of educational organizations, there is a chance to solve problems with the unification of information scientific and educational resources (INOR) in a single cloud database, performing a triune role: support of scientific research, raising the level of education (sometimes retraining) for all segments of the population, an effective system of transfer of scientific - educational knowledge into the economy due to unlimited access to this knowledge not only for traditional users in the person of researchers, students and teachers, but also, as indicated in [2], future applicants and employers, government agencies, spruce trees, business, management, and other categories of the population. Such a space will also allow solving the problem of extracting the necessary knowledge due to the exponential growth of information volumes in recent years.

The economic rationale for this is the so-called "Brooks Square" (Fig. 1) [3].

This work provides research on the costs of developing a software product. In order for a program developed on the basis of the original design and suitable for launch only by its author on the system on which it was developed, it turns into a software product that anyone can launch, test, fix and develop, threefold costs are required. To integrate a program into a software package, which is a set of interacting programs, coordinated in functions, formats and interfaces, three times the costs are also required in comparison with the original program. Then the cost of developing a software product, which is replicated and integrated with other software products into some information system (IS), is about an order of magnitude higher than the cost of development during the original design. Consequently, when investing in the development of complex ISs when implementing them, starting from the second ten enterprises, the level of self-sufficiency of development will be achieved.

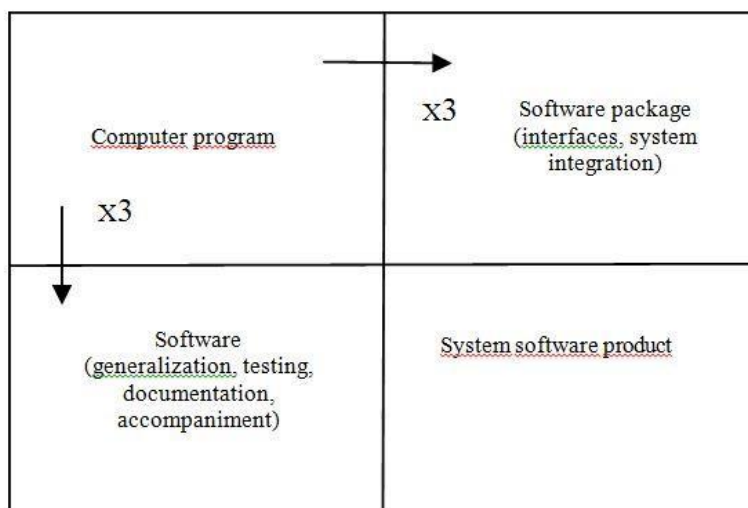


Fig. 1 Brooks square

SOLUTION OF THE PROBLEM

At the same time, a significant role in the integration processes, in addition to information resources (IR) and information systems (IS), is played by the third component in the form of website development software. This is a consequence of one of the basic general principles of digital transformation of world social development, which was mentioned above, and which requires the development of digital standards for all three main axes of the project space of information systems, which are the basis of such a transformation [4]. Universities in this case are no exception (Fig. 2).

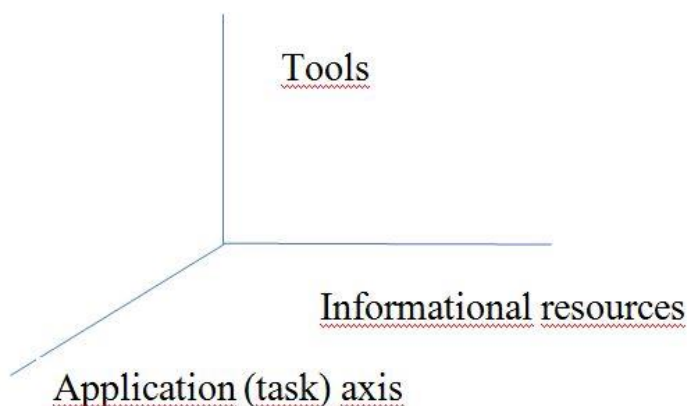


Fig. 2 Project space of information systems

Analysis of 54 sites of agricultural universities allowed us to identify 395 types of software, which can be combined into 16 different classes (tab. 1).

TABLE I. DESIGNATION AND BRIEF DESCRIPTION OF THE FUNCTIONS OF SOFTWARE CLASSES

Cod e	Software class designation	Brief description of software classes functions	Number
1	CMS	Automated website content management	54
2	JS framework	Website page design	94
3	JS graphics	Graphics on site pages	12

4	Analytics	Information about the site	56
5	Web server	Server on which the site is launched	57
6	Web framework	Similar to item 3	24
7	Video player	Services for displaying video on the site	5
8	Widget	Show small program inserts	4
9	Map	Displaying geographic maps on the site	1
10	Mobile framework	Creating a mobile version of the site	1
11	OS	Operating system running the site	27
12	Other	Software not included in other groups	3
13	Web Server Extension	Additions to clause 5 for specific needs	4
14	Advertising network	Organization of advertising on the site	1
15	Font	Additional fonts	17
16	Programming language	Language used in the site	50

As follows from tab. 1, the most significant class is the "JS framework" class, which includes 94 representatives (23.8% of the total number of all software from 54 sites). Next, with a significant number are classes of software "Analytics", "Web server" and "Programming language". In the middle of the list are the software classes "CMS", "Web framework" and "Operating system". The remaining classes are represented by a small number of their representatives. Based on this, we will give a detailed composition of the most important classes. Those interested in a more complete analysis of all software are referred to work [5].

TABLE 2. PRESENTATION OF SOFTWARE IN THE "CMS" CLASS

No	Name	Number	% of the total number of sites
1	1C-Bitrix	17	31,5
2	DataLife Engine	1	1,9
3	DNN	2	3,7
4	Drupal	1	1,9
5	InstantCMS	1	1,9
6	Joomla	16	29,6
7	OpenCms	1	1,9
8	"no data"	15	27,8
TOTAL		54	100,0

As follows from tab. 2, with a slight advantage CMS "1C-Bitrix" was in the lead (31.5% of the total number of sites). Next comes the CMS "Joomla" (29.6% of the total number of sites). The third position is occupied by the indicator "no data", which indicates that the so-called. "Self-written" CMS, or very rarely used CMS, which is impossible to determine. All other CMS listed in tab. 2, occur a small number of times (1-2 times). These CMSs are unfamiliar with the exception of the CMS "Drupal", which is fairly well known and widespread in the academic environment. However, it has no distribution in agricultural universities. Note that the commercial CMS 1C-Bitrix is one of the most popular in the country, and at the same time the most expensive to support. Joomla is one of the most popular non-commercial CMS.

The class of software "JS-framework" (tab. 3) is the most numerous, found on the sites. The reason for this is quite simple: this software is currently in great demand, since it allows you to present information on the pages of the site at low cost in an attractive way.

TABLE 3. REPRESENTATION OF SOFTWARE IN THE CLASS "JS-FRAMEWORK"

No	Name	Number	% of the total number of sites
1	ExtJS	1	1,9
2	jQuery	49	90,7
3	jQuery UI	9	16,7
4	Lightbox	3	5,6
5	Modernizr	3	5,6
6	MooTools	15	27,8
7	Select2	1	1,9
8	Slimbox	3	5,6
9	spin.js	9	16,7
10	Twitter typeahead.js	1	1,9
TOTAL		94	-

As follows from tab. 3, jQuery JS framework is used on 90.7% of sites. Currently, this software is the main universal JS tool that provides access to DOM objects of web pages for working with panels, drop-down menus, etc., animation effects, image galleries, etc. On a significant number of sites (27, 8%), the MooTools JS framework is used, which is close in functionality to JQuery, which is why it is also a fairly popular framework. The JS framework spin.js is growing in popularity, which, however, has very limited functionality (working with the so-called "spinning" - animated indicators of activity on a web page). The remaining JS frameworks are used on the websites of agricultural universities occasionally and in isolated cases.

TABLE 4. PRESENTATION OF SOFTWARE IN THE CLASSROOM "ANALYTICS"

No	Name	Number	% of the total number of sites
1	Google Analytics	12	22,2
2	Liveinternet	9	16,7
3	Yandex.Metrika	35	64,8
TOTAL		56	-

As follows from tab. 4, Yandex.Metrika is the undisputed leader in the Analytics software class, followed by Google Analytics. Closes the LiveInternet class. At least one type of analytical software is presented on 44 sites out of 54 (81.5% of the total number of sites), two types of software from the Analytics group are presented on 12 sites out of 54 (22.2% of the total number of sites).

CONCLUSION

On the websites of leading agricultural universities, the CMS standard for site management has been de facto established - this is 1C-Bitrix. This CMS is integrated with a number of powerful DBMS. However, studies have shown that not a single university uses a DBMS when creating sites, which, along with the absence of certain standards for software for developing sites, its wide variety, makes it impossible to automatically receive information from the site for use in other IS, including, in the IS of the Ministry of Education and Science of Russia

and postpones the prospect of creating a unified information Internet space for scientific and educational resources.

ACKNOWLEDGMEN

This work was supported by RFBR (grant № 20-07-00836)

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EXPERIENCE IN APPLICATION OF INTERNET TECHNOLOGIES FOR REMOTE WORK ON SCHOOL SCIENTIFIC PROJECTS IN THE CONTEXT OF UNIVERSITY-TO-SCHOOL INTERACTION

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Abstract — Remote work of universities with secondary school students is very important for to get students right vision of their future profession, to gain experience in participating scientific and technical projects, to broaden their horizons. This kind of work is important not only for schools but also for universities, it allows to identify students who are interested in subject of the university, who are able to perform scientific and research work. In the digital age it is very important to teach secondary school students to use digital Internet technologies for performing work on projects. It is especially important to be able to apply such technologies if the university is located at a considerable distance, in this case implementation of such kind of Internet resources is the only way to successfully execute and present scientific projects giving children the opportunity to prove themselves at such an early age. This paper is about our experience in performing remote research work of the secondary school with the university and observation of internet resources and technologies that were used.

Keywords: internet technologies; school projects; remote work; project management.

INTRODUCTION

Profession-oriented engineering classes alongside with a country-wide acceptance of school scientific projects and deliverables presentation testify to the growing interest in career guidance training at secondary schools of the Russian Federation. There are different methods to translate these initiatives into action, among them:

- additional academic hours in Mathematics, Physics, Chemistry and other sciences;
- encouragement of project-based learning or research activities of schoolchildren;
- organization and running of various career guidance events at the universities;
- training of schoolchildren for various Science and Technology Conferences, academic competitions, etc.

In addition, there is a number of activities, which are implemented in certain regions only, not country-wide, some of them are developed and introduced by particular universities. For illustrative purposes, mention can be made of such initiatives as “Moscow School’s Engineering Class”, “Phystech Classes” at Moscow Institute of Physics and Technology (MPTI), “Special Preparatory Class” at Tomsk State University of Control Systems and Radioelectronics (TUSUR), “Center for Work with Gifted Children” at Tver region and many others. Some of these initiatives, for instance “Moscow School’s Engineering Class”, provide educational programs for both schoolchildren and teachers.

Of all the activities considered, scientific and research projects for schoolchildren is the best way to inspire interest in scientific activities. Participation in such projects is critical not only in terms of research practice and solving of real-life problems, but also in terms of gaining experience in public presentation of project results.

PRACTICAL DIFFICULTIES

Judging from project work experience, the schoolchildren are most interested if the project scope is related to real scientific research and real-life scientific problems that are dealt with at enterprises or in research laboratories of institutes and universities of our country. Such projects allow schoolchildren, first of all, to get a vision of what they will have to do if they opt for a technical professional qualification and, in the next place, to gain experience of working on real projects and facing the challenges of modern science.

On the other hand, the implementation of such projects is complicated from the point of view of ensuring proper interaction between scientific supervisors and students performing the project. This problem is especially acute if the school is not located in the same city as the University and the University teachers involved in the project. High School No. 7 in Torzhok with its School Center for Gifted Children is an illustration of the described situation. The schoolchildren of this Center have been successfully presenting their projects at regional and all-Russian Olympiads and conferences for many years. The Center interacts with the nearest major technical universities, one of which has the status of a National research University (for location see the map in Fig. 1). The map proves it might be hard to arrange physical presence of the University teachers to the extent necessary for effective project work. That is why the management of such research projects requires modern Internet technologies that allow for remote interaction between project managers and schoolchildren involved into the project under the supervision of schoolteachers, responsible for project activities.

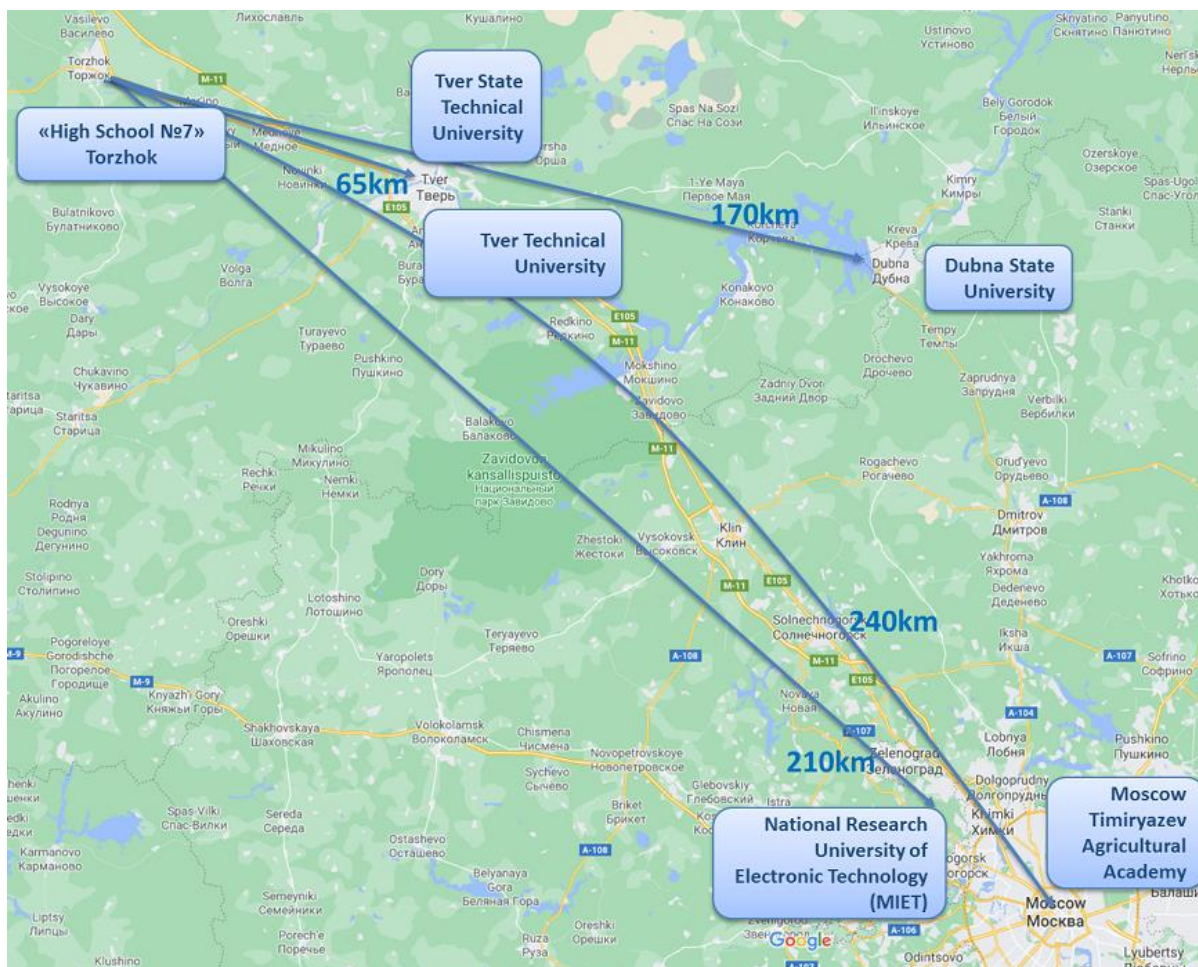


Fig. 1 The location of educational institutions

This paper deals with the approaches we implemented and the results of research projects delivered by the schoolchildren of the Municipal Budgetary General Education Institution “High School No 7” in the context of online project management under the guidance of research workers from the National Research University of Electronic Technology (MIET), Zelenograd, Moscow district.

OVERVIEW OF SOFTWARE TOOLS FOR REMOTE TEAMWORK

Nowadays we actively use various software applications and tools for remote interaction in everyday life. Examples of such programs are instant messengers (Viber, WhatsApp, Telegram, Skype, etc.), electronic mail, and various social networks (Vkontakte, Facebook, Instagram, Twitter and others). Even cell phones provide an opportunity to communicate remotely via voice calls and text messages. However not all of the mentioned options are suitable for managing scientific and research or research and practice projects.

There are 5 criteria to decide if a certain software tool(s) is (are) suitable for remote project work:

1. an option to provide the impression of a “physical presence” to discuss project details via audio and video, including the communication of several participants at the same time;
2. an option to demonstrate presentations/desktop/an imitation of the board to illustrate the ideas and to prepare speeches;
3. project planning option with a breakdown by tasks and persons responsible for task fulfillment in case there are several people working on the project;

4. an option to supervise the work performance and the progress of project tasks fulfillment;

5. a shared access to project materials (at least to materials in electronic form – documents, presentations, relevant files) to ensure team work.

Zoom [1] and FreeConferenceCall [2] are the most popular means for immersive collaboration via video conferencing today. These programs, unlike, for example, Skype and Discord, have the functionality to effectively demonstrate presentations.

Since the scientific and practical works of secondary school students are focused on the topics directly or indirectly related to the program code development, we conducted a review of various project management tools for software development [4-7]. In our experience, Trello [8] Mastertask [9] appeared to be the most user-friendly.

All the products reviewed above grant an opportunity to work online via a browser and have versions for mobile applications and desktop computers.

EXPERIENCE IN APPLICATION OF SOFTWARE PROGRAMMS

Despite a number of limitations (limited number of participants and duration of video conferences in a free version), Zoom has significant advantages [3] over FreeConferenceCall. Examples of these advantages include session rooms and an option to use graphical drawing tools during a presentation. This feature is critical, because it helps to increase interactivity when demonstrating project materials and allows to explain complex issues in a flexible way, replacing convenient conventional markerboards or chalkboards while working online.

While the choice of videoconferencing tools was obvious, it was more complicated to decide about the tools for project management, follow-up and progress tracking. All the considered products (both MeisterTask and Trello) have a convenient graphics-based environment (Fig. 2), allow you to divide a project into tasks, assign task performers, set the deadlines and people responsible for specific tasks, and many other features.

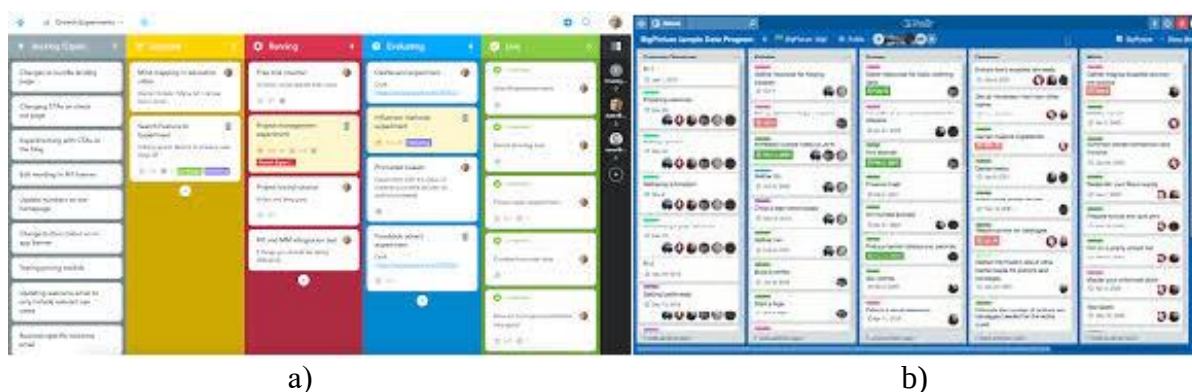


Fig. 2 MeisterTask (a) and Trello (b) User Interfaces

Due to external factors we opted for MeisterTask, since it has, in our opinion, a more user-friendly graphical user interface, its own “desktop” displaying a progress report for all ongoing projects and an option to log in MindMeister [10], a “mind mapping” tool, which interface is shown in Fig 3, with the same account details.



Fig. 3 MindMeister User Interface

Mind mapping tools allow creating a graphical representation of the project structure and the hierarchy of subtasks to solve the higher-ranked problems.

Fig.4 displays the format of the task card in Mastertask using the example of a project task for modeling the behavior of a charged particle beam in modeling the processes of electron-beam lithography.

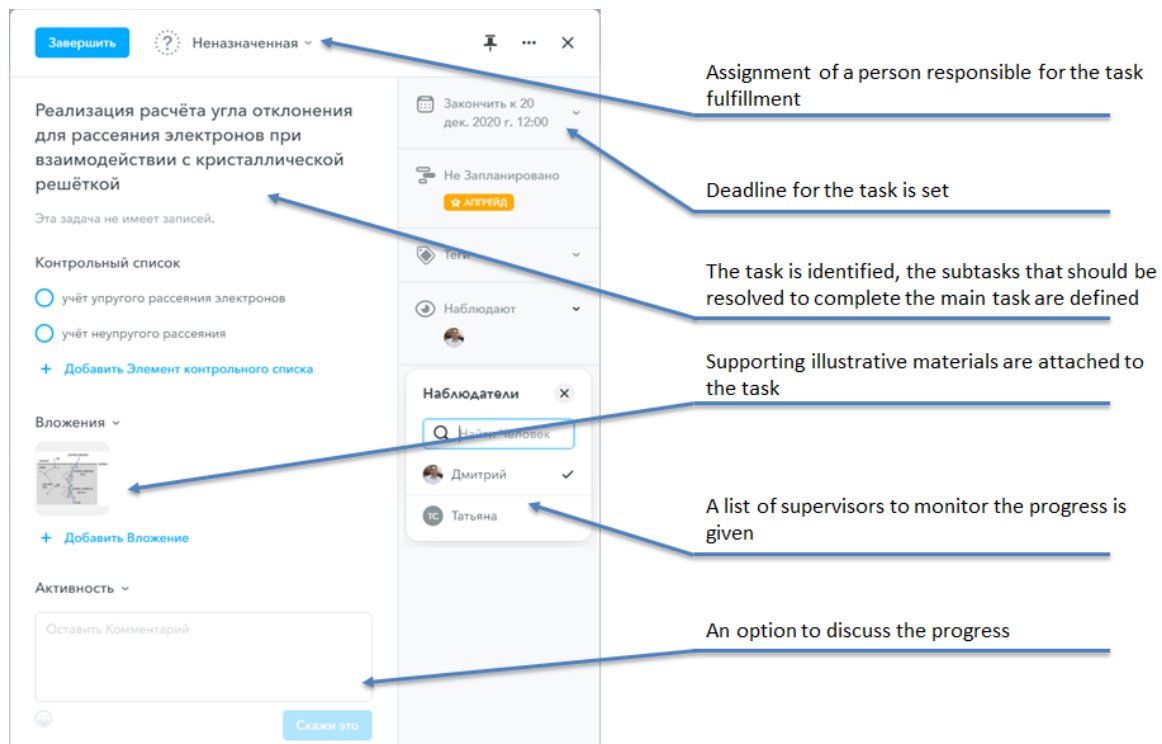


Fig. 4 MeisterTask Task Card

Interaction of the project manager from the university, the schoolteacher in charge and the student, engaged in the project work was arranged by analogy with Agile project management methodology [11] and is shown schematically in Fig. 5.

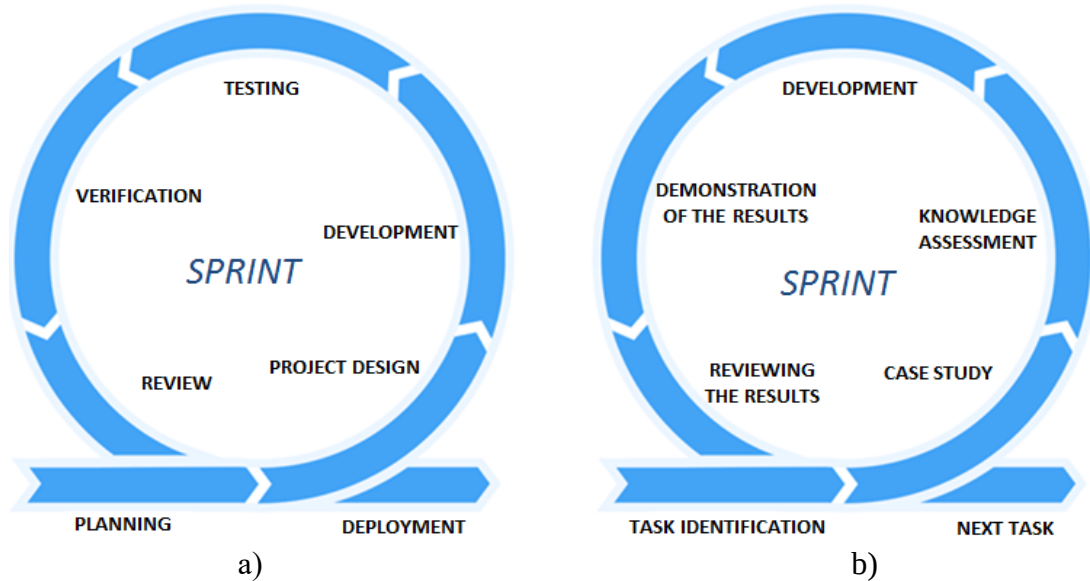


Fig. 5 Agile project management methodology (a) compared to the project management methodology adapted for schoolchildren (b)

Generally, two types of sprints are used for scientific and practical projects: one for hardware and another one for software development. For a purely software development project, only one type of sprint is used. The areas of responsibility within each sprint are distributed as follows:

- *task identification* – in online mode – a supervisor from the University;
- *case study* – in offline mode – a student (supported by a responsible schoolteacher);
- *knowledge assessment* – in online mode – a student demonstrates his/her knowledge of the project-related material to the University supervisor and to the responsible schoolteacher;
- *development* – by a student (with online help from the University supervisor);
- *demonstration of the results* – in online/offline mode – a student demonstrates the results of the software and hardware development to the University supervisor and to the responsible schoolteacher;
- *reviewing the results* – in online/offline mode – discussion of project performance and project activities for the long run.

A UML-activity diagram with a month-by-month breakdown of the project scope with an indication of the applied software tools is shown in Fig. 6.

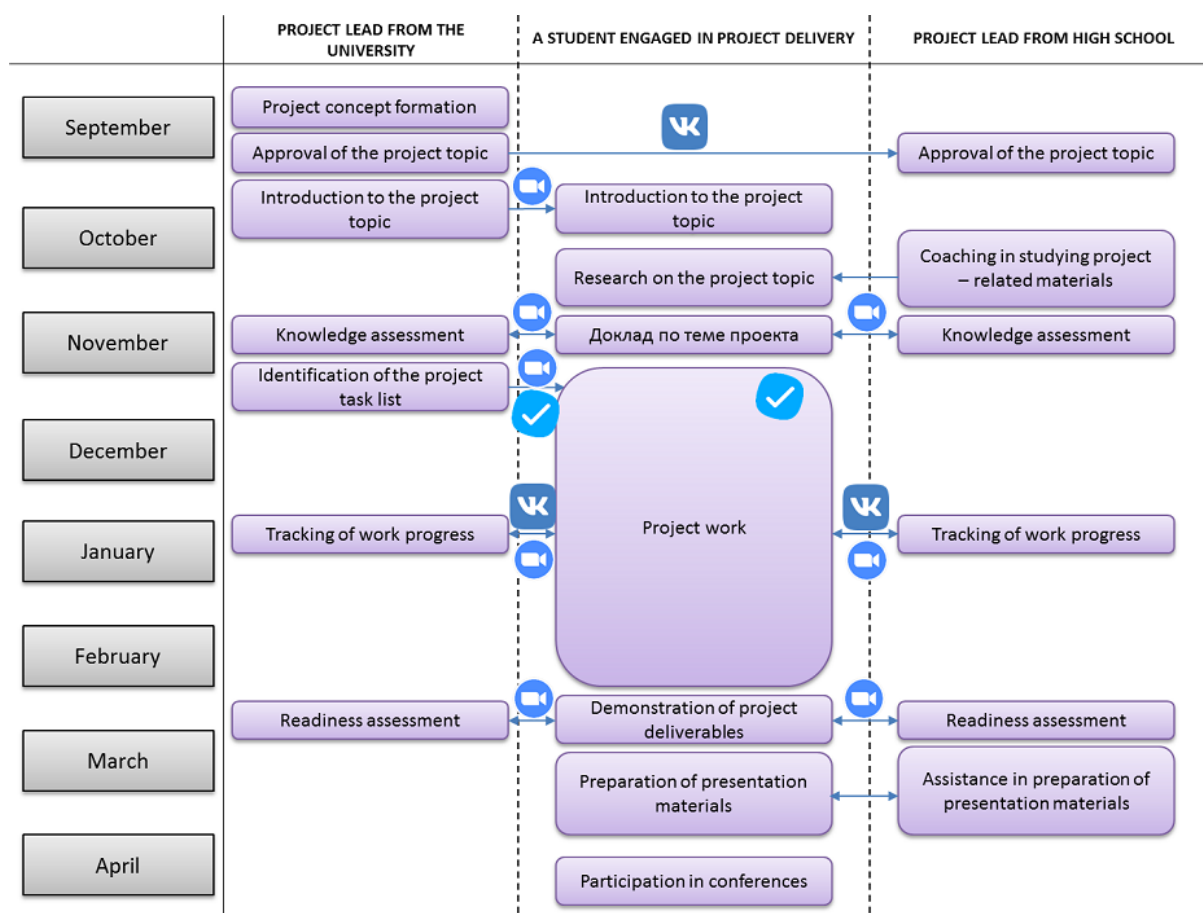


Fig. 6 Activity diagram with a month-by-month work breakdown structure

CONCLUSION

A similar mechanism of interaction was developed, implemented and tested over a two-year period of joint project work under the leadership of the teaching staff of the Municipal Budgetary General Education Institution “High School No 7” in cooperation with the faculty staff of the National Research University of Electronic Technology (MIET), Zelenograd, Moscow district.

After the project close, the deliverables were successfully presented and awarded at various conferences and competitions, for instance, at the all-Russian competition of youth research works named. V. I. Vernadsky, scientific and practical conference “Scientific Creativity of the Young”, the regional conference on natural sciences for schoolchildren held by Dubna State University.

The specified Internet technologies used for remote work on research and scientific & practical projects of schoolchildren have proved remarkably effective and easy-to-use. The application of such technologies allowed to involve the higher-education teaching personnel into project management and expand the scope of school projects up to the challenging issues of contemporary science and technology.

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TEACHING THE FUNDAMENTAL BASES OF ARTIFICIAL INTELLIGENCE AS THE IMPLEMENTATION OF THE CONCEPT OF NEW SCIENTIFIC KNOWLEDGE

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Abstract — The paper examines the current situation of the development of society, when it came close to the perception of methods and means of Artificial Intelligence (AI) in everyday life as the implementation of the principles of new scientific knowledge (teaching), based on the foundation of Data Science. The author's concept of constructing educational trajectories for training specialists in the field of AI is offered.

Keywords — Artificial Intelligence, Higher Education, Data Scientist, Data Engineer, Data Analyst.

INTRODUCTION

Today, human society has reached that turning point in the history of the development of artificial intelligence (AI), when the technologies being created moved from the field of theory to the "real world", that is, they became available to almost all sectors of the economy. This shift is all-encompassing, but at the same time poses many new problems, since it combines the complexities of using AI with the complexities of organizing human activities, of which there are many. For the adequate use of new algorithms, it is required to prepare a whole class of specialists who are able to coordinate all aspects of the life cycle of AI-controlled production and social processes with the development and improvement of scientific, economic and social models, their introduction into human activities, their monitoring and control.

PROBLEM STATEMENT

AI was born in the 1950s. There are two main eras of AI research, 1974–1980 and 1987–1993, but at the time, the high level of enthusiasm for the application of AI technologies fell short of expectations – there were splashes of hype followed by disappointment, which led to a

decrease in research funding, loss of interest in the further development of AI. Of course, there are serious concerns now about how the future of AI (and its social implications) will shape. The short answer will most likely be this: due to the much larger (and very large) amount of actual data and the emergence of processors of extremely high computing power (as well as graphics processors – GPUs), the next winter of artificial intelligence should not be expected. Today, when processing zettabytes (ZB) data, very high accuracy of AI algorithms is achieved in various spheres of human activity: from smartphones to the ever-expanding role of the Internet of Things. More than 59 ZB data were generated in the world in 2020. At the same time, data are generated at a five-year CAGR of 26% [1], so the field of AI applications is expanding at an incredible rate.

AI in the modern sense is a fairly broad concept that actually combines several different concepts. In English, the conception "Artificial Intelligence" does not have the anthropomorphic coloration that it acquired in the traditional Russian translation: the word "Intelligence" in the context used rather means "the ability to reason reasonably" rather than "Intellect" (for which there is an English term – "Intellect"). There are various definitions of Artificial Intelligence as a field of research and production activities of society. Within our sphere of interest, we define this area as follows:

"AI is a scientific area within which the tasks of hardware or software modeling of those types of human activity that are traditionally considered to be intellectual are formulated and solved." AI is a complex discipline that is both a form of intelligence, a type of technology and an area of scientific research, and does not imply an explicit immersion in the creation of complex software codes.

Today, no one doubts that the success in the development of the country's economy, especially in its digitalization, is to a very large extent associated with the introduction of AI technologies. In this regard, a fundamentally new task of integrating AI into all sectors of the economy, literally in all areas of our life, arises. This is very difficult. Science is faced with a task that is unrealistic to solve within the framework of any one direction. The development and widespread introduction of AI technologies is a goal that can only be achieved by serious advances, both in Computer Science and Information Technology, in Data Science, in Machine Learning, and in Brain Physiology, Psychology, Ethics, Philosophy and Law. Significant achievements in this area can be made only by united teams of scientists at the intersection of different disciplines. But this is only one side of the problem.

Its other side is the lack of ready multidisciplinary specialists. To meet the challenges of developing AI technologies, for example, in the medical field, computer scientists must understand physiology, and physiologists must understand computer science. We understand this well and believe that universities need to develop scientific and educational programs, according to which students will learn everything they need for their further successful career in the chosen field, as well as participate in the development of real projects (for example, in student constructor bureaus). These tasks are now being solved at our university within the framework of the recently organized scientific and educational school "Brain, Cognitive Systems and Artificial Intelligence", which unites groups of researchers and teachers from a number of faculties and institutes of Moscow State University.

In our scientific and educational activities, we accept a paradigm shift in building the educational trajectory of future AI specialists. Namely, we believe that society has come close to perceiving the methods and means of AI in everyday life as the implementation of the principles of new scientific knowledge (doctrine) based on the following foundation (the theses of the authors' conceptual approach are outlined in [2]).

The basis of the doctrine is Data Science, data representation, storage, transmission and analysis, as a conceptual basis for models of life processes.

The meaning of the doctrine is the comprehension and presentation of life processes in a scientific, digital form, focused on further analysis and control of processes, both in natural and in systems created by people using advanced AI tools.

The mission of the doctrine is the successful solution of various tasks of human activity by methods and means of Artificial Intelligence, based on the achievements of Data Science, as a fundamental basis.

Missionaries (AI science and technology evangelists) are Data Scientists, AI specialists.

Knowledge transfer tools are highly advanced data processing environments such as Python with many module libraries and other easy-to-use data processing, presentation and analysis tools.

The scope of the doctrine is the total training of representatives of all kinds of human activity in the basics of AI, the widespread introduction of standard methods and tools. Training of scientists and engineers involved in the development and application of AI tools.

We will try to substantiate the need for a new conceptual perception in building the educational process of future specialists. Currently, the following classification of specialists working in the field of AI has been adopted [3]:

- Data Scientist;
- Data Engineer;
- Data Analyst;
- Software Engineer.

To these four main roles, we need to add the roles required to bring AI tasks to production:

- Operations and Development Specialist (DevOps);
- Risk Manager / Auditor (Model Risk Manager/Auditor);
- Data Architect (Machine Learning Architect).

Even taking into account a certain blurring of boundaries in the activities of these specialists, it can still be argued that both educational standards and their practical training should be different. Let's consider some aspects of the future activities of such specialists.

Data Scientists.

The needs of the Data Scientist are the most important – they need to be considered when building an AI implementation strategy. Data Scientists in most organizations today often deal with disparate data, processes, and tools, making it difficult to effectively scale their efforts. While most experts see the role of Data Scientists in the lifecycle of machine learning models as just part of building a model, this role should be much broader. From the outset, Data Scientists need to connect with subject matter experts to understand and help frame business problems so that together they can create a viable AI solution.

Data Engineers.

Data pipelines are at the heart of the life cycle of manufacturing process models, and Data Engineers, in turn, form the backbone of data pipelines. Because data pipelines can be abstract and complex, Data Engineers can greatly improve the efficiency of AI. In large organizations, data flow management, in addition to managing the manufacturing processes themselves, is an ongoing job.

Data Analysts.

The roles of a Data Scientist and Data Analyst have a lot in common, but the former usually requires deeper knowledge and experience in mathematics (linear algebra and multivariate calculus), as well as more advanced technical skills.

Data Analysts are concerned with extracting relevant data from various sources and preparing it for further analysis. Based on the analysis, the Data Analyst must draw conclusions, fill out reports and support them with visual effects. Along with the reports, they should explain what the differences in numbers mean as viewed from month to month or for different audiences. The bulk of the work of Data Analysts is focused on analyzing and describing past or previous strategies based on past or current data.

Software Engineers.

It would be easy to exclude classical Software Engineers from consideration of the field of development of AI methods, but from a broader organizational point of view, it is important to consider their needs in order to build a unified corporate strategy for implementing AI.

Software Engineers usually do not create models of AI-driven processes, but on the other hand, most organizations create not only such models, but also classic software and applications. It is important that Software Engineers and Data Scientists work together to make the larger system work. After all, AI models are not just individual experiments – application code, training, testing, and deployment must match the continuous integration / continuous delivery (CI / CD) pipelines that the rest of the software uses.

Operations and Development Specialists (DevOps).

The development of AI tools is based on the principles of DevOps, but this does not mean that they can work in parallel as completely separate and disparate systems. DevOps teams play two main roles in the lifecycle of an AI model.

The first are the people who run and build operating systems and tests to ensure the safety, performance, and availability of AI models. Second, they are responsible for managing the CI / CD pipeline. Both of these roles require close collaboration with Data Analysts, Data Engineers, and Data Architects.

Model Risk Managers/Auditors.

In certain industries (especially the financial services sector), the Risk Management Model (MRM) function is critical to regulatory compliance. But not only highly regulated industries need to be affected or have a similar function, MRM can protect companies in any industry from losses caused by poorly performing AI models.

Moreover, auditing plays an important role in many industries. When it comes to the lifecycle of an AI model, Risk Managers play a critical role in analyzing not only the outcomes of the model, but also the underlying goals and business issues that the AI models seek to solve in order to minimize the overall risk to the company. They should be brought in together with industry experts early in the lifecycle to ensure that an automated AI approach is not in itself risky.

Data Architects (Machine Learning Architects).

Traditional Data Architects are responsible for understanding the overall architecture of an enterprise and ensuring that it meets the data requirements of the entire business. They usually play a role in determining how data will be stored and used. Today, the requirements for Architects are much higher, they often need to be aware of not only the intricacies of storing and consuming data, but also how machine learning models work in tandem. This complicates their role and increases their responsibility in the life cycle of AI assets.

SOLUTION OF THE PROBLEM

As we can see, the field of AI itself is multi-level, in each layer specific tasks are solved. Therefore, the training of AI specialists should be singled out as an independent scientific and educational area, at the foundation of which is, first of all, Data Science along with adjacent areas

of knowledge. The implementation of this idea in one form or another is carried out in a number of leading universities in the world (see, for example, [4]).

The problems of teaching students “Data Science” and training a “Data Scientist” have their own specifics for classical universities that train specialists in the framework of academic higher education programs. Many works of Russian and foreign scientists are devoted to the consideration of options for its solution. It is also interesting to note that, in addition to the well-established, formed areas, curricula are now being developed directly for “Data Science” [5].

CONCLUSION

Having considered (albeit incompletely) the range of activities of specialists in the field of AI, we come to the conclusion that, despite the conventionality of the boundaries of their spheres of activity, it is necessary to take into account the further specialization of graduates in the learning process. Different educational trajectories need to be developed for different professionals without trying to train “generalists” in the field of AI. Of course, in the future, specialists can change the profiles of their activities, but in the learning process, it is necessary to train specialists of various profiles in independent educational programs. And the subject saturation of these programs must be carried out taking into account the new educational paradigm.

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TOWARDS A METHOD FOR DETERMINING SIGNS OF AUTHOR STYLE FOR TEXTS IN RUSSIAN

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Abstract — This paper is devoted to the determination of the authorship of texts in Russian. The subject area is considered, and the results of its analysis are presented. The stages

of processing of texts in natural language are studied. The existing methods for solving the problem are presented. The article also describes the main provisions that formed the basis of the proposed method.

Keywords — natural language processing, text analysis, tokenization, normalization, text classification, morphological analysis, N-grams.

INTRODUCTION

First of all, it can be noted that the described problem lies in the field of computational linguistics [1]. This area is currently actively developing. This is largely due to the fact that every year the amount of text information used by humanity is increasing, therefore, the need for more efficient algorithms for processing and analyzing documents written in natural languages is growing. The growing number of available textual data sources, such as blogs, posts on social networks, etc., has a great impact on the development of text mining methods, which traditionally include methods of authorship and style determination.

PROBLEM STATEMENT

Author's style is understood as a set of characteristics by which an author can be identified. Distinctive features of an author's style include stylistic techniques, grammatical constructions, peculiarities of constructing phrases and paragraphs, or any other set of features that make a text unique [2].

Stylometry is the area of linguistics that studies style characteristics in order to organize and attribute texts; its object is a text created by a specific author. Subject of this research are style elements, which are understood as features of a particular author's style. Text style is described as a collection of some of its inherent characteristics.

An author invariant is understood as stylometric characteristics that uniquely characterize one author or a small number of «close» authors [3]. Analyzed characteristics should take significantly different values for works of different groups of authors. For successful attribution, the number of «different» groups should be large enough, and each group must include a number of works that are similar in style.

Revealing signs of author style enables linguists to attribute a text to a certain author (or to a group of authors of a very close style). The relevance of this area in computational linguistics is due to the fact that numerical methods for determining authorship are used in the study of classic literature (establishing unknown or controversial authorship, identifying influence of one author on another), in criminal and civil law (analysis of evidence in electronic form, disputes about copyright), etc. Among tasks of determining authorship, following can be highlighted: authorship verification (for determining whether the text was written by a specific author), plagiarism detection (for revealing the similarity of two texts), author profiling (for obtaining information about author's age, education, etc.), rubricating in automated or automatic electronic library systems. In order to determine an author's style, it is necessary to mark out characteristic features in texts.

SOLUTION TO THE PROBLEM

The method under development is applicable for determining authorship of a text or, in some cases, for making an assumption on possible author(s) of the text. The suggested approach is based on analysis of selected morphological features and connections between words in a sentence. The latter can be established in several ways. Syntactic analysis of a sentence [4] is the most accurate, but the most difficult method. Full syntactic analysis guarantees high quality parsing as it determines all existing dependencies when parsing a sentence. But since a free word order is common in Russian language (unlike English, for example), this analysis often requires intervention of an expert for correctives in addition to machine parsing. Due to these features of

the chosen language, syntactic analysis is considered as very time consuming and often lacking quality in difficult cases. In addition, most of the syntactic parsing software is commercial and off-limits.

The method proposed in this paper is based on the use of N-grams. It is intended for classifying texts in Russian by author style signs, and is based on morphological analysis results, without using more complex and less accessible syntactic analysis.

One typical use for N-grams is for considering the word order, which is important when determining an author's style. An N-gram is a sequence of N consecutive words in a text. The more the N (the «window» size of an N-gram), the more features will be obtained (but most useful N-grams should be selected, which is subject to further research). In this case, an increase in the parameter N can lead to overfitting. For example, if N is the length of the text, then each document will have a unique feature, and the algorithm will be able to retrain for the training set.

An N-gram is based on a mathematical model and is defined as follows: «An N-gram in the alphabet V is an arbitrary string of length N, for example, a sequence of N letters of the alphabet V of one word, one phrase, one text, or, in a more interesting case, a sequence of grammatically acceptable descriptions of N consecutive words» [5].

The proposed method is 4-fold.

(1) First of all, a text in a natural language must be pre-processed. The first stage of processing is tokenization – splitting a continuous string into separate «words» [6]. Tokenization consists of several stages. First, the text is converted to lower case. The next step is to replace all punctuation marks and other symbols with spaces. In the presence of complex compound words (for example, «bluish-green»), it is not very reasonable to replace the hyphen with a space in them: the meaning of the word may be lost. Then, each word separated by a space is declared as a separate token. At this stage, it should be borne in mind that some sets of words should be considered as one.

(2) The next stage after tokenization is the normalization of words in the text, that is, bringing each word to its initial form. There are two main approaches to normalization: stemming and lemmatization [1]. Stemming is an approach, the essence of which is as follows: according to some rules, the end of each word is cut off. This approach may result in loss of information if the word changes entirely when changing the form (so that the constant part of this word's forms is null). During lemmatization, a dictionary is used, in which a large number of words and their forms are pre-recorded. First of all, the word is checked over the dictionary. If it is already in the dictionary, then according to the dictionary one can find what form the given word can be in. Otherwise, according to a certain algorithm, a method for changing a given word is deduced, based on which conclusions about the initial form are made. Lemmatization is better for working with unfamiliar words, but due to dictionary lookups and normalization algorithms, it is a slower approach compared to stemming. In Russian, pymorphy [7] is the most promising library for today, as it is trained on a manually-annotated corpus.

(3) The next stage is the classification of texts from the training sample, for which the author is known in advance [8]. For each of the texts from the training sample, an N-gram analysis of sentences is carried out and the calculation of the statistical distribution of N-grams typical for the style of each author is carried out. The N-grams themselves will be a bunch of parts of speech, that is, a tuple of word forms will be represented as a tuple of parts of speech of these word forms (for example, noun-verb-adjective-noun).

In the course of compiling the statistical distribution of N-grams, it is proposed to compare the results of using different N in order to parameterize and study the accuracy of the method on a given sample of texts. It is also worth noting that N-grams are extracted within the same sentence.

Parts of speech of words are determined using morphological analysis. For morphological analysis, it is proposed to use the pymorphy2 library of the Python programming language. In

pymorphy2 library for the Russian language, OpenCorpora dictionaries and grammemes adopted in OpenCorpora (with minor changes) are used [9]. Grammeme – grammatical meaning, understood as one of the elements of the grammatical category; different grammemes of the same category exclude each other and cannot be expressed together. So, in Russian, singular and plural are grammemes of the category of number. In the course of work on the implementation of the method, it will be necessary to check how accurately it is necessary to determine the part of speech. For example, it is necessary to determine how accurately the classifier will determine the author if verbs are used instead of participles or gerunds. The pymorphy2 library also allows to make an assumption about the part of speech of an unfamiliar word form based on the training data available in the corpus.

After analyzing each text from the existing database, a set of data will be obtained – a statistical characteristic of the distribution of N-grams with certain parts of speech, characteristic of a particular author. To assess the importance of the N-gram data for a given author's text, it is proposed to use the TF-IDF (TF - term frequency, IDF - inverse document frequency) statistical measure [10]. TF is the frequency of a term, which measures how often a term appears in a document. TF is measured as the ratio of the number of occurrences of a word to the total number of words in the document. IDF is the inverse of the frequency with which a word occurs in documents collection. IDF accounting reduces the weight of commonly used words. Thus, the TF-IDF measure is the product of the two factors – TF and IDF.

The next stage of the method is to carry out morphological and N-gram analysis for a new text not included in the training sample. The method ends with text classification based on the obtained distribution of part-of-speech N-grams (as these POS-N-grams were previously shown to be applicable for classifying texts by functional style [11]). As a result, it is possible to establish the author of the text or assume who may be the author (in this case, the decision is left to the expert).

After determining the authorship of the text, it can be saved to the existing database and the results of the analysis can be attributed to a certain author's style. Thus, the method implies additional training as new texts are added and analyzed.

The functional diagram of the proposed method for determining the features of the author's style in the IDEF0 notation is given on Fig. 1, it reflects key stages of analysis.

A vector of morphological features for a text is a set of tuples: an N-gram with part-of-speech tags – frequency of its use in this text. Therefore, each text will be presented as a vector, comprising morphological features. Classification of a new text is carried out according to the following short algorithm: align (or normalize) the lengths of vectors of morphological features of texts, normalize the values of the vectors, combine the vectors of texts into a matrix, and classify the new text. Normalization of a text is carried out as follows: given a part-of-speech trigram $T(p_1, p_2, p_3) = p_1-p_2-p_3$ and its Frequency $(T) = K$, its

$$Normal(T) = \frac{K \cdot 27}{n_1 + n_2 + n_3}, \quad (1)$$

where 27 is the number of placements of parts-of-speech in a trigram; n_1, n_2, n_3 are numbers of parts of speech p_1, p_2, p_3 in the text, respectively.

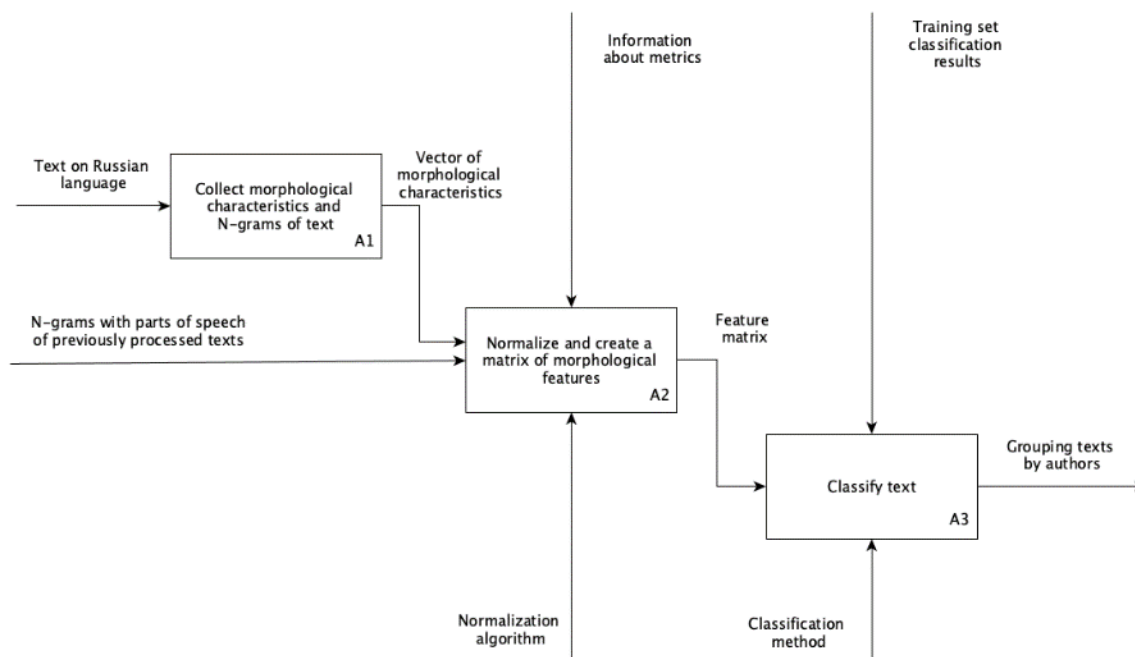


Fig. 1 Functional diagram for method for determining signs of the author's style

CONCLUSION

In this paper, a method is introduced for determining features of author's style for texts in Russian using part-of-speech N-grams. This method is based on the following hypothesis: classification of texts in Russian according to the author's style can be carried out based on results of morphological analysis, without using more time-consuming and less accessible syntactic analysis. Further research should consider possible metrics for analysis in more detail, and should pay more attention to the affect of the quality of morphological analysis on classification.

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DEVELOPMENT OF A GOOGLE DOCUMENTS WORKBOOK

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Abstract — Nowadays a significant part of activities is moving to the online format. In particular this applies to the educational sphere. Existing solutions that are in the public domain do not allow satisfying all the necessary aspects for studying process at universities. The goal of the project is to develop a possible solution that could satisfy some of the narrow requirements of the academic disciplines. The designed tool is based on the Google technologies which allow real time interaction. The offered program that could be implemented at universities and other educational institutions.

Keywords: grader; feedback; evaluation.

INTRODUCTION

It is not a secret that education today is rapidly moving into online format thanks to developing technologies. This makes certain changes in the usual mode of work: as a result, there is a huge number of students' works than it was before. At the moment, there is a need to check assignments of a whole course instead of a few groups [1]. This is where inconveniences arise: it is impossible to manually check a large number of works in a short time, and besides, provide to each student a personal detailed commentary on his work. Moreover, the majority of requests that receive teachers refers to basic rule assignments and it is not rational and correct idea to repeat the same materials to every student [2]. This situation is potentially repeated many times, and the teacher is wasting time ineffectively looking for these errors and repeating the rule many times, the essence of using which lies on the surface.

Therefore, it makes sense turn to technologies that allow you to create your own course and automatically validate it. However existing tools cannot fully solve this problem.

BACKGROUND

It is reasonable to review existing solutions. The first alternative is using well-known MOOC platforms, whose representatives are Stepik, Coursera, EdX, Khan Academy. They provide a wide range of methods for generating test assignments for courses, however, in most of them, it can be found significant disadvantages [3]. Primarily, the platforms do not take into account the previous results of the students' assignments [4]. Then, the majority online systems are predominantly aimed at the classic test type of tasks, where there are several answer options.

Implementing open-ended question checking in such systems is a very laborious task, since it requires at least the connection of an external program.

Coursera, being popular and useful platform needs to be described in particular. This platform is actively used in universities around the world, especially at the Higher School of Economics.

It is important to mark out the advantages of this platform [5]. Coursera has a wide range of options for creating quiz assignments. Also, one of the distinguishing features of the platform is the presence of a peering mode. It allows you to check any types of tasks, both standard and, for example, programming.

However, this platform has drawbacks [6]. First, it is not suitable for high-quality study of linguistic disciplines. In addition, according to a 2016 study by Coursera, the most popular courses on it were courses in programming or applied skills, but not languages.

Secondly, the disadvantage of this platform is that it is impossible to ask the teacher a question directly.

Thirdly, as mentioned earlier, the platform contains a limited number of types of tasks, which, as a rule, are not written, but such as choice of answer.

There are also specialized platforms for languages: ororo.tv, BBC podcasts, babbel, duolingo. The most interesting and narrowly focused examples are Babel and Duolingo [7], that provide a wide range of interactive tasks with different words and language constructions. The main point is that they are intended for self-study, so students need to register and submit the results by themselves. In addition, these platforms do not allow to create your own course, so training materials may be very limited [8].

There is also Learningapps platform. It differs from the previously discussed services. It is an interactive service that specializes in the gaming format [9] and its benefits are:

- Multilevel training,
- Increasing adaptability to information and computer technologies,
- Health-saving function,
- Game methods.

Using each of these categories, you can create an interactive language learning task in which the user can check the data learned in the theory block. However, this service cannot be integrated in studying process as the platform is closed and it is impossible to create own functionality, using only types of tasks that are presented at it [10].

Problems that were mentioned earlier can be solved using uniform standards such LTI and xAPI. There is another one called SCORM, but it is mostly used to transfer various contents between online systems. LTI standard is supported by MOOC platforms (Coursera, Stepik, EdX) and LMS (Moodle, Canvas) [11]. For example, Moodle is used in HSE SmartLMS, so all developments with LTI will be compatible with this particular LMS.

METHODS

The main issue of this project is to test the literacy of students and to return useful feedback for them. Many platforms allow creating tasks in a test format, but this is not the most reliable source for testing knowledge. A more stable option would be creating text assignments where the student will not have any ready answers. This format seems more successful, because it allows to have both theory and practice within one document, and the result will resemble a workbook.

This format was approved by the specialists of the HSE faculties - the School of Linguistics and the School of Foreign Languages, test materials of which will be used in the work. The format of the work allows reacting to the user's answer not in a binary way, but to give various explanations in case of an error. In addition, all the user's progress and the feedback

received by him will be saved in one document, which will serve as a kind of statistics and, for example, will help to identify typical errors.

It is necessary to consider how the students will access their individual workbook files. The most obvious option would be developing a website, but it is not the optimal way, because there is always a risk of breakdown that can seriously interfere with learning. In addition, if the project will be expanded, the site should be improved. Google Documents can serve as a ready alternative, since they are reliable, have a wide functionality that allows to work in them, and also it is easy to share various documents among several people. In addition to documents, other Google products can also be used as they are easy to integrate with documents. Google Spreadsheets are convenient for storing both service data and tasks with ready-made answers. Google Drive stores workbooks of all students, as well as theoretical and practical materials. Google Classroom can structure the work of a large number of users.

RESULTS

An analog prototype of this service is a workbook in English (or any other foreign language). Taking it as a basis, it is important to describe the workflow, based on this idea. The architecture of designed program is presented at Fig. 1:

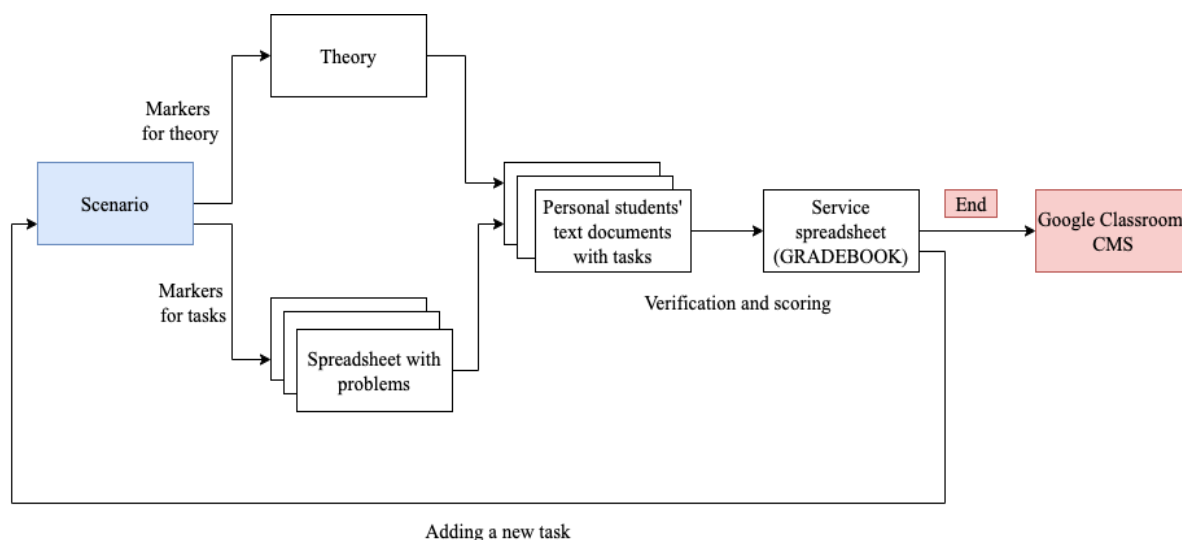


Fig. 1 Service architecture

The final product can be divided into five entities:

1. Scenario;
2. Practice;
3. Theory;
4. Service table;
5. Google Classroom or customer's CMS.

Every part of this Figure is shortly described below.

Scenario allows controlling the creation of workbooks. It is a table in which the teacher indicates the order of practice and theory.

The practice table contains materials for testing knowledge. Each exercise has complexity, type, contains statement, the expected answer, and the reaction to a wrong answer.

All theory for the course is in a separate document. For ease of use, all blocks of material are marked, which allows to select the desired part with minimal risk of making a mistake.

The service table is the link between the student and the CMS. It contains the student's mail, a link to his document, grade, accomplishment time and the number of completed assignments.

Consider the work of the entire project. At the first step, the user is asked to fill out a script according to which tasks will be created. A script is an online spreadsheet that lists the sequence of markers for theory and practice. Each task in the table has its own sheet. When the program script is executed, this table is read and the next step is used to create a task in the workbooks.

The input data are also theory and practice. Theory is an online document in which blocks of the theory are indicated, framed with special characters, for the purpose of convenient access to each of them in the future.

The practice is a set of online tables that contain a set of questions, answer options, difficulty levels of each question, reaction to an incorrect answer. For each module of the course, a problem book is assumed.

There is also a service table that is automatically generated. It indicates where each student stopped, how many assignments he completed, what grade he received, as well as a link to his workbook. The table also contains a separate sheet with links to theory, problem books, a dictionary, as well as an indication of the distribution of tasks by module.

In the course of work, students' personal online text documents are generated, which process students' decisions in real time. As the student writes the answer, comments from the teacher are added to the document, which are taken from the book of problems. If a student has worked poorly on a certain topic, a new task is created for him in the document, depending on a predetermined level of complexity and option.

At the end of the script, the score is returned to the training course in the CMS or LMS system.

CONCLUSION

Despite the fact that developing graders is not a new idea, this product can find its niche among its kind. It was developed with the analysis of existing graders, among which the rather popular and well-known Coursera. Results of this project can be used in training programs and are expected to be used in some HSE courses. In the future, this work can be improved by adding new types of tasks, improving the validation or creating a brand new interface.

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AUTOGRADING SYSTEM FOR GRAPHICAL ASSIGNMENTS FULFILLED IN DRAW.IO EDITOR

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Abstract — This article introduces a web application which is an auto grading system based on graphical web editor draw.io for engineering courses in National Research University “Higher School of Economics”. The proposed system automatises typical actions, provides immediate feedback, Google sheet user interface for library generation, integration with the University’s digital environment and features for setting conditions of a task. The described approach to grading includes analyzing the drawn schemes saved as XML string. The developed software could be used for making the process of education more efficient as it automates students’ assignments’ checking.

Keywords: autograding; grading draw.io schemes; software for engineering education; assessment; variable feedback.

INTRODUCTION

Nowadays the software systems designated for autograding of students’ assignments are gaining popularity due to their advantages. Firstly, as these systems grade students’ tasks automatically, teachers would have additional time for doing scientific research or preparing their courses. Secondly, autograding systems are likely to provide more objective feedback and marks for all students because they do not have a subjective attitude to anybody. In addition, such systems can provide students with an unlimited number of attempts in fulfilling any task and nobody would bear costs in this case. Another reason why autograding systems have witnessed a significant development in recent years is the permanent increase of the demand for self-study courses, such as online courses. All these courses contain theoretical material along with a set of tests and various practical tasks which are usually graded automatically.

Not only do online platforms use autograding systems but they are included in academic curriculum in some universities, for instance, the usage of such systems is described in [11] and [13]. Nevertheless, nowadays not all universities are provided with the autograding systems which can meet every particular subject requirement. This article aims at developing an autograding system based on draw.io for engineering disciplines in HSE University. The system under consideration should provide students and academic staff with the following opportunities.

First of all, the system should allow teachers to compose new tasks which means to generate graphic objects libraries for use in the task and to set correct links between these objects. Secondly, the developed system should check that the drawn schemes meet both basic rules of circuitry and conditions set by the teacher. Thirdly, the created task should be assigned to students via the University's Learning Management System (LMS) and since a student has submitted his task, the task should be graded, and the final grade should be published in the LMS. Furthermore, the system should be able to provide immediate feedback about the compliance with basic rules of circuitry immediately after any change in his scheme has been made.

Only a few number of autograding systems based on draw.io are described in the literature. However, to our knowledge, these software systems do not automatise typical actions performed by users in draw.io editor. Consequently, our contribution is as follows:

1. our web-application is the first application based on draw.io which automates typical actions and is able to provide immediate feedback and which is integrated to the university's LMS;
2. our system is the only one that allows users with to generate draw.io libraries with use of the Google Sheet user interface (UI) and to set the tasks' conditions;
3. the introduced approach to grading can perform precise and complete analysis of the drawn draw.io schemes.

The academic staff and students may benefit from the developed system as the system introduces highly interactive tasks for students that can be easily composed. Moreover, the grading of such tasks does not consume teachers' and students' time in terms of performing the routine actions connected with using the editor and grading so the usage of the system can provide academic staff and students with additional free time that they could use for covering more complicated themes of the course and fill the course with additional material. Also, the students could have unlimited number of attempts to fulfill unclear tasks, so the students are likely to acquire better understanding of the tasks which seem difficult for them.

The paper is organized as follows. At first, we analyse the existing approaches to autograding of various graphical objects. Then we focus on the significant features of the editor. After that we describe the architecture of the developed system and particularly the library generator. Next, we introduce our approach to grading draw.io schemes. Then we describe the system's integration with LMS. Finally, we point out possible directions for future work and conclude this paper by providing its brief overview.

RELATED WORKS

The research on automatic grading of students' assignments started more than sixty years ago. Jack Hollingsworth pioneered the research into this area in 1960 [1]. He proposed the idea of automatic grading of students assignments on programming and implemented such software system. According to [1], usage of this system named "grader", allowed the academic staff to increase the number of students on the course drastically and to reduce teachers' time and money spent on holding laboratory-based classes. Moreover, the author claims that using the grader allowed students to understand the course's material better. The following decades witnessed a significant development of the idea of automatic grading: a big number of systems for autograding has been developed so far. Automatic grading is used in many computer science areas, for instance programming [2], [3], computer networks [4], [5], databases [6]. In [2], the authors claim that nowadays such systems are mainly used in the following areas: massive open online courses (MOOC), grading academic assignments and online contests. According to [7], autograding systems depending on their purposes are usually integrated in a certain platform. This platform can be either a MOOC platform, for instance EdX [8], or a platform for holding programming competitions [9] or a learning management system (LMS) [10].

As this paper is dedicated to development of an autograding system of graphical schemes, this related works section focuses on systems which automatically grade assignments that

suppose various graphical objects to be submitted as answers for them. Moreover, in this section we will address the questions of integrating such systems to the platforms of supporting online learning.

Autograding systems have been actively investigating in terms of their application for grading different types of images, for example, two-dimensional pictures, 3D models, 3D animations. Many articles that deal with autograding two-dimensional RGB images have introduced an approach based on subtraction of the submitted image from the reference image that is marked as the correct answer for the task. A task is considered to be completed correctly if the result of the subtraction is an image that consists only of black pixels which means that the value of each RGB-channel of their pixel is zero. This method is described in more detail in [8] and [10] and the main purpose of software systems based on this method is checking the assignments which require the submitted image to be the result of execution of the student's code or a command for a program processing of graphical objects. [8] indicates that such autograding system may be developed in a MOOC in EdX platform by using its external grader mechanism that assumes that submitted code is executed by an external server that also compares the output with the reference image. After that the grader returns the result of checking and comments to the platform via HTTP-request to EdX server.

For grading 3D models built by students, there exist other approaches. Yet, these methods also include comparison of submitted work with the reference one. For instance, [12] describes an autograding system that deals with 3D model's parameters kept in the submitted 3D model's file. The described system checks the submitted model by comparing the parameters from the submitted file with those parameters of the reference model. This system has been integrated into a MOOC in EdX platform and at present it is used for grading one of the course's assignments.

At the same time, another method which is more complex is proposed in [13]. This article describes an autograding system based on finding the correspondence of a student's 3D animation to the reference animation by computing Euclidean distance between key points of these two animations and provides a grade according to the distance value. This system was developed for supporting a 3D animation course in Politecnico di Torino University, therefore it was designed for grading files submitted in the University LMS.

A 3D-model can be depicted by its several two-dimensional projections drawn in the same canvas in such a number which is enough to reconstruct the initial model. [14] introduces a software system for grading a model's projections, created with use of AutoCAD. The system's method of checking students' schemes is based on comparing them with the reference scheme. For evading the system's possible errors, which can be made due to admissible differences between a submitted scheme and the reference one, affine transformations are applied to the submitted schemes. Moreover, the authors attempt to automate the grading process by introducing functions that do the typical actions which are usually carried out by people while completing and checking the task. For instance, there is an embedded convertor from the proprietary format dwg to the free format dxf which accepts this autograding system. The authors do not mention if the developed system is integrated in any LMS.

As it follows from this related work section, there are many various autograding systems aimed at autograding graphical objects and circuits resulting from completing a task. All the considered systems use the comparison between the submitted graphical object with the reference one usually set by the task's composer. Also, the majority of the aforementioned systems before producing the comparison, apply certain transformations to the submitted image with a view to extract the key properties of the submitted image. It is also remarkable that nearly all the systems are integrated to a certain platform for online learning, for example a MOOC platform or the university's LMS, where the student is supposed to submit his work and where the student can see his grade.

PECULIARITIES OF DRAW.IO EDITOR

This section focuses on draw.io editor's peculiarities that have influence on the implementation of the system. First of all, the drawn scheme is saved as an XML string. This string contains complete information about the scheme's graphical objects and their display properties, for instance, coordinates, shape and colour. These properties are kept as XML object's properties inside the correspondent XML tag or as the object's children nodes. It is remarkable that each graphical object has a property named "id" which contains its unique identification. Moreover, the editor allows adding custom properties with any name that does not contain spaces and any value to each object. The second peculiarity is that the scheme's string is always kept in an encoded and compressed way. The algorithm that is applied to the string for compression is Deflate and the algorithms that are applied for encoding are URLEncode and Base64. The last peculiarity is that the editor allows use of their custom libraries of graphical objects. A library's format is a list of JSON objects that keep all information about one library's object which include the XML-string that describes the object's graphical representation and other properties, the object's dimensions and name.

THE SYSTEM'S ARCHITECTURE

The developed system is a web application which is based on the client-server model, consequently it has a client's part and a server's part. The client's part of the system is mainly made of the draw.io editor's source code distributed under Apache 2.0 license. We have completed the source code by several functions required for implementing the autograding system's features. The description of these functions takes place in the next paragraph. The client part of the editor is written in JavaScript, so all our client functions are written in JavaScript. Moreover, JavaScript framework Vue.js is used for the client code. The application's server part is written in Java and of Java's framework Spring MVC is used for it. As it results from the framework's name the application is based on the MVC (model-view-controller) pattern. The web-server for the application's deployment is Apache Tomcat.

A http request is sent to the server by the client part of the application after each modification of the scheme which is currently opened in the editor. The type of this request is POST and its body contains the XML string of the drawn diagram which is stored in an encoded and compressed way. The received string is transformed to the original XML string by its decompression and decodement executed by the server part of the system. Then the system grades the scheme and generates its feedback which has a format of a JSON object and contains the objects' identifications as keys and their status after checking as values. There is one more pair key-value in the feedback which contains the server's text comment about the errors made in the scheme. The feedback is sent as an http response to the request. Since the client part has received the response of the server part it parses the JSON kept in the body of the http response and displays the server's comment in the special text area of the UI. The drawn objects are also coloured according to their status in the feedback by the client part. For this purpose draw.io API is used. The object is coloured in green if its status is "correct", in red if its status is "incorrect" and in black if its status is "neutral".

GENERATOR OF DRAW.IO LIBRARIES

There are three types of graphical objects defined in the developed system. These types are the following:

1. electronic devices that are called "objects";
2. the devices' ports that are called "ports";
3. cables.

Each object has at least one port that can be connected with the other ports of the other objects by cables. The library generator uses Google Sheets as its UI for inputting information

about objects, ports and cables. The sheet contains three tables for filling the information about the objects, ports and cables. The tables' columns are named after the objects' ports' or cables' properties and each row of the table describes one certain object, row or cable. As the devices, ports and cables have different properties, they are described in different tables. Each cell of these tables should be filled with the value of the corresponding object (port or cable) and property. If an object does not have a particular property or its value is not known, it is possible to put "none" in the corresponding cell. There is a column for selecting to which object each port belongs to in the table for describing ports.

The xml string for all the described objects is generated by a script written in Google Apps Script language which gets the information from cells of the table with use of Google Sheets API and puts the got properties' values to the corresponding positions of custom properties in the library-object template. The XML string of each object is concatenated with the string which contains the objects that have already been generated. The result XML string contains all XML objects that have a common parent object. Fig. 1 depicts one library object that was generated by the script.

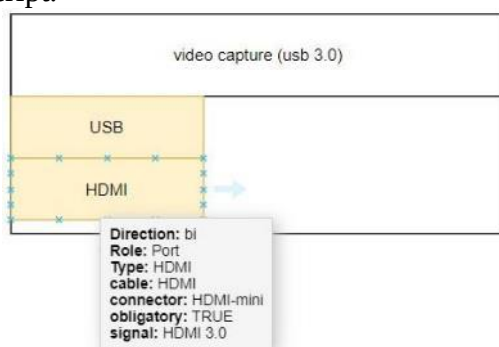


Fig. 1 Generated library object

As soon as the string has been generated a POST request to the server is sent by the script. The body of the request contains the result string. The corresponding server's controller (class that processes http requests) calls a function for generating the library which transforms each XML object to string separately and encodes and decompresses the string in order to make it a string of draw.io format. Moreover, the function extracts the object's properties' values which should be put into its JSON library object and writes the stores this information into a corresponding JSON object. A list of JSON library objects is formed and converted to a string by this program. The output of the program is a string which is saved to a file on the server to be used in tasks.

THE METHOD OF GRADING

According to the Related works section the most widely used method of graphic objects grading is the comparison between the reference object and the object submitted by a student. Yet, this approach may provide students with a lot of wrong feedback and reasons for it are the following. First of all, many tasks for making a scheme can be solved correctly by many different ways and sometimes it can not be possible to foresee all right answers that can be given by students. Also, sometimes there is an unlimited number of correct solutions to a task and obviously they all can not be set to an autograding system which deals with a limited number of reference objects. Secondly, sometimes the scheme's objects' parameters may not be equal to the reference scheme's objects' parameters and yet the task can be completed correctly. For instance, the objects' coordinates may differ from the reference objects' coordinates, while the scheme's correctness does not always depend on the objects' location. That is why, the autograding of draw.io schemes requires another approach which can allow more precise analysis of the scheme.

As far as a draw.io scheme is saved as a XML string the most obvious method to its autograding is to parse and analyse this XML string. The developed system transforms the scheme's string into an array of Java objects. These Java objects are instances of three Java classes (Object, Port or Arrow) according to their roles in the diagram. These classes are developed as a part of the system's server part and contain the same fields as the corresponding library objects that are initialized with the values stored in the XML string of the drawn scheme's objects. If this method is used the information about any property becomes easily available during the program's whole runtime. The process of grading the correspondence to the circuit rules includes iteration over all objects of class Arrow that represent the drawn cables and checking that they met the following conditions:

1. The cable connects two different devices
2. The ports in which the cable is inserted have compatible with the cable type of cable and signal
3. The ports that are connected by the cable have compatible with each other types of cable and signal

The grading of the scheme's correspondence to the conditions set by the task's composer is also based on the array of Java objects that represent the drawn graphical objects. The conditions that are set by the task composer are stored in the database and are received by the Java object which checks the schemes when its method for checking schemes is called. After receiving the conditions the method analyses the presence of the objects and connections between them which are required by the conditions in the array of arrow objects which is formed in the initial step of checking.

The conditions are set as an array of strings in a formal language which is developed for the system and there is no limit for the number of conditions. The task is graded as a correct one only in case when all the conditions are fulfilled. Every condition consists of primitive conditions connected with each other by basic logical operands such as and, or and xor. The primitive conditions determine such basic operations in the drawn scheme as connection between particular types of objects, the presence or absence of objects which have a particular type in the diagram and their number. The fulfilment of these conditions can be easily checked because the information about all scheme's graphical objects is stored as arrays of Java objects and values of all properties can be easily accessed. After the primitive conditions are checked the system determines if the whole condition is true based on the logic operands that connect the primitive conditions and adds the according feedback to its feedback string. In such a way the system checks all the conditions which are set by the task's composer.

For avoiding the analysis the connections between the primitive conditions of all the conditions set by the teacher each time when the checking function is called the string of the condition is expanded in a set of primitive conditions in the moment when the task is created. The conditions are stored as primitive conditions in one table of the database and the connections between them are stored in the other tables.

INTEGRATION TO THE UNIVERSITY'S DIGITAL SERVICES

The integration with the University's LMS in terms of assigning tasks and putting grades is implemented with use of other digital services of the university. This service redirects the students from the assigned task in LMS to our service and convey the information about the tasks and the student. Our system receives this information, decrypts it, and carries out grading according to the required task's conditions. The setting of mark is also implemented via this external digital service. Since the student submits his work the system sends a request to the external service for putting grade to the LMS.

FUTURE WORK

Our plan for future work includes making the web-application applicable for grading not only tasks which require to create schemes of electronic devices as the introduced approach could be used for grading other types of objects that can be connected with each other. These objects may be not only electronic devices but represent other essences such as business-processes, economic agents, to name but a few. The system also can be used for evaluating solutions among technically correct ones according to specified parameters (working schema could use cheaper, smaller, lighter elements). Moreover, the approach might be applied in other types of tasks that differ from autograding but require the precise analysis of draw.io schemes. For instance, it could be used for development of a system for remote management of the laboratory bench of the network equipment. Using the approaches introduced in this paper we could analyse the schemes of a network topology drawn in the editor and to form a bash-command for the laboratory equipment that would perform the connection required by the user who has drawn the topology.

At the same time we would develop the scheme grading module in order to check more complicated rules of circuit design. For instance, we plan to add the checking of the condition that all devices' ports which have been marked as compulsory ports for the circuit's operation are assigned correctly. Moreover, we could change the architecture of the application from monolithic to microservices in order to make our system more flexible.

CONCLUSION

This article introduces a new web application for automatic grading schemes made graphical editor draw.io. First, this paper deals with the architecture of the system under consideration, then our methods of grading schemes considering their specific draw.io format and of generating the comments on the scheme drawn by a student automatically are described. The paper describes two aspects of autograding draw.io schemes. The first is checking the scheme's correspondence to the basic rules of circuit design and the second one is checking the scheme's meeting to the criteria set by the teacher. Also, the paper covers the issues of composing new tasks for the autograding grading, which includes generating draw.io libraries of necessary electronic devices, and the system's integration with the other digital services of the University.

Our system introduces a more complicated and extendable approach to the analysis of the schemes compared with the existing approaches. To our knowledge, no identical software that automates the typical operations performed by draw.io editor's users is described. Moreover, this article proposes a new software module for automatic generation of draw.io libraries based on Google Sheets. This module can also be the first implementation of an application with a user interface for generating graphical draw.io libraries for electronic devices. Therefore, the system under consideration is likely to help the teachers to reduce time spent on checking students' assignments and provide them with the opportunity to cover more advanced topics of the course. Also, if students used the developed software in their study, they would have additional training on unclear topics and be able to acquire additional knowledge.

The result of the work is the described a web-application that has been deployed and can be accessed in the Internet. The application is partly integrated with other digital services of the university in order to provide access via the services, so this allows identifying the user. In addition, user and developer documentation has been published at the university's website.

The academic staff could use the developed system for composing graphical tasks and assigning them to the students. The application could be used for holding various types of tasks in engineering courses such as ungraded training or control works. At present the system fits only for grading tasks on disciplines connected with circuitry as it allows checking only the correspondence to the circuit design rules.

ACKNOWLEDGMENT

This work is based on [15] that describes the research on draw.io application to autograding systems. The work is carried out as a project work in HSE University in the project environment of Moscow Institute of Electronics and Mathematics (project number 553).

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Section 2
INFORMATION TECHNOLOGIES IN SCIENCE AND INDUSTRY

**APPLICATION OF FACTOR AND CLUSTER ANALYSIS METHODS TO ASSESS THE
EFFECTIVENESS OF THE SCIENTIFIC RESEARCH**

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Abstract— The paper analyzes the performance indicators achieved in the implementation of various projects supported by state funds and carried out at the Ulyanovsk State Technical University. The output indicators are analyzed in the form of published articles, speeches at conferences and the results of intellectual activity, as well as the number of trained personnel within the framework of the project. As input parameters, the amount of funding, the duration of the project, as well as the numbers of participants and young participants (up to 35 years old) and other factors are examined. Methods of factorial and cluster analysis are applied to the resulting dataset, in particular, the dimensionality reduction method, Principal Component Analysis and the K-means clustering algorithm. New important components for the description of scientific research are highlighted and the optimal clustering of such studies is obtained.

Keywords: information technology; factor analysis; data mining; cluster analysis; scientific research.

INTRODUCTION

Now days there are several sources of funding for the development of scientific research on the territory of the Russian Federation. At the same time, decisions on providing grants today are made solely on the basis of the opinions of experts involved in reviewing the application. At the same time, usually, when analyzing the backlog of participants, only the experience of participation in certain projects is taken into account, and the effectiveness of these projects is not taken into account. The use of automatic assessment methods for previously completed projects would potentially increase the level of expertise. In this case, the final decision in any way remains with the expert. Another problem is the fact that, generally speaking, each application is characterized by a variety of input and output parameters. Effectiveness cannot be directly related to the sum of the funded money, and different performance indicators are highly dependent on the type of competition. One of the options for solving this problem can be the use of data mining methods [1-3], factor analysis methods [4] and cluster analysis methods [5].

ORIGINAL DATASET

For the analysis of research projects carried out at the Ulyanovsk State Technical University, some input and output factors were selected. The chosen input factors are as follows: the funding sum, the implementation period, the number of performers, the number of performers under the age of 35. The output factors are as follows: the number of publications, the number of publications indexed by Scopus / WoS databases, the number of patents (results of intellectual activities), the number of conferences with the presentation of research report abstracts, the number of Ph.D. theses defended, and the number of doctoral dissertations defended. Table 1 presents the input parameters for projects sorted by year from 2013 to 2020.

TABLE I. INPUT FACTORS OF SCIENTIFIC PROJECTS

Project number	Sum	Duration	Performers	Young performers

International Scientific – Practical Conference
«INFORMATION INNOVATIVE TECHNOLOGIES», 2021

1	940	3	4	3
2	1000	2	1	1
3	4800	3	8	5
4	2100	3	5	2
5	1000	2	2	2
6	1800	3	5	3
7*	3750	1	10	6
8*	500	1	4	1
9*	300	1	3	1

At the same time, in tables 1 and 2, the symbol "*" means that the project is still being executed and for it the terms and indicators are taken only for the reporting period. The abbreviation "RIA" means the result of intellectual activity.

Let's sort the data in descending order of the amount of funded money and look at the output indicators (Table 3).

Table 3 shows that the training of scientific personnel was carried out only for projects with the maximum investment. We will keep this factor in mind, but due to the zero values of these indicators, we will delete the last 2 columns. As a result, the general initial data table for analysis will take the form of Table 4.

TABLE II. OUTPUT FACTORS OF SCIENTIFIC PROJECTS

Project number	Articles	WoS/Scopus	Patents (RIA)	Conferences	PhD	Doctoral
1	25	2	0	7	0	0
2	4	2	1	2	0	0
3	21	7	2	11	1	0
4	35	10	1	9	0	0
5	28	7	3	10	0	0
6	20	6	0	6	0	0
7*	25	16	3	11	0	1
8*	10	3	0	2	0	0
9*	1	1	0	0	0	0

TABLE III. OUTPUT FACTORS OF RESEARCH PROJECTS SORTED BY THE SUM OF GRANTS

Project number	Articles	WoS/Scopus	Patents (RIA)	Conferences	PhD	Doctoral
3	21	7	2	11	1	0
7*	25	16	3	11	0	1
4	35	10	1	9	0	0
6	20	6	0	6	0	0
2	4	2	1	2	0	0
5	28	7	3	10	0	0
1	25	2	0	7	0	0
8*	10	3	0	2	0	0
9*	1	1	0	0	0	0

TABLE IV. DATASET TO BE ANALYZED

Project number	Sum	Duration	Performers	Young performers	Articles	WoS / Scopus	Patents (RIA)	Conferences
1	4800	3	8	5	21	7	2	11
2*	3750	1	10	6	25	16	3	11
3	2100	3	5	2	35	10	1	9
4	1800	3	5	3	20	6	0	6
5	1000	2	1	1	4	2	1	2
6	1000	2	2	2	28	7	3	10
7	940	3	4	3	25	2	0	7
8*	500	1	4	1	10	3	0	2
9*	300	1	3	1	1	1	0	0

It should also be noted that projects were renumbered for analysis to make clustering more convenient in the future.

Let's carry out a factor analysis of the prepared data and try to reduce the dimensions.

FACTOR ANALYSIS

Factor analysis is performed separately for the input parameters and for the output parameters. First, let's build a correlation matrix for the input parameters. Table 5 shows the results.

From the presented correlation matrix, it can be seen that the sum has a high correlation with the number of participants and the number of young participants, since the last 2 indicators are even more strongly correlated with each other. This can be used successfully for dimensionality reduction.

Table 6 shows similar data for the output features.

TABLE V. CORRELATION MATRIX OF INPUT FEATURES

Features	Sum	Duration	Performers	Young performers
Sum	1	0,2888	0,8495	0,8829
Duration	0,2888	1	0,015875016	0,174347418
Performers	0,8495	0,015875016	1	0,907037125
Young performers	0,8829	0,174347418	0,907037125	1

TABLE VI. CORRELATION MATRIX OF OUTPUT FEATURES

Features	Articles	WoS / Scopus	Patents (RIA)	Conferences
Articles	1	0,657242727	0,450287428	0,869279066
WoS / Scopus	0,657242727	1	0,718706203	0,772711492
Patents (RIA)	0,450287428	0,718706203	1	0,737028634
Conferences	0,869279066	0,772711492	0,737028634	1

Based on the results of the analysis of the presented data, we note that for almost all positions the correlation coefficient exceeds 0.5. This also suggests that the dimension of the output features can be significantly reduced.

Let's calculate eigenvectors and eigenvalues for input features. The eigenvalues make up a vector $\lambda = (2.802 \ 1.001 \ 0.117 \ 0.079)$. Eigenvectors are presented in Table 7.

TABLE VII. EIGENVECTORS OF INPUT FEATURES

v1	v2	v3	v4
-0,57218882	-0,06387812	-0,81750741	0,01418345
-0,15251253	-0,96370504	0,17987715	-0,12512684
-0,56175368	0,24751376	0,36166779	-0,70168807
-0,57773064	0,07700073	0,41051461	0,70126739

Let's use only the feature vectors v1 and v2, since for them $\lambda > 1$. Fig. 1 shows a plot of the precipitation of the share of explained variance for the new components. Fig. 1a corresponds to absolute component-wise values, and Fig. 1b corresponds to accumulated values.

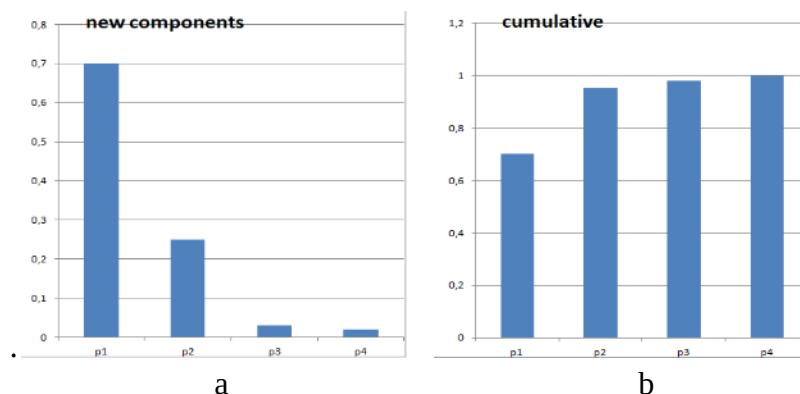


Fig. 1 Plots of explained variance proportion in new input features

Finally, we get 2 new components that explain the variance by 95%. Let's calculate new data using the formula $NewData^T = FeatureVector^T * Data^T$. Let's perform similar transformations for the output data. We obtain the following eigenvalues $\lambda = (3.114 \ 0.576 \ 0.254 \ 0.056)$. The eigenvectors are presented in Table 8.

Let's use only the feature vector v1, since for it $\lambda > 1$. Fig. 2 shows a plot of the precipitation of the share of explained variance for the new components for output features. Fig. 2a corresponds to absolute component-wise values, and Fig. 2b corresponds to accumulated values.

Finally, we get only 1 new component that explains the variance of the output data by 78%. New inputs and outputs are presented in Table 9.

TABLE VIII. EIGENVECTORS OF OUTPUT FEATURES

v1	v2	v3	v4
0,48049924	0,67319058	-0,55113199	0,11040132
0,50651415	-0,19597042	0,03416745	-0,83897056
0,46454255	-0,69061933	-0,35294661	0,42740362
0,5447606	0,1773555	0,7553243	0,31822336

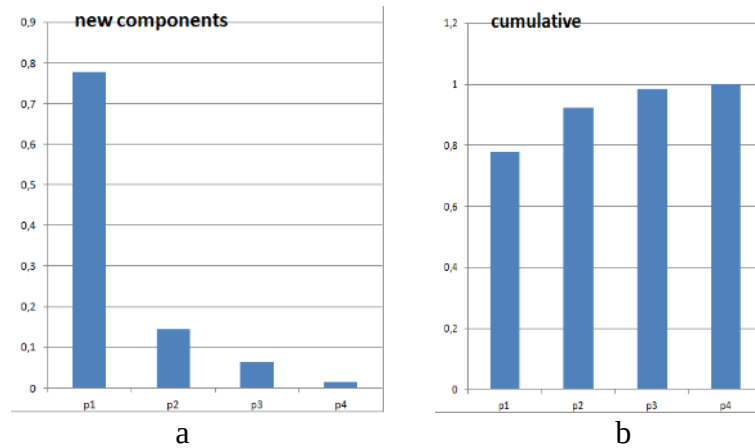


Fig. 2 Plots of explained variance proportion in new output features

TABLE IX. SPACE OF NEW FEATURES

Project	I1	I2	O1
1	-2754,347	-307,1	20,5575349
2*	-2154,945	-237,6	27,5027018
3	-1206,018	-135,6	27,2500029
4	-1034,939	-116,4	15,9176334
5	-573,6333	-65,48	4,48908902
6	-574,7728	-65,16	23,8408115
7	-542,2952	-61,72	16,8388336
8*	-289,0717	-31,84	7,41405608
9*	-174,0721	-19,31	0,98701339

For the data in Table 9, we obtain a multiple regression model of the relationship between the output and inputs as $O_1 = 8,152 + 0,072 * I_1 - 0,719 * I_2 + e$, where e is difference between model and real data. Determination index in the model $R = 0,4$, which indicates not the strongest descriptive connections between new factors, but, nevertheless, there is a connection.

CLUSTER ANALYSIS

After the initial feature space has been reduced, clustering by new components can be performed. At the first stage, we will perform data standardization. So two new input and one output features will have unit variance and zero mean. Let us check the optimal number of clusters using the elbow method. Fig. 3 shows the deviation graph for different number of clusters. For each number of clusters, we will choose 10 starting points of the cluster centers. Fig. 3a shows the graph for the elbow method and Fig. 3b shows the graph for the silhouette coefficient method.

Finally, let's perform clustering into 3 clusters, since according to the analysis of the graphs in Fig. 3 the number $k=3$ is the best option. The results are shown in Table 10.

TABLE X. CLUSTERING RESULTS

Project	1	2*	3	4	5	6	7	8*	9*
Cluster	1	1	2	2	0	2	2	0	0

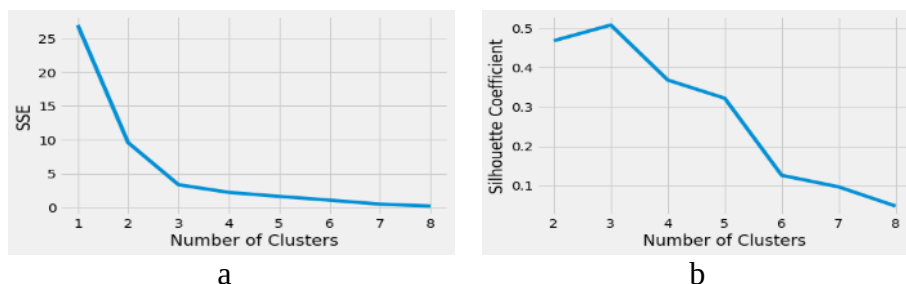


Fig. 3 Selection of the optimal number of clusters

From Table 10, we see that a large amount of funding provided one cluster, but with medium and small amounts, there are variations in performance indicators. Fig. 4 shows the results of clustering using dimensions I_1 and O_1 .

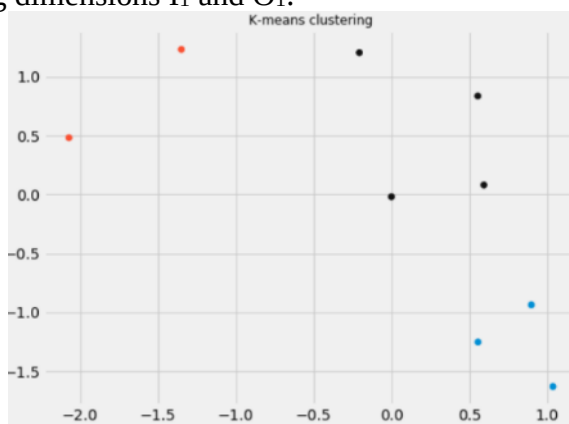


Fig. 4 Clustering results

The analysis of the figure shows that the main components did indeed help to separate the investigated projects according to new factors.

CONCLUSION

Thus, a factor and cluster analysis of research data was carried out, it was found that the efficiency is strongly influenced by a large sum of funding, and with medium and small sum of funding, the weight of other factors also increases.

ACKNOWLEDGMENT

This work was supported by RFBR (grant № 19-29-09048)

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PORTABLE GAMMA RADIATION DETECTOR

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Abstract— The article presents the results of research on the creation of a device for monitoring the radiation background of the environment. A distinctive feature of the developed device is its compactness and high reliability of results. The device registers ionizing radiation and, via a USB port, transmits the processed information to a personal computer or laptop to obtain amplitude spectra of ionizing radiation for the purpose of their further processing and interpretation.

Keywords: Design, development, spectrometry, radiation safety.

INTRODUCTION

As a result of the widespread use of radioactive fuel at nuclear power plants, for medical purposes (X-ray examination, radiation therapy) and other institutions of the branches of the national economy, a large amount of waste appears, which storage and disposal sometimes goes out of control.

The above factors determine the relevance of the development of devices for detecting gamma radiation. The relevance of environmental monitoring is beyond doubt.

PROBLEM STATEMENT

The purpose of the research done and the work carried out is to develop a portable device for registering gamma radiation and the corresponding software that ensures its operation in conjunction with a personal computer. The device under development should not be inferior to and surpass the analogs of Russian production in terms of the main technical characteristics for such devices, as well as have significantly lower weight and dimensions. The cost of the device should not exceed the cost of its larger counterparts.

SOLUTION OF THE PROBLEM

Based on the results of the studies, the results of which are presented in this work, a gamma-ray detector was developed. The device registers ionizing radiation and via the USB port transmits the processed information to a personal computer or laptop to obtain the amplitude spectra of ionizing radiation. Further, the received information is processed by specialized software. The device is wearable and powered by a USB connector. Due to the low consumption of the laptop battery, it is enough for long-term operation without additional recharging. The device implements an active controlled baseline restorer. The device allows you to refuse the use of any additional tools in the construction of measuring complexes for the registration of ionizing gamma radiation.

Compared with existing domestic counterparts, the developed device surpasses them in the following main parameters, namely: energy resolution, maximum spectrometer load, integral

nonlinearity. In comparison with foreign counterparts, the device significantly surpasses them in terms of price - quality.

Dosimeters built on Geiger counters are usually used to survey areas with possible contamination. These devices allow us to assess the surrounding background quantitatively, but in order to determine which specific element we are dealing with, a more complex device is needed.

Gamma radiation is a type of electromagnetic radiation characterized by an extremely short wavelength - less than $2 \cdot 10^{-10}$ m - and, as a result, pronounced corpuscular and weakly expressed wave properties [1]. At the moment, there are several types of detectors that allow you to register gamma quanta, you can scintillation, gas, semiconductor, etc.

The assembly of a photomultiplier tube and a scintillation crystal has proven itself well in the field of registration of radiation pollution of the environment, analysis of radioactive materials, and spectrometric research of substances. Counters produce both high-quality registration of radiation and can measure the value of its energy.

Structurally, the gamma radiation detection device is a unit that includes several functional units, combined inside a sealed housing. The block diagram of the device for detecting gamma radiation is shown in Fig. 1 [3].

The gamma radiation detection device includes:

- scintillation crystal NaI (Tl) 40 mm in diameter. height 40 mm;
- photomultiplier tube Hamamatsu R6231;
- PCB for the high-voltage power supply unit for the PMT;
- multi-channel analyzer board, this board contains the main control and processing elements, such as: microcontroller, FPGA, analog input part and a communication device with a computer USB port.

In addition to recording activity, the device allows using specialized software to determine the type of isotope or several detected isotopes.

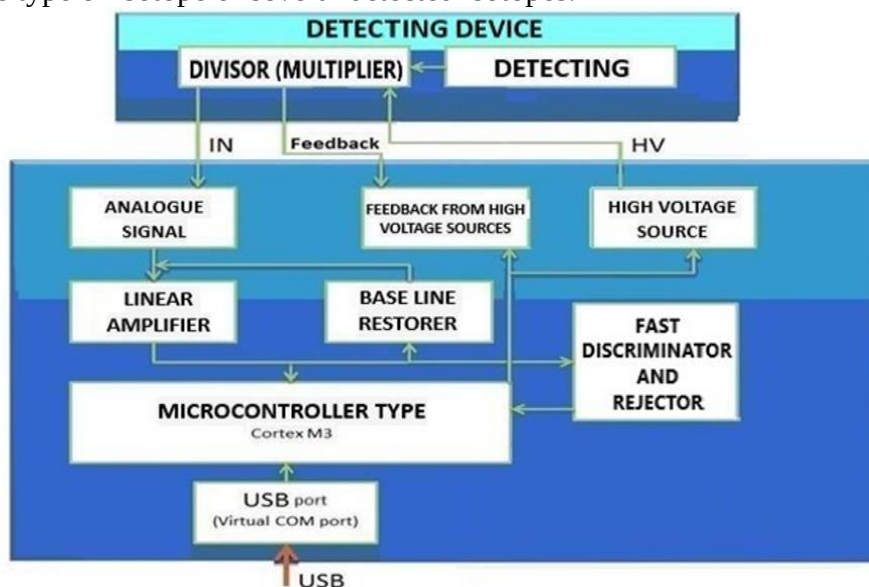


Fig.1 Block diagram of a gamma radiation detector

The device for detecting gamma radiation uses charge conversion into a digital code. With a large charge from the detector and not too long a signal cable, you can abandon the use of ZCH or use a buffer linear amplifier. The signal-to-noise ratio can be optimized by changing the charge collection time. This method provides a good energy resolution of the detecting device.

The signal from the detector is fed to the input circuit of the detecting device, which converts the shape of the input signal for further processing. A simplified input circuit diagram is shown in Figure 2.

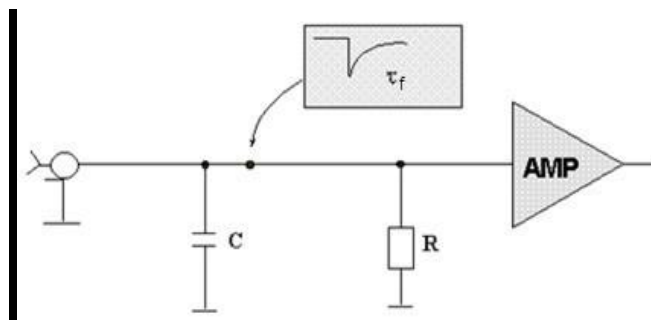


Fig. 2 Input circuit diagram

The filter time constant is determined by $\tau_f = R (C + C_{\text{cable}})$. In this case, a signal is formed with a rise edge equal in duration to the current signal and a falloff determined by the filter time constant τ_f .

Then the signal is fed to a linear amplifier, which provides “packing” of the spectrum segment of interest to the required segment of the complex scale. The gain adjustment range is 42 dB - 8 values every 6 dB roughly using a key and 6 dB in 1/512 steps smoothly (performed by software).

The amplifier is equipped with a baseline restorer based on a controlled active differentiator, and a control circuit (software) for a useful signal detection threshold.

The charge-to-code converter collects charge on a controlled ideal integrator and, using a linear discharge device, converts the accumulated charge into code. The charge collection time is determined by the duration of the one-shot pulse, adjustable by software.

Signal conversion is performed according to a sequential charge-time-code principle, which ensures high uniformity of the channel width without the use of additional spreading schemes.

Then the converted signal goes to the ADC. A microcontroller acts as an ADC in this circuit. The microcontroller software ensures the operation of data exchange with a personal computer, for the subsequent processing of the received data by the program installed on the computer.

The device provides the ability to connect via a PC via a USB port. On which the software is installed that allows you to work with the data received from the ADC, process it and present it to the user in a form that is convenient for perception. The software used to process the received data was developed by the GreenStar group of enterprises.

The high voltage source supplies high voltage to the bias circuits of the detector or to power the photomultiplier tube (PMT). The high voltage value at the source output is set by software with an accuracy of 1/1024 of the maximum value. The rise and fall times of the high voltage are also programmable.

To accomplish the tasks set, components were selected that would make it easy to design and manufacture a printed circuit board with low power consumption, small dimensions and high reliability. When designing, the price / quality ratio was taken into account to make the device affordable.

So, during the design, an ARM controller from ST Microelectronics - STM32F101RET6 was chosen. The ARM controller based on the ARM Cortex-M3 core offers a high level of performance. A device designed on the basis of this controller is easily upgradeable, since ST Microelectronics controllers are interchangeable.

Various programming environments are used to program this controller. CooCox IDE (ColIDE) is the most commonly used one. This development environment is easy to use, there are many examples available for download. Among the shortcomings, it is worth noting the possibility of using this environment only under Windows, which in our case was not critical.

The STM32F101RET6 microcontroller based on the ARM Cortex-M3 core includes: a 32-bit microcontroller. Has several separate buses and a three-stage pipeline and more than 10 general-purpose registers, which allows operations to be performed in parallel; instruction set - Thumb-2 (a mixture of 16- and 32-bit instructions designed for C / C ++ compilers).

The microcontroller has more than 100 pages of official documentation and a book on ARM Cortex-M3 translated into Russian [4]. To master this microcontroller, various debug boards have been produced that are connected to personal computers via the USB port.

Using this microcontroller, you can refuse additional elements such as RAM, ROM, ADC, etc. All this has already been created on the basis of this microcontroller.

Flash memory in the selected microcontroller is 512 KB, system memory (SRAM) - 48 KB. Sixteen channels of a 12-bit, sufficiently fast (conversion time 1 μ s), analog-to-digital converter are capable of providing information processing even with large loads of the input signal. The D / A converter is responsible for controlling the high voltage supplying the photomultiplier tube.

The microcontroller contains a temperature sensor that processes information from external sensors via the common I2C channel. The operating temperature of this microcontroller is from -40 ° C to 85 ° C, and the device at maximum load consumes about 1 W of power, which in our climate makes it possible to do without cooling (even passive) [2].

Debugging of the microprocessor can be carried out by connecting via two interchangeable interfaces SWD (Serial Wire Data) or JTAG (Joint Test Action Group). Communication with a personal computer or laptop is carried out using the built-in Universal Asynchronous Receiver-Transmitter (UART).

The device is powered from a USB connector to which 5 V is supplied, for most microcircuits to work, 3.3 V. is required, and for some, even 1.8 V. To convert 5V to 3.3V, the Recom converter is excellent, the efficiency of which is about 88%, the heat generation for this device will be minimal. For further conversion of 3.3 V to 1.8 V. you can take almost any linear converter, take a linear converter from Maxim MAX8881.

To connect the device to a computer, you must use the most common type of connection. The Scottish company FTDI is specialized in the field of USB bus. It develops, manufactures, and supports devices and associated software drivers for converting RS-232 serial or TTL levels to USB signals, so that modern computers can use a simple classic RS-232 interface without having to delve into the complexity of the USB interface [5]. The FT-232R UART / USB converter is suitable for solving the task. All necessary drivers are in the public domain. And the computer will perceive the connected device without additional actions.

In the analog part of the gamma radiation detector, standard signal processing methods are used, which include an input amplifier, a baseline restorer, a low-pass filter, a high-pass filter, etc. microcontroller input.

The baseline restorer is software controlled using FPGA.

After choosing a microprocessor, let's talk about the rest of the piping.

The main circuitry harness (necessary for the operation of the device and does not affect the characteristics) is arranged based on the documentation for the components and based on specific needs. Therefore, explanations are unnecessary at this stage.

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The baseline restorer is software controlled using FPGA.

The Royer circuit is used to power the photomultiplier tube, this circuit allows you to "swing" the voltage up to 1536 V. The current consumption is low (about 1 mA) and this circuit design is sufficient. The voltage is controlled by a microprocessor, the programmable step of values is - 1024. Then the voltage is distributed over the dynodes of the photomultiplier tube.

Photomultiplier tubes from Russian manufacturers are much inferior in characteristics to foreign PMTs and are inferior in terms of price-quality ratio. It is worth considering Russian manufacturers if the technical task requires it. In this case, there was no such restriction. The choice was between the English company ET Enterprises and the Japanese company Hamamatsu. PMTs from Hamamatsu were chosen, this company is a leader in the production of PMTs. Hamamatsu photomultiplier tubes are equipped with screens that protect the device from electromagnetic interference, which makes it possible to register even weak signals. Electromagnetic shields allow you to move the device and use it in different geometries without fear of exposure to the electromagnetic field.

The selected PMT R6231 has a diameter of 51 mm. the effective area is 46 mm. This is due to the diameter of the cathode grid, which records the flashes that occur in the scintillation crystal. This is important when choosing a scintillation crystal. If the crystal is larger in diameter than the effective registration area, then it will not be possible to collect the entire flux of light photons.

When choosing a scintillation crystal, several types of crystals were considered: Sodium iodide thallium doped NaI (Tl), cesium iodide doped with thallium CsI (Tl), lanthanum bromide doped with cerium LaBr₃ (Ce) (trade mark BrillanCe380) - by the French company Saint-Gobain Crystals, iodide strontium doped with europium SrI₂ (Eu) [6].

Comparing the four types of crystals, strontium iodide certainly wins. It does not have its own activity, like that of lanthanum bromide, and has the best resolution among all four samples - 2.9% at an energy of 662 keV for cesium-137. Cesium iodide is inferior to sodium iodide in resolution and has a higher price, so it was decided to use a crystal of sodium iodide doped with thallium. This crystal will provide good resolution, about 6-8%, which will make it easy to process the obtained spectral diagrams. Выбирая размер кристалла, стоит учесть следующие факторы:

- Large crystals provide a fast collection of statistics and a short time for averaging the measurement results, but they have a large size and weight; for their correct operation, a PMT with a large cathode grid diameter is required. For such PMTs, a higher supply current is required, which reduces the battery life.

- For small and medium crystals, the time for collecting statistics and averaging the measurement results is higher, but these crystals are lightweight, they can be used with smaller PMTs, which provides long-term autonomous operation.

Considering the above factors, it is necessary to take a small crystal. As mentioned earlier, the crystal diameter should not exceed the diameter of the effective registration area of the photomultiplier tube, hence it follows that it is better to take a finished crystal with a diameter of 40 mm and 40 mm high.

Further, given that the device should be as compact as possible, it makes sense to unsolder the connectors: the connector for power and data transmission - one USB type-B, one LED.

It is better to take the most common connector for power supply, for example, USB type-B, and make the circuitry of the board with the expectation that the supply voltage will be 5 volts.

The LED serves to indicate the operation of the device, as well as to indicate emergency situations. It can also be connected to GPIO.

Software part. Conventionally, the software part can be divided into several parts: system software (loader, drivers) and application software (using this software, the user can see a visual image of the spectrum).

When talking about system software, we mean the firmware of the microcontroller and FPGA. The CooCox IDE (ColIDE) was used to write the software.

Due to the fact that the libraries used in the device are designed for use in systems built on the basis of microcontrollers, their installation in the device did not cause any special problems. Moreover, these libraries work reliably and do not fail, since they have been designed to handle error situations.

The processing of the obtained spectra is carried out using the specialized software "eSBS" developed by the specialists of "Green Star". This software provides a visual representation of the obtained spectra and provides the ability to dynamically update them (see Fig. 3).

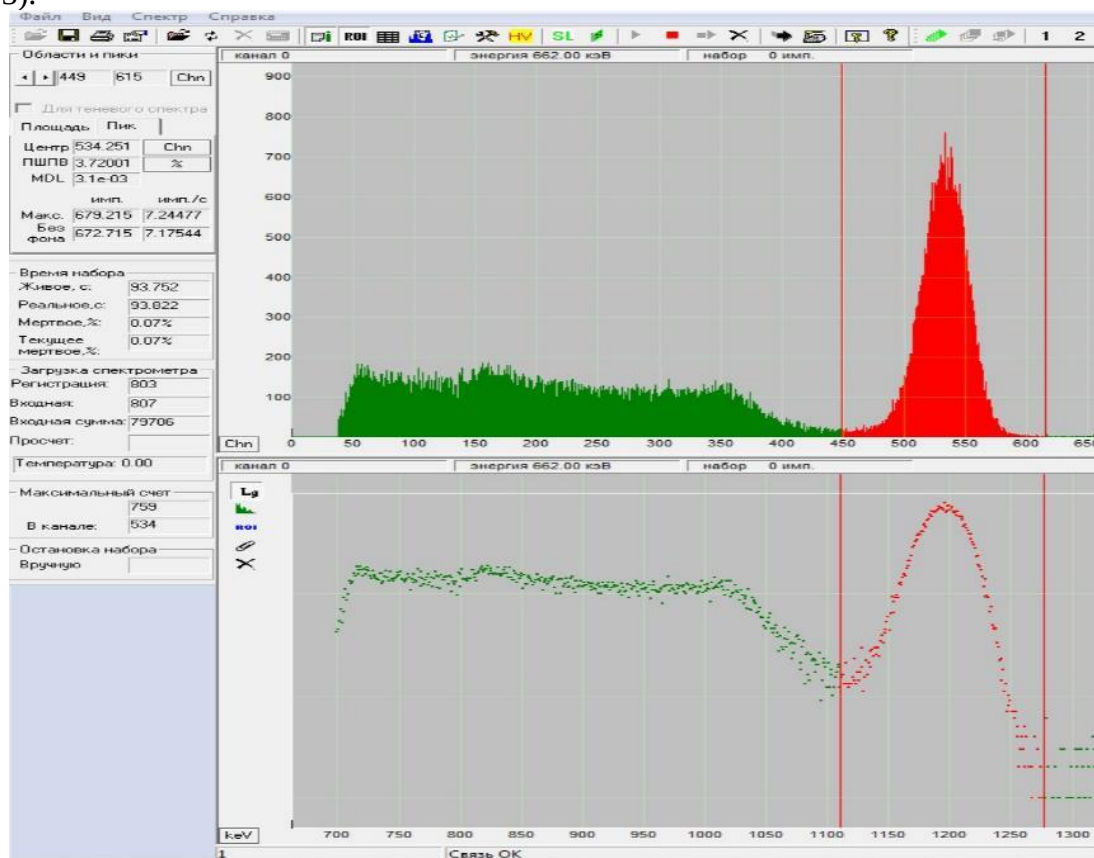


Fig. 3 Emulator of the eSBS analyzer

CONCLUSION

Thus, a device has been developed that, having a low cost and simplicity in production and operation, allows solving various problems related to the registration of ionizing gamma radiation, including monitoring the background radiation of the environment.

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LOCAL COMPUTER NETWORK DATA PROTECTION DEVICE WITH VOICE WARNING OF UNAUTHORIZED ACCESS

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Abstract— This article presents a hardware-software complex for monitoring a LAN with voice audio notification of unauthorized access, developed and used to protect a local area network from unauthorized access. The process of designing a device, the choice of the main components of the device, the selection of auxiliary functional modules, the choice of the system software part and the development of the applied software part of the device are considered. A brief overview of the capabilities of the developed device is carried out.

Keywords- Design, development, software, information protection.

INTRODUCTION

It seems very relevant to develop a LAN monitoring device with sound notification, which, being in the premises of technical personnel or security guards, carried out multi-level control of access to the LAN resources of an internal unit or a small organization and provided information about unauthorized user actions for taking operational measures. The above factors determine the relevance of the development of a LAN monitoring device with audio notification of unauthorized access. The urgency of the problem of protecting information within the enterprise is beyond doubt. Such a device can be quite relevant for organizations of any form of ownership and their subdivisions that use small LANs and have a system administrator who comes as needed.

PROBLEM STATEMENT

The main task to be solved in the work is to develop a hardware and software complex for monitoring a LAN with an audio notification of unauthorized access, which, being in the premises of technical personnel, security guards or security services, carries out multi-level

control of access to enterprise LAN resources using small LANs. , and provides the necessary information about unauthorized actions of the user for taking operational measures.

SOLUTION OF THE PROBLEM

As a result of the research carried out, a device has been developed for monitoring a local area network with a voice sound notification of unauthorized access. The device notifies about all important events occurring inside the LAN, such as: connection or disconnection of known or unknown computers to the LAN (when reading all information about them), the physical state of the network ports of devices, information about the issuance of PC network parameters, changing the state of Internet access and much more. Work in both wired and wireless network segments is supported. Passive and active monitoring has been implemented, since in the wired segment some types of scanning are possible only by the active method [4].

Structurally, a LAN monitoring device with voice audio notification is a block of electronic equipment that includes several functional cells, united inside a single housing. The block diagram of the device is shown in Fig. 1 [2].

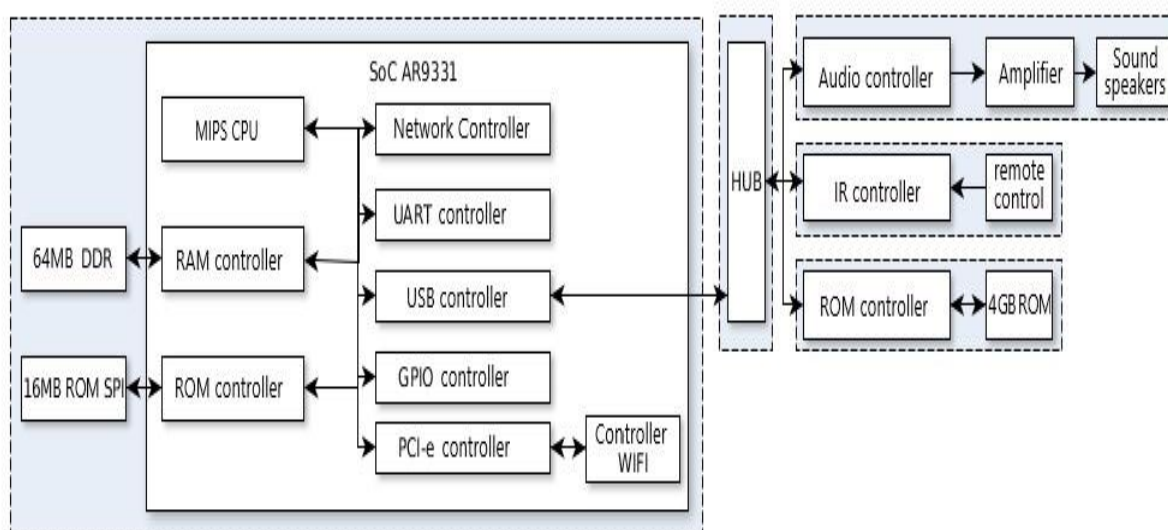


Fig. 1 Block diagram of a LAN monitoring device

The LAN monitoring device includes:

- system board, which, in fact, is a microcomputer with an operating system based on the Linux kernel, the basis of the electrical circuit of which is a SoC (System-on-Chip) chip. Also, the motherboard contains RAM, ROM and other elements (in the ROM of this microcomputer, in addition to the bootloader with the operating system, developed application programs are written that carry out network monitoring);

- a splitter board for the interface bus for internal and external devices;
- audio controller board with class D amplifier and speaker;
- IR remote controller board (the remote control is used to control the device or configure it);

- an external ROM controller board with 4GB ROM for the user's needs (ROM is in microsd format and, if necessary, the drive can be replaced).

As mentioned above, the LAN monitoring device with voice notification is designed to play audio notifications in the event of any events on the LAN. Alerts can optionally be in audio format (this is not always convenient), therefore, as an option, an alert by e-mail or SMS is implemented.

There is a possibility of monitoring both wired and wireless segment. Both active and passive monitoring are supported. The main events are monitored:

- Connection or disconnection from the network of various nodes (maintaining white, black and neutral lists is supported);
- Changing the states of wired devices at the physical, channel and network levels;
- Changing the state of Internet access;
- Monitoring the states of wireless interfaces at the channel and network levels;
- Tracking the fact of assigning static parameters to devices;
- Additional functions related to logging, management and notification.

The device can be controlled and configured via an IR remote control (main method), a mini-keyboard, HID devices or from a computer through a developed shell program running on the device (the fastest and most convenient method).

Such an extended list of functions performed by the device became possible due to the peculiarities of the developed design of the hardware part of the device, the use of publicly available system software based on the Linux kernel, open drivers and a bootloader, as well as writing specialized application software based on a high-level programming language that does not depend on the architecture.

The motherboard is a microcomputer, or, to be more precise, a system on a single chip, since the microcomputer is based on only one SoC (System on Chip) chip - in our case, it is a Qualcomm Atheros AR9331 chip. The microcircuit is specially designed to create cheap highly specialized microcomputers (so-called embedded systems). These microcircuits work on operating systems with the Linux kernel. The microcircuit is ideal for creating smart highly specialized devices and is actively used in routers, wireless smart devices, music centers and other equipment. This microcircuit is almost a full-fledged microcomputer, since it has all the components necessary for this, with the exception of RAM and ROM (which are implemented by separate microcircuits). This approach is convenient, since devices based on such microcircuits are very cheap, easy to design and manufacture, have low power consumption, small dimensions and high reliability.

Most often, devices based on such microcircuits contain a board with directly the SoC microcircuit itself and RAM and ROM microcircuits (with strapping). If desired, you can add other controllers. The selected SoC has a very rich functionality, which is many times superior to all microcontrollers in both capabilities and computing power.

At maximum load, the device consumes about 1.5 W of power, while the SoC microcircuit practically does not heat up (according to the documentation, the microcircuit can operate at temperatures up to 85 ° C). Therefore, in our climate, it makes no sense to talk about cooling [1].

Qualcomm Atheros AR9331 includes: MIPS 24K microprocessor operating at 400 MHz, WIFI 802.11n network controller (1T1R, 150 MB / s), Fast Ethernet network controller (100 MB / s), 16 bit SDRAM / DDR1 / RAM controller DDR2, ROM controller (SPI NOR flash), 5-port Fast Ethernet switch (100MB / s), USB controller (v2), I2S / SPDIF audio, other functions of little importance for the developed device.

A more detailed diagram of AR9331 is shown in Fig. 2.

SoC from Qualcomm was not chosen by chance. This company does its best to support free software, so most likely there will be no problems with ready-made operating systems, open drivers and documentation for chips from this company.

The microcircuit has more than 300 pages of official documentation for both ordinary users and developers, which allows even novice developers to create their own devices on this microcircuit without much difficulty.

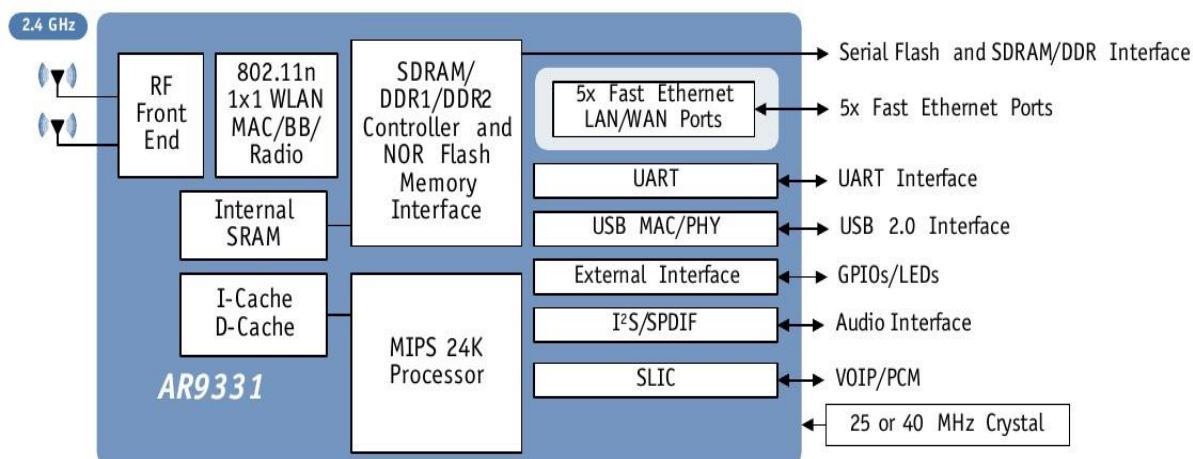


Fig. 2 Block diagram of Qualcomm Atheros AR9331

It may seem that this SoC is already hopelessly outdated, but this is not at all the case. Faster and more expensive analogs, of course, exist, but this power is more than enough for network monitoring. As for the choice of the type of RAM, in our case, the ideal solution would be to use the DDR1 type. Let's clarify: probably, it's not worth saying that the use of the SDRAM type is unacceptable, since this type of memory is very outdated, slow and in short supply. But choosing the best of the supported DDR2 memory types is also not worth it, since when using DDR1 there are a number of advantages: Firstly, on this configuration, DDR2 will have high latencies (which is typical for this type of memory on many configurations), so the gain the use of DDR2 in this device will be almost invisible. Secondly, the use of DDR2 will entail additional costs and difficulties in production and design - after all, starting with DDR2, memory chip cases have been made in BGA design.

The best solution would be to set the memory type to DDR1, the maximum size is 64MB. This is the maximum capacity, as there are no larger 16-bit DDR1 chips. Note that not all DDR1 chips are compatible with each other, therefore, you should always look at the complete documentation for both the memory chip and the memory controller. This product uses the Hynix HY5DU121622DTP-D43 chip. The chip has about 30 pages of official documentation for developers, and is a 64 MB DDR1 chip with 400 (200 MHz) @ CL3-3-3-3 timings.

As for the choice of the type of flash memory, the choice is obvious - the SPI controller is already built into the SoC, so any 8-pin SPI NOR FLASH microcircuit will be an excellent cheap solution (even with single purchases, the price will be around \$ 1 - 3 per piece). It was the 8-pin microcircuit that was chosen for easier installation and design. With compatibility, the situation is similar - not all SPI FLASH chips are compatible with each other. Moreover, the OS bootloader must also be able to work correctly with ROM, so, again, you cannot do without reading the documentation. In our case, a 16MB Winbond W25Q128 microcircuit will be used, which has about 100 pages of official documentation, works without problems with the controller of the selected SoC, and some free bootloaders.

Having chosen microcircuits for the device core, let's talk about the rest of the components.

It is better to take the most common connector for the power supply, for example, miniusb or microusb, and the circuitry of the board should be done with the expectation that the supply voltage will be 5 volts. Then, in the absence of a power supply unit at hand, the device can be connected to any usb port (in these ports, the supply voltage is 5 volts with a minimum power of 2.5W), or to charging from the phone.

To internal USB connector type-A connects an internal switch. It serves for communication with the internal devices described above and for communication with external devices that will be connected to the external USB type-A connectors located on the switch board (which is a good start for emergency situations). If necessary, it is possible to connect other devices for which software support will be implemented.

It makes no sense to make more than one Ethernet connectors. One connector is sufficient to monitor the wired segment. True, you will also have to add a standard microcircuit of the transformer unit, as the voltage levels in the twisted pair and in low-power devices differ [3]. As a transformer block microcircuit, for example, the standard H1601CG is suitable. The microcircuit provides one ethernet 10 / 100Base port.

The button will serve for any programmed function (for example, restarting the device). It should be connected to GPIO pins.

The LED will be an indication of the operation of the device, as well as an indication of emergency situations. It can also be connected to GPIO.

It makes sense to leave pads for UART and JTAG connections on the board. This is necessary for direct emergency communication with the device: the UART will allow you to get direct access to the bootloader console or to the OS console, and JTAG will allow you to directly issue commands to the processor. In service centers, similar devices are usually restored via UART and JTAG.

Also, for more compactness, it will be more expedient to make a thick track on the board as a WIFI antenna. This action will affect the signal level, reducing it from several hundred meters to several tens of meters (for line of sight), but in our case this is not critical, and for extreme cases a miniature platform for an external antenna will be left on the board.

Software part. Conventionally, the software part can be divided into two parts: system software (loader, OS, drivers) and application software (with the help of this software, the device monitors the LAN).

The OS and other system software for the device are taken from open source projects - since developing a bootloader or operating system from scratch for such a device is long, laborious and makes no sense.

Free uboot was chosen as the bootloader, and free OpenWRT was chosen as the OS [5]. All these components were assembled from source codes for the microcomputer architecture and flashed into ROM.

LAN monitoring applications - have been developed. Most of the program modules were developed and tested on a regular PC, and after debugging they were transferred to the device's ROM (that's why, a scripting language was chosen that does not depend on the computer architecture). But it was inconvenient to develop some network components in this way, so the main network modules were developed and debugged directly on the device itself. For debugging, the operating system event log and the UART console of the device were used.

Programs were developed according to the classical principle, which formed the basis of unix and similar systems, which implies breaking any task into a number of smaller ones. In the end, we got more than 50 highly specialized scripts and the main script core, which is constantly in the device memory and calls other scripts as needed.

CONCLUSION

Thus, a device was developed that, having a low cost and ease of production and operation, allows you to control a LAN, transmit voice and other messages about authorized and unauthorized access to network resources, thereby helping to control and ensure the security of small and medium-sized local networks.

The developed LAN monitoring device with voice sound notification allows you to quickly and effectively help in suppressing attempts of unauthorized access to LAN resources

due to the design features and features of the software implementation, and at the moment the authors have not found hardware and software analogues of the device.

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AERODROME COATING QUALITY CONTROL DEVICE

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Abstract— This article discusses a system for quality control of the surface of runways of small airfields based on the radiometry method and a microprocessor system. The analysis of methods for detecting coating defects was carried out, the characteristics of electronic diagnostic support were investigated.

Keywords- Design, development, IR - radiometers, runway strip, defects.

INTRODUCTION

The issues of efficiency of airfield pavements have recently become of paramount importance. This is explained by the fact that in modern airports, coatings are characterized by high material consumption and occupy significant areas. Therefore, continuous diagnostics and timely detection of coating defects, and better identification of the preconditions of their formation, can significantly reduce the cost of operating airports, save most of the funds for repair and restoration work.

PROBLEM STATEMENT

In this regard, it became necessary to create operational diagnostic equipment capable of examining in a short time a huge area of coverage of airfield runways in order to identify by non-destructive testing methods and timely elimination of defects in runway coatings.

SOLUTION OF THE PROBLEM

There are nine physical principles of non-destructive testing. One of them is thermal control. Distinguish between passive and active thermal control. With the passive method, the thermal fields of the object are analyzed in the course of their natural functioning. The active method involves heating an object with an external energy source. The use of a non-contact method for measuring the distribution of thermal fields, especially in combination with a passive method, makes it possible to carry out diagnostics of operated objects without disrupting their mode of operation. It is this property of thermal control that provided him with an important role in the examination of energy-saturated objects, medicine, remote control of inaccessible objects.

When implementing any of the thermal control methods, it is important to get a visual representation of the distribution of thermal fields. This problem is solved with the help of IR - radiometers, devices that provide a visual representation of the intensity of thermal radiation from objects in real time. Modern infrared radiometers operate in the mid-wave infrared range. The atmosphere has two areas of relative transparency of 2-5 microns and 8-15 microns. This range corresponds to a temperature from -50°C to 600°C. Depending on the principle of operation, IR radiometers are divided into two main types: cooled and uncooled.

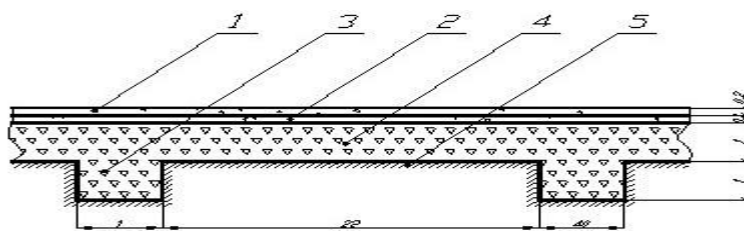
On the domestic market of equipment there are mainly “matrix” IR - radiometers of foreign production.

When designing an IR - radiometer, the first task is to create a device on the basis of a matrix IR - receiver that meets all the requirements of the modern market at a much lower cost than similar devices from other manufacturers of such equipment.

By the nature of work under the load from aircraft, airfield pavements are divided into two groups - rigid and non-rigid.

A distinctive feature of rigid coatings is that under load they work in bending due to the ability of the material in the actual coating layer to withstand certain tensile stresses. Cement concrete is commonly used as such material in rigid pavements.

Of the hard coatings, the most widely used in practice are monolithic concrete, reinforced concrete and reinforced concrete coatings. Figure 1 shows a typical runway design.



- 1- Cement concrete coating; 2- Skinny cement; 3- Drainage ditch with crushed stone filling; 4- Artificial crushed stone base; 5- Natural foundation

Fig.1 Block diagram of a gamma radiation detector

Non-rigid coatings, in comparison with rigid ones, are less resistant to bending under load.

Depending on the materials used (in the layer of the actual coating), the following types of non-rigid coatings are distinguished:

- asphalt concrete;
- from durable stone materials of selected composition, treated with organic binders;
- from crushed stone and gravel materials.

Asphalt-concrete non-rigid pavements built on various artificial foundations using the listed materials are most widely used in practice.

Figure 2 shows the appearance of the runway in Bukhara from the take-off side. The photo was taken from a helicopter from a height of 100 m.

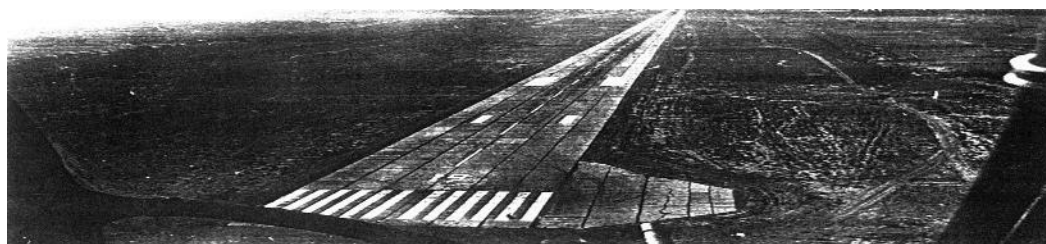


Fig. 2 The appearance of the runway from a helicopter

Currently, there are several methods for assessing the quality of the surface of airfield pavements.

To quantify the condition of the coverage, the PCI method is used, which uses certain weighting functions and weighting factors (numbers) for each defect. Weight functions are presented in the form of graphs for each type of defects, taking into account the degree of damage: low, medium, high. This applies to both rigid and non-rigid coverings. The graphical (mathematical) representation of weight functions makes it possible to more accurately determine the contribution of a particular defect to the value of the state index, since these functions have many values, each of which corresponds to a specific amount of damage. Based on this method, the PCI index ranges from 0 to 100, where 0 is the worst condition and 100 is the best [4].

The top of the slab heats up faster during the day and cools at night, the temperature of the bottom of the slab changes less due to the influence of the heat capacity of the base soil. The temperature difference between the top and bottom of the slab causes warping, which is prevented by the resistance of neighboring slabs and the slab's own weight. This process is depicted in Figures 3 and 4.



Fig. 3 The temperature of the top surface is higher than the bottom



Fig. 4 The temperature of the bottom surface is higher than the top

The experience in the construction of rigid coverings for airfields has shown that the temperature stresses that develop in them can cause the destruction of these coverings (Figure 5).



Fig.5 Uniform plate cooling

When soils freeze at the base of hard coatings, as a result of winter migration of moisture and accumulation of ice lenses, a vertical uplift of the coating occurs - heaving. This process can be uniform, then the entire coating rises to the same height, but due to the heterogeneity of soil strata or the uneven flow of moisture into the freezing thickness, the swelling is often uneven, local drillings are formed. By lifting the slab, drilling out induces bending stresses in the slabs, as shown in Figure 6.



Fig. 6 Deformation of concrete pavements with a change in the volume of soil in the base with uneven swelling of soils

During spring thawing of the soil, the surface of the base that has risen during the winter period settles, as shown in the figure in Fig. 7. Due to uneven thawing, sediment can occur unevenly even with uniform heaving in winter.



Fig. 7 Uneven settlement of the base during thawing of soil

In case of uneven swelling or thawing of the base, the slab is rolled up raised and resting on the ground in some places. The resulting stresses only from the influence of their own weight can significantly exceed the ultimate strength of concrete in bending and cause destruction of the coating of airfields.

On airfields and roads built in areas where intense heaving of soil foundations can occur, damage to the pavement occurs. Observations have shown that the number of slabs with through cracks caused by heaving of the underlying soils is continuously increasing.

In recent years, remote sensing methods for studying the condition of the coating and its foundation have received significant development. The following instruments and associated control methods exist:

- Thermal imaging cameras - designed to visualize the distribution of the thermal field of the surface layers of objects, observation in conditions of atmospheric and other interference (fog, smoke, rain, etc.), diagnostics of energy-saturated objects, detection of overheating zones, places of heat leaks in buildings, on heating mains, accumulations of liquid and voids under concrete pavements - an effective tool for solving search problems.

- GPR - devices, the principle of which is based on the emission of an electromagnetic signal, reception and measurement of the parameters of signals reflected from the structural inhomogeneities of the subsurface space.

- Ultrasonic flaw detection - devices working according to the pulse echo method.

- Electrical prospecting - devices based on the determination of soil resistivity (determination of various horizontal geological layers by vertical electrical sounding, determination of leaks in landfills and burials, determination of fracture zones in bedrocks, detection of underground voids, determination of seepage through dams, search for groundwater water, search for sand and gravel, check the integrity of the insulation of landfills).

The choice of the thermal method for monitoring the runway surface is primarily due to the fact that the thermal imaging system allows you to quickly identify possible places of defect formation. No other system offers this high performance. The thermal method will make it possible to assess the state of the airfield strip as a whole, along its entire length. Thermal vision control is easy to automate, which is very difficult with acoustic and electromagnetic methods. Georadar equipment, despite all its positive aspects, has a very high cost, as well as low productivity. When carrying out diagnostics, it is advisable to use complex verification methods, for example, obtaining a general picture of emergency coverage areas and examining them using GPR or ultrasonic equipment, which will more accurately assess the state of the detected defects [2].

When implementing any of the thermal control methods, it is important to get a visual representation of the distribution of thermal fields. This problem is solved with the help of IR - radiometers, devices that provide a visual representation of the intensity of thermal radiation from objects in real time. Modern infrared radiometers operate in the mid-wave infrared range. The atmosphere has two areas of relative transparency of 2-5 microns and 8-15 microns. This range corresponds to a temperature from -50°C to 600°C. Depending on the principle of operation, IR - radiometers are divided into two main types: cooled and uncooled [1].

The geometric resolution of the pyrovidicone-based IR radiometer is determined by the “spreading” of the charge over the target surface during the half-frame time. To combat this phenomenon, structured pyrovidicones have been developed, the target areas of which are

isolated from each other. However, they have not found widespread use due to their high cost and reduced sensitivity. The disadvantages of IR - radiometers based on pyrovidicons include the impossibility of measuring absolute temperature values without additional technical means. However, this problem can be solved by introducing a reference heat source into the working area of the device. Recently, the development of uncooled IR - radiometers based on matrices has been actively carried out. Unfortunately, the work on the creation of domestic medium-wave uncooled large-capacity matrices is far from the stage of completion due to insufficient funding [3].

In terms of the achieved values of the temperature difference equivalent to noise and some other parameters, pyroelectric matrices are close to bolometric ones, and with the previously mentioned presence of the "panning" mode, they have no analogues. A matrix of any type is housed in a thermo-protective (sometimes in an evacuated) case. By analogy with pyrovidikon, a pyroelectric matrix requires an optical modulator (chopper) of the heat flux projected onto it.

Thermal imaging equipment is at the stage of changing generations of technical solutions. Traditional technologies are giving way to new, promising areas. At the same time, the introduction of new technologies is not always justified in terms of reliability and efficiency.

The runway control system is depicted in Figure 8.

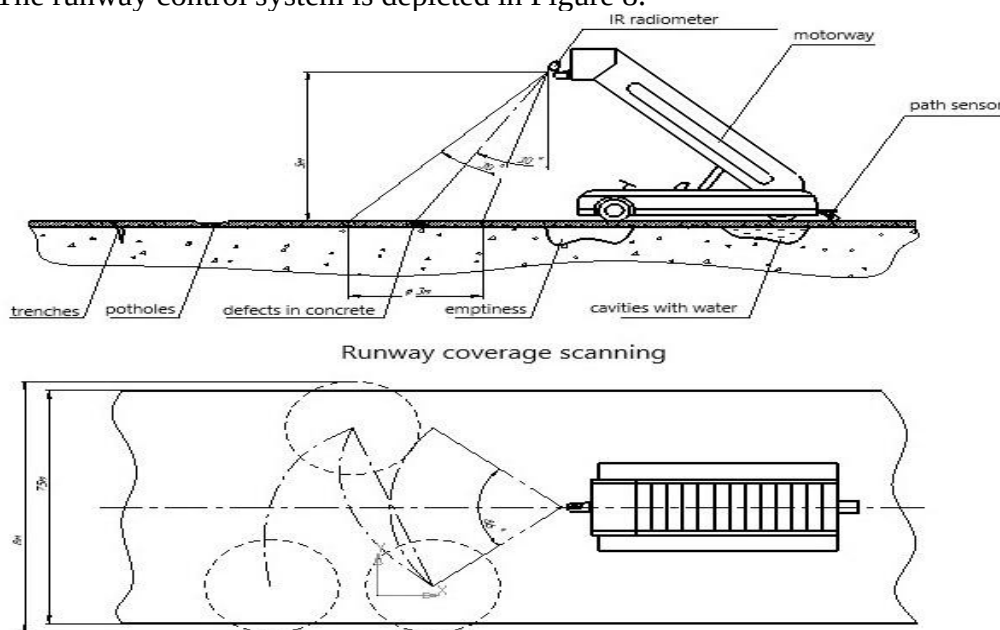


Fig. 8 Runway control system

The block diagram of the quality control system for the coverage of airport runways is shown in Figure 9.

After analyzing the electrical block diagram, we come to the conclusion that, for this type of device, low-power, high-frequency elements are required. In addition, to minimize the dimensions of future cells, elements of small dimensions will be required. The use of the element base, oriented for surface mounting, allows you to fulfill both requirements. Based on these requirements, we are forced to turn to a number of foreign electronic components, since the modern domestic industry does not produce radioelements of this class.

Because the operation of an IR - radiometer at low temperatures is envisaged. An important factor when choosing an element base is to take into account the operating temperature ranges of the corresponding elements. Of the electronic components offered on the market for the temperature ranges of their operation - commercial (from 0 to + 70 oC) and industrial (from -40 to +85 oC) - the reference point is made to the latter, which satisfies the operating conditions of the IR radiometer [6].

The microprocessor performs the main data processing and general control of the system. To process a stream of video data in real time, large computing resources are required. In addition, it is necessary to switch a larger number of nodes among themselves. The best way to solve this problem is to use a powerful programmable logic integrated circuit (FPGA) of the XC2S50-5PQ208I type. Possessing high performance (transit time 2 ns per cell) and flexibility, it allows parallel processing of input and output video data streams, switching the data bus of a central microcontroller, and a convenient interface for accessing peripheral devices. The advantage of the XC2S50-5PQ208I is the convenient XilinxFoundation development system, which allows not only designing a circuit, but also debugging it through a special technological connector provided on the board. The use of an FPGA chip in a larger, 208-pin package made it possible to solve the problem of commutation and dimensions of the printed circuit board. Most of the nodes are connected directly to the XC2S50-5PQ208I, which multiplexes the microcontroller's data bus. This allows you to significantly reduce the size of the printed circuit board, reduce the total number and length of lines with high frequency. In addition, this solution allows you to easily solve the problem of access to individual nodes (non-volatile memory card and real time clock).

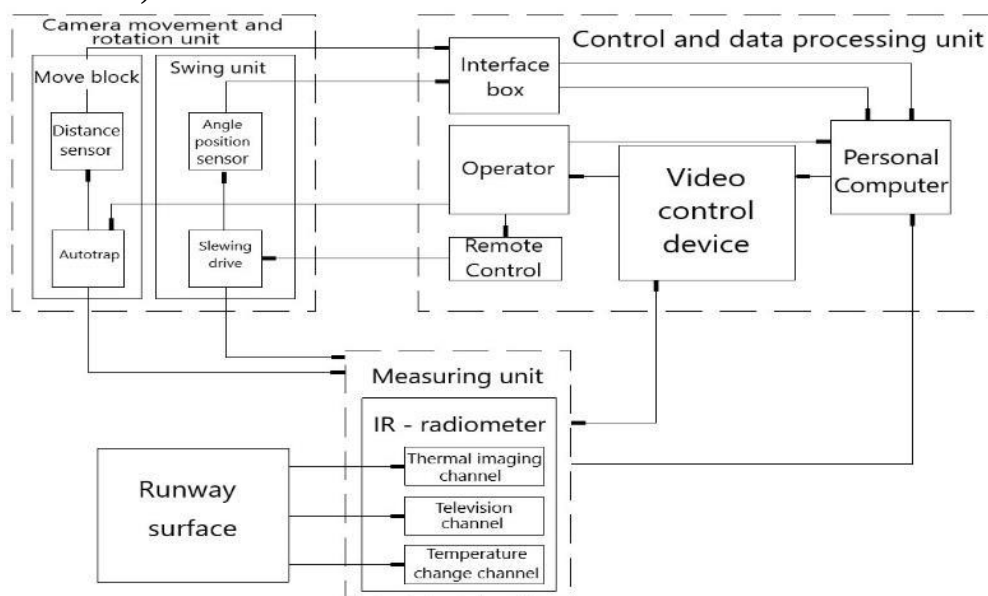


Fig. 9 Block diagram of the quality control system for the coverage of airport runways

The general control of the device is carried out by an ATmega163L microcontroller (MC). It is executed on the basis of RISC (reduced instrumentation computer) instruction set and has a performance of about 4 MIPS (millioninstructionpersecond). This performance is quite enough for general control of the device. MK is made on the basis of Harvard architecture. The advantage of this type of architecture is that the program and data memory blocks are integrated inside the microcircuit. This allows you to reduce the total number of cases on the board, and increase the reliability of the system. The MK peripheral set includes an I2C serial bus used to work with digital video decoder and video encoder chips, a multichannel low-speed ADC used to measure temperature with a pyrometer and monitor the battery charge level. A distinctive feature of the selected MK model is the presence of rewritable program memory. This makes it possible to repeatedly modify the program code of the device, which is especially important for devices with a small volume of production, such as an IR radiometer. The speed and convenience of developing the program code is ensured by the presence of a software emulator for the operation of the MC and an in-circuit programmer, which allows reprogramming of the device installed on the board through a special technological connector [5] .

To digitize the original video signal and generate an analog video signal from digital data, microcircuits from PHILIPS are used: digital video decoder SAA7113H and video encoder SAA7121. But unlike the microcircuits of other manufacturers, those selected for performing all the required functions have packages with a smaller number of pins, which ensures a reduction in the area of the printed circuit board covered by them.

CONCLUSION

This development is cheaper than the previous one, and is more cost-effective both in production and in operation, since during the development it was possible to significantly reduce the costs of technical preparation of production, as well as reduce the amount of annual operating costs for new - your product.

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DEVELOPMENT OF A CONTROL SYSTEM FOR A HYDROPONIC PLANT

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Abstract – The article discusses the capabilities of the ESP32 microcontroller when designing a control unit for a closed-loop hydroponic system, describes the principle of its operation, considers the structural and electrical schematic diagram. An example of constructing a lighting element (phyto lamp) has been analyzed.

Keywords: electrical schematic diagram, structural diagram, microcontroller, control system, hydroponics, phyto lamp.

INTRODUCTION

Hydroponics is the technology of growing cultivated plants without the participation of soil. Roughly speaking, the essence of this method is reduced to immersing the root system in a nutrient solution. Thus the plant has direct access to the necessary materials for his life. In recent years, this technology has gradually gained popularity all over the world.

PROBLEM STATEMENT

One of the important advantages of growing plants using a hydroponic method is that we can fully control the growing conditions of plants: proof of the creation of such a regime of root system power, to which the ripened fully satisfy the needs for nutrients, control the environment, the conditions in which they grow, controlling ripening and palatability of fruits.

Any portable hydroponic system should consist of five modules: lighting, a timer for turning on the water pump (compressor), and a power source. In addition, we need a container in

which the plant roots will be located and where the nutrient will go, as well as a place where it will be stored, if any.

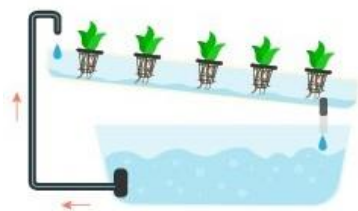


Fig. 1 The principle of operation of the plant based on the nutrient layer technique

RESEARCH

This article will consider the design of a system based on the nutrient layer technique (Fig. 1), the essence of which is the spontaneous overflow of liquid along an inclined plane, in the path of which plant roots are placed. Plants will be located in a chamber in which both air circulation and ventilation will be carried out; an ultrasonic humidifier will also be installed in the chamber to maintain certain climatic conditions

To design a lighting element, consider the optical spectra required by a plant at each stage of its growth (Fig. 2).

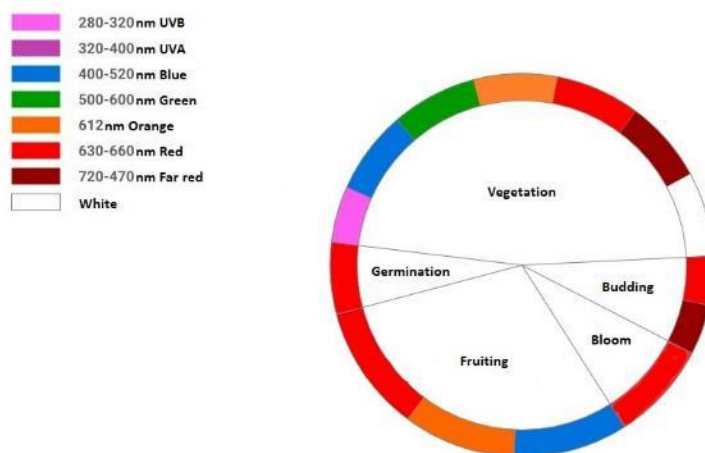


Fig. 2 Radiation spectra required by a plant for growth and development

It can be seen from the figure that the radiation of the blue, orange and red spectra is actively absorbed by the plant at several stages of its growth.

As a result, for the assembly «phyto lamp» decided to use the following SMD LEDs:

- **LTPL-C034UVH385.** Their radiation lies in the range 380 - 400 nm (ultraviolet A); small doses of which will have a beneficial effect on the taste of the fruit.

- **XPEWHT-L1-0000-00DE3** These diodes have a light temperature of 5000K.

Since radiation in the blue range is not used separately anywhere, but is combined with other parts of the spectrum, this is the best option; and the presence of green contributes to the better development of the lower levels of the plant in conditions of a lack of light.

- **XP EE PR-L1-0000-00C01.** LEDs emitting red wavelength range, c wavelengths 650 - 670 nm

- **XPEFAR-L1-0000-00701.** Their radiation is in the far red spectrum (720 - 740 nm and carries a "signal" function, informing the plant about the approach of cold weather and accelerating the phases of flowering and fruiting.

To control the temperature and humidity of the air in the chamber, the «SHT20» sensor is used. The device is powered by 3.3V and connects to the controller via the I2C interface. It can be purchased separately or as a ready-made module.

The ESP32 microcontroller will be used to control the system. This device is part of the family of IoT devices and has advanced functionality, including Wi-Fi and Bluetooth modules, 12-bit ADC for 18 channels, two 8-bit DACs $4 \times$ SPI interfaces $2 \times$ I2C and $2 \times$ I2S interface and more. The module is powered by a 3.3V voltage and has 5 operating modes that differ in power consumption.

Of course, the pump is an integral part of the system. For example, let's take the «R385» model with a supply voltage of 6-12V and a current of up to 1A.

For the ventilation system, we will use any computer cooler and a pair of servos responsible for opening and closing the air ducts.

Basically, system management is planned to be carried out using an application on a smartphone or a web interface, all also implemented using a microcontroller; but on the control unit itself there will also be several buttons: turning on the unit, and activating the Bluetooth module; as well as indicator LEDs.

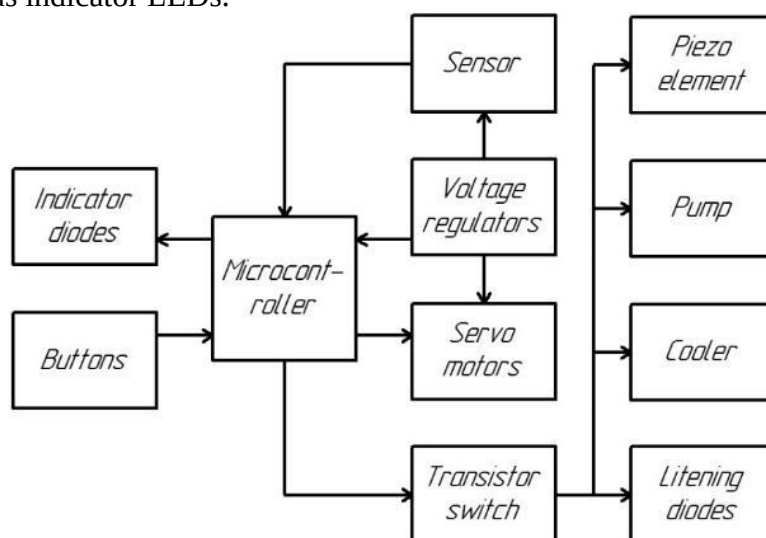


Fig. 3 Block diagram of the installation

The central unit is a microcontroller. It collects and analyzes the data coming to him from the temperature and humidity sensor, and also controls the lighting and other modules based on the instructions provided. Basically, the controller will use four power modes: Active (when using a wireless connection), modem (awake mode, in which a wireless connection is not used), light (only ULP coprocessor is working) and deeper sleep (the output of the controller from this state is carried out either by a timer or GPIO0). To change its state, either buttons or a built-in timer will be used.

When power is applied, the MCU will enter the active mode, if it has access to the Internet, it will synchronize the time, read the latest events in the log and, based on them, or resume the operation of the unit in one of two modes: normal, when no failures were observed before, or emergency, when synchronization failed or the previous shutdown was incorrect. The countdown in this mode starts from zero, and if it is possible to synchronize the clock, it is recalculated.

For most of the day, MCU it will be in a light sleep mode, since two programmable hardware timers (DAC) will be used to clock both the pump and the piezoelectric element (humidifier). Occasionally, the controller will interrogate the sensor and compare the temperature and humidity readings and, if necessary, take predetermined actions based on the received data, as well as ventilate the chamber.

The rest of the 8-10 hours it will work in modem mode, since LED PWM control is performed by software, and, therefore, electric motors too.

The circuit provides 3 indicator LEDs, they show whether the unit is on, show the status of the wireless connection and notify about the presence of errors during operation. There are also two buttons: to enable the installation and to activate the Bluetooth connection. Figure 4 shows the electrical schematic diagram of the installation.

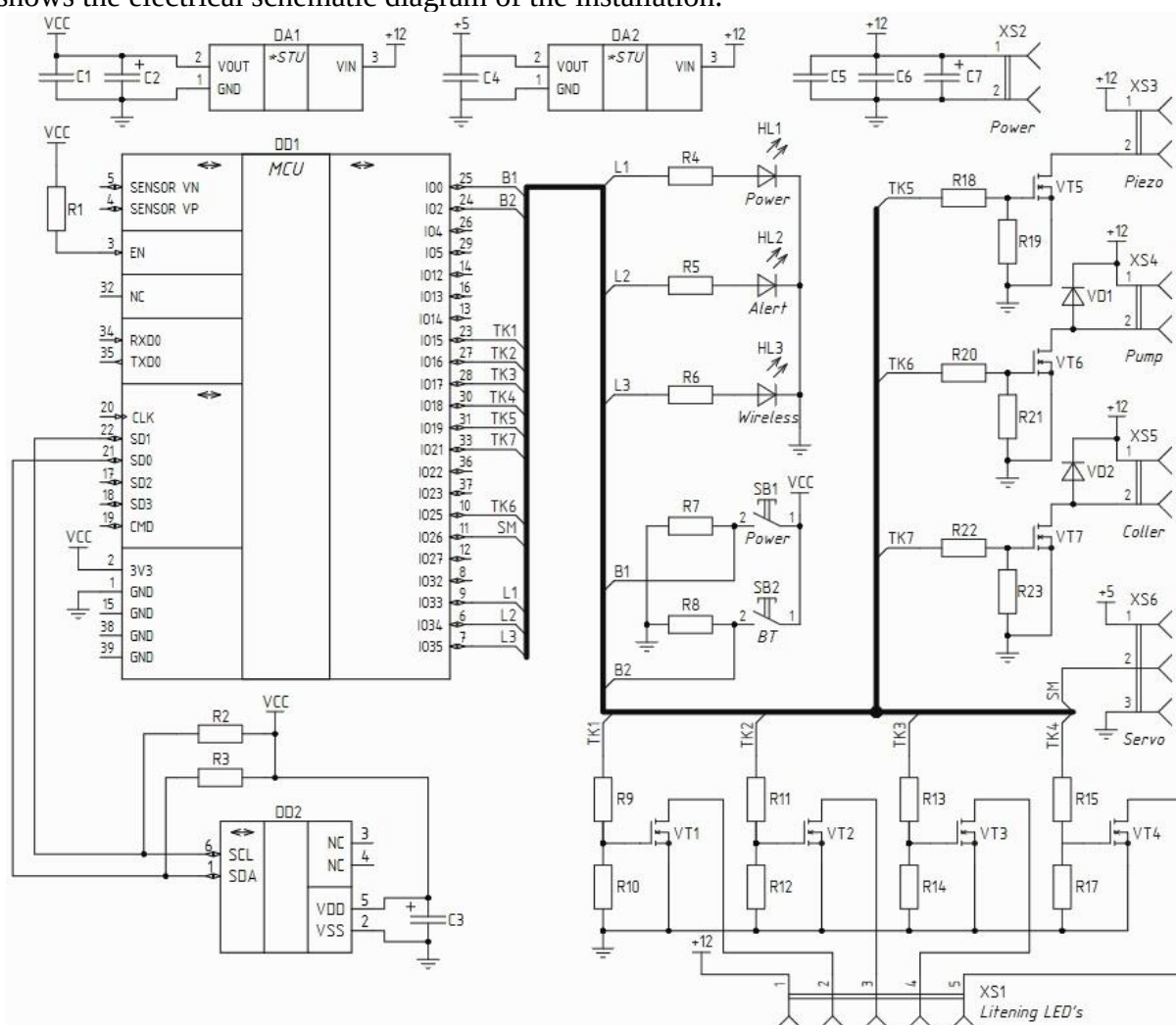


Fig. 4 Electrical schematic diagram

The supply voltage, 12 volts, is supplied to the input filter. Since the microcontroller and the sensor operate from 3.3V, the current flows to them through the LD1117S33CTR voltage regulator; the same situation with servomotors, only the stabilization module is already 5 volts.

All peripheral devices are controlled by generating a PWM signal. The pulse signal to the servo is fed directly from the microcontroller, and all other components are controlled through transistor switches. Depending on the load power, the following n-channel mosfets can be used: IRL3709ZPBF and IRL8113PBF at currents of about 40A, IRL3713PBF at currents less than 20A. They must be installed on the radiator.

When connecting an inductive load such as a motor, it is necessary to install a powerful diode in the opposite direction so as not to burn the transistor with surges. And on the electric motor itself, it is recommended to solder ceramic capacitors with a capacity of 0.1-1 μF between the terminals, as well as between each terminal and the case.

Since the frequency of the signal generated by the PWM microcontroller exceeds several tens of kilohertz, you can refuse output filters for both electric motors, and not be afraid of a strong squeak, and for lighting diodes, thereby simplifying the final circuit.

As a result, we can have a home hydroponic plant, in which there is both humidity and lighting control, and we have 4 independently adjustable channels and, therefore, we can make separate irradiance maps for each growth cycle, and with reference to time. It is possible, for example, to integrate heating elements or additional sensors for monitoring the feed liquid or the level of carbon dioxide. We can also add up to 12 more lighting channels.

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DEVELOPMENT OF THE PRODUCTION SYSTEM OF A MACHINE-BUILDING COMPANY BASED ON THE APPLICATION OF LEAN PRODUCTION

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Abstract - The main features of the development of production systems at machine-building enterprises based on the application of lean production methods are considered. The basic principles, goals, tasks and directions of development of production systems are developed to improve the competitiveness of enterprises, the quality of products and reduce production losses.

Keywords: production system, machine-building enterprise, losses, lean manufacturing (lean production).

INTRODUCTION

One of the most advanced concepts of production system management in modern machine-building enterprises is the concept of "Lean Production", which combines various management methods and tools [1].

Lean manufacturing is aimed at eliminating losses in all areas of the organization's activities [2,3], including building relationships with consumers, product design, building supply chains, production management, transport and logistics operations. At the same time, losses are understood as any action that consumes resources, but does not create value for the consumer of the product.

When implementing lean manufacturing, increased attention is paid to continuously reducing the time required to perform all types of activities in the company, while ensuring better quality, lower costs and faster response to changes in external and internal factors affecting the organization's production processes.

Analysis of the results of the introduction of lean manufacturing in large holdings of Russian engineering (aviation, shipbuilding, engine building) showed that the enterprises have developed different types of production (from experimental to large-scale) for different groups of manufactured products. At the same time, the management of production systems does not

have time to adapt to the production conditions. Automation of individual management processes is carried out without developing a general concept of the entire management system, which creates duplicate unsynchronized data sources and does not exclude duplicate functions of structural divisions.

BASIC PRINCIPLES

When implementing lean production tools, the company's management must confirm its commitment to the following basic principles, on the basis of which the company's production system is developed and improved:

1. Strategic focus. The development of the production system of the enterprise is based on the strategic goals, plans and programs of activity, the requirements of consumers, the state and society, taking into account the industry characteristics.

2. High-quality and timely satisfaction of the needs of external and internal customers. Understanding and meeting the current and future requirements of consumers, gaining and maintaining their trust makes a significant contribution to the company's sustainable success.

3. Constant striving for the best through continuous improvement. Continuous improvement of all aspects of the company's activities in order to increase value for the customer, eliminate all types of losses, continuously adapt to changing conditions and maintain a high level of production efficiency.

4. Scientific approach to the organization of activities. The production system is considered as a set of interrelated elements (components), having an output (goal), input (resources), connection with the external environment, feedback; each element (component) of the system is considered as a large and complex system and at the same time as an element of a more general system; The functioning and development of the system is based on a cyclically repeated decision-making process (planning-action-verification-adjustment), based on the results of studying and adapting the best domestic and international practices of enterprise and production management, taking into account the basic provisions of the NOT.

5. Involvement of the organization's employees in the processes of continuous improvement. The involvement and development of the company's personnel at all levels of management is a prerequisite for effective continuous improvement activities. Competent, empowered, and cooperative employees enhance an organization's ability to create value.

6. Focused attention to places of value creation. Research and problem solving, as well as evaluating the effectiveness of decisions made, is carried out directly in the places of value creation.

7. Priority security. The priority in decision-making is a guaranteed level of technical, economic, social, environmental and other types of security.

GOALS AND OBJECTIVES

The main strategic goal in the field of development and optimization of the production system of a machine-building enterprise in the case of applying lean production methods is to reduce the development time of products at a given level of their quality and cost.

The goals in the field of development and optimization of the production system of a machine-building enterprise, ensuring the implementation of the main strategic goal, are grouped according to the principles laid down in the basis of the methodology of the Balanced Scorecard (BSC) [4], and are detailed in the following areas:

1. Development potential. This area includes goals, the achievement of which will ensure the effectiveness of the current production activities and the development of the production system of the enterprise.

2. Processes and management system. This area includes goals, the achievement of which will improve the efficiency of the production system of the enterprise.

3. External environment. This area includes goals, the achievement of which will ensure appropriate results of work with stakeholders (co-executors, suppliers).

4. Financial results. This area includes goals, the achievement of which will ensure compliance with the specified financial indicators.

The conceptual structure of the goals for the development and optimization of the production system of a machine-building enterprise is shown in Picture 1.

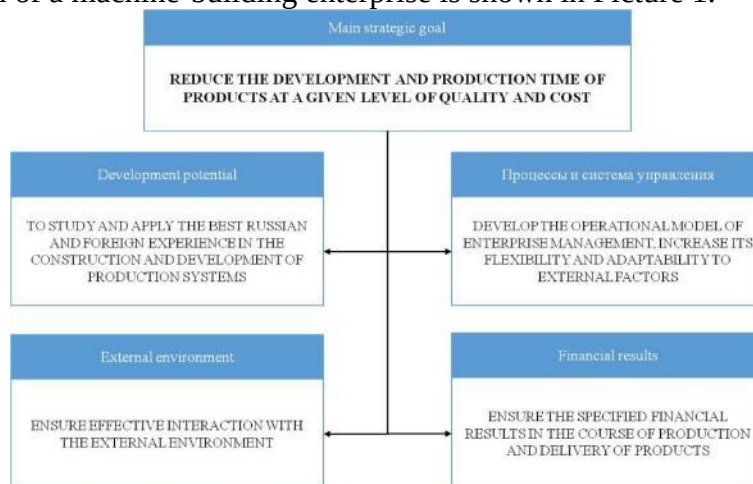


Fig. 1 Conceptual structure of the goals for the development and optimization of the production system of a machine-building enterprise

Based on the basic conceptual structure of the goals, depending on the specifics of production, a machine-building enterprise can develop independent goal-setting directions.

To achieve the goals in each area, a consistent implementation of individual tasks should be planned. The goals in the area of "Development Potential" are achieved by solving the following tasks:

1. Develop the product portfolio by increasing:
 - the volume of products in the developed market segments;
 - production volumes in new market segments.
2. Expand the product range:
 - update and unify the element base;
 - develop products that meet the customer's needs.
3. Ensure the timely introduction of new technologies and capacities:
 - identify needs for new technologies and capacities;
 - ensure the introduction of new technologies and capacities in accordance with the approved plan.
4. Develop human resources potential:
 - develop the necessary professional competencies for strategically important job positions;
 - adapt the motivation system to the target tasks of the production system.

The goals in the field of "Processes and management system" are achieved by solving the following tasks:

1. To ensure the adaptation of the production system to the growth of output in product areas in accordance with the unification of the used element base and the implemented technological processes:
 - increase production volumes and the number of simultaneously executed orders;
 - ensure that the products produced meet the required quality level;
 - shorten the production cycle of manufacturing products;

- ensure uniform loading of equipment and production personnel;
- 2. To ensure safe, reliable and trouble-free operation of all objects of the production and technological complex of the enterprise:
 - provide up-to-date information on the current state of the technical infrastructure;
 - ensure that production plans are synchronized with the maintenance and repair plans for the main process equipment;
 - ensure the availability of effective approaches to eliminate emergencies and violations of production discipline.
- 3. Ensure the relevance of economic indicators for the implementation of "rolling" planning:
 - ensure the availability of complete information about planned and actual costs in the context of orders (order stages), topics, and structural divisions;
 - provide information on orders (order stages) no more than 3 days in advance;
 - ensure the availability of current technological standards.

The goals in the field of "External environment" are achieved by solving the following tasks::

1. Meet the requirements of consumers (customers):
 - ensure the quality of products in accordance with the established requirements;
 - conduct a flexible pricing policy that takes into account the characteristics of the market (market segment) and the product portfolio;
 - conduct a flexible financial policy in the framework of settlements with customers, taking into account the characteristics of the market (market segment) and the product portfolio;
2. Interact with suppliers who provide the best price / quality ratio for the delivery:
 - ensure the quality of supplies in accordance with the established requirements;
 - have a flexible financial strategy within the framework of settlements with suppliers, taking into account the characteristics of the market (market segment) and the product portfolio.

The goals in the area of "Financial results" are achieved by solving the following tasks::

1. Increase the company's profit:
 - provide target revenue volumes at the required rate of return;
 - provide the required rates of return on investment projects (modernization);
 - reduce costs (production, administrative);
2. Effectively manage assets:
 - effectively manage production capacity;
 - effectively manage non-production fixed assets.

AREAS OF DEVELOPMENT

Improvement of the production system of a machine-building enterprise is associated with constant development and adaptation to changes in the external environment, new goals, tasks, and requirements, and is implemented by:

1. Development of human resources and changes in the composition of employees;
2. Customizations, optimizations, and changes to internal requirements;
3. Modernization, optimization and changes in the structure of production assets.

The development of human resources is ensured by a harmonious combination of personal and public interests of each employee, ensuring the comprehensive development of the individual, maintaining health, and prolonging working capacity.

Changes in internal requirements are implemented in conjunction with the improvement of equipment, technology, organization of production and management, development and preservation of the integrity of the production system and its links with other systems.

The development of the structure of production assets involves:

- creating a scientific and technical reserve;
- protection of the results of intellectual activity;
- modernization of production facilities;
- development of advanced technologies;
- development of new competencies.

CONCLUSION

The implementation of the proposed concept in the activities of machine-building enterprises allows for the construction of flexible and efficient production systems with a low cost per unit of production. The full implementation of the proposed approach increases the competitiveness of products, contributes to the sustainable development of production, as well as timely response to changes in both external and internal working conditions of enterprises.

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INTELLIGENCE DECISION SUPPORT SYSTEMS UNDER THE KNOWLEDGE-BASED PROJECTS MANAGEMENT

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Abstract. This article presents the basic principles and specific features of the intelligence decision support systems (IDSS) implementation, the component composition of IDSS information architecture, and defines the specific tasks for IDSS implementation under the management of complex knowledge-based projects in engineering and instrumentation.

Key words: decision support, intelligence systems, projects management, information support.

Any modern company performs its activities under risk and uncertainty and is constantly dealt with the problem of providing the continued operation and development. Analysis of the large industrial companies' activities, and their management is the main point of managers, analysts and experts working in the area of information processing. To solve this problem, chief executive officers have to make managerial decisions on choosing the company development directions, on maintaining and expansion of the market power and share, on preventing losses and reducing costs, on maintaining and improving competitiveness. The sufficiency and professional level of the decisions made finally determine the company activities efficiency.

Intelligence Decision Support System (IDSS) is the decision support system that makes heavy use of artificial intelligence methods (AI). The AI methods use in information management systems has a long history. In fact, such terms as “knowledge-based systems” and “intelligence systems” have been used since the early 1980s to describe the management systems’ components. It is assumed that the concept of “decision support system” originated with Clyde W. Holsapple and Andrew B. Whinston during the late 1970s. Examples of specialized intelligence decision support systems include the flexible automated manufacturing systems, intelligence marketing decision support systems and diagnostic systems [1].

In regards to AI methods application, any system, applying for “artificial intelligence system” must include the following subsystems [2]:

- information entry and clarification subsystem;
- teaching subsystem, allowing for obtaining information through the system;
- knowledge representation subsystem, using for accumulation and storage of information;
- objectives definition subsystem, i.e. generation of objectives and making of decisions;
- subsystem of integrity maintaining system;
- interaction and communication subsystem;
- decision support subsystem.

The special features of tasks to be solved with fuzzy IDSS, including real-time IDSS, are [3]:

- difficulty, and sometimes even impossibility to obtain complete and objective information required for making a decision, that leads to use of subjective information;
- multivariance of searching for the most effective decision of the task in hand, the necessity of using for decision plausible (fuzzy) search methods and active participation of the decision-maker in it;
- necessity of entering new additional information into the knowledge base, and its updating, while searching for the decision.

It is possible to point out particularly the features of IDSS application for solving the quality management tasks at the product life cycle various stages, and for information support of quality management methods and means [4].

It should be noted that the use of intelligence accounting systems (IAS) rather than intelligence decision support systems, does not expect the human participation in the decision-making process. The basis for the fuzzy intelligence accounting system development is the accounting system with participation of an expert who, based on his own knowledge and experience about the object under study, composes the management process description. Following that, the object description is converted into the fuzzy rule base, which is subsequently used in the intelligence accounting system without the expert participation. The idea of such object fuzzy management involves the imitation of experienced expert actions. Fuzzy rules are the fuzzy condition action rules that describe the management strategies at qualitative level with the specified management object. Fuzzy intelligence accounting systems are used in areas where traditional control systems are ineffective and inapplicable, namely in the case of nonlinearity of the control system, in conditions of uncertainty, as well as in control systems based on the use of expert information. In fuzzy ISU, input and output variables are linguistic, and the control function is approximately described by a set of fuzzy production rules.

Thus, it is possible to determine the basic principles of fuzzy IDSS and real-time IAS development [5]:

1. The principle of openness and agility - intelligence accounting systems are focused on the open and dynamic subject domains;

2. The principle of semiotics assumes that the intelligence real-time decision support system is the semiotic-type distributed intelligence system, including the model base, intelligence modules of problem simulation and prediction, interface organization modules: text, graphic, voice and in the form of various diagrams and graphic charts in addition to the modules standard for expert systems (data and knowledge bases, information input module, decision output (search) subsystem);

3. The principle of data and knowledge presentation models adaptivity, and the search for decision, which implies maintaining the ability to learning, acquisition and accumulation of knowledge, maintaining the high capacity even under unexpected and unforeseen changes of object properties, management objectives, etc;

4. The principle of information distributed and parallel processing, due to which it is possible to perform the quick and high-quality analysis of a vast amount of information and the search for acceptable decision under tight time constraints;

5. The principle of maximizing the convenience and simplification of the decision maker interaction process with IDSS that is achieved through the use of cognitive graphics and hypertext procedure.

In regards to forming of IDSS information architecture, the following main interacting components are specified:

- language subsystem (mechanism, providing the communication between the user and other IDSS components);
- information subsystem (storage of data and its processing means). It consists of the database (DB), database management system, query means, data directory, external data sources;
- knowledge subsystem (knowledge store on the problem domain, such as procedures, heuristics and rules, knowledge processing means);
- model subsystem (store of models, simulation languages, simulation management means). It consists of the model base, model management system, simulation languages, model reference table and processor that provides the implementation on the model, integrates the models and conduct the modeling process;
- subsystem of processing and solving tasks (the link between other systems). The subsystem of processing and solving tasks implements its individual specific functions within their framework. This subsystem has the basic facilities to manipulate and process tasks for decision-making.

The performed analysis of IDSS forming principles and component composition allows developing the specific tasks for IDSS implementation during the management of complex knowledge-based projects in engineering and instrumentation within the research and development (R&D) contracts execution by the company.

1. Tasks, solving by IDSS at the stage of preparation for the contracts award:

- assessment of the load and justification of the project terms and cost, considering the company human resources, with the participation of internal and external co-contractors (preparation of materials for the calculation and cost-accounting development);
- modeling of the most suitable options for allocation of resources and development of plans for the public and commercial orders execution within the specified budget and time period;
- analysis and development of measures to minimize risks in the contracts execution through the formation of reserves in time, identification and assessment of critical paths.

2. Tasks, solving by IDSS during the contracts execution:

- formation of summary projects implementation plan on the horizon of up to 3 years (summary planning of the projects program), and the budgets assessment;
- formation of end-to-end, resources-and-time period-balanced plans for the projects implementation on the horizon of up to a year (intershop planning);

- management of end-to-end contracts execution in the shared pool of resources in real time, based on incoming events;
- prompt response to unforeseen events, emerging changes, and flexible reallocation of resources (introduction of additional employees, taking overtime on the weekends, etc.);
- plan / fact / prediction analysis according to the projects implementation calendar plans;
- financial and economic monitoring of the orders progress with advance identification of problem situations (exceeding of the budget, allocation of fact, etc.).

3. Tasks, solving by IDSS after the contract execution:

- accumulation and updating of knowledge on projects and items, processes, employees and their competencies, work performance standards, etc.;
- analysis of results and search for “bottlenecks” during the projects implementation;
- development of proposals for problem situations solving (replacement of employees, clarification of processes and tasks, employees training and education, etc.).

4. Tasks, solving by IDSS at the whole stages of contracts execution:

- formation of the knowledge base on items, projects, processes, tasks, staff and work results, production operations;
- integration of various systems data to form the centralized information and knowledge storage, concerning the projects;
- automation of the project management business processes, including the procedures for plans approval and for the required reports generation.

The IDSS integration will allow the modern companies to achieve the following results during the knowledge-based projects implementation:

- to reliably assess the amount of resources required to solve the projects tasks;
- plan flexibly the project tasks for executors due to their structure and interconnection;
- efficiently allocate resources between projects to execute the work schedules;
- keep plans up-to-date by specifying and analyzing the facts of tasks execution;
- implement the complex projects under the limited resources and in a timely manner, within budgets and with specified quality level;
- increase labor productivity at all levels of project management;
- develop and maintain the single knowledge base on the experts competencies and on the departments work results;
- accumulate experience in the projects implementation for reuse in works with good prospects;
- provide the transparency of projects management processes;
- promptly solve emerging problems and respond to unforeseen events in real time;
- provide the efficient use of resources (Lean-approach);
- take into account and evaluate each employee contribution to the project;
- manage risks by predicting the results generation time periods.

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ANALYSIS OF THE CDFP MSA CONNECTED TRANSCEIVER STANDARD FOR HIGH SPEED TELECOMMUNICATIONS

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The scope and main advantages of high-speed transceivers of the CDFP type and similar form factors are considered. The content of the CDFP MSA standard for 400 Gbps in terms of the description of the interface interfaces, the design and the effects of the external environment for the transceiver has been investigated. The analysis of the main sections of the CDFP MSA 400 Gbps specification is carried out. The design and other features of the CDFP MSA transceiver for 400 Gbps are revealed.

Keywords: DCI, high speed transceiver, MSA, quality indicators, interface, printed circuit board.

INTRODUCTION

The innovative 400 Gbps CDFP form factor provides the highest port density and bandwidth among similar pluggable form factors (SFP, QSFP, SFP+, CFP, etc.) [1-3], is used to connect high-performance servers, switch chassis and router. These chassis interconnects in data centers have previously been parallelized for ultra-high bandwidth, and are serialized in the CDFP form factor.

The CDFP MSA standard [4, 5] is promoted by Avago Technologies, Brocade Communications Systems, Inc. IBM, JDS Uniphase Corporation Juniper Networks Molex Incorporated TE Connectivity. CDFP MSA members are FCI, Finisar, Huawei, Inphi, Ixia, Mellanox MoSys Nextron Oclaro, Inc., Semtech, Sumitomo Electric, Xilinx, Yamaichi. In order to expand applications for the 400G interface, a Multi-Source Agreement (MSA) group was formed [4]. Participants include companies representing system integrators and vendors interested in a common form factor solution. CDFP MSA supports the requirements of the data center industry and plans to implement several standards. Specification [5] is related to the following industry interface standards:

- GR-253-CORE;
- OIF CEI 3.1 clause 13;
- IEEE Std 802.3bm annex 83E;
- IEEE Std 802.3bs;
- InfiniBand Architecture Specifications;
- INCITS T11.2 FC-PI-6;

- SAS 4.0;
- SFF-8679 QSFP (Quad SFP) 25 Gbs 4X Transceiver;
- SFF-8636 Cables Common Management Interface;
- SFF-8472 Diagnostic Monitoring Interface for Optical Transceivers;
- SFF-8431 Enhanced Small Form Factor Pluggable Module SFP+;
- JESD22A114-B ESD specifications.

SFF standards are performance oriented.

Analysis of the content and main sections of the CDFP MSA standard for 400 Gbps Standard [5] describes:

- electrical interfaces, including data, status, configuration and test signal leads, electrical connector, and recommended PCB layout requirements;
- requirements for power supply and power consumption of CDFP transceiver;
- management interfaces, including functions from the SFF8636 and SFF8472 specifications, with the ability to support multiple physical media (copper, optics, etc.), set the baud rate and implement multiple protocols;
- optical interfaces, including optical connector and mating fiber optic connector and recommended interconnect cable assembly (optical characteristics are in accordance with applicable standards for each protocol);
- design of the case with a latch and an optical connector socket, details of the electrical connector for the module and the main board, recommended dimensions of the cutout on the front panel;
- thermal requirements;
- recommendations for ensuring immunity to electromagnetic interference, including the necessary shielding functions and requirements for electrostatic discharge;
- CDFP firmware update method.

The standard provides for 3 variants of CDFP transceiver implementation, differing in architecture, design, numbering and arrangement of electrical and optical I / O ports. The reference architecture of the CDFP transceiver, shown in Figure 1, includes a high-speed data interface between the ASIC (SerDes) and the CDFP module. For the optical interface, MP016 parallel fiber optic connectors can be used.

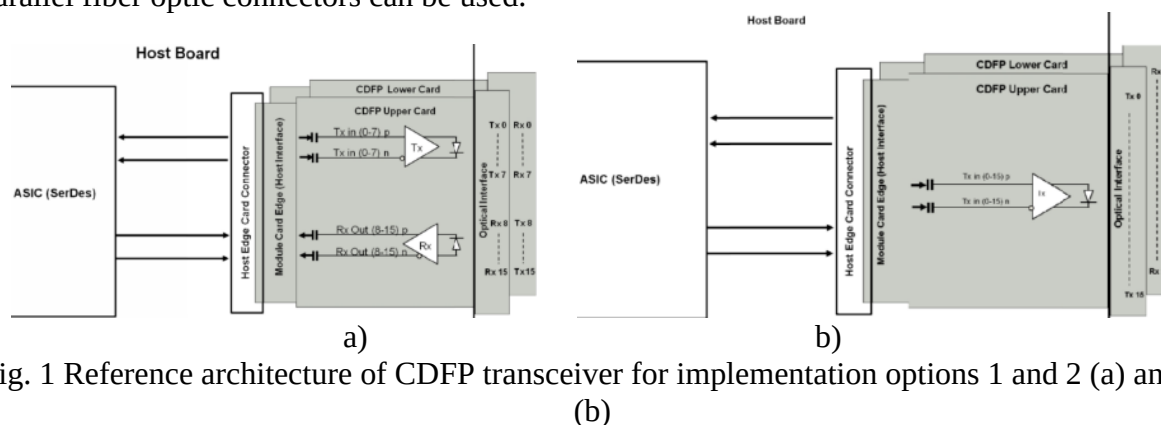


Fig. 1 Reference architecture of CDFP transceiver for implementation options 1 and 2 (a) and 3 (b)

The pin layout and pin numbering (Figure 2) of the electrical interface for the CDFP module is consistent with Fiber Channel, InfiniBand, Ethernet and OTN applications [6-9]. The CDFP plug-in end connector consists of two double-sided cards with 30 top and bottom pins each for a total of 120 pins for high speed, low speed signals, power and ground connections.

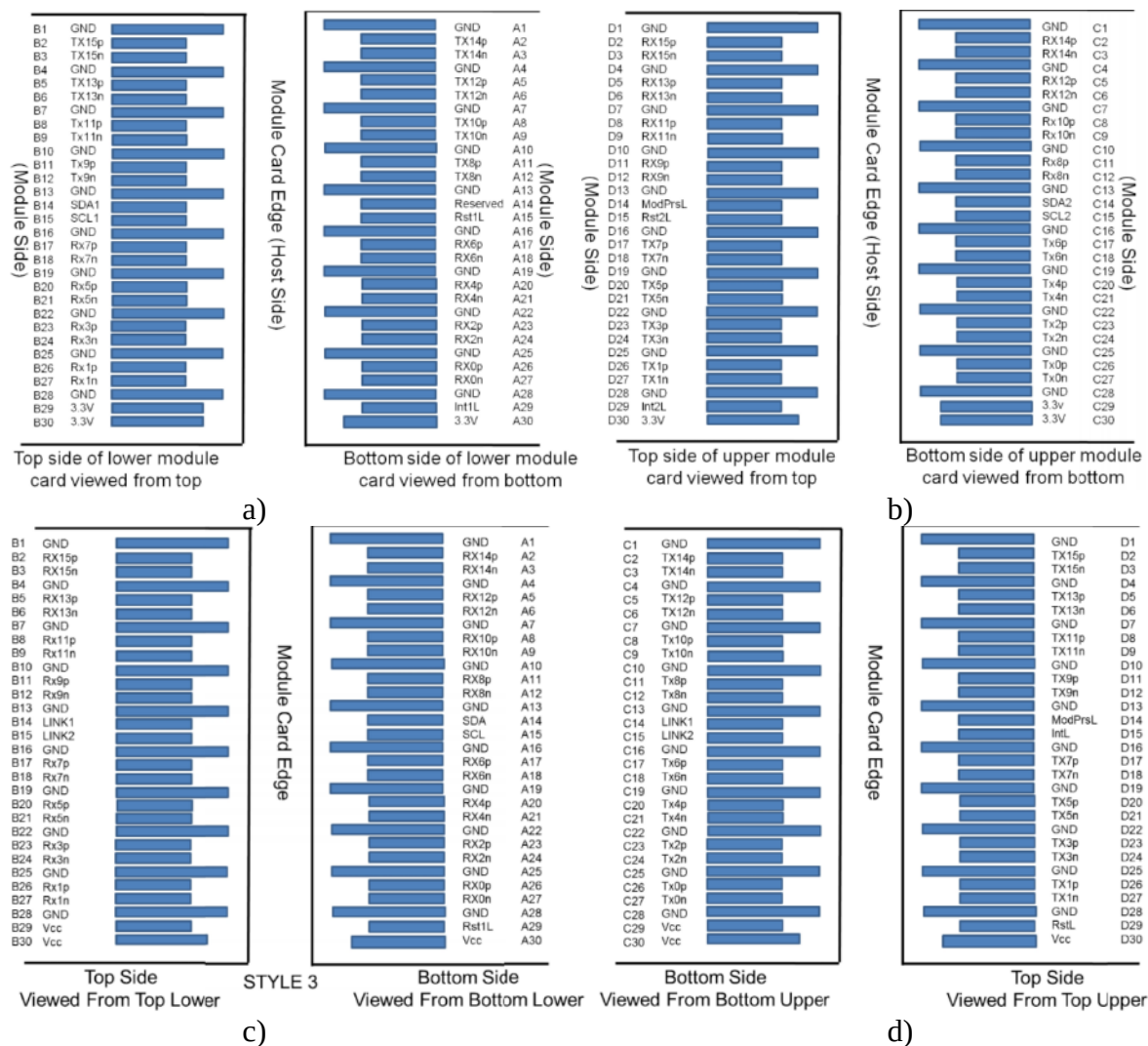


Fig. 2 Signal symbols and numbering of contacts for the edge connector of the CDFP module according to options 1 and 2 for the lower (a) and upper (b) cards, option 3 for the lower (c) and upper (d) cards

For high speed electrical signals, the compliance methodology IEEE802.3bm, OIF CEI-28G-VSR should be used. Measurements made with CDFP compliance cards should be adjusted for any difference between the loss of those compliance cards and the loss of the compliance cards specified in the standard.

Each of the two cards in the CDFP module has three power pins labeled Vcc. When a CDFP module is inserted into a slot with already hot power applied, three pins are powered simultaneously. CDFP modules are classified into several power classes listed in Table 1.

TABLE 1 - CDFP POWER CLASSES

Power class	Max power dissipation of modular cards, W	Max total power dissipation of modular cards, W
1	3.0	6.0
2	4.0	8.0
3	5.0	10.0
4	6.0	12.0

5	>6.0	>12.0

Each module board power supply has a high-frequency noise and ripple filter from the host. During hot-plugging, the filter network limits any voltage drop across the host power supply so that neighboring modules sharing the same power remain within the specified supply voltage limits.

The management interface, similar to the GBIC, SFP and XFP form factors, provides flexible use of the multi-channel module with respect to timing, and the increased interface speed has been increased. The [5] CDFP specification is based on the SFF-8636 specification but is not backward compatible — the 128 PageOO address is used for the CDFP memory card, not the QSFP.

The microcontroller controls the operation of both optical transmitters / receivers and timers and counters and is a standard control interface for the host computer system. The provided management interface is the standard QSFP specification (SFF-8636), expanded to sixteen channels. Each PCB reports its own measurements of temperature, voltage, etc.

On power-up or in the CDFP slot, the host system detects the presence of the module by changing the state of the ModPrsL signal (module present, active low) from the module card. Then the module card is initialized and signals that it is ready to communicate with the host system by setting the IntL signal low. Then, the host computer system must poll the module card through the two-wire serial interface to determine the status of the module card. The SCL and SDA 2-wire serial interface differs from the QSFP specification in the addressing for the bottom and top PCB. The two 2-wire serial interfaces (one on each PCB) operate independently of each other. CDFP modules do not have ModSelL input and must be selected using alternative means.

Like the QSFP specification, CDFP provides a memory map with a bottom page (addresses 00h to 7Fh) and several top pages (addresses 80h to FFh). The bottom page is always accessible and contains important monitoring information and control fields.

The CDFP optical interface port must be either MP016 male as specified in IEC 61754-7 (Figure 3) or dual LC as specified in IEC 61754-20. The rest of the optical interfaces are left to the discretion of the module manufacturer.

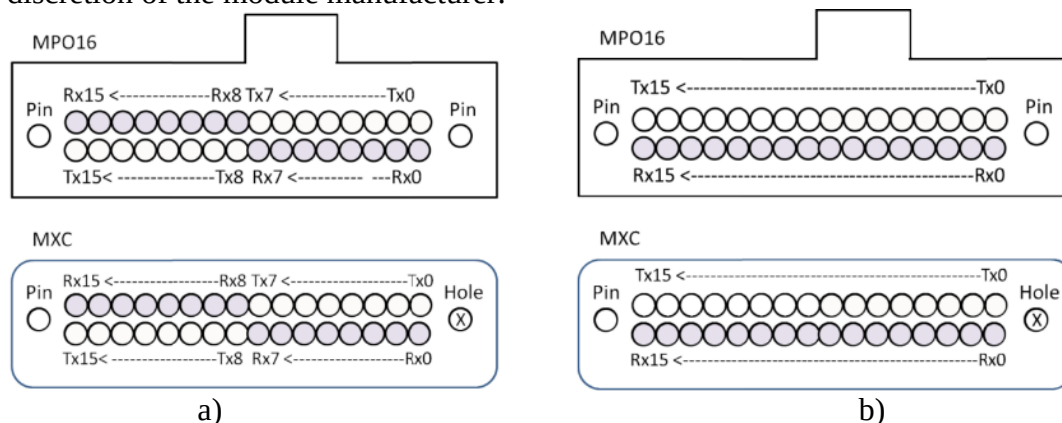


Fig. 3 Optical CDFP interface for MPO 16 and MXC connectors for options 1, 2 (a) and 3 (b)

There are two designs of the module / cage: option 1 is a short body module (Figure 4a), and options 2 and 3 are a long body module (Figure 4b). Moreover, for all three options, the modules / cells are incompatible, since they have their own mechanical key. The CDFP optical interface must comply with the MP016 dimensional characteristics over the interface 7-3 I EC 61754-7. Other optical interface solutions such as MXC are left to the discretion of the optical module supplier. The MP016 adapter must optically mate with the fiber optic plug. Heat sink / clamp designs are application dependent and not specifically defined in this specification; however, as an example, Figure 4c-e shows the general design of a cell with a radiator and a

mechanical key for each of the three options. In this case, to suppress electromagnetic interference in option 1, an O-ring is used, and in options 2 and 3, spring fingers.

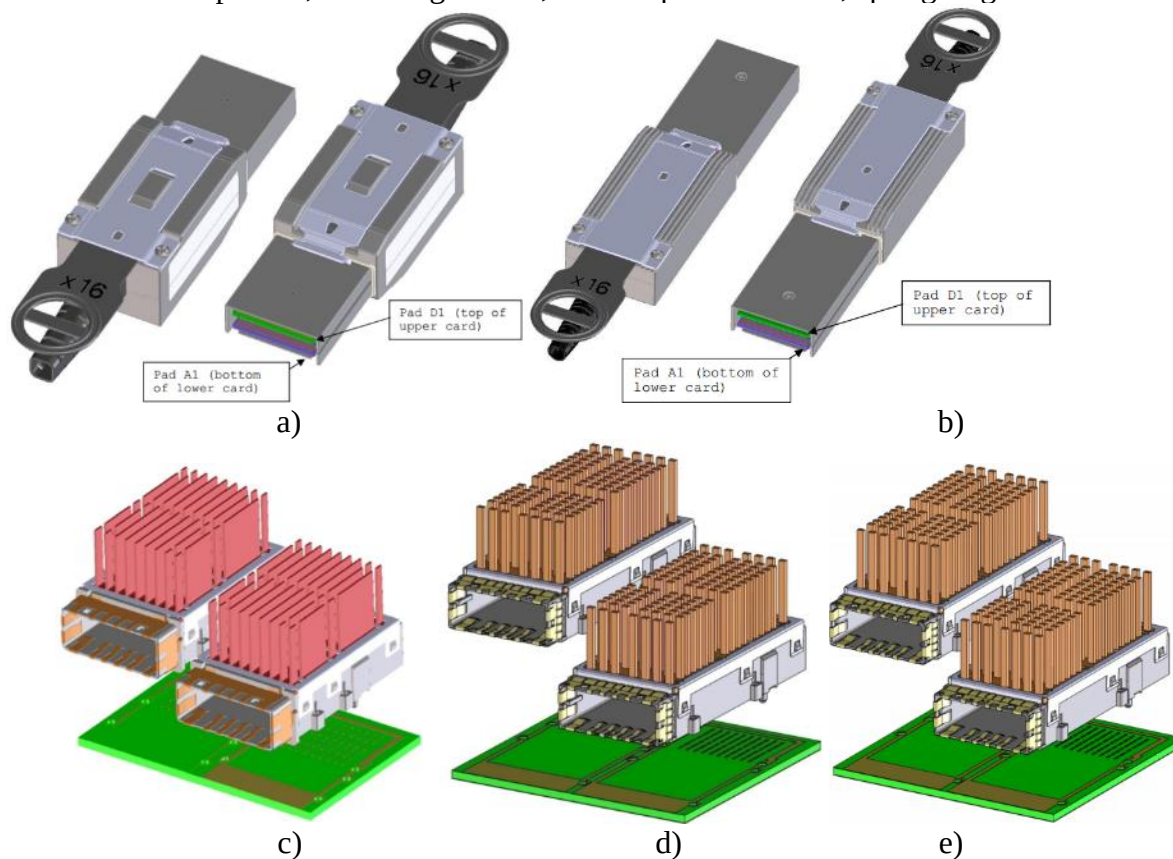


Fig. 4 Design of the CDFP module for direct connection for options 1 (a) and 2, 3 (b), an exploded view of a cell with a radiator for options 1 (c) and 2 (d), 3 (e)

When attached to the cell, the clamp provides a minimum force of 5 Newtons at the interface between the heatsink and the CDFP module. The clip is intended for fixing the heatsink and then installing it into the casing, and also slightly expands when the module is inserted to ensure contact force.

The CDFP module must operate at one or more enclosure temperatures (table 2). The Dual LC fiber patch cord is defined in the TIA / EIA-604-10A standard. Temperature ranges are applicable for heights from 60 m below sea level and up to 1800 m above sea level (Ref. NEBS GR-63) using the air flow of the main system. The CDFP is designed to accommodate up to 13 contiguous modules in a standard 19-inch rack. The rack operating temperature class range with associated thermal design for cooling and airflow is defined in NEBS GR-63.

TABLE 2 - CASE TEMPERATURE RANGES

Class	Case temperature range
Standard	0 to 70°C
Extended	-5 to 85°C
Industrial	-40 to 85°C

To ensure optimal temperature control of the CDFP / AOC module, the part of the case that contacts the heatsink must have mechanical properties (roughness) for maximum heat transfer. However, these roughnesses, detailed in the drawings of the CDFP standard [5], are applicable to new modules, since the installation of the module in the connector and heat sink causes scratches, which erase the roughness.

To prevent contamination of internal components and optimize EMI performance, it is recommended to insert a dust and EMI cover into the cage assembly when the module is not present. During installation, the front flange on the cover must be in contact with the front face of the bezel to prevent dust from entering the equipment. The electrical conductivity of the selected materials should provide EMI suppression.

In addition, standard PCB layout methods are recommended for EMI protection: connecting to Vcc and GND via vias, using differential signals, microstrip lines, and 50-ohm terminations. The chassis ground (common chassis) of the CDFP module must be isolated from the module's GND circuit ground to provide the equipment designer with flexibility in the connections between the external EMI shields and the module's GND circuit ground.

The method of updating the firmware in CDFP modules after their installation in the communication network meets the following requirements:

- the update is performed without removing the modules from the system in which they are installed;
- the update method is the same for modules of several suppliers;
- the host system is not tied to the internal details of any particular module;
- the firmware files must be able to be sent over the Internet without being damaged or blocked by corporate firewalls and anti-virus filters.

CONCLUSION

The CDFP MSA standard defines the performance of a 16x25 Gb/s plug-in CDFP module, including straight-through cable connectors, and provides a common specification for high-speed telecommunications system manufacturers, system integrators, and module vendors.

The content of the standard covers electrical interfaces, power and power requirements, control interfaces, optical interfaces, enclosure design, thermal requirements, EMI and ESD recommendations, and CDFP firmware update methodology.

The CDFP MSA standard is more of a schematic and general description of the transceiver architecture. Details of the transceiver control system - addressing, command system, control protocol are presented in detail. However, the standard does not disclose the production, technological and economic features of the manufacture and manufacture of the transceiver. Structural and weight-dimensional indicators are not fully described. Indicators of safety, transportability, maintainability are not indicated.

This specification is intended to support applications defined by IEEE 802.3 Ethernet (400Gigabit, 100Gigabit and 25Gigabit Ethernet), the Infiniband Architecture specifications (FDR and EDR), Fiber Channel-PI-6 (32GFC), and FC-PI-6p (128GFC) and provides a common solution for combo 16-channel ports that support OTN, Ethernet and / or InfiniBand and / or Fiber Channel specifications. The CDFP interface can support plug-in modules or straight-through cables based on multimode fiber, single mode fiber, or copper. The CDFP host electrical interface is a 120-pin, right-angle plug-in connector.

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9. 10 Gigabit Ethernet serial PMDs; and 68, 10GBASE-LRM)

COMMUNICATION SYSTEM FOR MONITORING AGROMETEO PARAMETERS

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An info-communication diagram of a monitoring system for agrometeorological parameters using a cloud service is presented. A full stack of Influxdata technologies for cloud storage and processing of agrometeorological parameters data using the Mosquitto broker, which is based on the MQTT protocol, is presented. The scheme of the microcontroller system of an autonomous agrometeoposta is disclosed, which carries out data input from a plurality of sensors of agrometeorological parameters.

Keywords: monitoring of agrometeorological parameters, cloud service, microcontroller system, MQTT protocol, sensors.

INTRODUCTION

Natural conditions have a complex effect on the growth of agricultural plants, while meteorological factors are the most active and changeable. Their influence largely determines the size of the crop, the quality of products, and its cost. The wise use of climate resources is one of the key factors in increasing productivity.

Monitoring of agrometeorological parameters is both an integral part of the operational management of the agrocomplex and an important source of data for medium and long-term weather planning. So, an example of data affecting operational management can be the value of soil moisture, on the basis of which an operational decision on the intensification of irrigation can be made [1].

The possibility of using modern approaches of science and technology about data in the analysis of statistics of agrometeorological parameters, in particular, the use of machine learning and the subsequent delegation of operational control to artificial intelligence, seems promising. Therefore, to solve the problem of operational monitoring of agrometeorological parameters, a special information and communication system is required [2, 3].

INFO-COMMUNICATION SYSTEM FOR MONITORING AGROMETEOROLOGICAL PARAMETERS

An info-communication diagram of a monitoring system for agrometeorological parameters using a cloud service is shown in Figure 1.

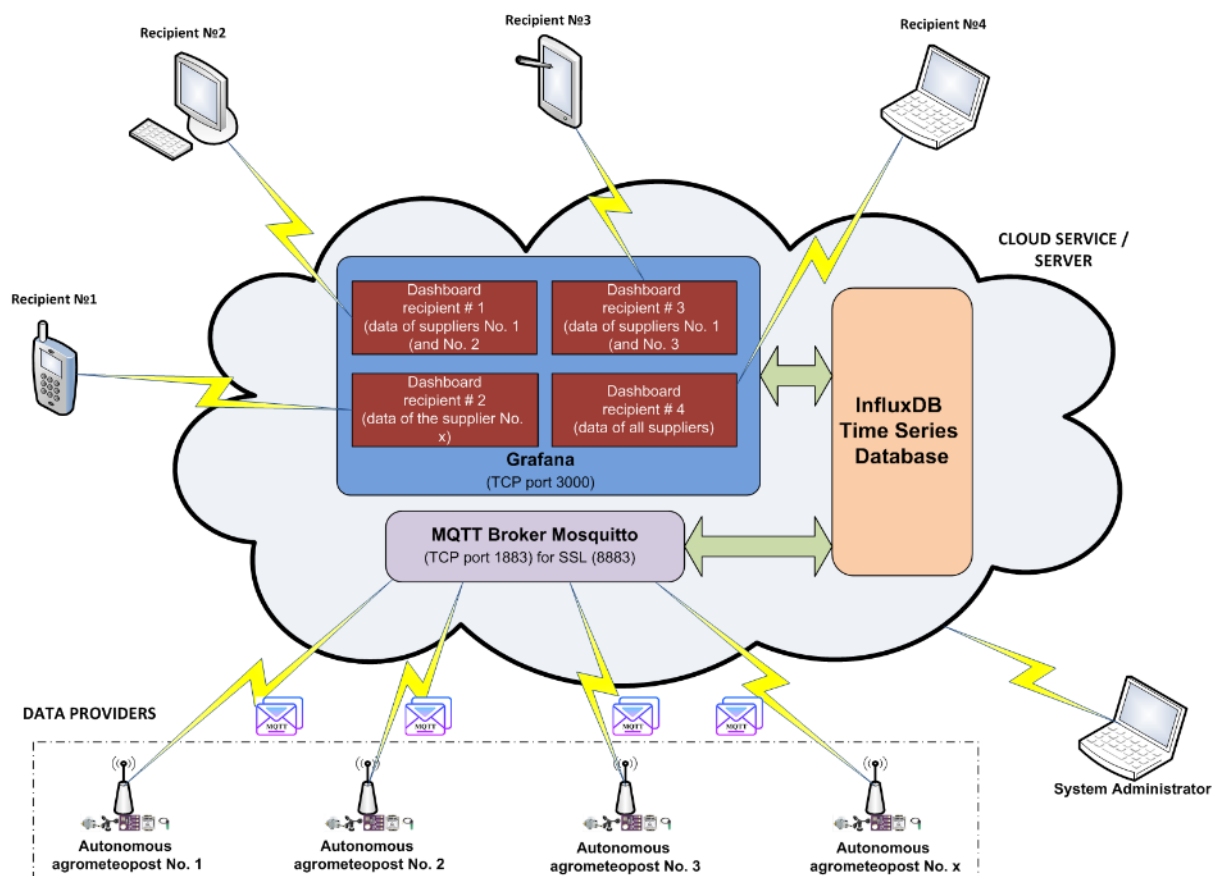


Fig. 1 Info-communication diagram of the agrometeorological parameters monitoring system

Here, the data access interface is implemented as a cloud service, or as a set of physical servers. The providers of information for stationary or mobile workstations of users are autonomous agrometeoroposts based on microcontroller systems with sensors and other modules for exchanging information according to the required protocol. The following software products are deployed on a physical or virtual server:

- Mosquitto broker is installed to communicate with data providers using the MQTT short message exchange protocol;
- InfluxDB (technology stack) [4] is installed as a database;
- Grafana software as a tool for data analysis and graphical visualization.

MQTT has a client-server architecture, uses a publisher-subscriber model to transfer messages over TCP / IP. Messaging takes place through a central server, also called a broker. Under normal conditions, all customer data exchange takes place through the broker. Clients can act as both data providers and recipients of data. An example of non-critical data loss: regular measurements of humidity or temperature parameters. QoS = 1. The behavior of the broker when working with messages will change and will correspond to the principle: "At least once". That is, the data provider requires the broker to confirm the delivery of the message to the subscriber, and will send the message until the confirmation arrives. Therefore, the subscriber must receive this message at least once. QoS = 2. This value of the QoS flag indicates the requirement for the broker to provide the highest degree of guarantee of message delivery through the use of additional confirmation and publication completion procedures (PUBREC, PUBREL, PUBCOMP). It is used for cases when it is necessary to exclude any loss and duplication of data

from sensors. For example, when an alarm is triggered from a received message, a call to emergency services.

InfluxDB, written in Go, is a database for storing time series, metrics, and event information. Key-value pairs are stored in the database. At the bottom level, the LevelDB database is used. The developers tested LMDB, RocksDB, the latter showed the best performance. InfluxDB supports the ability to work with dashboards for Grafana metrics and several ways to write data: JSON for transmission via HTTP API, etc.

The technology stack for receiving, processing and displaying metrics from the InfluxDB developers includes (Figure 2):

- directly the time series database itself;
- Telegraf agent for collecting various metrics, including from the MQTT broker Mosquitto;
- processor for real-time processing of the received data Capacitor;
- Chronograf imaging software.

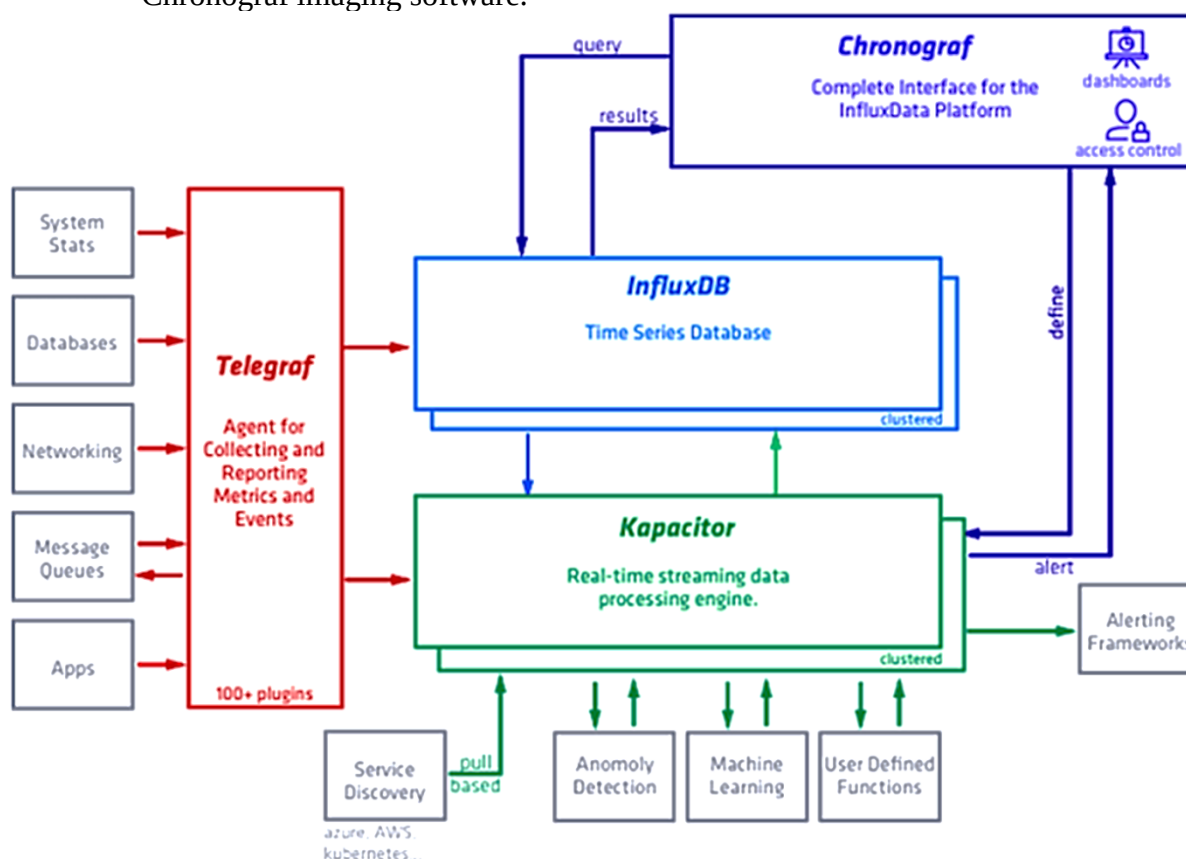


Fig. 2 Full stack of Influxdata technologies

Since the monitoring system already uses a much more powerful display and visualization tool Grafana, the tools built into the InfluxData technology stack are not used. The open source Grafana software platform for data visualization, monitoring and analysis contains:

- panel for visualization of indicators (metrics) selected from the Influx database;
- dashboard - a collection of universal individual panels placed in a grid with a set of properties (for example, the name of the server, application and sensor).

In the Grafana platform, panels can display graphs, single statuses, tables and plugins such as a world map or a clock. Panels allow you to customize style and format, size and other properties, and can be freely moved to any location. By changing properties, you can switch the

data displayed on the dashboard (for example, data from two separate servers). Dashboards are highly customizable. They can be partitioned and the data presented in them fragmented according to the needs of the end user, displaying specific indicators over a set period of time. For different types of data and sources, there is a large selection of ready-made dashboards.

It is possible to use general annotations for the panels presented in the dashboard to display certain events on different panels. In plots, annotations are displayed with vertical red lines. When you hover over the annotation, you can get a description of the event. Annotations make it easy to analyze time, event and consequences of its occurrence when studying the behavior of the system. Examples of panels for meteorological parameters recorded from an autonomous agrometeopost are shown in Figure 3.

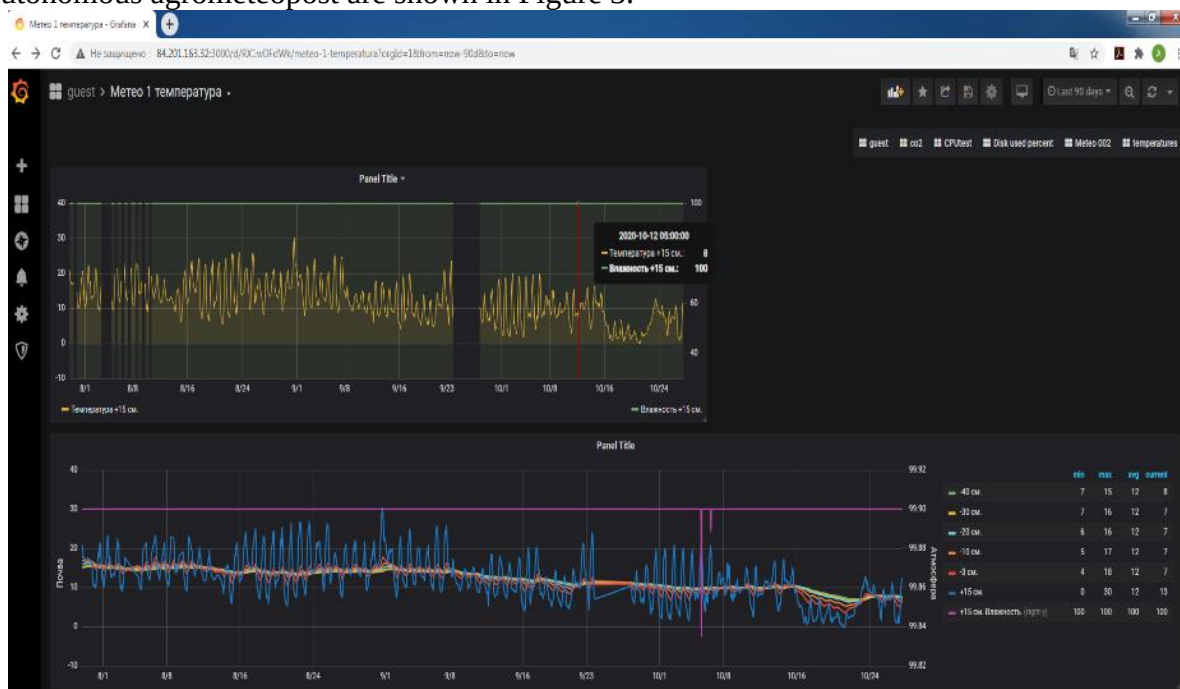


Fig. 3 Example of data visualization

MICROCONTROLLER SYSTEM OF AN AUTONOMOUS AGROMETEOPOST

The block diagram of the hardware of the autonomous agrometeopost [5] is shown in Figure 4.

The presented scheme works to obtain data of various characteristics about weather conditions. The core of the circuit is a control board based on an ESP 32 microprocessor, which is interfaced with the following modules and sensors, such as:

- BME280 temperature, humidity and pressure measurement module - BME280 module is designed to measure atmospheric pressure, temperature and humidity. Compared to the first sensors in the series (BMP085 and BMP180), it has better performance and smaller dimensions. The difference from the BMP280 sensor is the presence of a hygrometer, which allows you to measure the relative humidity of the air and create a small weather station on its basis, connected via the I2C interface;

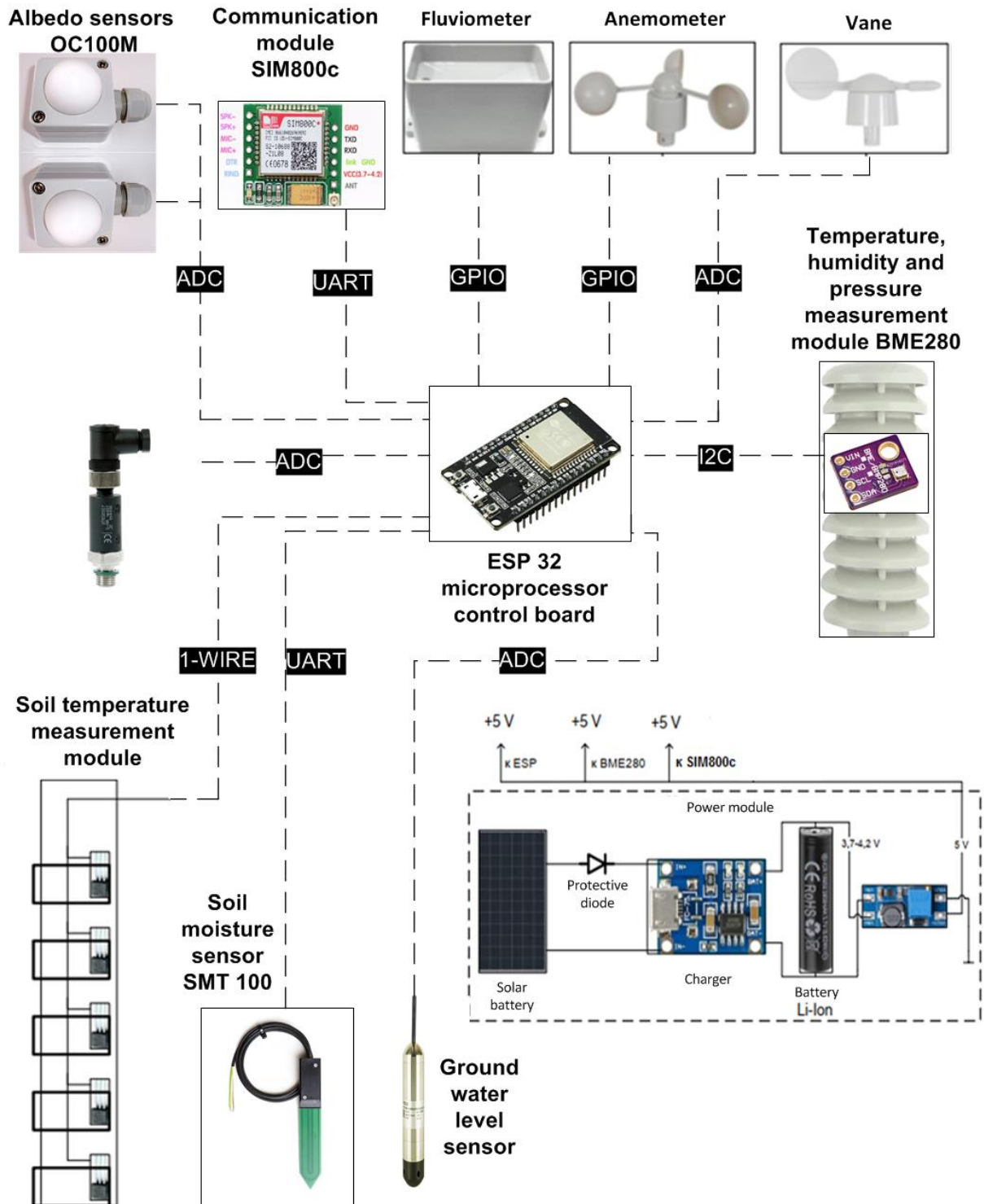


Fig. 4 Diagram of the microcontroller system of an autonomous agrometeoropost

- Weather vane - WAV151 is a balanced, low threshold, optoelectronic weather vane. Infrared LEDs and phototransistors are mounted in six orbits on each side of the 6-bit GRAY disk. When the wind vane is turned around, the disc changes the code received by the phototransistors. The code changes with a step of 5.6° , one bit per time unit to eliminate coding ambiguity, connected via the ADC interface;
- anemometer - designed to measure the speed of the air flow (wind) in closed systems and in open areas provides continuous measurement of the speed of the air flow, - measurement

of the average wind speed for any period of time in the range from 1 to 1200 sec. with the allocation of the maximum and minimum values of the gust, connected via the GPIO interface;

- fluvimeter - a device for measuring the amount of rain. The device consists of a sediment collection cone and a system of tilting vessels connected to a magnetic switch. Each impulse from the magnetic switch - 0.2 mm of precipitation (optional 0.1 and 0.5 mm), connected via the GPIO interface;

- communication module SIM800c - a miniature GSM / GPRS module in an LCC case with end contacts, in addition to its ultra-miniature dimensions, there is support for Bluetooth 3.0 at the chipset level, as well as very excellent power consumption indicators, connected via the UART interface;

- OC100M albedo sensor - Class B (first class) analog spectral flat albedometer, consists of 2 SR11 pyranometers with cable (cable length is user-selectable) and 1 AMF02 mounting kit, connected via ADC interface;

- sensor, pressure transducer in the pipeline OT1 - A large number of output signal options allows you to easily integrate the gauge pressure sensor OT-1 into a wide range of applications in various fields of industry and energy, automation systems for housing and communal services (Housing and Communal Services), in pneumatic hydraulic industrial systems, automotive equipment, connected via ADC interface;

- EasyTREK channel water level sensor - EasyTREK represents a class of ultrasonic level transducers. This particular modification is designed to work with liquids. Thanks to the principle of operation, measurements are carried out without physical interaction with the product. This makes it possible to make the design of the device compact and protect it from the harmful effects of the product. Measurements do not depend on the physical or chemical properties of the product, connected via the ADC interface;

- Soil temperature measurement module - Soil temperature sensor is well suited for accurate measurement of soil temperatures. All materials are carefully selected to resist various types of environmental influences and a wide range of temperatures. The accuracy and stability of the temperature sensor measurements is based on the Pt-100 type element, which belongs to the 1/4 DIN43760D accuracy level, connected via the 1-WIRE interface;

- Soil Moisture Sensor SMT-100 - Resistive Soil Moisture Sensor - an easy-to-use sensor for determining soil moisture. For measurements, it is enough to immerse it in the soil to a depth of 40 mm. The sensor will allow you to find out about insufficient or excessive watering of your home and garden plants, as well as detect water leakage, connected via the UART interface;

- groundwater level sensor MPU-01 - Level measurement in reservoirs and storage tanks. Overflow and idle speed control. Level measurement in rivers and lakes. Control of deep wells and groundwater level. Battery powered level measurement systems, connected via ADC interface.

The power module shown above consists of a solar cell, a charger, a Li-Ion battery, a circuit, and a protective diode. The outgoing voltage to the circuit elements is 5 V. The voltage coming from the battery is 3.7-4.2 V.

CONCLUSION

In the information and communication system for monitoring agrometeorological parameters, the data access interface can be implemented as a cloud service, or as a set of physical servers. Information providers include any devices, sensors, etc. that exchange information using the required protocol.

The main advantages of the MQTT protocol are compactness, guaranteed delivery, asynchrony, QoS, textual, intuitive names of data fields. MQTT has a client-server architecture and uses a publisher-subscriber model to transfer messages over TCP / IP. Messaging takes place

through a central broker server. Under normal conditions, all customer data exchange takes place through the broker.

InfluxDB supports dashboards for Grafana metrics. The technology stack for receiving, processing and displaying metrics from the InfluxDB developers includes:

- database of time series;
- Telegraf agent for collecting various metrics, including from the MQTT broker Mosquitto;
- processor for real-time processing of the received data Capacitor;
- Chronograf imaging software.

The microcontroller system of an autonomous agrometeoposta consists of a control board based on an ESP 32 microprocessor, a soil temperature measurement module, a SIM800c communication module, a pluviometer, an anemometer, a weather vane, a BME280 temperature, pressure and humidity measurement module and various sensors such as Albedo OS100M sensors, a pressure conversion sensor in the OT-1 pipeline, water level sensor in the EasyTREK channel, soil moisture sensor SMT100, groundwater level sensor MPU-01.

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THERMAL REGIMES INVESTIGATION OF 3D PRINTED UNITS OF ELECTRONIC DEVICES

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Abstract— The paper presents calculations performed in the SolidWorks computer-aided design system, displaying the thermal characteristics of components inside printed circuit boards, made using additive 3D technologies.

Keywords: lossless compression algorithm; FPGA; telecommunication system.

INTRODUCTION

Developers always pay great attention to ensuring the correct operation of the electronic components of electrical devices, since this part of the design work affects all aspects of its use and storage. Improving performance, functionality, miniaturization and thermal performance are critical design considerations. These requirements create the need to implement new approaches to the design and implementation of printed circuit boards of non-standard form factor, using

curved surfaces for printed layers, as well as printed circuit boards with embedded components. The creation of these products is carried out using additive technologies.

The subject of the research is to find the main factors, affecting the thermal characteristics of the device when designing and using additive technologies, as well as finding methods for correction of temperature conditions in 3D-printed version.

PROBLEM STATEMENT

Today, 3D printing is a revolutionary technology for PCB manufacturing, providing faster development times, flexibility and design variability. Among the directions for the creation of printed circuit boards using additive technologies, the most prominent is the technology that allows you to create volumetric products with integrated electronic components inside.

Thermal design is one of the important factors in PCB design. To estimate the thermal parameters of the product, calculations are used using such a parameter as thermal resistance θ_{ja} , K/W, for which the following equation is true $\theta_{ja} = \frac{T_m - T_a}{P_{max}}$, where P_{max} is the maximum power dissipation, T_m – is the maximum temperature of the material, and T_a – ambient temperature [1]. When performing these calculations, it is necessary to take into account the set of parameters of each element of the circuit section, where each of the elements has its own thermal resistance, temperature indicators and power dissipation, a simplified model is shown in Figure 1a).

To obtain the value of the dissipated power, the long-calculated values of the thermal resistances of the copper layer, interlayer holes and the surface of the dielectric printed circuit board are used, depending on the specific thermal conductivity and natural convection. Using these indicators, it is possible to adjust the dimensions of the conductive layer, add heatsinks on the reverse side of the interlayer holes to improve heat dissipation, and also make the necessary casing that provides protection against electromagnetic radiation [2].

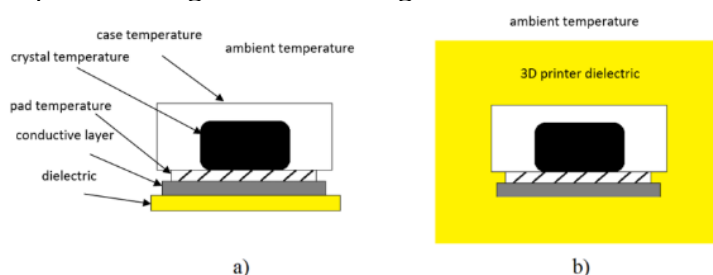


Fig. 1 Thermal parts of the printed circuit board and 3D-MID of the printed circuit board

Thermal design of 3D-MID printed circuit boards with embedded elements is very different from the standard, since all the components of the circuit are inside the dielectric layer, which complicates the calculations (Fig. 1b). Also, a feature of printing these products is the use of hardening pastes, where the first repeats the properties of materials of the FR4 group, and the second is a conductive layer containing silver nanoparticles [3]. The form factor of these products and the specifics of materials are currently not studied, and the calculation of thermal processes of structures requires a lot of research.

RESEARCH

The main purpose of this study is to determine the thermal modes of operation of electrical devices in the form factor of a 3D-MID product in order to obtain information on the possibility of using additive technologies when creating functional units with high heat release, as well as to determine the limit values for the power released by the elements. The creation of bulk printed circuit boards using a 3D printer is a poorly studied industry due to the lack of unified data on the characteristics, parameters and methods of developing electrical products. Printing of such devices makes it possible to leave holes for installing components, followed by the application

of conductive and dielectric layers, which allows you to place components at different heights, as well as increase the efficiency of distribution of the conductive layer. This feature limits developers in the choice of ERI for installation, excluding the use of nonplanar components inside the product. Taking into account these features in CAD SolidWorks, models of 3-D printed circuit boards were designed using SMD elements in different thermal conditions.

As an object for the first study, a voltage regulator circuit was modeled using resistors in a 2512 package, a transistor in a SOT1061 package and a zener diode in a SOT1061 package. The linear voltage regulator circuit is shown in Figure 2.

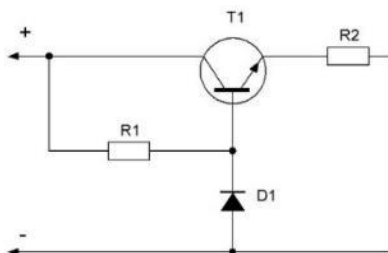


Fig. 2 Circuit of a simple linear regulator

The initial data for the linear stabilizer circuit, as well as the characteristics of the materials, are given in Table 1.

TABLE 1 THE INITIAL DATA

Linear Regulator Data	The name of indicators	Value	Conductive Material Data	Specific electrical resistance	0.016 $\mu\text{Ohm}\cdot\text{m}$
	Input voltage	8 V		Ultimate tensile strength	200MPa
	Output voltage	5 V		Relative elongation at break	50%
	Load current	0,01 A		Conductor diameter	20 microns
	Resistance R1	590 Ohm		Electrical conductivity	$\approx 30 \text{ MS/m}$
	Resistance R2	500 Ohm		Thermal conductivity	418 $\text{W}/^\circ\text{C}\cdot\text{m}$
	Min. current D1	0,005 A		Heat capacity	234 $\text{J}/(\text{kg}\cdot^\circ\text{C})$
	Stabilization voltage	5V			
Dielectric material data	Dielectric constant	3.2(1 MHz), 2.9 (1 GHz)	Additional sources of convection	The name of indicators	Value
	Decomposition temperature	341°C(2%), 376°C (5%)		Atmospheric pressure	760 mm Hg.
	Glass transition temperature	135°C		Ambient temperature	21 °C
	Maximum working temperature	130°C		Component operating temperature range	From -55 °C to +150 °C
	Thermal conductivity	0.25W/°C·m		Thermal conductivity of air	0.0259 W / (m °C)

In the Solidworks CAD system, 3-D models have been developed in two different form factors:

- Planar printed circuit board made according to standard technology, PCB size 20x30 mm, fig. 3a).

- Volumetric printed circuit board manufactured using additive technologies, the area of the volumetric dielectric is 2400 mm², fig. 3b).

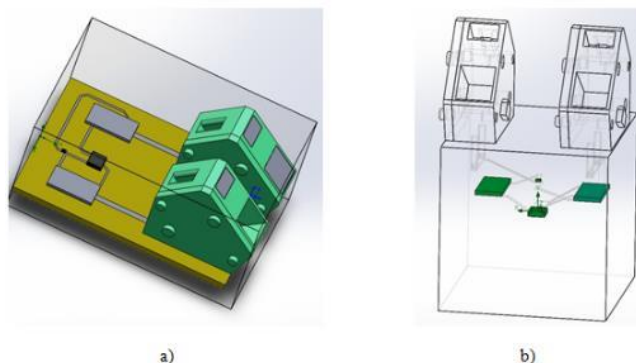


Fig. 3 Printed circuit boards of the linear voltage regulator in different versions

To perform thermal calculations without taking into account additional sources of convection, the Flow Simulation tool was used, the initial data for modeling are given in Table 1.

The calculation results of printed circuit boards of a linear voltage regulator in different versions are shown in Fig. 4

According to the obtained data, in each of the cases, the thermal values are within the acceptable values for stable operation, while the temperature of the bulk PCB is much lower than that of a flat one. This is due to the fact that the dielectric applied by a 3-D printer is similar in parameters to conventional glass fiber laminate, and therefore has a higher thermal conductivity. However, with the introduction of more powerful heat sources, the thermal conductivity of the dielectric may not be sufficient to ensure the operating mode of the volumetric device.

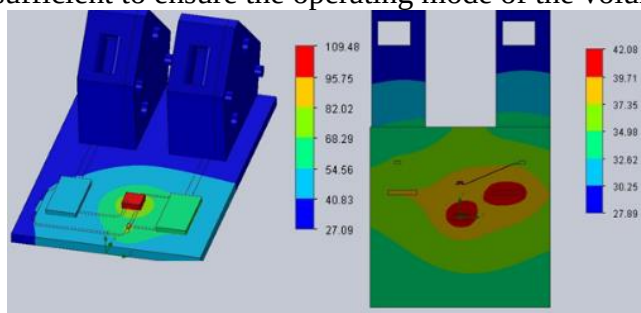


Fig. 4 Results of thermal modeling of printed circuit boards

The next step was a series of calculations to determine the thermal characteristics that provide the necessary operating modes for which the optimal operation of the device is possible. SMD resistor 2512 was chosen as the element used, placed in different areas inside the 3D-MID product with dimensions of 10x10x10 mm. Variations in the distribution of the resistor inside the bulk dielectric are shown in Fig. 5.

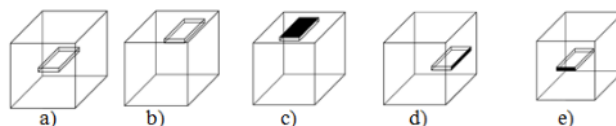


Fig. 5 Variations in the distribution of the resistor inside the bulk dielectric:

- the central part of the dielectric product;
- at a distance of 1 mm from the edges;
- the top edge of the resistor coincides with the top edge of the dielectric;
- the lateral long edge of the resistor coincides with the lateral edge of the dielectric;

e) the lateral short edge of the resistor coincides with the lateral edge of the dielectric.

Resistor 2512 and its size are shown in Fig. 6.

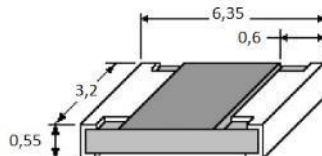


Fig. 6 Resistor 2512 and its size

TABLE 2. THE RESISTOR DATA

The name of indicators	Value
Power at 70 ° C	1.0 W
Working voltage	200 V
Operating temperature range	- 55° + 125°C
Maximum voltage	400 V
Temperature coefficient of resistance	100 ppm /°C

Initial data when performing calculations are specified in accordance with table 1.

The task of this stage is to find the thermal values of resistors located in different planes of the dielectric in order to determine the best variations in the placement of the hottest elements. To determine the most acceptable operating temperature, as well as the peak heat load, according to the initial data, not exceeding 130 ° C, various indicators of power dissipation were used in the calculations.

Figure 7 shows the calculated data of the thermal simulation of the resistor 2512 with a power dissipation value of 0.5 W.

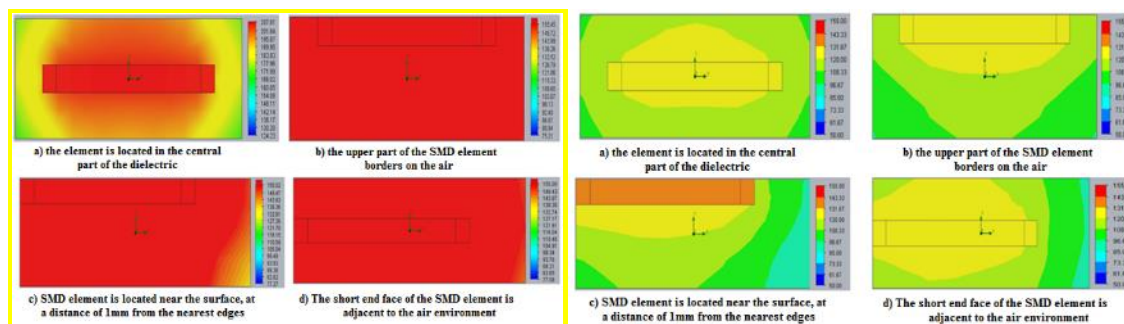


Fig. 7 Calculated thermal simulation data for the 2512 resistor with a power dissipation value of 0.5 W and 0,25W

According to the results of the first simulation, with a dissipated power of 0.5 W, the object temperature exceeds the permissible values ≤ 130 ° C in each of the positions, which indicates the impossibility of using the product under these conditions.

Figure 7 also shows the calculated data of the thermal simulation of the resistor 2512 with a power dissipation value of 0.25 W.

According to the results of a thermal calculation with a power dissipation of a resistor of 0.25 W, it can be determined that under such conditions a high heating level for the elements and a critical for the dielectric layer of ≈ 130 ° C is achieved.

Figure 8 shows the calculated data of the thermal simulation of the resistor 2512 with a power dissipation value of 0.125 W.

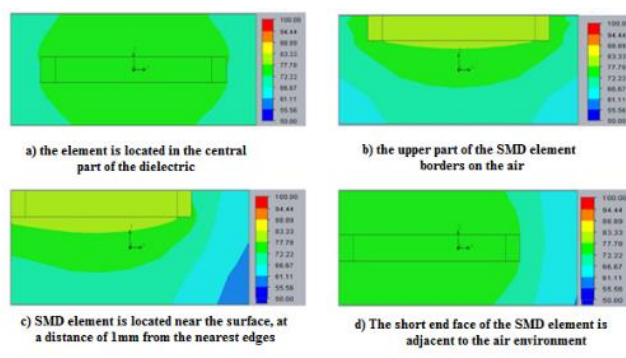


Fig. 8 Calculated data of thermal simulation of the resistor 2512 with a power dissipation value of 0.125 W

The third calculation shows the values up to 80 degrees, which can be called the optimal operating temperature for ERI and dielectric. It should also be noted that the location of the source of the dissipated power in different planes does not have a strong effect on the temperature indicators.

To display the heating of the elements in more realistic conditions, during further research, a conductive material with the parameters according to Table 2 was introduced. 25W and 0.125W.

Fig. 9 shows the calculated data of the thermal simulation of the resistor 2512 with a power dissipation value of 0.25 W using a conductive layer.

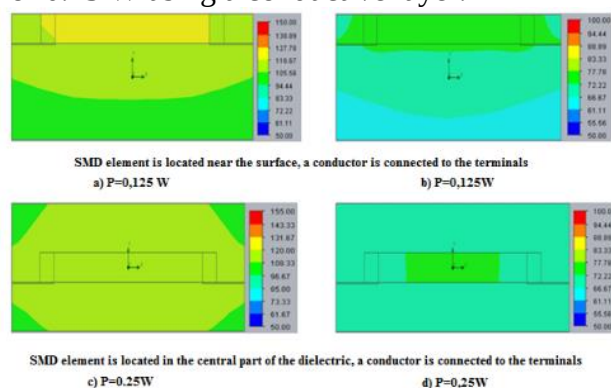


Fig. 9 Calculated thermal simulation data for a 2512 resistor with a power dissipation value of 0.25 W using a conductive layer

According to the obtained data, the conductor used by the 3-D printer provides good thermal conductivity, which reduced the temperature by $\approx 10^\circ \text{C}$ of each of the samples under study, which makes it possible to use elements with a power output of up to 0.25 W with an increased fill factor, thereby consuming most of the heat from the source [4].

In order to use more powerful elements in the composition of 3-D MID products, models were created that provide good thermal conductivity from components. In the first study, a miniature aluminum radiator embedded in the dielectric and adjacent to the surface of the resistor was used as a heat sink. For modeling, powers of 0.25 W, 0.5 W and 1 W were considered, the results of the research are shown in Fig. 10 a), 11 a) and Table 4.

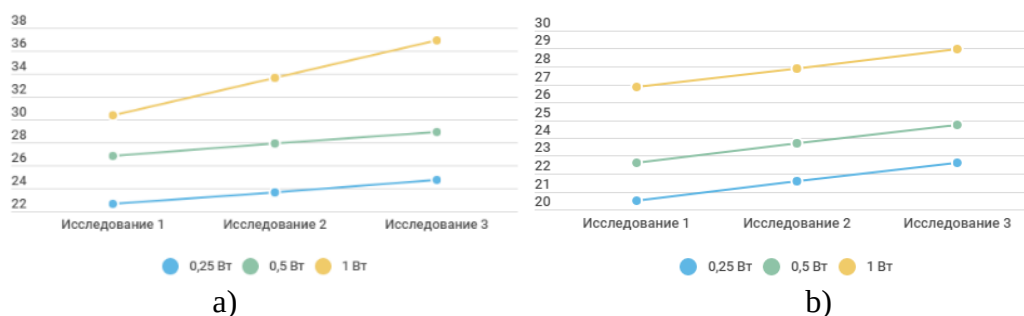
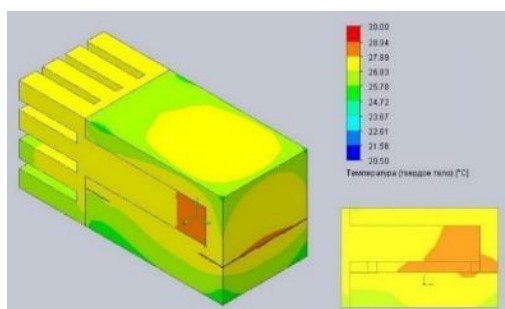


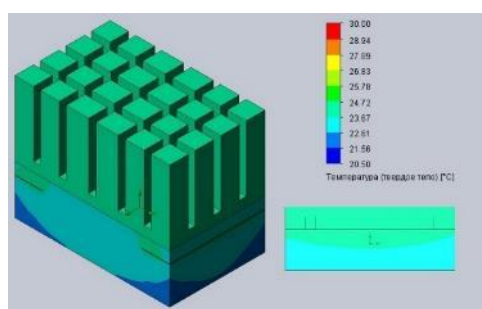
Fig. 10 Graph of temperature values for three results of modeling a resistor with an embedded and external heatsink radiator at different values of power dissipation

TABLE 4. TEMPERATURE VALUES

Research №	Embedded heatsink radiator			External heatsink radiator			Max element temperature
	Power dissipation						
	0,25 W	0,5 W	1 W	0,25 W	0,5 W	1 W	
1	22.61 °C	26.83 °C	30.33° C	20.50 °C	22.61 °C	26.83° C	
2	23.67 °C	27.89 °C	33.61° C	21.56 °C	23.67 °C	27.89° C	
3	24.72 °C	28.94 °C	36.89° C	22.61 °C	24.72 °C	28.94° C	



a)



b)

Fig. 11 Computational model with a heat sink embedded inside the dielectric and with a radiator placed on the surface of the heat source

The introduction of such a heat sink made it possible to reduce the element temperature by up to 80%, coping not only with the released power of 0.5 W, but also with more heating elements.

As a more effective method to reduce the heating of the structure, a model was calculated with the addition of an external radiator placed on the surface of the resistor using the same powers. The research results are shown in Fig. 10 b), 11 b) and Table 4.

The use of a planar placement of the heatsink on the surface of the 2512 resistor provided an additional temperature decrease to 10 ° C, reducing the performance at a power dissipation of 1 W to ≈ 27 ° C. According to the data from the calculations, when using such types of heat removal in bulk printed circuit boards, it is possible to use more powerful ERIs, increasing the number of permissible devices developed using this technology.

To ensure a decrease in the temperature of less heated elements, calculations were carried out using through holes through the dielectric [5]. A model of such passive heat sink in the active state with a resistor dissipated power of 0.5 W is shown in Fig. 12.

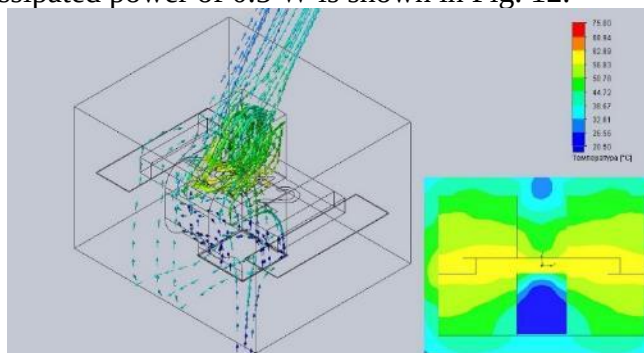


Fig. 12 Calculation model of heat removal with the introduction of through holes

The calculated indicators of such models showed a decrease in heating to 90 ° C, which makes it possible to apply this technique for constructing volumetric printed circuit boards in the absence of the possibility of introducing other heat sink sources.

CONCLUSION

The studies carried out give an understanding that the use of technology for the production of bulk printed circuit boards with built-in discrete components does not make it possible to use powerful elements inside the structure without the use of additional sources of heat removal. With the help of calculations in the software environment, data were obtained that reflect the thermal characteristics of radioelements integrated into 3D products, as well as the dielectric surface itself. The use of the models presented in the work with additional sources of heat removal showed a significant decrease in the heating of structures when using elements with a much higher dissipated power than the maximum allowable power of elements without a heat sink, which makes it possible to introduce more energy-intensive radio products in this form factor.

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ON EQUIPPING F-2 THE AFFECTIVE ROBOT WITH TACTILE SENSORS

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Abstract – This paper discusses the possibility of equipping the F-2 robot with tactile sensors. The analysis of the types of touch sensors and representatives of each type on the market is given. An FSR 400 Series sensor was selected to equip a robot with. A wiring diagram for connecting the sensor using the Arduino board along with the algorithm for reading the sensor data are shown.

Keywords: Robot F-2; affective robots; tactile sensors; Arduino.

INTRODUCTION

In the modern world, robots are becoming more and more common. They are used in many areas and take on some of the work, making life easier for people. As robots have become a part of everyday life in society, it is important that they would effectively interact with humans. This requires robots to behave in communication with a person as naturally as possible and create the impression of contact with a human, and not with a machine. To achieve this effect, robots are equipped with a variety of devices capable of perceiving signals from the outside world. The data from these devices should then be collected and processed to form the robot's response to the stimuli. And at present, the most significant task is to correctly determine the reaction depending on the multimodal signals for a full-fledged imitation of human behavior by the robot. This work is dedicated particularly to processing signals from tactile sensors.

F-2 THE AFFECTIVE ROBOT

F-2 is a research platform for studying human-robot interaction and for developing communication strategies for robots. It is an affective robot which has the ability to communicate with people. It allows researchers to develop dialogue strategies using facial expressions, gestures, direction of gaze and other responses. The robot is designed as simple and easy to assemble as possible. The simple design of the robot allows avoiding the uncanny valley problem [1], as it is not an android, but rather a cartoon-based robot [2]. Thus, it is possible to explore respondents' emotional contact based on the behavior of the robot without being influenced by its appearance. A robot consists of several software components: it accepts a text in a natural language as input, builds the meaning of this text, selects a communicative goal to be expressed, and performs some set of gestures characteristic for this communicative goal (e.g. to express happiness, sadness, doubt, etc.). Using the robot, one can program predetermined sequences of behavior or more complex dynamics corresponding to modelled surface emotional phenomena. The robot's interface also allows checking various behavior patterns by means of transmitting commands to the robot from external program [3]. At the moment, the robot is only able to recognize voice and visual signals. In this regard, the task arises to expand the capabilities of the robot and enable it to recognize tactile signals.

TACTILE SENSORS OVERVIEW

Implementation of the response to tactile stimuli is possible using tactile sensors. There are 4 general classes of tactile sensors: capacitive, resistive, piezoelectric and optical.

The essence of capacitive tactile measurement is to change the capacity by mechanically changing the geometry of the capacitor. Capacitive sensors generally have good frequency response, high spatial resolution, and large dynamic ranges, although they can be susceptible to several types of noise [4]. An example is TTP223. The TTP223 is a touch panel sensor with one touch key. The touch detection sensor is designed to replace traditional direct-action keys with selectable button size. Low power consumption and wide operating voltage are the key features of the instrument for use in AC or DC environments [5].

Resistive tactile sensors are implemented by mechanically changing the resistivity of a sensitive structure. Resistive sensing is robust to noise, making it the best choice for array-based

applications. In terms of limitations, resistive sensing is highly dependent on hysteresis, resulting in a lower frequency response and can only be used for dynamic measurements with limited spatial resolution. Effective resistive sensing can be realized as long as the sensor can effectively contact the object to be detected [4]. As a possible example Interlink FSR 400 Series can be taken. FSR 400 Series sensor resistors are robust polymer thick film (PTF) devices that exhibit reduced resistance as the force applied to the sensor surface increases. This force sensitivity is optimized for use in touch control of electronic devices such as automobiles, electronics, medical systems, and industrial and robotics applications. They come in different shapes and sizes, which will allow them to be placed on different surfaces. They are connected via two pins, making it possible to use them with Arduino or Phidget microcontrollers. To control the sensors, the appropriate software is used for programming microcontrollers, along with software that allows collecting signals from external boards is used [6].

There are two different sensing principles for piezoelectric tactile sensors: passive and active. Passive tactile sensing uses a direct piezoelectric effect. As a result of polarization of the material, an electric charge is generated under the action of an external voltage. Active tactile sensing uses an inverse piezoelectric effect. Piezoelectric sensitive structures are electrically activated at a first order resonant frequency. When an external voltage is applied, a resonant frequency shift occurs, linear with respect to the external voltage. Piezoelectric tactile sensors have a very high frequency response, making them the best choice for dynamic signal sensing [4]. Piezoelectric sensors are not as widely available on the market as other types of sensors. Most often they are used in laboratory conditions or in acoustics. Such sensors are not suitable for equipping a robot with, therefore they are not further discussed in detail.

Optical tactile perception is realized by linking the geometric variation of the electromagnetic waveguide to the modulation of wavelength, phase, polarization, or wave intensity. Optical tactile perception is immune to electronic noise. Optical sensors typically have high spatial resolution and a wide dynamic response range. Optical tactile perception can be used to determine surface roughness, compliance, shear and vertical stress [4]. Neonode Airbar is an example to such optical sensor. It is an optical touch sensor designed for laptops. Importantly, the technology works on any type of display and display surfaces of any shape, including concave surfaces. Connected via USB, it uses its own drivers and the touch control capabilities supported by the operating system [7].

Basing on the conducted analysis of existing tactile sensors and their characteristics, following conclusions are drawn on sensors applicability for solving the task at hand. For placement on the robot's arms, it is best to use flexible sensors that can bend with the arm. The shape of such sensors can be rectangular, linear or arbitrary. Round sensors may also be suitable for placement on the palms. The ability to detect the touch location will be useful for reducing the number of sensors on one hand. In this regard, it can be concluded that small sensors from the FSR 400 series of round shape are best suited for placement in the palm, and rectangular or round sensors of the same series can be selected for placement on the hands. The robot head can be covered with several resistive sensors in the same way as the hands. The number, size and location of sensors will affect the accuracy of determining the location of the touch.

SENSOR SETUP AND READING

Based on a market analysis, FSR 400 Series resistive sensors were selected. Figure 1 shows a graph of resistance versus applied force [8]. The change in the resistance of the sensor is not linear in the force applied. When a small force is applied, a sharp decrease in resistance is observed, but with an increase in force, the rate of decline in resistance decreases. As a result, the dependence of the voltage at the analog input of the board is also not linear. To read the correct values, one needs to select a suitable resistor. Figure 2 shows the dependence of the

voltage on the applied force for resistors of different resistance [8]. These graphs give a reason to conclude that 3.3 k Ω and 10 k Ω are optimal [8].

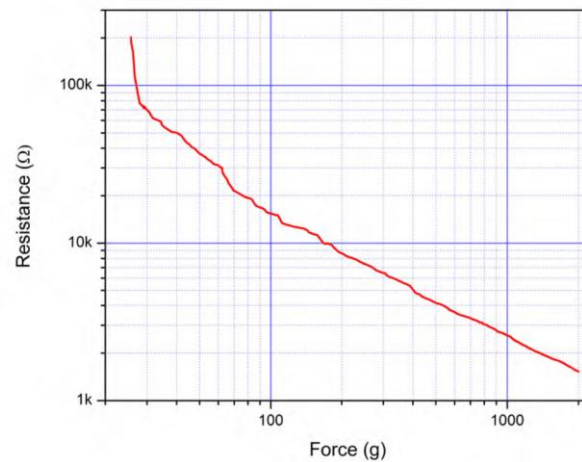


Fig. 1 Dependence of the sensor resistance on an applied force

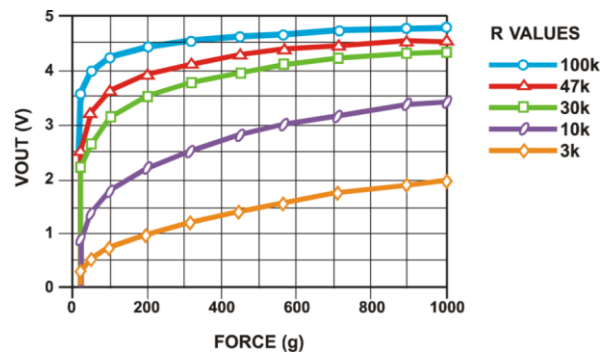


Fig. 2 Dependences of the output voltage on an applied force

Since the selected FSR 400 Series sensors do not have an interface for connecting to a computer and a controller, in order to operate they must be connected using a third-party programmable controller. The Arduino UNO board was chosen as such a controller. The following materials are required to connect the sensor:

- Arduino breadboard;
- Jumper wires;
- Resistor;
- USB A to B cable.

Figure 3 shows a wiring diagram of connecting a sensor to an Arduino board [8].

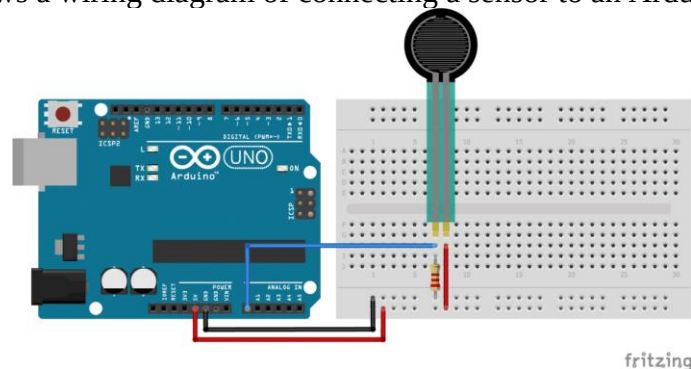


Fig. 3 Wiring diagram for connecting a sensor

An Arduino controller allows to read values from its analog ports, mapping voltage values from the range from 0 to 5V to integers from 0 to 1023. These values can be read and sent via the USB port to the computer for further processing. Listing 1 shows a simple algorithm for reading values from a sensor.

Listing 1

```
1.  #define FSRPIN A0
2.
3.  int fsrreading;
4.
5.  void setup() {
6.      Serial.begin(9600);
7.  }
8.
9.  void loop() {
10.     fsrreading = analogRead(FSRPIN);
11.
12.     Serial.print(fsrreading);
13.
14.     delay(10);
15. }
```

CONCLUSION

Based on the results of this work, it was decided that the most optimal solution is to equip the F-2 robot with FSR 400 Series resistive sensors, which come in a variety of shapes and are suitable for placement on F-2's hands, palms, body and head. The sensor is connected to the processing device via an Arduino controller using a USB cable. The controller reads the voltage values that change when a force is applied to the sensor at a given frequency. In the future, it is planned to create a software module for processing values from sensors and converting them into commands for the robot.

ACKNOWLEDGEMENTS

This research is supported by the grant of the Russian Science Foundation (project №19-18-00547).

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METHODOLOGY FOR ASSESSING THE EFFECTIVENESS OF THE PRODUCT QUALITY MANAGEMENT SYSTEM AT THE STAGES OF THE LIFE CYCLE

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One of the main tasks of the developed product life cycle management system is product quality management. Important components are the calculation of quality and reliability indicators, as well as the evaluation of the effectiveness and efficiency of the product quality management system. In this paper, a unified methodology for the effectiveness of the product quality management system at the stages of the life cycle, including at the stage of operation, is developed.

Keywords: quality, efficiency, life cycle.

Currently, various methods of evaluating the effectiveness and efficiency of the quality management system of enterprises have been developed and are being implemented. [1-3].

The existing methods and techniques are focused on the assessment of the activities of enterprises in the field of quality assurance. Each company uses methods depending on the specifics of its activities, mainly at the stages of product development and production. It should be noted that such methods are rather narrowly specialized.

The methodology proposed in this paper suggests evaluating the quality of a specific product within the framework of a life cycle management system and taking into account the quality of the product at the operational stage.

Evaluation of the effectiveness of the product quality management system is carried out according to five main criteria defined in the table 1.

The composition of the main indicators is presented in the Table 1

TABLE 1 – THE MAIN CRITERIA

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (α)
2	R ₁	Characterizes customer satisfaction with the quality of products	1
3	R ₂	Characterizes product compliance with the requirements	1
4	R ₃	Characterizes the degree of compliance with the requirements	0,9
5	R ₄	Characterizes the degree of compliance with the requirements	0,9
6	R ₅	Characterizes the degree of maintaining the quality of the product at the stage of operation	0,9

The main criteria include the corresponding partial criteria.

The contents of the particular criteria R1 are represented in Table 2.

TABLE 2 – PARTIAL CRITERIA FOR CALCULATING R₁

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (β)
1	B ₁	The share of acceptance certificates of research and development works, their stages that do not contain the customer's comments, in the total number of acceptance certificates of scientific and technical products	1
2	B ₂	Share of products delivered from the first presentation to the customer	1
3	B ₃	Percentage of products for which no complaints were received	1
4	B ₃	The share of products for which the customer has not received comments that are not issued by the complaint acts	0,6

$$R_1 = \frac{\sum_{i=1}^4 \beta_i \cdot B_i}{\sum_{i=1}^4 \beta_i}, \quad (1)$$

где B_i – value of the i-th criterion;

β_i – the weight coefficient of the i-th criterion given in Table 2.

To calculate the R2 criterion, the private criteria presented in Table are used 3.

TABLE 3 – PARTIAL CRITERIA FOR CALCULATING R₂

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (γ)
1	S ₁	Percentage of products not rejected by the quality control service during the control of technological operations	0,7
2	S ₂	Share of products delivered from the first presentation	0,7
3	S ₃	Percentage of products accepted without deviations in agreement with the customer	1
4	S ₄	Percentage of non-recurring product inconsistencies based on data from records	1

$$R_2 = \frac{\sum_{i=1}^4 \gamma_i \cdot S_i}{\sum_{i=1}^4 \gamma_i}, \quad (2)$$

где S_i – value of the i-th criterion;

γ_i – the weight coefficient of the i-th criterion given in Table 3.

The R3 criterion is calculated based on the particular criteria presented in Table 4.

TABLE 4 – PARTIAL CRITERIA FOR CALCULATING R₃

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (δ)
1	N ₁	Percentage of design tasks and contracts that have documentary evidence of the analysis of input data	1
2	N ₂	The share of research and development works, their stages, which have a documentary confirmation of the analysis of the performed works	1
3	N ₃	Percentage of prototypes with documented test programs and methods	1
4	N ₄	Percentage of prototypes with documentary evidence of the analysis of defects detected during their testing	1
5	N ₅	Percentage of changes in projects and developments that have documented the analysis of changes, including an assessment of the impact of changes on components and products already delivered	1

$$R_3 = \frac{\sum_{i=1}^5 \delta_i \cdot N_i}{\sum_{i=1}^5 \delta_i}, \quad (3)$$

где N_i – value of the i-th criterion;

δ_i – the weight coefficient of the i-th criterion given in Table 4.

The R4 criterion is determined based on the particular criteria presented in Table 5.

TABLE 5 – PARTIAL CRITERIA FOR CALCULATING R₄

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (ν)
1	P ₁	Percentage of technological equipment for which the planned time limits for the verification of technological accuracy were met	1
2	P ₂	The share of technological equipment for which the planned terms of commissioning and repair work have been completed	1
3	P ₃	Share of the most responsible technological processes with certification certificates	1
4	P ₄	Share of technological operations without violation of technological discipline	1

5	P ₅	Percentage of measuring, control and testing equipment that has passed verification and certification within the established time frame	1
6	P ₆	Percentage of products produced and accepted in accordance with the production plan	1
7	P ₇	Percentage of personnel trained and certified in accordance with the established requirements	1

$$R_4 = \frac{\sum_{i=1}^7 \nu_i \cdot P_i}{\sum_{i=1}^7 \nu_i}, \quad (4)$$

где P_i – value of the i-th criterion;

ν_i – the weight coefficient of the i-th criterion given in Table 5.

To determine the R₅ criterion, the following particular criteria can be proposed, presented in Table 6.

TABLE 6 – PARTIAL CRITERIA FOR CALCULATING R₅

№	Designation of the criterion	Content of a particular criterion	Criterion significance coefficient (μ)
1	V ₁	Percentage of works performed in compliance with the requirements of operational documentation, rules and operating conditions	1
2	V ₂	Percentage of maintenance and repair work performed in accordance with the documentation	1
3	V ₃	Percentage of improvements made in the course of operation related to the elimination of design and production shortcomings	1

$$R_5 = \frac{\sum_{i=1}^3 \mu_i \cdot V_i}{\sum_{i=1}^3 \mu_i}, \quad (5)$$

где V_i – value of the i-th criterion;

μ_i – the weight coefficient of the i-th criterion given in Table 6.

The value of the final criterion for the effectiveness of the quality management system is determined by the formula:

$$R_{res} = \frac{\sum_{i=1}^5 \alpha_i \cdot R_i}{\sum_{i=1}^5 \alpha_i}, \quad (6)$$

где R_i – value of the i-th criterion;

α_i – the significance coefficient of the i-th main criterion given in the Table 1.

Note that the significance coefficients of the criteria can be determined by the method of expert assessments of a group of quality specialists.

The interpretation of the values of the final criterion for the effectiveness of the quality management system is given in Table 7.

TABLE 7– SYSTEM PERFORMANCE ASSESSMENTS

The obtained quantitative assessment of the system's performance	The degree of effectiveness of the system
$R_{res} < 0,60$	invalid
$0,60 < R_{res} < 0,75$	acceptable
$0,75 < R_{res} < 0,95$	sufficient
$R_{res} > 0,95$	high

Using the gradation of the degree of effectiveness of the product quality management system, a conclusion is made about the state of the product at the stages of the life cycle.

The application of the methodology allows you to monitor the quality level at the stages of development, production and operation, and take appropriate measures to prevent the appearance of product inconsistencies.

The developed method can be automated with the help of modern applied software tools [4-5], but this is the topic of the next article.

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GEOECOLOGICAL RISKS OF TECHNOGENIC NOISE AT LOW FREQUENCIES

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Abstract — The tasks of evaluation of geoeological risks related to transport vibrations in the ground and acoustic vibrations in the atmosphere generated by moving transport, such as railway, automobile, tracked transport are considered. The main ecologically harmful frequency areas on the basis of spectral and spectral–time analysis of the records of technogenic noises are identified. Estimates of vibro–acoustically conditioned risks in the allocated frequency bands are

calculated. Comparative analysis with critical norms and discussion of the obtained results were carried out.

Keywords — Technogenic noise, geoeological risks, numerical estimates, transport types, experimental records, critical norms, comparative analysis.

INTRODUCTION

The problem of estimation and prevention of harmful influence of technogenic noises generated by various kinds of transport and productions now becomes especially acute. The level of noise pollution is among the most important indicators characterizing comfort of living of people in an urban area [1]. The World Health Organization conducted research and gave estimations of noise levels to which inhabitants of European countries are exposed. According to this data during the daytime about 40% of European residents are exposed to noise levels exceeding 55 dB and 20% are exposed to noise levels exceeding 65 dB [2]. This is contributed by active development work, an increase in the number of cars, and various landfill and quarry explosions, etc [1]. Noises of a natural character are added to this (for example, noise of sea surf, hurricanes, sharp fluctuations of atmospheric pressure).

The problem of harmful effects on the environment increases sharply in the area of low and infra-low frequencies, the most ecologically dangerous for humans, as well as the most destructive for large structures (bridges, buildings, industrial premises, etc.). The latter is determined by the fact that in the area of infralow frequencies are natural frequencies of vibration of structures. This determines the relevance of the research.

PROBLEM STATEMENT

The acoustic impact of technogenic noises on the surrounding infrastructure and humans is related to the concept of geoeological risk, defined by the equation:

$$L_{Aeg} = 10 \lg \frac{1}{T} \int_0^T \left(\frac{p_A(t)}{p_0} \right)^2 dt, \quad (1)$$

where L_{Aeg} is equivalent corrected noise level for a given period T , $p_A(t)$ is the current value of root mean square sound pressure, Pa; p_0 is the reference sound pressure in the air, it is taken equal to $p_0 = 2 \cdot 10^{-5}$ Pa; T is time of noise, hour [3].

Along with the negative impacts of the processes of acoustic transport noise in the atmosphere, it is also necessary to consider the impact of vibrations arising as a result of seismic vibration propagation in the ground. Of these vibrations are: transport, which occurs as a result of traffic on the roads; technological – occurs during the operation of machinery and equipment in the process of carrying out technological operations on the production sites. The environmental risk indicator attributed to vibrations is determined as follows:

$$L_v = 20 \lg \left(\frac{v}{v_0} \right), \quad (2)$$

where L_v is vibration velocity level; v is the root mean square value of vibration velocity, m/s; v_0 is the reference value of vibration velocity, taken as $5 \cdot 10^{-8}$ m/s [4].

Since noise exposure has a cumulative effect, a summary noise and vibration velocity level may be calculated for each mode of transport, taking into account the duration of exposure.

The summary noise level may be determined by the equation:

$$L_{Aegsum} = 10 \lg \int_0^T \left(\frac{p_A(t)}{p_0} \right)^2 dt, \quad (3)$$

where $p_A(t)$ is the current value of the root mean square sound pressure, Pa; p_o is the reference sound pressure in the air, is taken to be $2 \cdot 10^{-5}$ Pa; T is the time of action of noise, hour.

The summary vibration velocity level can be determined by the equation:

$$L_{vsum} = 10 \lg \int_0^T \left(\frac{v(t)}{v_0} \right)^2 dt, \quad (4)$$

where v is the current value of the root mean square value of vibration velocity, m/s; v_0 is the reference value of the vibration velocity, is taken to be $5 \cdot 10^{-8}$ m/s.

The weighted average daily noise may be calculated by the formula:

$$L_{den} = \frac{\sum L_i \cdot p_i}{\sum p_i}, \quad (5)$$

where L_i is equivalent corrected noise level for a given period, dB; p_i is the fraction of event time from day [3].

Estimation of ecological risks (1) – (5) represents a multifactorial problem, which solution depends on power of a noise source, their frequency range, conditions of distribution of noise fluctuations in the atmosphere, etc. [5].

The purpose of this work is related to the allocation of the most ecologically dangerous low frequencies of noises of various types of transport – railway, automobile, tracked, as well as industrial noise. The following stage is connected with obtaining of numerical assessments of risks (1) – (5) depending on noise frequencies, acoustic pressure levels and seismic vibrations.

NUMERICAL MODELING AND EXPERIMENTAL RESULTS

The approach to numerical modeling consists in determining the boundaries of emerging events (associated with the passage of one or another type of technique) by experimentally obtained records of traffic noise. This stage of the work is implemented with the application of the threshold algorithm according to the 3σ rule. The spectral-temporal functions (STF) are calculated on the selected parts of the recordings. This type of analysis is applied to the records of railway transport, heavy tracked and wheeled transport noises.

As a result of data processing, graphs were obtained, which allow tracing the dynamics of spectrum changes, determining characteristic frequencies of the types of transport under consideration. As an example, the STF graph of tracked transport noise, presented in Fig. 1a, is shown below. STF graph of KAMAZ noise is shown in Fig. 1b. It can be seen, that frequencies of about 1 – 100 Hz with predominance of frequencies in the range of about 10 – 50 Hz are typical for tracked transport. KAMAZ is characterized by frequencies about 1 – 90 Hz with the predominance of frequencies in the range of about 5–30 Hz, 50 – 65 Hz. The given data corresponds to a distance from the noise source of 20 m and an average speed of about 20 – 60 km/h.

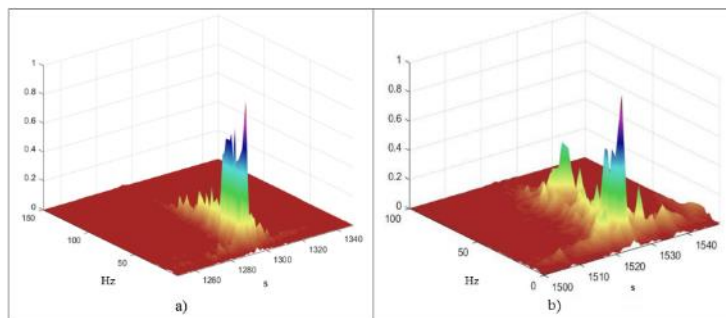


Fig. 1 Spectral–time functions (STF) of seismic noise: a) – tracked transport; b) – KAMAZ.

Acoustic and seismic noises of railway transport (passenger and freight trains) were recorded at a distance of 30 m from the railway track. For each type of railway transport were obtained STF graphs in the amplitude-frequency-time coordinates, as well as their projections on the "frequency-time" plane. The obtained graphs are presented below.

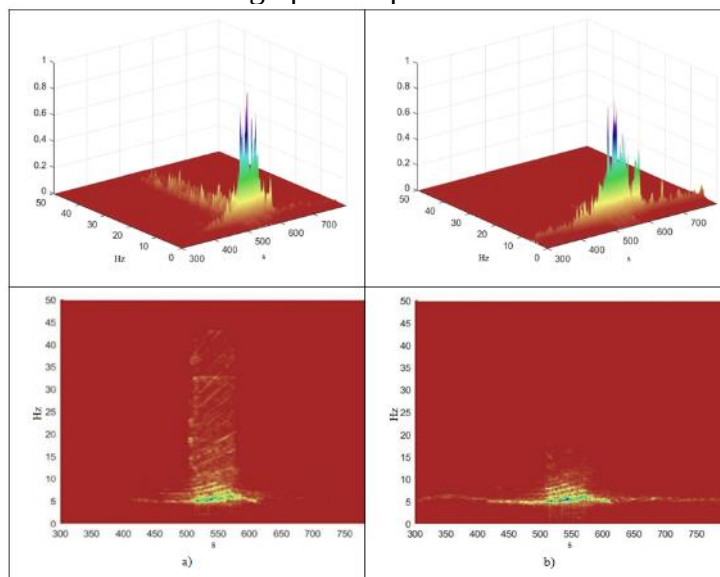


Fig.2 Spectral-time functions (STF) and their projections on the "frequency–time" plane for heavily loaded freight train noises a) –seismic; b) – acoustic

According to the STF analysis results, it was found that at a speed of 40 – 70 km/h, the predominant frequency range of seismic (Fig. 2a) and acoustic (Fig. 2b) noises of a freight train covers the frequency range of 4 – 10 Hz. At that, the main spectral mode lies in the area of 6 – 7 Hz.

Seismic noise of passenger trains at a speed of 50 – 80 km/h is characterized by the frequencies in the band of 5 – 44 Hz (Fig. 3a) with the location of the main spectral modes in the area of 8 – 9 Hz, 20 Hz. The frequency range of acoustic noises (Fig.3b) covers the band in the range of 3 – 15 Hz, and the main mode of noises lies in the region of 7 – 8 Hz.

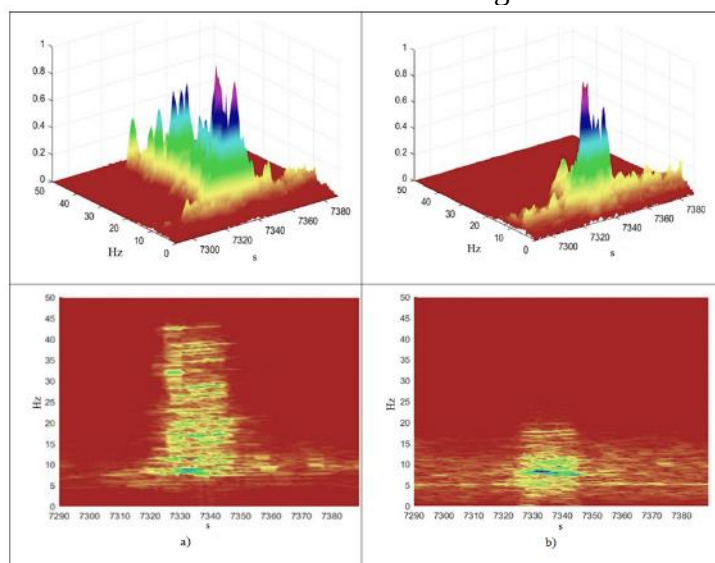


Fig.3 Spectral-time functions (STF) and their projections on the "frequency–time" plane for passenger train noises a) – seismic; b) – acoustic.

Seismic noises of electric trains moving at a speed of about 50 – 80 km/h are characterized by frequencies in the 5 – 44 Hz band with the location of the main spectral modes around 8 – 11 Hz, 33, 38 Hz. The frequency range of acoustic noise is in the range of 3 –15 Hz, and the main mode of noise lies around 7 – 8 Hz.

Acoustic noise level according to (1) and vibration velocity level according to (2) were calculated for the considered types of transport. For KAMAZ and tracked transport the vibration velocity level was calculated according to the data obtained by the transport moving from the seismic station at distances of 20 m to 500 m. Calculations were performed in frequency bands typical for the type of transport that was considered.

The results of calculations of the transport noise level with regard to the types of transport under consideration are presented in Table 1. Table 2 presents the results of calculations of the vibration velocity level.

TABLE I. NOISE LEVEL

№	Transport type	Frequency range, Hz	Distance, m	Averaging time, s	Noise level, dB	Summary noise level, dB
1	Freight train	4–10	30	190	64,0	106,8
		1–49	30	178	64,2	107
2	Electric train	1–49	30	30	51,2	86
		3–15	30	30	50,8	85,6
3	Passenger train	6–44	30	23	53,6	87,2
		1–49	30	23	54	87,7

TABLE II. VIBRATION VELOCITY LEVEL

№	Transport type	Frequency range, Hz	Distance, m	Averaging time, s	Vibration velocity level, dB	Summary vibration velocity level, dB
1	Freight train	4–10	30	190	59,1	101,6
		1–49	30	178	75,5	118,0
2	Electric train	6–44	30	30	50,7	85,4
		1–49	30	30	50,8	85,5
3	Passenger train	6–44	30	23	47,1	80,8
		1–49	30	23	47,2	80,9
4	KAMAZ	1–90	20–50	10	47,2	87,2
			50–100	7	38,9	77,4
			100–150	7	35,3	73,8
			150–200	13	31,2	72,4
			200–300	18	23,4	66,0
			300–400	14	20,0	61,5
			400–500	14	18,3	59,8
5	Tracked transport	1–100	20–50	9	63,2	102,7
			50–100	5	54,1	91,1
			100–150	5	44,9	81,9
			150–200	11	36,5	76,9
			200–300	13	34,0	75,1

		300–400	10	26,0	66,0
		400–500	11	21,2	61,6

Noise levels in the railroad area were calculated for each hour during the day. The data on the hourly dynamics of changes in the noise situation are shown in Fig. 4. It has been established that the average level of noise in the area of the railroad noise impact during the day at a distance of about 30 meters is about 53,7 dB. Average noise level during daytime (time interval 7 a.m. – 7 p.m.) is 57 dB. The average noise level at night (23 p.m – 7 a.m.) is around 51,8 dB. Average weighted daily noise level of railway transport is about 60 dB. Summary noise level during trains running during 24 hours was 117,4 dB (summary time of trains running during 24 hours was about 1 hour 9 minutes). Thus, if we take into account the influence of noise sources as separate events, the noise level is within the established norms (does not exceed 76-83 dB) [6]. At continuous action of sources, taking into account accumulation, the noise level can exceed norms.

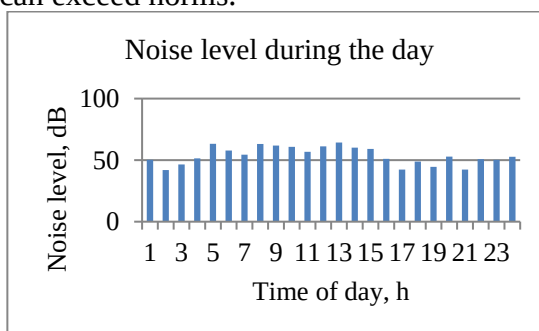


Fig. 4 Hourly dynamics of the noise situation in the city territory in the area of the railroad noise impact

Fig. 5 shows graphs of noise level changes at the simultaneous passage of two oncoming trains: Fig.5a – freight trains, Fig.5 b) – electric trains in the daytime.

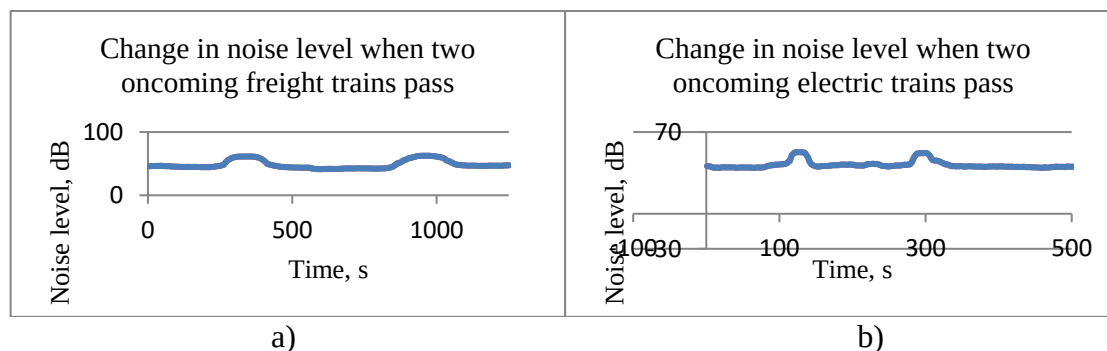


Fig. 5 Change of noise level when passing two oncoming trains: a) – freight trains, b) – electric trains

In the first case, the averaging window was 100 s, in the second – 20 s. The choice of the averaging window is determined by the duration of the passage of the train in the area of the recording sensors. From Fig. 5a shows that the noise level increases approximately 1,5 times when trains pass. In the second case, the noise level increases approximately 1,3 times.

CONCLUSION

The problem of the harmful effect of technogenic noises on the environment in the area of low and infra-low frequencies, the most ecologically dangerous for humans and destructive for large structures, is considered. Experimental records of seismic and acoustic noises of

railway, heavy tracked and wheeled transport were analyzed using the method of spectral-time analysis. The frequency ranges most typical for each of the considered types of transport were identified. On the basis of the data processing it was determined that the prevailing levels of transport noise are in the range of ecologically dangerous frequencies. The levels of noise and vibration velocity, occurring during the movement of transport at different distances in the allocated frequency ranges were determined.

ACKNOWLEDGMENTS

This work was supported by RFBR (grant № 20–07–00861A)

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MULTIFUNCTIONAL MOBILE APPLICATION "MIEMAPP"

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Abstract—Mobile devices have large distribution across the world. Almost everyone has either a tablet or smartphone. Thus, applications for mobile operating systems are useful in solving a variety of problems. For instance, MIEM HSE has several online services, which can be accessed with applications. However, it is unnecessary to develop separate programs for each service, because it is uncomfortable for users to install a new application each time, they need a new service. This paper is being carried out as a comprehensive solution to develop a project based on client-server architecture. Goals of this work are designing a suitable client app "MIEMapp" and servers.

Keywords: client-server architecture; internet of things; mobile app; server application; REST API; python; modular application; Kurento.

INTRODUCTION

There are unique useful web services for teachers and students inside HSE MIEM with media and schedule features for convenient interaction with the growing community within the university. For example, LMS system is a website for marks and paperwork handling, MIEM

Cabinet is a web service for scientific and project activity appointment, any participant can propose his project or submit an application to an already existing, RUZ, which is a timetable application, ELK is a unified authentication system with Google login integration and many other services being developed to carry university activities. The goal of the paper is to develop one mobile application that will use all these services as embedded modules. Such an application is called a superapp, that concept improves the user experience because they do not need to install several applications. MIEMapp application uses a unified authentication with all services and tokens to validate users. Various modules can be unlocked or added on a screen depending on the user role or his needs. Additionally, it improves security and allows to add new functional features in less time in comparison to a standard application development.

PROBLEM STATEMENT

Today, several companies tend to develop multi-functional mobile superapp. It allows developers to keep users from deleting it, because one of the reasons users delete applications is no need in it [1]. If a program has more than one function it is less likely to be deleted. Therefore, finding a useful architecture to make responsive and storage efficient multifunctional web and mobile applications is an important task for software engineers.

Main goals of the approach are how to design architecture, which allows to add new modules without additional work on the main codebase, how to develop an application according to architecture, how to develop modules for project cabinet and media services of MIEM HSE, how to embed modules into application and development of real time video preview for ONVIF cameras control module. Additionally, it should have a simple way to show different screens and add modules to the menu.

The first planned embedded application into the solution was MIEMcam. Its purpose is to help the university media center to handle the recording and streaming of video content from IP cameras which are placed all over the university classrooms. Primarily, the media center records the lectures, but other in-class events could be handled as well. Before the MIEMcam module release, a broadcast could only be processed from the special control room via specific programs and technical equipment. This room is located in the MIEM university and such a placement is not convenient since always during events recording an operator should be in the control room otherwise broadcasting is not possible. MIEMcam mobile application intended to remove these drawbacks, so a university camera can be moved, recording can be scheduled, and other features could be done remotely with the mobile application from all over the world, not only from the one room.

Mostly, university cameras support the ONVIF control protocol and currently, there are a vast variety of prepared mobile programs to work with it. Nevertheless, such programs clients must be in the same local network with the controlled camera so remote control could be done only through a VPN connection. More than that, other cameras such as VISCA could be placed in the university auditoriums so the second mobile application is needed. Also, these programs are not compatible with the already prepared MIEM university services such as lectures recording booking modules. Thus, it is required to design an architecture to consider described drawbacks and implement a mobile application consisting of a remote camera control module and internal media services using tools.

SOLUTION OF THE PROBLEM

In this part of the paper, it will be explained the methods used to reach the project's goal: development of multifunctional iOS application and backend servers (control and media) for MIEM HSE services.

Firstly, the control server architecture is based on client-server architecture. By the concept of REST API [2], various web services are accessed via HTTP requests. A server has

access to the cameras installed in the classrooms and the vMix studio software mixer and it acts as a proxy due to the need for access to equipment in a network that is closed from external access, as well as to reduce the size of the mobile application. Figure. 1 shows a general schema of the project architecture. Main developed parts here are Python FastAPI Backend-server as a camera control server, Kurento as a media server and a client application.

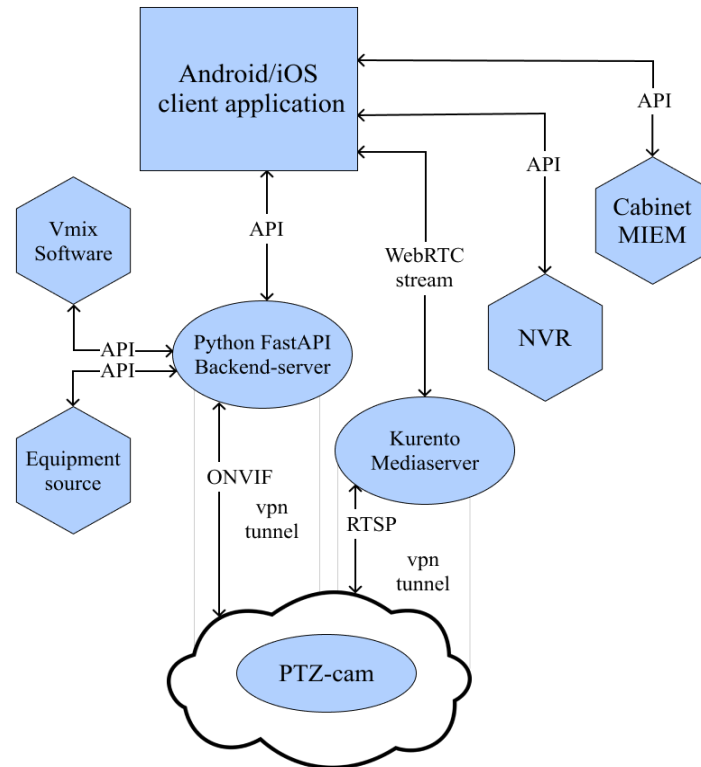


Fig. 1 The Schema of the project architecture

The hexagons on figure are external digital services developed by MIEM HSE students, their functions are partially integrated into the result of our project.

CONTROL SERVER

The project is developed in a student environment, so we need to use development tools with a low entry threshold. For this reason, the preferred development tool is Python due to its flexibility. New students, such as first-year or second-year students, can become a participant of the project in less time. The second reason is the existing library [3] for specific focus of the project to manage cameras over the ONVIF protocol. It was development for recent work in MIEMcam module. The third reason is access to various web frameworks to implement the REST API principles. REST API (also known as RESTful API) is an Application Programming Interface (API or Web API) that allows interaction with RESTful web services. An API is a set of definitions and protocols for building and integrating application software. FastAPI framework is one of the fastest Python web frameworks. In fact, its speed is at par with Node.js and Go. It supports native Python asynchrony (asyncio), gives detailed and easy-to-use developer docs. By following documentation developers will reduce errors by minimizing code duplications. FastAPI validates the developer's data type even in deeply nested JSON requests. And most importantly, developers get product-ready code with interactive API and documentation out of the box. Figure 2 illustrates a standard implementation of API schema in a web service, that is used in this paper.

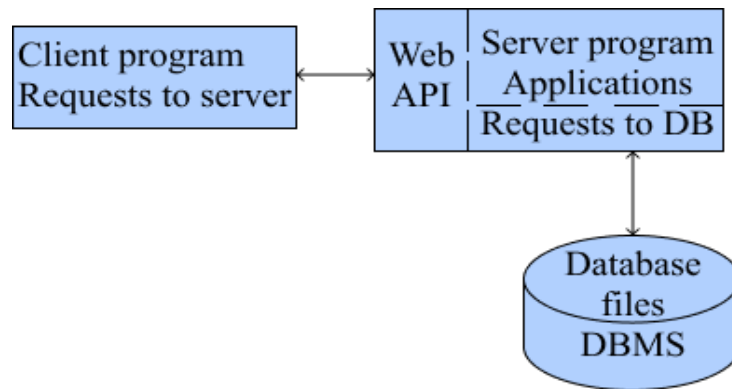


Fig. 2 A standard schema of an API application

The server works on Ubuntu 18.04 or later. It uses Python 3.6 or higher scripts to be able to access asynchrony. Data stored on the running PostgreSQL server, database schema consists of user attributes (id, email, hashed password, user rights, username), equipment attributes (id, equipment IP addresses, available ports, logins, passwords, rtsp-url), presets for cameras (id, cam id, presets on cam) and logs of interaction with the equipments. The database schema shown below on Figure. 3.

It is important to note that the server uses VPN software [4] to allow external access to a closed network, which the cameras work. Another way is installing OpenVPN on a mobile phone as an additional application or a software inside a mobile application, but this way leads to more issues in the UX.

API was developed in discussion and tips [5] with all developers to confirm what forms and types of data are more convenient to receive from server requests to all parts in the project.

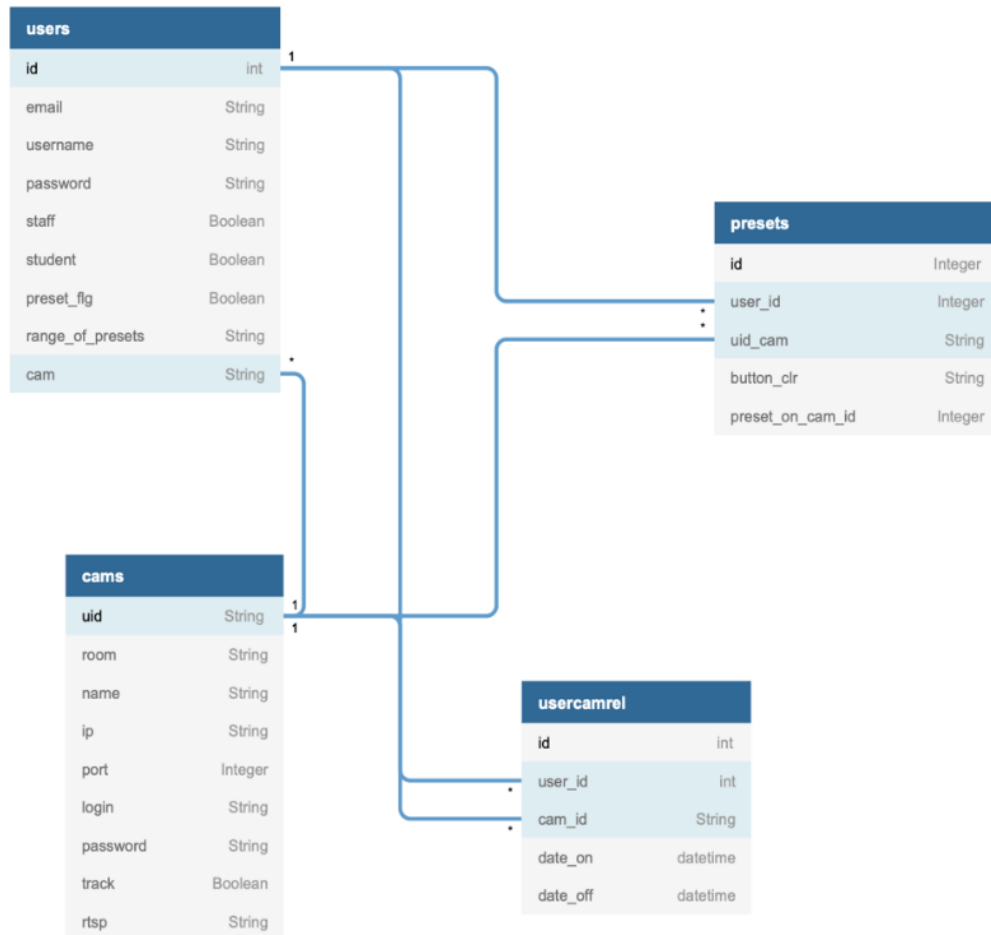


Fig. 3 The database schema

MEDIA SERVER

To control a camera during broadcasting it is required to observe the video stream which the camera gives out, so the mobile application should be equipped with the video translation window. To implement this feature, it is needed to embed another entity to the solution - a media server. Its purpose is to deliver media content from a camera on the local university network to a client on the Internet.

To implement this idea the first determined instrument should be media streaming protocol. According to wowza investigation [6] WebRTC has the least latency among other protocols which is essential in the task of remote camera control during broadcasting.

Secondly, the WebRTC media server implementation must be chosen, and Kurento Media Server prevails in this field. Thanks to it, a media server that simply takes RSTP video from an IP camera and gives it away through WebRTC technology could be loosely programmed. As mentioned in the tutorial from official Kurento documentation [6] this can be built by creating a special pipeline that receives video through PlayerEndpoint and sends it through WebRtcEndpoint.

It is worth noting that Kurento Media Server is controlled through the network requests which describe the pipelines. After pipeline command receiving Kurento implements this pipeline and processes media according to it. Thus, in the proposed architecture Kurento should be controlled from the special mediator server which ought to receive commands from a client and prepare pipelines description for sending to Kurento. Sending commands directly from clients to Kurento Media Server is not possible because of security vulnerabilities. Thereby

mediator control server implementation was produced with Kurento client library for Java Spring framework.

Also, Kurento has a Javascript client library. Thanks to it, a web client for video receiving could be built and integrated into the mobile application through the WebView which is another benefit of Kurento use.

Finally, to make the solution secure it is required to integrate TURN server into the project [7]. This is a server that allows to resolve the symmetric NAT problem and connects two media clients when both of them are located behind the different NATs and cannot establish a direct connection. Such a scheme allows the media server on the local university network so it cannot be resolved from the internet directly and could be available only through secure credentials authentication on the TURN server which is located on the Internet and available for both client and media server. According to Kurento official documentation [8] Coturn server is recommended as an implementation of TURN server.

IOS CLIENT APPLICATION

It was started with designing architecture. Application's architecture built upon the common iOS architectural pattern "VIPER" (View Interactor Presenter Entity Router [9]). In this architecture View is responsible for displaying data. Interactor handles all the business logic in the application. Presenter is a layer between view and Interactor and handles user actions and requests data from Interactor, according to actions. Entity is raw data representations for everything in the application. Router's only responsibility is managing all screen changes, it describes how one view can be replaced by another one. This pattern has several advantages. Firstly, it allows to distribute responsibilities between five layers, which makes each object simpler and easier to understand. Secondly, these layers interact with each other through protocols (this is how interfaces called in iOS development). This allows testing each layer with other layers being mocked. However, this pattern has an issue. In early stages of development, it requires extra work to make all these five layers. MIEMapp introduced Graph objects. It is the main entity for each module. Graph is responsible for requesting all needed dependencies from the base application. It also creates all needed objects, and then returns the view to the main application. This approach makes embedding of modules easier. Also, each module has only one place where it is connected to the main app, which helps developers to make new modules in parallel without conflicts in code. All modules will be developed according to this architecture.

Another problem in development of applications is finding a good way to show real time video streams from media services' cameras. This video contains sensitive information from university cameras. Thus, RTSP stream is not suitable, instead WebRTC was used. Native libraries for this protocol have some issues: it dramatically increases the size of the application and they are not actively developed. To solve this problem instead of native libraries will be used WKWebView [10], where html page with JavaScript will be loaded. These sources will be embedded into the application. It will solve the problem of loading the same page many times. This JavaScript source uses libraries which are actively developed and less space consuming.

CONCLUSION AND OUTLOOK

This work has introduced solutions for development of multifunctional application MIEMapp for iOS, which will provide a convenient way to use several MIEM HSE online services. Designed architecture, based on existing pattern View Interactor Presenter Entity Router, which allows effortlessly including new modules into the main application. Moreover, it improves its testability. Modular architecture simplifies concurrent development of the application. It allows to add new functions in less time. This architecture fully satisfies all assigned requirements. Found a solution to embed real time video preview from cameras, using HTML and JavaScript web pages, loaded in WKWebView. Low storage consumption and

constant development of JavaScript library for WebRTC makes it more preferable than native iOS libraries. It does not have significant performance issues. Thus, this solution fulfills tasks demands. Furthermore, the article has presented the realization of the web server which implements the application REST API. Such architecture will make the MIEMapp rather one of the most used mobile programs among MIEM HSE services family. This experience describes a plan on how to create an adaptable and extendable program solution for a web application and avoid malfunctions in design. The proposed backend server will securely handle the process of broadcast and other resources control. A camera image receiver via Kurento and TURN servers is designed to deliver video all over the Internet with rather low latency. Additionally, such a method is flexible because it supports different types of media clients such as mobile, desktop and web so further in-browser MIEMcam version creation is predicted to be straightforward. Multifunctional application will allow new students and teachers to install only one application. If they need another function access can be granted from the server. This will improve user experience, because they do not need to do any additional actions. Moreover, security benefits from this approach, because validation of user actions occur on the server. It will increase user experience from services. Developers and administrators can not worry about unauthorized attempts to access the equipment since architectural principles and solutions provide the data's security. To sum up, the obtained results will help the university to bring the quality of the recording and broadcasting educational material to a new level.

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SOLVING THE PROBLEM OF TWO-DIMENSIONAL PACKING BASED ON THE WOLF PACK ALGORITHM

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Abstract— The article analyzes the problems related to the problem of packing blocks of different sizes in the metric of binary space. The main aim is to solve the problem of optimal placement of two-dimensional objects on the cutting map in order to minimize the cost of cutting. To solve the problem, we developed a modified bioinspired algorithm based on the behavior of grey wolves in nature. Based on this method, a software product was developed and implemented using the developed architecture and augmented virtual reality. The results of the experimental studies proved the effectiveness of the approach and theoretical estimates of the time complexity of the algorithm.

Keywords: two-dimensional packing, genetic algorithm, bioinspired algorithm, wolf pack algorithm.

INTRODUCTION

Information technologies are being developed very rapidly today. Electronics, computer science, together with the current level of technological progress allow the scientists to implement their most challenging ideas. Computer-Aided Design (CAD) systems compose one of the branches of modern scientific and technical subjects. The development of CAD systems is closely related to the application of extensive scientific and technical foundations. We can notice the following branches: advanced computing tools, state-of-art principles of representing and processing masses of information and databases, development of innovative calculation methods for solving engineering and optimization problems. Based on the above, we can conclude that CAD systems now compose a topical and highly important scientific and technical field these days [1-3]. For a long time, the idea of virtualizing the space around people and creating artificial reality has been relevant for the mentioned field [4-6].

PROBLEM STATEMENT

The problem of two-dimensional packing has different cases. Let us introduce the following constraints for our case [7-10]:

- Objects are represented as rectangles in geometrical terms;
- Intersection of objects is not possible;
- Objects cannot exceed the container;
- Objects sides are strictly parallel or perpendicular to the container sides.

Let us represent the initial data as follows: $I = \{1, 2, \dots, n\}$ represent the set of rectangles; w_i and h_i represent the width and height of the i^{th} rectangle respectively.

The variables can be introduced in the following way. Let x_i and y_i represent the position of the bottom-left angle of the i^{th} rectangle; W and H represent the width and height of the wrapping rectangle respectively; variable $l_{ij} \in \{0, 1\}$ is equal to 1 if the i^{th} rectangle is left of j^{th} one and 0 otherwise; variable $b_{ij} \in \{0, 1\}$ is equal to 1 if the i^{th} rectangle is under j^{th} one and 0 otherwise

Considering the notations written above, the problem can be modeled as follows [5,6]:

$$\begin{aligned}x_i &\geq 0, & i &\in I; \\y_i &\geq 0, & i &\in I; \\x_i + w_i &\leq W, & i &\in I; \\y_i + h_i &\leq H, & i &\in I.\end{aligned}$$

To avoid the intersection of two rectangular objects, we need to place one of them either under or above the other one. Another solution is to put one of the objects either on the left or right regarding the other one. Let us represent the mentioned constraints for each pair of the objects as follows:

$$x_i + w_i \leq x_j + (1 - l_{ij}) \sum_{k=1}^n w_k, \quad i, j \in I;$$

$$y_i + h_i \leq y_j + (1 - b_{ij}) \sum_{k=1}^n h_k, \quad i, j \in I;$$

$$l_{ij} + l_{ji} + b_{ij} + b_{ji} = 1, \quad i, j \in I.$$

The objective function is quadric, and all the constraints are linear since the problem statement uses real and binary variables. Thus, the problem can be related to the class of mixed-integer quadratic programming.

ARCHITECTURE OF THE ALGORITHM

Bioinspired and genetic algorithms allow us to find optimal solutions and reduce time spent for solving. To solve the particular case of the two-dimensional packing problem, we developed a modified architecture. The scheme of the architecture is shown in Fig. 1.

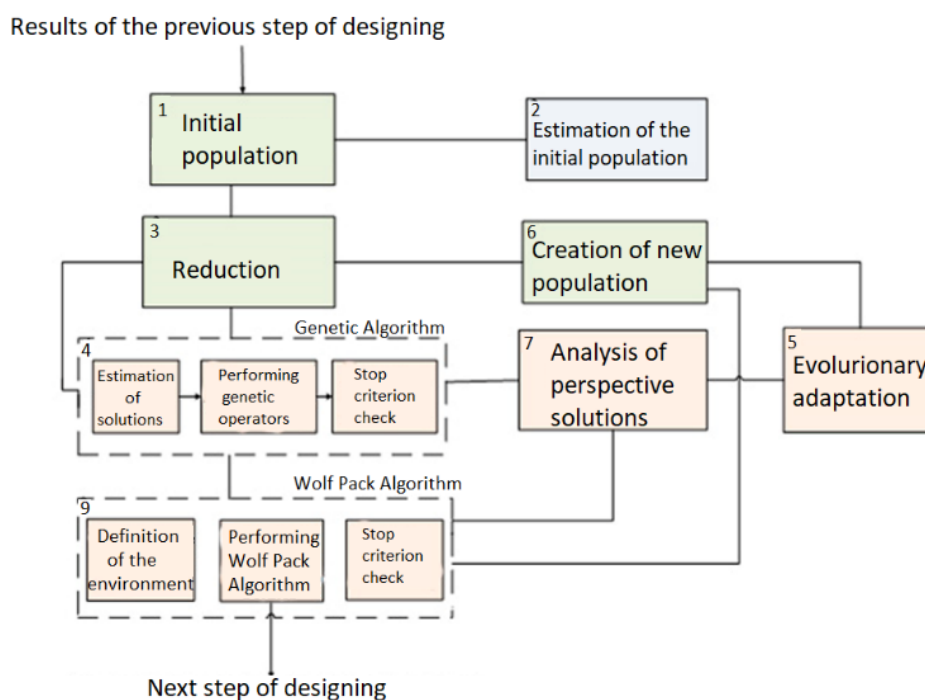


Fig. 1 Architecture of modified algorithm for solving the problem

The first block creates the initial population of agents. The second block is to estimate the fitness of the initial population. The third block is responsible for the reduction of the existing alternative solutions. In the fourth block, the Genetic Algorithm estimates the solutions, performs the genetic operators (crossover, mutation, and inversion), and checks the stop criterion. After that, we need to estimate the fitness of new solutions. The fifth block implements the adaptation mechanisms to change the order of genetic operators. The seventh block collects and analyses the solutions obtained after the Genetic Algorithm. This block estimates each solution as perspective, complicated, or non-perspective. The eighth block is the most complicated yet the most important one. It includes the architecture of the grey wolf method. The method is based

on the behavior of wolves in nature. The wolves have a strict hierarchy of dominating, which needs to be defined. There are four usual types of wolves [11-13]:

- Alphas are leaders that make the most important solutions in a pack.
- Betas are controlled by the Alphas. They can be described as “right-hands” of the Alphas.
- Omegas are controlled by other wolves and allow them to unleash their anger. This preserves the stability of the pack.
- Deltas are higher than Omegas but lower than Alphas and Betas in the hierarchy. Deltas include scouts, hunters, and elders (former Alphas or Betas).

There are three types of hunting: searching, encircling, and attacking the prey. At the first stage, agents research the area for the “prey”. The other two stages are attacking the prey and repositioning and reassigning the Alphas, Betas, and Omegas. In the algorithm, the wolves’ ranks are changed more quickly than in nature.

After the prey is found, the wolves start encircling it. The encircling model is shown in Fig. 2 and can be described with the following equations:

$$\begin{aligned}\bar{D} &= |\bar{C} * \bar{X}_p(t) - \bar{X}(t)| \\ \bar{X}(t+1) &= \bar{X}_p(t) - \bar{A} * \bar{D}\end{aligned}\quad (1)$$

In equations (1) $\bar{A}$ and $\bar{C}$ denote support vectors; $\bar{X}_p$ denotes the vector of the prey’s position; $\bar{X}$ denotes the vector of a wolf’s position; t denotes the current iteration. $\bar{A}$ and $\bar{C}$ are calculated by the formulas below:

$$\begin{aligned}\bar{A} &= 2\bar{a} * \bar{r}_1 - \bar{a} \\ \bar{C} &= 2 * \bar{r}_2\end{aligned}\quad (2)$$

In equations (2) case a linearly declines from 2 to 0, r_1 and r_2 are random vectors from $[0;1]$, which provide the wolves’ repositioning. This allows the agents to identify the prey’s position using the encircling mechanism as shown below.

$$\begin{aligned}\bar{D}_\alpha &= |\bar{C}_1 * \bar{X}_\alpha - \bar{X}| \\ \bar{D}_\beta &= |\bar{C}_2 * \bar{X}_\beta - \bar{X}| \\ \bar{D}_\delta &= |\bar{C}_3 * \bar{X}_\delta - \bar{X}| \\ \bar{X}_1 &= \bar{X}_\alpha - \bar{A}_1 * (\bar{D}_\alpha) \\ \bar{X}_2 &= \bar{X}_\beta - \bar{A}_2 * (\bar{D}_\beta) \\ \bar{X}_3 &= \bar{X}_\delta - \bar{A}_3 * (\bar{D}_\delta) \\ \bar{X}(t+1) &= \frac{\bar{X}_1 + \bar{X}_2 + \bar{X}_3}{3}\end{aligned}\quad (3)$$

In equations (3) each wolf improves its position and gets closer to the prey. The prey represents the objective function, which is located randomly in the circle determined by the Alpha as shown in Fig. 2 [14,15].

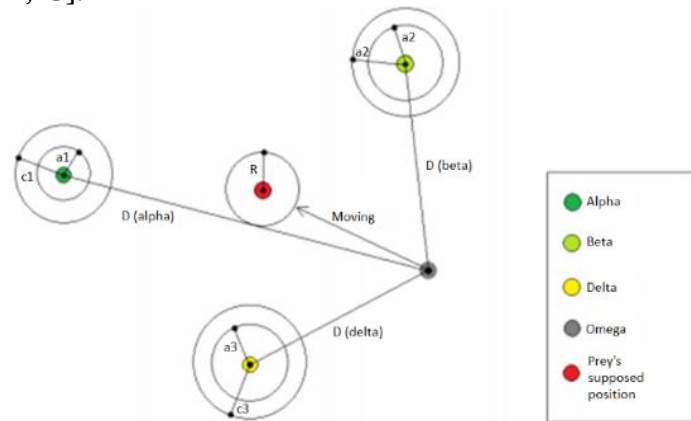


Fig. 2 Encircling the prey by the wolf pack

BIOINSPIRED ALGORITHM FOR SOLVING THE PROBLEM

Let us introduce the search method to make the algorithm able to solve the problem. In our case, the problem of two-dimensional packing can be interpreted as minimization of the waste amount in terms of cutting some material. We also need to maximize the number of two-dimensional objects placed in the two-dimensional container. If we know the number of objects, the amount of waste is predefined. Then, the main parameter to optimize is "length of cut" i.e., the less distance the saw covers, the more optimal the solution is. For example, in "Leroy Merlin" they can cut the plywood according to your design, and the price is formed by the number of cuts or meters the saw trims. Thus, we should place the objects in such a way that we can simultaneously cut them. Another way is to put them so that the longest edges comprise the edges of the workpiece and do not need to be cut. Then, the objective function is equal to 0, but the optimization process considers the length of the required cut and the number of sides needed to be cut. The objective function tends to the minimum amount of cutting waste and the maximal number of objects.

Let us introduce the encoding of the solutions. The "prey" represents the optimal solution X_0 , which depends on the conditions mentioned above. Each agent aims at getting closest to the prey. Achieving this solution is almost impossible, so we will search for the solution that is closest to the optimal. The "wolves" represent random solutions, where the objects are randomly located in the container at the first iteration. The wolves' fitness is further compared with the objective function. Depending on the fitness, the best solution becomes the Alpha X_α , the second, and the third best solutions become Beta X_β and Delta X_δ wolves respectively. Consequently, the rest of the wolves are Omegas X_ω . The positions of the wolves are then updated according to the position of the best solution (Alpha). The process is developed as follows.

All wolves represent solutions and try to improve them. A random generation is created to optimize the initial solutions. All the Omega wolves are expelled, and the wolves are getting closer to the Alpha. This step deletes all poor solutions. The results are then compared with each other. If the current Alpha does not represent the optimal solution, the best wolf at the current iteration becomes an Alpha. The algorithm is repeated until the Alpha solution does not change. Thus, the optimal solution is found.

The steps of the algorithm are following:

1. Set the population size n
2. Set the maximum number of iterations
3. Create and perform the initial disposition of the grey wolves' population X_i ($i = 1, 2, \dots, n$)
4. Initialize the alpha wolf and support coefficients
5. Calculate the fitness of each wolf
6. Set the status X_α to the best search agent
7. Set the status X_β to the second best search agent
8. Set the status X_δ to the third best search agent
9. While $t < \text{maximum number of iterations}$:
 - Recalculate the positions of each wolf
 - Update the value of α
 - Update the value of support coefficients $(\bar{A}, \bar{C})$
 - Calculate the value of the objective function of each wolf
 - Update X_α , X_β , and X_δ
 - Update the count of iterations ($t = t + 1$)
10. Output X_α

The next subsection presents the experimental research of the developed architecture and algorithm.

EXPERIMENTS

We carried out the experimental research to determine the following [16-18]:

- Estimation of the execution time of the developed algorithm;
- Effectiveness of the developed algorithm in terms of the quality of solutions;
- The most effective values of the control parameters of the developed algorithm.

To carry out the experiments, we created a mobile application for iOS that provides optimal solutions in real time. The application works as follows. The smartphone camera is pointed at the material. The parameters are set automatically or manually. The application then creates the optimal cutting chart and packs the objects in the most optimal way depending on the parameters of the material and criteria of the problem. The application becomes more useful due to the ability to identify major construction materials using “markers” in the database.

We carried out several experiments to compare the following algorithms:

- 1) Genetic Algorithm (GA);
- 2) Wolf Pack Algorithm (WPA).

Tables 1 and 2 and Figures 4 and 5 represent the results of the experiments.

TABLE I. THE RESULTS OF THE EXPERIMENTS AFTER 500 ITERATIONS

	Initial Placement	Genetic Algorithm	Wolf Pack Algorithm
300_300	205966	198985	215102
600_600	215640	200131	136627
1200_1200	1093221	864311	648884
3000_4500	1593160	1501702	1303222
8000_7600	2562719	2399182	2179763
12000_9000	3004285	2961622	2639925

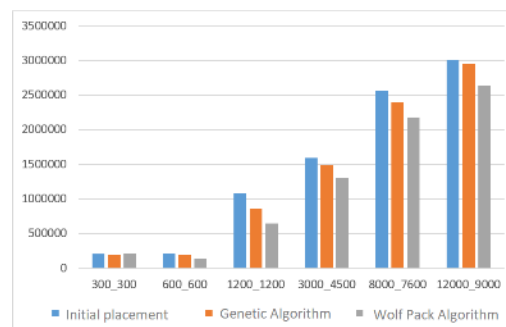


Fig. 4 The results of the experiments after 500 iterations

TABLE II. THE RESULTS OF THE EXPERIMENTS AFTER 1000 ITERATIONS

	Initial Placement	Genetic Algorithm	Wolf Pack Algorithm
300_300	205882	93112	73233
600_600	212345	179621	125335
1200_1200	108766	775118	580076
3000_4500	1592245	1465161	1165372
8000_7600	5661927	2557481	1961026

12000_9000	3456285	2961262	2319865

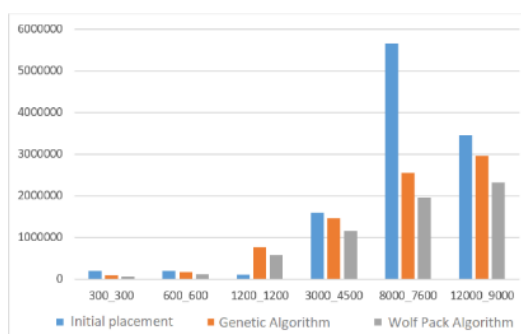


Fig. 5 The results of the experiments after 1000 iterations

Let us analyze the execution time depending on the number of iterations. The research was based on several test samples, the size of the population is 50 species, probability of crossover is 85%, probability of mutation is 20%, colony count of GA is 4, the migration level is average. The aggregated results of the experiments are represented in Figure 6.

TABLE III. EXECUTION TIME OF THE ALGORITHMS

Algorithms	Number of elements									
	100	200	300	400	500	600	700	800	900	1000
Genetic Algorithm	0.2	0.6	0.9	1.2	1.5	1.9	2.3	3.3	4.7	7.5
Wolf Pack Algorithm	3.6	5.6	8	9.4	13.1	17.8	28.6	32.8	46.4	87.7

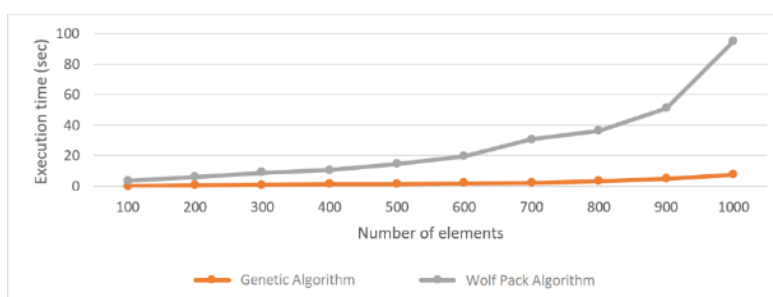


Fig. 6 Diagrams of execution time of the algorithms depending on number of elements

The time complexity of the developed algorithm is polynomial and can be represented by the formula: $O(\alpha N^2) - O(\beta N^3)$, where N denotes the number of elements of the scheme (dimension of the solved problem).

CONCLUSION

To solve the problem of two-dimensional packing, we developed a bioinspired algorithm based on the behavior of grey wolves in nature. The main problem was to find the optimal method for packing the two-dimensional container with the preassigned objects. We developed the architecture that provides the optimal solution for the mentioned problem. The application of bioinspired methods in CAD systems is one of the most popular methods for solving different design problems. We developed the mechanism for finding optimal solutions with the method of grey wolves. We also created a mobile application that provides optimal solutions in real time using the camera and sets of objects. The experiments carried out confirmed the effectiveness of

the bioinspired algorithm. The wolf pack algorithm developed allows us to obtain the sets of quazi-optimal solutions in polynomial time.

ACKNOWLEDGMENT

The reported study was funded by the Russian Foundation for Basic Research according to research project No. 20-01-00148

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METHOD OF DOCUMENT CLASSIFICATION BY FULL-TEXT PAYMENT DESCRIPTION IN RUSSIAN

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Abstract - the work is devoted to the problem of document classification by full-text description in Russian. The review of methods of selection of terms and of classification methods is carried out, their advantages and disadvantages are revealed in connection to the problem. The applicability of the methods to this problem is analyzed.

Keywords: document classification; terms selection; “naive” Bayesian classification algorithm; support vector machine algorithm; Rocchio algorithm; k-nearest neighbors algorithm.

THE URGENCY OF THE PROBLEM

Currently, due to the rapid growth of the amount of textual information, in particular on the Internet, there is a need to develop applied software systems (applications) for automatic or automated processing of natural language texts (NL-texts).

In the area of bank payments, there is also a need for such programs. In particular, every bank payment has a destination code. Payment purpose code is a unique number that allows to identify a financial transaction. Coding simplifies financial flows analysis, it is most important for generating bank and tax documents. Each destination code in a payment document is accompanied with a natural language description, which differs from one accountant to another, as well as from one company to another (e.g. when there is a corresponding guideline in a corporation). Hence, the task is to automate the selection of the destination code basing on user input of a given short full-text payment description. In this regard, when determining a code with a given description in Russian, urgent problems arise with inaccurate wording of a text query as well as with a big variety of possible text descriptions per each code. Therefore, a software is to be developed for automatic or automated processing of texts in Russian, which will allow to determine the payment code even in case of an inaccurate request, i.e. a request that does not exactly repeat the name of the payment code. Such request can be entered as a free description, and it can contain words which are connected to a particular company business profile and which indicate a particular payment purpose.

The specificity of the task is the short form of a given description of the payment purpose (approximately 10-20 words). This allows, in particular, not to use term frequency in the image of the document (in the description of the purpose of the payment, hereinafter - in the document). Furthermore, if there is a collection of typical or reference descriptions of the payment purpose, it would be prospective to narrow down the search area by pre-filtering the terms under analysis.

REVIEW OF EXISTING METHODS FOR SELECTING TERMS

The task of finding a payment code by description in Russian refers to the task of classification. The input data in NL-texts processing problems is a set of document images $D = \{d_i\}, i = \overline{1, |D|}$, where $d_i \in D$ is a document image, and D is a collection of documents, which is described using a set of indexed terms $T = \{t_k\}, k = \overline{1, |T|}$. A term t_k is any single word that occurs in at least one document in any morphological form, with the exception of stop words (prepositions, conjunctions, particles, etc.). There are many categories $C = \{c_j\}, j = \overline{1, |C|}$. In the task at hand, the document is a short description of the purpose of a banking operation in Russian. Many documents are related to one specific banking transaction and have the same destination code; such documents form one class c_j .

The input data in the classification problem requires preprocessing, since in its original form it may cause some additional problems. The sample of input data often includes so-called "noise" features, which have a weak classification ability. In particular, the excess of terms in the input text set is associated with high computational costs when obtaining measures of documents proximity and low result quality when assigning a document to a certain category. This can lead to overtraining the classifier, and hence to inappropriate results on new data. Therefore, in classification problems, it is necessary to possibly reduce the number of initial terms to the most informative ones, given a dropout criterion [2]. The correct feature selection allows improving the classification quality, as well as reducing the training time and the required computational resources for classification of a document with a trained classifier. Different approaches are used to determine the "importance" (classifying force) of a term, and there is a number of methods for calculating it. Hereinafter the most common ones will be considered.

TERM DOCUMENT FREQUENCY AND DOCUMENT FREQUENCY

The simplest, but quite effective method for assessing the "importance" of a term is to calculate the frequency of occurrence of a term in a specific document (TF - term frequency) and in documents of a collection - document frequency. The latter is applicable in particular for preliminary removal of stop words (at high document frequency). The main essence of the frequency of use of the term in the document is that the most informative are those words that are often used in the text, however, in the problem under consideration, the volume of the document is small, so the value of the frequency of the term in the document will not be informative (approximately 0.05-0.1). Document frequency is more applicable here, since a significant number of terms are found in a small number of documents. In practice, a threshold value equal to 1-5 documents is used [1].

For the following methods for assessing the importance of a document attribute, we will consider local values, that is, we will select terms for each category separately. To work with a common set of terms for all documents, you need to calculate either the usual amount, or a weighted amount, or find the maximum.

MUTUAL INFORMATION

Another approach that evaluates the "importance" of a term is mutual information. Mutual information is a statistical function of two random variables that describes the amount of information contained in one random variable relative to another. The amount of mutual information of a term t_k and a category c_j :

$$MI(t_k, c_j) = \log_2 \frac{P(t_k, c_j)}{P(t_k) \times P(c_j)}. \quad (1)$$

In particular, if a term t_k and a category c_j are independent, then knowledge t_k does not give information about c_j and vice versa, thus, their mutual information is zero.

INFORMATION GAIN

Another method of evaluation will consider the information gain. Information gain determines the amount of information on the category c_j of accessories that brings the presence / absence of the term t_k .

$$IG(t_k, c_j) = \sum_{c \in \{c_i, \bar{c}_j\}} \sum_{t \in \{t_k, \bar{t}_k\}} P(t, c) \times \frac{P(t, c)}{P(t) \times P(c)}, \quad (2)$$

where $\bar{c}_j$ is all categories, except c_j ; $t_k, \bar{t}_k$ are signs of the presence and absence of the term, respectively.

In the event that a term t_k is present if and only if the document belongs to a category c_j , the informational benefit is greatest, since the term uniquely identifies the category. If the term t_k has the same distribution both in the category c_j and in the entire collection of documents, the information benefit is the smallest and is equal to zero. In practice, a threshold value is used to select terms.

CHI-SQUARE TEST

Another approach to calculating the "importance" of a term for classification is the chi-square test. The chi-square test is a measure of the degree of discrepancy between real and expected probabilities. The calculation uses the probability observed on the training set $P(t, c)$ and the expected probability $P_{exp}(t, c)$, provided that the term and class are independent. The chi-square test is calculated as follows:

$$CHI(t_k, c_j) = \sum_{c \in \{c_i, \bar{c}_j\}} \sum_{t \in \{t_k, \bar{t}_k\}} \frac{(P(t, c) - P_{exp}(t, c))^2}{P_{exp}(t, c)}. \quad (3)$$

The smaller the chi-square value, the smaller the difference between the actual and expected probabilities. Therefore, chi-squared is zero if the term t_k and category c_j are independent.

REVIEW OF EXISTING METHODS OF TEXT CLASSIFICATION

The task of text classification is to classify documents into previously known categories. When solving this problem, it is advisable to use text classification algorithms with a teacher, where a teacher means such a sample of documents where the belonging of a particular document to a certain category is known in advance. Such algorithms use a training set Ω to build a classifier.

ALGORITHM OF "NAIVE" BAYESIAN CLASSIFICATION

This algorithm is based on Bayes' theorem, which estimates the conditional probability of a document belonging to one of the known categories. The formula for determining the conditional probability is taken as a basis:

$$P(c_i | d_j) = \frac{P(c_i)P(d_i | c_j)}{P(d_i)} \approx P(c_j)P(d_i | c_j), \quad (4)$$

where $P(c_j)$ is the prior probability that the document belongs to c_j ; $P(d_i | c_j)$ is the probability of finding a document of the type d_i among documents of class c_j .

The name "naive" Bayesian classifier will receive due to the naive assumption that the words in the document are not related to each other, that is, each characteristic makes an independent and equal contribution to the final result.

The advantages of this algorithm include a small amount of data for training the model, as well as for parameter estimation and classification [3].

One of the disadvantages of the Bayesian classifier is the fact that if the value of the parameter and the class do not occur together, then the estimate of the probability calculated using the frequencies will be zero, as a result of which, after multiplying all the probabilities, the

result will be zero. However, in the tasks of evaluating documents of a small volume, the Bayesian classifier can nevertheless give good results.

SUPPORT VECTOR MACHINE ALGORITHM

This algorithm searches in the vector space of documents for the surface that separates the classes, while the most distant from the points of the training set.

Let's call the classification gap the distance between the found surface and the nearest data point. Then support vectors will be called a small subset of documents, which is a decision surface.

The essence of the method is to find a dividing surface that would maximize the classification gap. In geometric space, the gap is the maximum strip width that can be drawn between the reference vectors of the two classes.

The dividing surface is given by the equation:

$$\vec{w}^T \vec{x} = -b. \quad (5)$$

where $\vec{w}$ is the normal vector to the dividing surface (weight vector); b is the shift parameter.

The advantages of the support vector algorithm include efficiency in terms of processing nonlinear data (if objects of the class are located in a convex volume), as well as the stability of the algorithm for relatively small data changes. As disadvantages, one should take into account the high algorithmic complexity and memory requirements and the complexity in the interpretation of the results.

ROCCHIO ALGORITHM

In order to use the Rocchio algorithm, it is necessary to consider documents in the vector term space, where the search for boundaries between classes represented by a set of points equidistant from the centroids of these classes is performed.

Center of mass of class members:

$$\vec{\mu}_{c_j} = \frac{1}{|D_{c_j}|} \sum_{i: d_i \in c_j} \vec{d}_i. \quad (5)$$

The essence of the classification by the Rocchio method is to determine the area where the document falls, in other words, the centroid is searched for, which is closest to the image of the given document. It is assumed that the classes are in the form of spheres with the same radii [4].

Despite the efficiency and simplicity of implementation, this algorithm cannot classify multimodal classes and their relationships (for example, in the case of fuzzy duplicates in the sample) [1].

K-NEAREST NEIGHBOR ALGORITHM

The k-nearest neighbors method is based on the assessment of the similarity of objects. Documents of different classes form unbroken compact areas in the term space. The k-nearest neighbors method assigns a new text document to the class that owns most of its k nearest neighbors in the training set.

In the learning process, the algorithm simply remembers all the document vectors and their corresponding class labels. When working with new documents, the class labels of which are unknown, the distance between the vector of the new document and the previously stored ones is calculated. For $k = 1$, the algorithm will lose its generalizing ability, since the new document will be assigned the class of the closest document.

An important task of this algorithm is the selection of the coefficient k . For $k = 1$, the algorithm is unstable to noise emissions. Increasing the k -value increases the reliability of the classification, but at the same time the boundaries between classes become less clear. Therefore,

in practice, the value of k is chosen based on the characteristics of the problem and expert opinion.

Despite its relative algorithmic and semantic simplicity, the method shows good results with a well-chosen distance function. Its main disadvantages are high computational complexity and the fact that the method is applicable to the convex form of classes, but poorly suits the non-convex form.

CONCLUSION

In this paper, the existing methods of selection of terms and classification algorithms with a teacher were considered. The advantages and disadvantages of the considered methods are revealed in relation to the categorization of documents by full-text description in Russian. As a result of the comparative analysis, the document frequency criterion was chosen as the main method for selecting terms, since this criterion is easy to calculate and quite efficient. You should also carry out preliminary calculations on the training sample in order to identify terms, the presence (or absence) of which will give high values of informational benefit (for example, the word “debit” will not be found in the class of payment descriptions of the group “loan payments”, and the presence of such a term will indicate unequivocally against the mentioned class): these values can be calculated in advance for significantly different terms in terms of the set of occurrences, based on the pragmatics of the textual description of the purpose of payments.

Depending on the form of representation of the document image (multiset or vector), either the “naive” Bayesian classification algorithm or the k -nearest neighbors algorithm can be used to solve this problem. The advantages of these methods include relative algorithmic and semantic simplicity with a proper level of efficiency. The hypothesis of class convexity in a multidimensional feature space should be checked, since the k -nearest neighbors method is applicable if it is true.

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CONTROL DEVICE FOR SILICON PIXEL DETECTORS ARRAY

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Abstract— Implementation of hardware and software solutions and creation of a device for configuring operating modes, control and reading information from pixel detectors designed to register ionizing radiation.

Keywords: silicon pixel detectors array; FPGA; control and reading system.

INTRODUCTION

Scientists from different countries are actively working to expand the scope of their innovations. An example of such work is the development of a family of hybrid pixel detectors Medipix and Timepix [1,2], which are solid-state ionization chambers for recording X-ray radiation. Medipix is a hybrid integrated circuit with a pixel array detector, in which an array of thousands of sensing elements is connected to the readout and control circuit. The matrix is capable of detecting single X-ray photons and allows the formation of X-ray images with high resolution, contrast and low noise level, which is important for a number of applications in medicine, as well as in radiation detection and control systems.

Currently, devices based on pixel detectors of the Medipix family are available in commercial applications, in particular, ASI [3], X-ray Imatek [4] and Advacam [5] company offers X-ray cameras based on position-sensitive detectors of the Medipix and Timepix series, however, the intensification of research and development in the field of applications of the Medipix family aimed at improving the parameters of pixel detectors and devices based on them, which is the subject of this work, is urgent. An illustration revealing the prospects for the use of solid-state ionization chambers of the Medipix family in medicine is the work [6], which indicates that the algorithms involved in the new bioscanner make it possible to use the information recorded in the new generation of Medipix3 receivers to generate three-dimensional images, and different colors of 3D models reflect the different energy levels of X-ray photons recorded by the detector, which makes it possible to identify tissues, as well as to identify markers of diseases.

PROBLEM STATEMENT

Object of research: an electronic circuit for configuring and controlling a microcircuit of a pixel detector and intended for registration of ionizing radiation. For experiments and approbation of the development, the Timepix detector with a silicon sensor was used.

Objectives of the work: study of hardware and software solutions designed to configure operating modes, control and read information from the detector.

Work methods:

- analysis of design options, development and manufacture of an electronic block (reader) that implements the connection of a personal computer and a detector and provides configuration of operating modes, control and reading information from the detector using a personal computer;
- development and testing of software loaded into the reader and designed to implement the operating modes of the detector;
- development of interface software to operate between the reader and the personal computer, providing the transmission of signals for the configuration of the detector and the storage of the readings from the pixels of the detector.

SOLUTION OF THE PROBLEM

For the implementation of the project, a methodology for constructing a system-on-chip (SoC) based on the MicroZed IP module of Avnet company, based on the 7Z010 Xilinx crystal of the Zynq-7000 family [7] was chosen. The functional diagram of the device is shown in Fig. 1. The reader is controlled using the Ethernet interface via the UDP protocol. The main functions of the reader implemented in this work are the following:

- Setting up the DAC included in the pixel detector;

- Control of the output signal level of the internal DAC;
- Configuring masking, threshold and operating mode for each pixel of the detector;
- Controlling the clock frequency of the detector in the accumulation mode in the range from 2 to 100 MHz;
- Control of the accumulation time in the range from 1 μ s to 100 s;
- 1Gb/s Ethernet connection in full-duplex mode; the maximum frame rate is 100 fps.

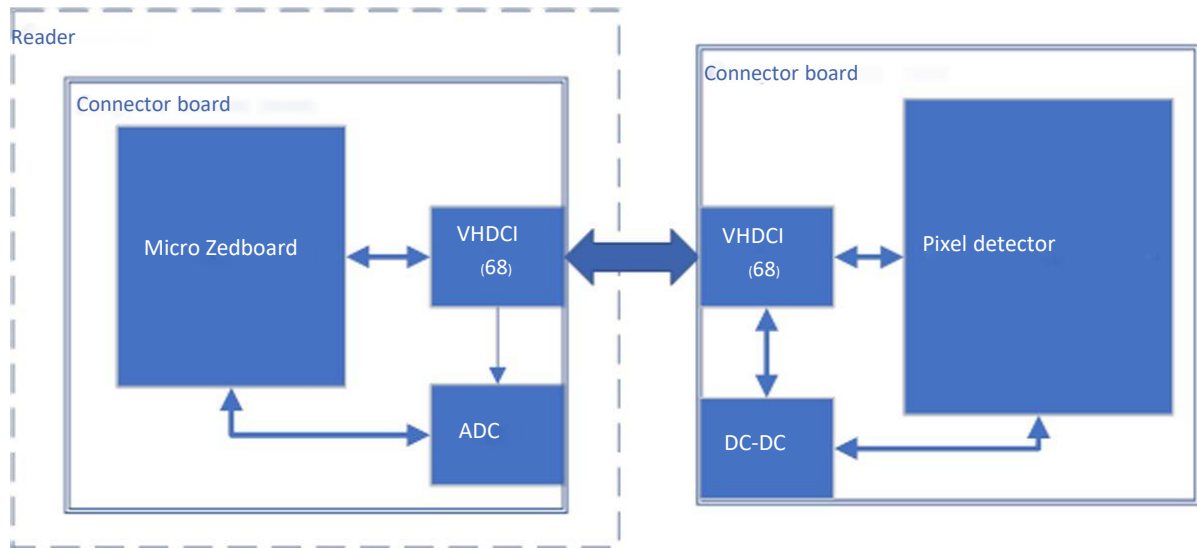


Fig.1 Functional diagram of the reader

To ensure a high speed of reading data from the detector, as well as to implement preprocessing of the received data in the FPGA of the system-on-chip, expansion blocks are implemented that allow the processor system to control the state of the detector, as well as to initialize the readout mechanism and pixel configuration. The project was developed using CAD systems from Xilinx Vivado 2019.2.

The main blocks included in the design for the FPGA, and together constituting the system-on-a-chip assembly, are shown in Fig 2.

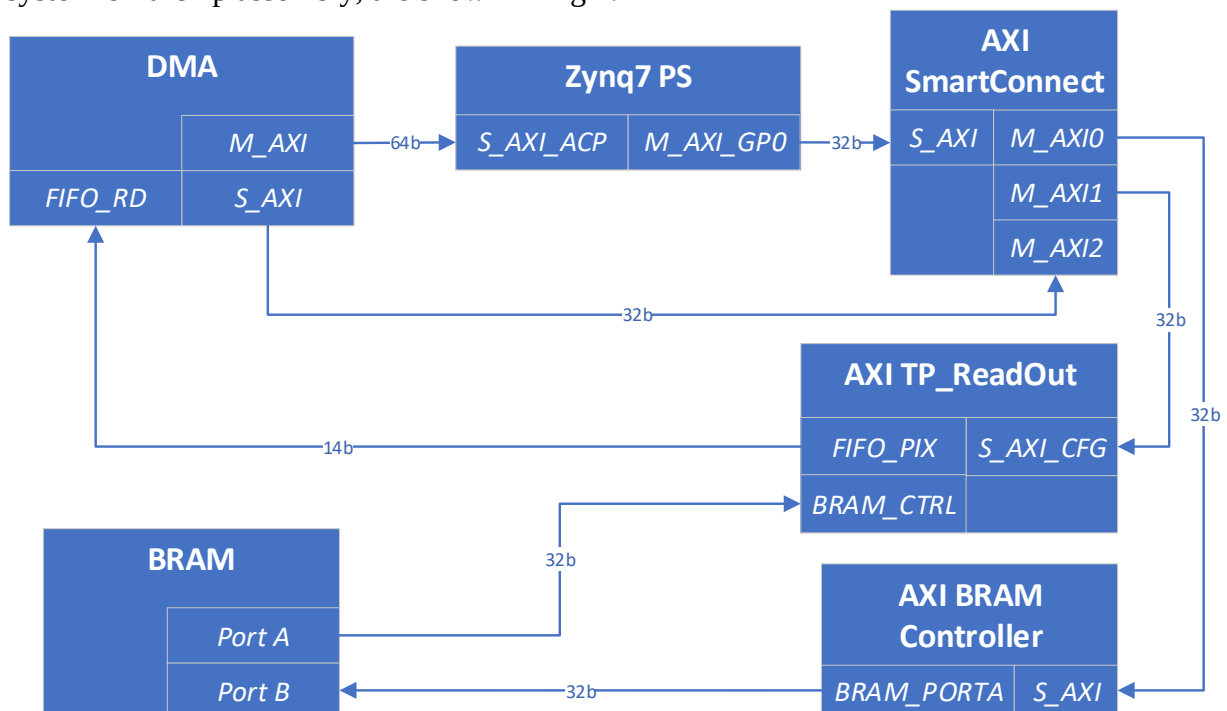


Fig. 2 SoC functional diagram implemented in Zynq-7000

Zynq7 PS - a standard IP core of the SoC processor system of the Zynq-7000 family, based on a dual-core ARM Cortex-A9 processor (physically implemented on a chip). Provides configuration and control of blocks implemented on FPGA, as well as system interaction via Ethernet interface.

AXI SmartConnect - standard IP core, allowing to implement a branched system for connecting AXI interfaces. In this project, they are used to implement the possibility of interaction from the processor system, through the M_AXI_GP0 interface with the configuration registers of the DMA and AXI TP_ReadOut block, as well as to write data to the block memory (BRAM) through the block memory controller (AXI BRAM Controller).

AXI BRAM Controller is a standard IP core providing interaction with block memory via the AXI interface.

BRAM is a standard IP core of dual-port block memory (physically implemented on a chip).

AXI TP_ReadOut is an original IP block that provides control over the state of the detector, as well as implements the mechanisms for serialization and deserialization of detector bit streams. The AXI TP_ReadOut IP core consists of several modules shown in the functional diagram (Fig. 3).

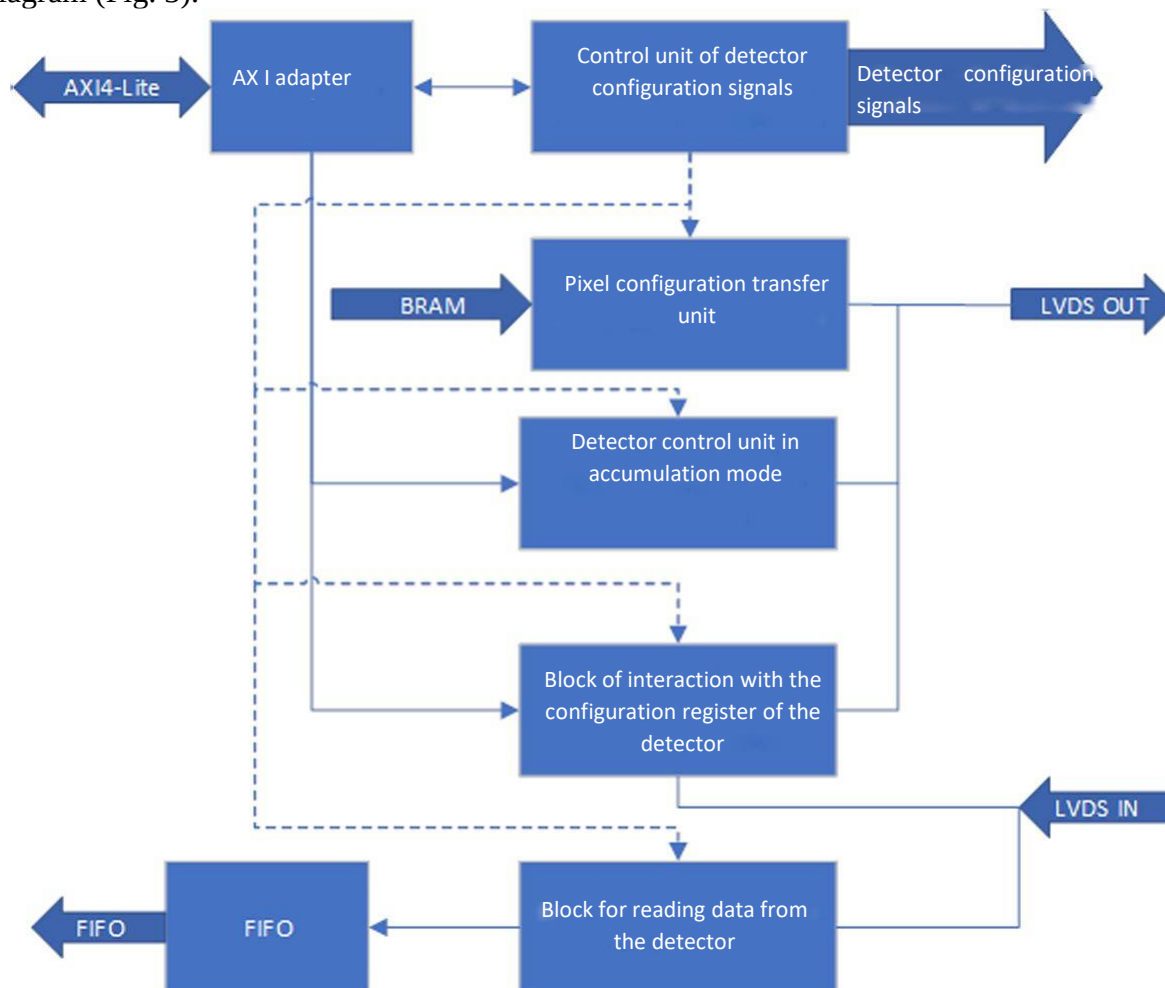


Fig.3 Functional diagram of the IP core AXI TP_ReadOut

The IP core is connected to the processor system using *AXI adapter* which implements interaction according to the AXI4 interface standard of the Lite version [9]. This interface allows

the processor system to: 1) control the detector modes; 2) adjust the accumulation time; 3) control the DACs included in the detector; 4) read the unique identifier of the detector.

DMA -is an original IP block designed to decode the deserialized bitstream from the detector and download the data packet from the detector to the processor system. It is connected to the S_AXI_ACP interface to load data into the L2 cache of the processor system to minimize the time required to send a received data packet to the control computer via the Ethernet interface. This IP core is developed using Vivado HLS high-level synthesis tool by Xilinx. The functional diagram of the IP core is shown in Fig 4.

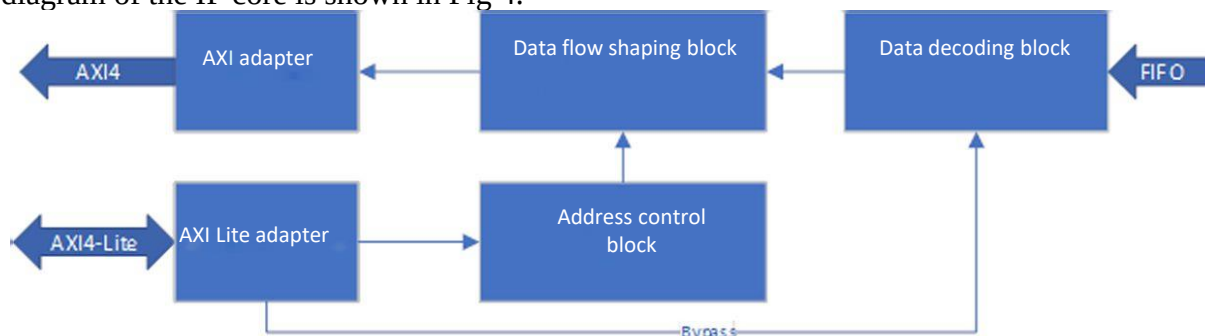


Fig. 4 Functional diagram of the IP core DMA

AXI Lite adapter provides a mechanism for controlling the operation of the unit through the AXI4 interface. Works according to the AXI4 Lite standard [9]. It allows you to start and stop the IP core, set the address at which the array read from the FIFO will be filled. It also allows you to set the skip decoding flag if you need to receive unprocessed data from the detector. The description of the registers is given in Annex 2.

AXI adapter provides a mechanism for recording data via the AXI4 interface [9]. The data bus size is fixed at 64 bits. The transmission is carried out in blocks with a duration of 256 samples (the size of one block is 2 kB).

Data flow shaping block provides accumulation of the required amount of data for block transfer through the AXI adapter in the internal memory of the IP block.

Address control block forms the starting address of transmission for each data block from the queue. The initial value is transmitted through the AXI Lite adapter.

Data decoding block provides decoding of the read data stream using the tabular method. If the skip decoding flag is set, then this block does not change the input data.

Thus, the following functions are provided using FPGA resources:

- Management of transitions between detector modes (TABLE I);
- Deserialization of the output stream of the detector operating in readout mode;
- Data decoding;
- Serialization of the input data stream for loading pixel settings;
- Serialization (for setting DAC values) and deserialization (for reading Chip ID) of data streams when operating in DAC setting mode;
- Transfer of data received from the detector to the RAM of the processor.

TABLE I. TRUTH TABLE FOR DETECTOR MODES [8]

M0	M1	Enable_IN		Shutter	Reset	Description
X	X	X		X	X	General chip reset
1	1	X		0	X	Count mode:
0	0	0		1	0	Reading mode
0	1	0		1	X	Pixel Settings Loading Mode
1	0	0		1	X	DAC setting mode

SoC processor part provides control over the state of the detector, and also implements the protocol of interaction with the control program via the network interface. The developed control program provides the following functions:

1. Initialization of the processor system and peripheral blocks, including the AXI TP_ReadOut block, the lwIP library, reading the unique identifier of the detector and constants for packets from the protocol of interaction with the reader.

2. At the stage of setting the operating modes, the values of each DAC are recorded using the driver for interaction with the AXI TP_ReadOut module, the operating modes of the detector pixels, including the ranges of operation and masking of individual pixels, are set, and the clock frequency and accumulation time are set. An example of the program interface in the mode of setting the threshold values for each detector element is shown in Fig. 5.

3. In the main loop of the program, the function of maintaining a network connection is called, as well as a check for the presence of commands from the control software in the buffer; then a check is made for the presence of data for transmitting the received frame from the detector, and if such data are found, a Frame packet is formed according to the device protocol and its transmission begins.

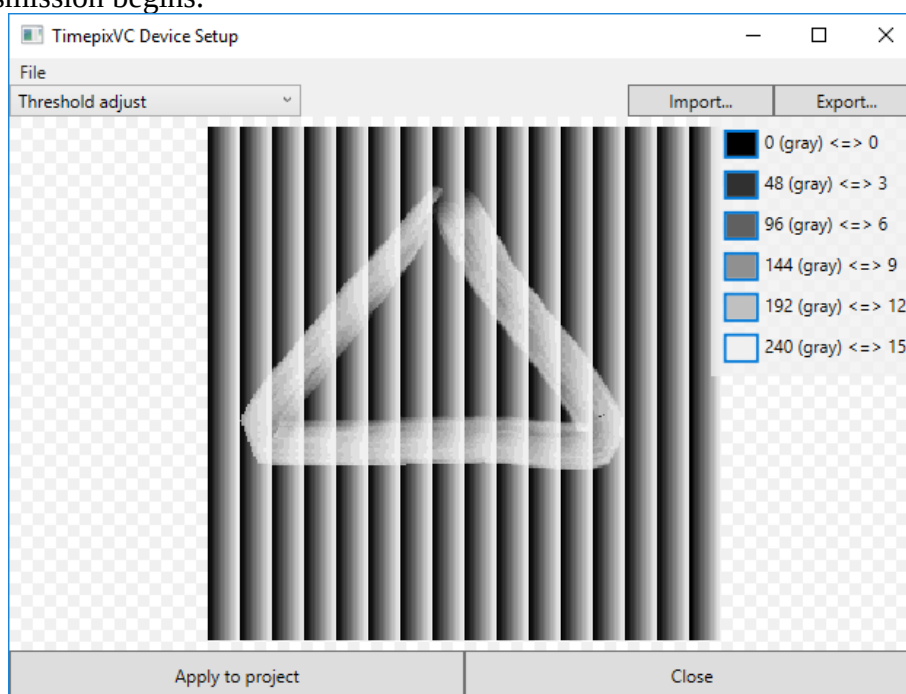


Fig. 5 Interface for setting the ranges of detector pixels

CONCLUSION

The device is intended to provide advanced development of pixel detectors with original technical solutions and software. Developed and manufactured electronic unit (reader), together with the original set of programs, implements the functions of configuring operating modes, controlling and reading information from the detector using a personal computer, expanding the functions of data processing and increasing the energy resolution of detectors operating in the energy range from 8 to 60 keV. The development of research is supposed to be devoted to improving the characteristics of ionizing radiation registration systems based on new generation pixel detectors for use in biology and medicine, as well as in non-destructive testing and recognition systems.

ACKNOWLEDGMENTS

This work was supported by Ministry of Education and Science of the Russian Federation (project No. FSFZ-0706-2020-0022).

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TRANSCIEVER MODULE FOR DIGITAL ACTIVE PHASED ARRAY ANTENNA

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Abstract — This article discusses the main aspects of the advantages of transceiver modules for digital active phased antenna arrays (hereinafter referred to as the digital TM APA) and methods for their design and improvement tasks, as well as a comparison of the developed module with existing analogs and other modules for APA.

Keywords: active phased antenna array, digital transceiver module, radiation pattern, interface SPI, signal processing, digital beamforming, quadrature modulator, quadrature demodulator, ADC, DAC.

INTRODUCTION

Due to the dynamic development of microwave electronics in recent years, despite such a large development of digital electronics, the development of antenna arrays is moving towards AFA, since they showed the highest performance in contrast to phased antenna arrays (PAA), and also gave an advantage to military radar equipment - this is the ability to work in a mode for many enemy targets and switch to the necessary frequency ranges without any delay.

PROBLEM STATEMENT

One of the main advantages that AFA gives is the implementation of a territory scanning mode, as well as a mode of transmitting large information at certain frequencies using various methods of coding and signal processing.) Active elements are included in the path of each emitter of the developed AFA: a low-noise amplifier, a synchronized generator, a frequency synthesizer and a carrier signal modulator. The block diagram of the developed AFA is shown in Figure 1.

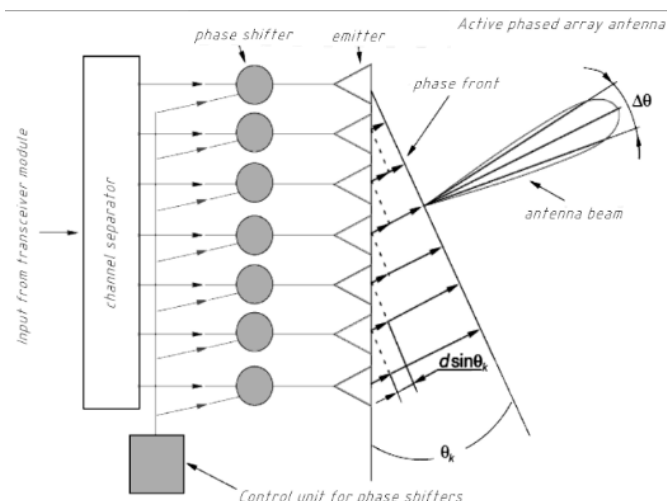


Fig. 1 General block diagram of AFAR

Antenna fabric will consist of the same type of weakly directional emitters, which will be built like a PCB antenna. Since a digital transceiver module is being developed for this, the algorithm for digital beamforming (DP) for a given antenna array with emitters located at its nodes will be calculated using formula 1.

$$S_{k,l}(\theta, \varphi) = \sum_{m,n} S_{m,n}(\theta_k, \varphi_l) S_{m,n}(\theta, \varphi), \quad (1)$$

Where k, l is the number of the sample formed by the digital radiation pattern; φ - angles of a spherical coordinate system, the axes of which are aligned with the axes of the antenna aperture; m, n - number of the emitter in relation to the central one; $W_{m,n}(\theta_k, \varphi_l)$ is a vector of weight coefficients that determine the amplitude and phase distribution in the lattice aperture; $S_{m,n}(\theta, \varphi)$ - digital signal at the output of the analog-to-digital converter of the emitter with the number m, n .

The phasing and amplitude AFA system forms the required phase-amplitude distribution of the excitation signals, which consist of a quadrature modulator device, respectively, and a quadrature demodulator on the receiving module, with digital control.

The distribution system is built on the basis of power dividers, which are built using the technology of micro-strip microwave lines, calculated in the corresponding computer-aided design systems such as AWR Microwave Studio and FEKO.

The beam control unit is a developed transceiver module that regulates the operating frequency range from 0.5 GHz to 15 GHz, the circuit has also been designed to operate at ultra-high frequencies, from 17 GHz to 26 GHz. Also, this block performs all the necessary signal transformations, which will be described in detail below.

In this regard, at the design stage of the AFA aperture, it was decided to use a completely digital method of receiving and transmitting information, it should also be noted that the directional pattern is formed using quadrature modulation, so the pattern will also be formed and controlled digitally. Taking into account the above, we can conclude that all this requires large computing power so that large amounts of information can be sequentially executed in each computing module. This requires fast and powerful digital-to-analog and analog-to-digital converters. Thus, at this stage, it is possible to obtain an approximate generalized block diagram of the transmit-receive module of the digital AFA, which is shown in Figure 2.

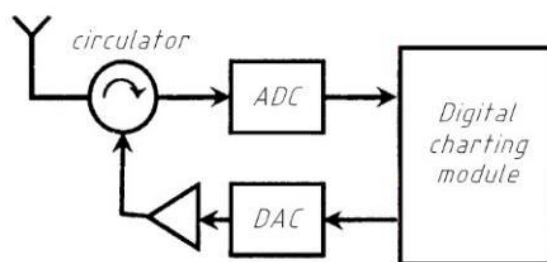


Fig. 2 Generalized block diagram of PPM

In the digital diagramming module, a sequence of a digital code is formed, which is fed to the demultiplexers and a parallel informational digital code is formed, which is formed at the input of the DAC, then the digital code is converted into an analog signal, which must be converted into the required form and the phase must be changed, for this, a mixer is used, located in scheme of a quadrature module, it was decided to choose a frequency grid synthesizer as a microwave signal generator, its advantage is that it can be used to work in the necessary frequency ranges and quickly switch to others, which gives an advantage over other phased array devices. The bandwidth is also set using a digital diagramming module in which there is a microcontroller, which switches the frequency ranges on command. The signal after the quadrature modulator must be amplified; for this, a low-noise amplifier is used, which is part of the microwave stage of this module and makes it possible to introduce a minimum of interference into the amplified signal. The signal received by the antenna is processed by the same analogy, only the other way around. First, through a quadrature demodulator, the frequency with the help of frequency synthesizers is reduced to the frequency at which the ADC operates, then the information goes to the digital diagramming module and is processed by the central processor. As a result, the electrical functional diagram was designed, shown in Figure 3.

What is inside the dotted line is already developed and presented in this work, outside it is in the perspective of further developments. Large arrows show the exchange of digital information between devices, an arrow with a filled tip is a microwave signal, an arrow with an open tip is a clock pulse, an arrow with a circle at the end is a power circuit.

As can be seen from Figure 3, a microcontroller is present in the circuit, it is necessary to control all devices of this module, and also processes the received and transmitted information, which is then sent via a separate communication channel to the central processor to detect and correct errors and to additionally correct the directional pattern. ... The central signal processor is the main computing unit of the entire radar complex, all mathematical calculations are performed in it, it also contains a large amount of RAM, where all calculated or necessary mathematical coefficients are stored. This system has a central master clock that clock and synchronizes all devices. The secondary power supply is a power device that has a power supply unit for each device in the module.

As a result of studying various sources, we came to the conclusion that the most appropriate way to control devices for this transceiver module is the international qualification interface SPI, with which the microcontroller controls all the main devices: ADC, DAC, quadrature modulator and demodulator, frequency grid synthesizer and amplifier power. The advantage of choosing an SPI interface over the others is that it can synchronize all devices simultaneously with a common clock pulse. Also, calculations showed that information exchange packets between devices should be 8 bits in weight, which is suitable for the selected interface.

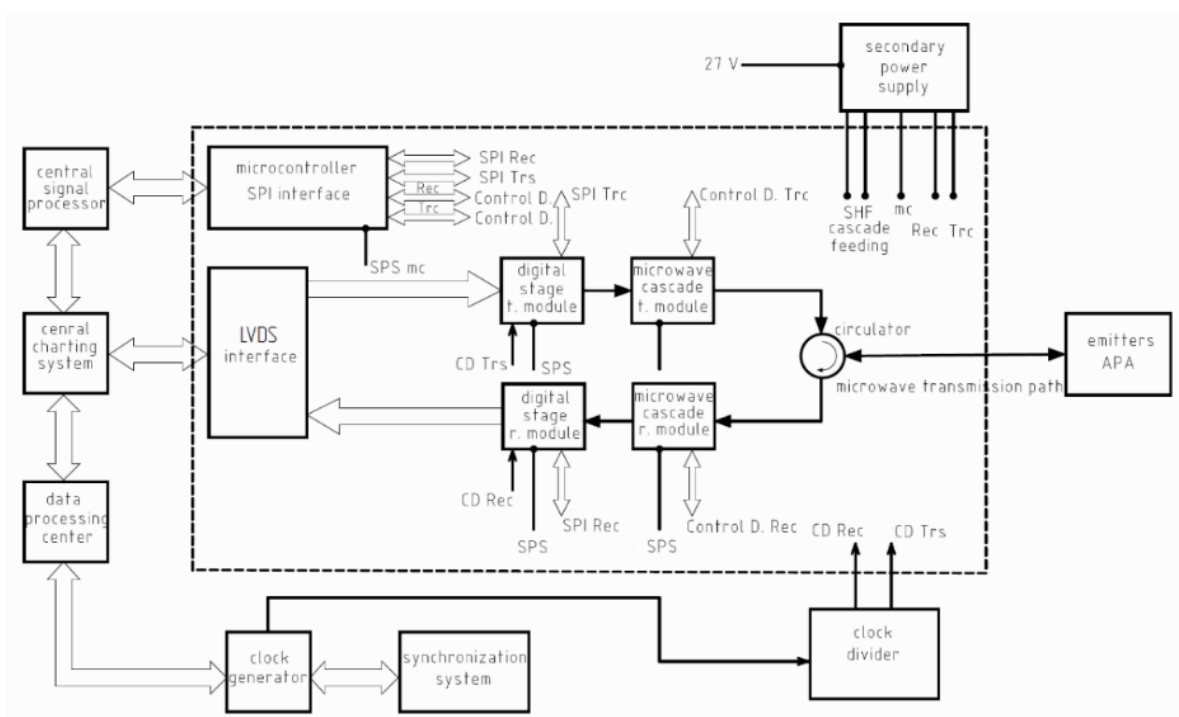


Fig. 3 Electrical functional diagram of the developed transceiver module

The process of information exchange is as follows, the slave and master device puts the necessary information into memory, in the microcontroller it is RAM, all slave devices have service registers where the information is placed, then the information is transmitted via the SPI interface line. The topology of the communication system in this SPI interface module is quite simple, all devices are connected in parallel. In addition, if the SPI interface line is suddenly loaded or it is necessary to transfer large amounts of information between the master and the terminal device, then a simple parallel connection of information channels between the microcontroller and the device can come to the rescue, the information-logical interaction protocol is also simple: at the request of the slave or master device, it is sent any command word for one or another transmission of information or for an operating mode.

Input and output information between the transceiver module and the central signal processor is transmitted via low-voltage differential signaling, LVDS interface. This is a standardized method that allows information to be transmitted at high frequencies using inexpensive twisted-pair copper connections.

The block diagram showing the principle and sequence of operation of the transceiver module is shown in Figure 4.

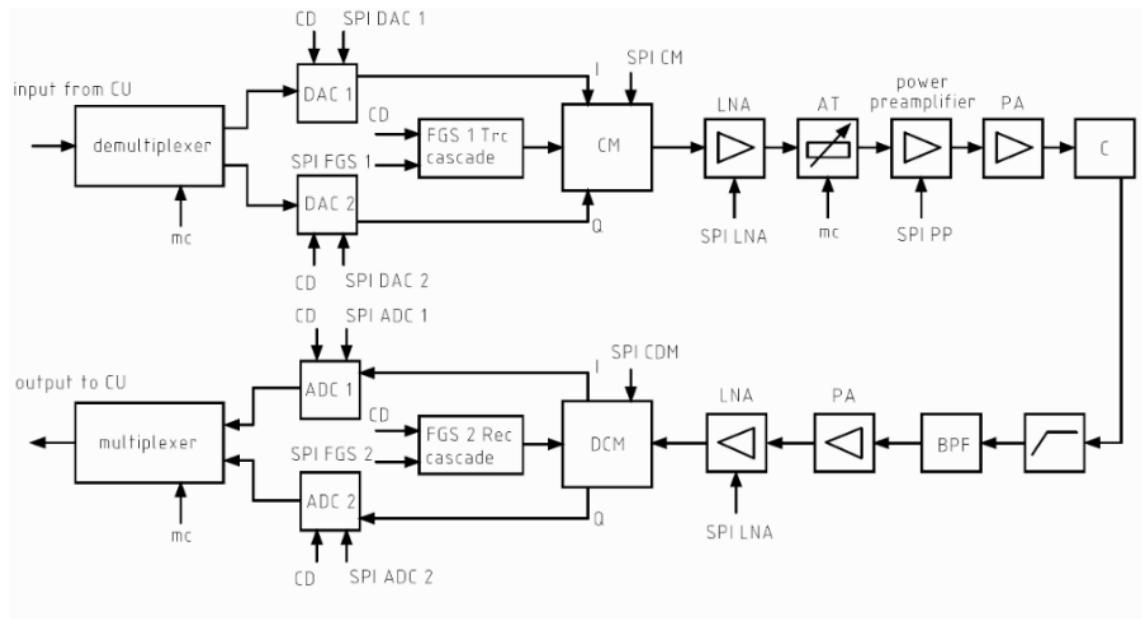


Fig. 4 Electrical structural diagram of the developed transceiver module

The diagram in Figure 4 shows that the transmitting and receiving stages each contain 2 DACs and 2 ADCs, respectively. The right part is completely a microwave path, which consists of a low-noise amplifier, a pre-amplifier, a power amplifier, a band-pass filter and a circulator. The microwave cascade also implements methods for controlling amplifiers and filters using an SPI interface and a microcontroller.

SOLUTION OF THE PROBLEM

As a result, 3D models of the transmitting and receiving module boards were designed, which are shown in Figures 5 and 6.

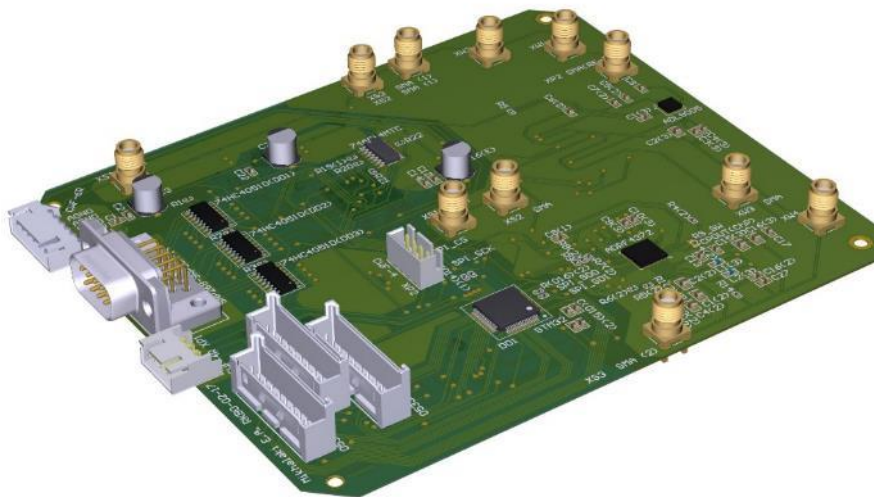


Fig. 5 Board of the transmitting module

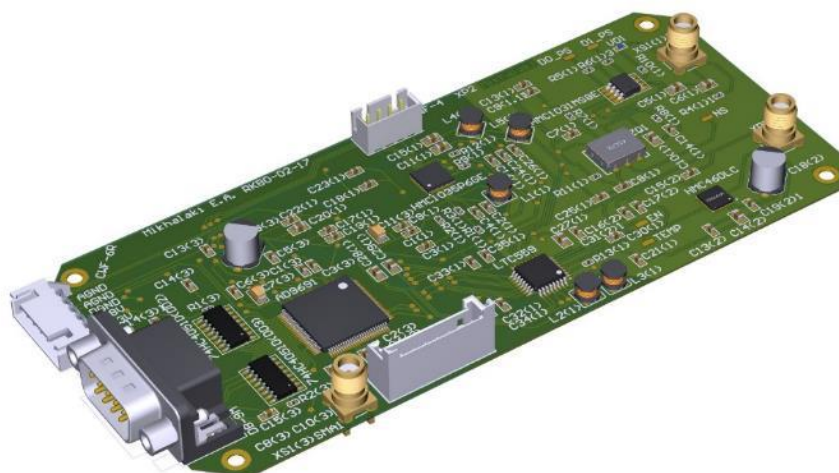


Fig. 6 Board of the receiving module

To implement this device, high-speed ADC and DAC with computing units were used, quadrature modulators and demodulators also contain computing units and service registers for fast adjustment of internal filters and computing sub-units. All this is the microcircuits of Analog Devices and Hestite Microwave companies. As a microcontroller, it was decided to take STM microcircuits, which contains all the necessary interfaces and outputs for receiving and transmitting digital information. These boards are modular devices. The developed device can completely replace all currently existing devices included in the AFA complex. In this device, the problem of introducing significant interference was also solved by eliminating expensive phase shifters, since their task is performed by a cavdratura modulator and a demodulator. The circuitry of such a device allows the elimination of complex systems for combining microwave signals, due to which the microwave distribution system of the excitation signal of individual elements or APA modules is greatly simplified. In addition, this device has an accelerated mode for converting digital information, since the ADC can operate at certain carrier frequencies at the command of a microcontroller or an on-board computer complex. The problem of overall dimensions was solved, thanks to the use of SMD elements and the use of digital circuits. The cost of this device is not much less than the existing solutions, but the cost of the presented solutions can decrease even more if you develop an integrated element base, which will give only those computing devices that will be needed for the given tasks of the future transceiver module. As for the cost of the antenna array, with the current level of technology, it is possible to reduce it by using SMD antennas or other types of antennas built using microstrip technology.

CONCLUSION

Based on the information presented in this scientific article, a number of practical important conclusions can be drawn. Thanks to digital methods of designing circuits, the use of control interfaces, various ways of switching on the device mode at different frequency ranges, this has improved the overall properties of the receiving-transmitting module, this has reduced the dissipated heat and power consumption. The study of integrated circuits showed that such large companies for the production of microwave radioelements are currently aimed at creating digital circuits for radar complexes, especially in the direction of AFA, the study also showed that methods for creating and designing ADCs and DACs are developing, this is an increase in the number of channels and sampling frequency , which allows you to increase the volume of transmission and reception of information and convert it into digital form. This study helped to reduce the number of unnecessary computing blocks during the electrical design phase.

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GEOINFORMATIONAL TECHNOLOGY FOR ESTIMATING THE VELOCITY CHARACTERISTICS OF THE MEDIUM

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Abstract — The paper describes a heuristic approach to determining the local velocities of seismic waves in complex mediums. Based on the results of vibration seismic sounding along two profiles of the volcanic zone of the mud volcano Mount Karabetova, a picture of the distribution of local P-wave velocities was obtained. The results obtained are consistent with the data on the geological structure of the considered area.

Keywords — complex medium; local velocities; seismic waves; inverse problem of geophysics.

INTRODUCTION

One of the important issues in solving inverse problems in seismology related to the determination of the geographic and energy characteristics of a source is obtaining a priori information on the propagation velocities of seismic waves. Along with other factors such as the levels of external noise, the geometry of the placement of the recording receivers, etc., the completeness of the availability of information about the speed characteristics determines the accuracy of solving the inverse problem. Obtaining such information is sharply complicated in relation to media with a pronounced heterogeneity of the structure. This is particularly the case for mediums in areas of volcanic edifices, including mud volcanoes. Consideration of the problem of clarifying the velocity characteristics of the medium with the presence of heterogeneity of its structure on the example of the volcanic zone of the mud volcano Mount Karabetova (Taman mud volcanic province) [1, p. 178–185] defines the content of this work.

PROBLEM STATEMENT

The aim of this work is to construct a numerical model of time-travel curves of local primary wave, typical for the area of mud volcanoes, based on the experimentally obtained arrival times of waves from vibration sources. On their basis, it is possible to construct the velocity characteristics of the medium and take into account the elasticity of the medium in the volcano zone.

The problem of estimating unknown local velocities of seismic waves in an inhomogeneous medium is reduced to solving a nonlinear system of conditional equations:

$$\vec{t} = \vec{\eta}(X, \theta) + \vec{\varepsilon}, \quad (1)$$

where $\vec{t} = (t_1, t_2, \dots, t_N)$ is the vector of seismic wave arrival times, $\vec{\eta}(X, \theta)$ is the N -dimensional vector of the calculated travel times (theoretical time-travel curve) or the regression

function, $\vec{\varepsilon} = (\varepsilon_1, \dots, \varepsilon_N)^T$ is the error vector, $\vec{\theta} = \left[(x_i^*, y_i^*), \vec{V}(\vec{v}) \right]^T$, where (x_i^*, y_i^*) — are the coordinates of the radiation points ($i = 1, 2, \dots, M$ is the number of radiation points), $\vec{V}$ is the vector of the average values of the velocities of seismic waves in the medium, $\vec{v}$ is the vector of local velocities of seismic waves; $X = (\bar{x}_1, \bar{x}_2, \dots, \bar{x}_N)$ is the matrix of receivers coordinates, N is the number of receivers. With known (x_i^*, y_i^*) the local seismic wave velocities $\vec{v}$ are used as the estimated parameters.

In estimating the parameters, information about the distribution of errors $\varepsilon_i = t_i(\bar{x}_i, \vec{\theta}) - \eta(\bar{x}_i, \vec{\theta})$ is used. In what follows, we will assume that ε_i are mutually independent random variables having a distribution with zero mean and given variances: $E\varepsilon_i = 0$, $E\varepsilon_i \varepsilon_j = \sigma_i^2 \delta_{ij}$, $\sigma_i = \sigma(\bar{x}_i)$, δ_{ij} is the Kronecker symbol, $i = 1, 2, \dots, N$. In cases of difficulties with setting the variances, they are taken to be equal and an unbiased estimate of the observation variance with a unit weight is obtained as the problem is solved.

The solution of equation (1) is reduced to the solution of the inverse problem of geophysics [2–5]. In this case, the accuracy of the solution depends, first of all, on the errors in estimating the time vector $\vec{t} = (t_1, t_2, \dots, t_N)$, the residuals $\vec{\varepsilon} = (\varepsilon_1, \dots, \varepsilon_N)^T$, and choosing the geometry of the placement of receivers on the Earth's surface.

Rigorous methods for solving equation (1) are based on minimizing the residual between the experimental and theoretical time-travel curves in (1) by the least squares:

$$\vec{\theta} = \arg \min_{\vec{\theta} \in \Omega} Q(\vec{\theta}), \quad Q(\vec{\theta}) = \sum_{i=1}^N \sigma_i^{-2} (t_i - \eta(\bar{x}_i, \vec{\theta}))^2 \quad (2)$$

There are well-known rigorous methods for solving (2) based on the multidimensional iterative Gauss-Newton method, generalized inversion based on singular value decomposition (SVD) [5,6], the adaptive Kaczmarz method (Algebraic Reconstruction Technique) [7], etc. One of the examples of applying the SVD method to refine the velocity characteristics of the medium using borehole explosions is the work [8].

At the same time, the use of such methods encounters computational difficulties in solving the optimization problem (2) due to the large dimension of the parameters in the form of wave arrival times $\vec{t} = (t_1, t_2, \dots, t_N)$ in the problems of monitoring heterogeneous zones. In this situation, solution simplification can be achieved by using a heuristic algorithm while maintaining the acceptable accuracy of the solution.

SOLUTION OF THE PROBLEM

As a method for solving problem (1), an approach is proposed for determining the velocity characteristics of complex media based on dividing the studied area of the medium into sections in which the local velocities of seismic waves are calculated. The equation for determining the average weighted seismic wave velocity $\vec{v}$ for each k -th section of the profile (on the plane) is expressed as follows [9]:

$$\vec{v}_k = \frac{\sum_{i=1}^N \sum_{j=1}^M \vec{V}_{ij} \cdot \frac{L_{ijk}}{L_{ij}}}{\sum_{i=1}^N \sum_{j=1}^M \frac{L_{ijk}}{L_{ij}}} \quad (3)$$

Where $\vec{V}_{ij}$ is the average velocity of the seismic wave from the seismic source i to the receiver j , L_{ij} is the distance traveled by the seismic wave from the seismic source i to the receiver

j , L_{ijk} is the distance traveled by the seismic wave from the seismic source i to the receiver j in the k -th section of the profile (at the k -th node mesh).

Fig. 1 explains the methodology for determining the weighted average seismic wave velocity. As can be seen from the figure, the Earth's surface is divided into one hundred sections, for which it is necessary to find the velocity values, where k is the section number. There are 20 receivers (marked with diamonds) and five seismic sources (marked with stars) on the Earth's surface.

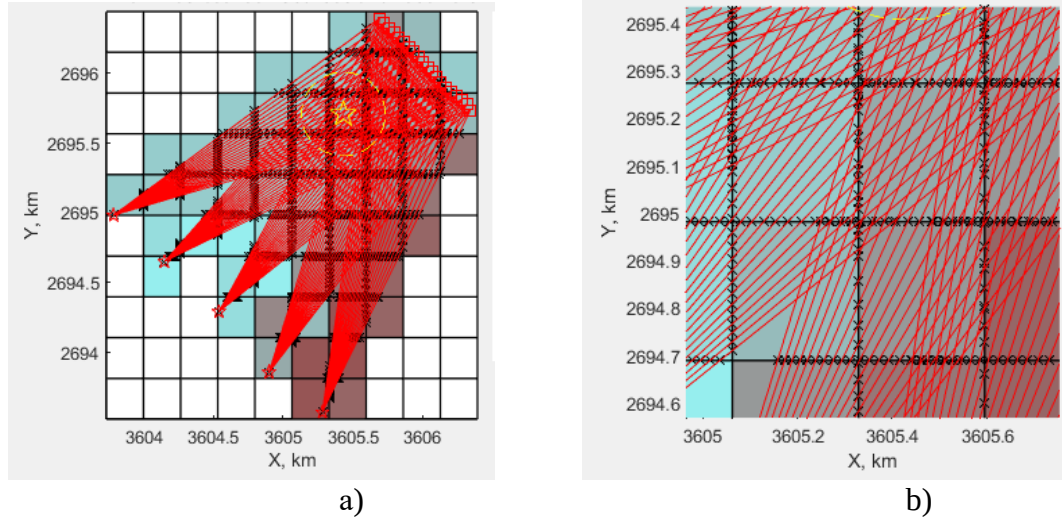


Fig. 1 a) Subdivision of the day surface in the volcano area to determine the weighted average seismic wave velocity for the selected area. The points of sources T1-T5, points of installation of receivers 1,2, ... 20 are presented. The area of the Mount Karabetova mud volcano is highlighted in yellow. b) The same area on an enlarged scale for a visual representation of the distribution of the front of propagation of seismic waves.

The following features of the algorithm follow:

- the longer the path of the seismic wave, the greater its influence on the accuracy of determining the weighted average wave velocity in general and for a specific area;
- the fewer “source-receiver” lines cross the grid section, the less reliably the velocity will be determined for it.
- the choice of the shape of the mesh section affects the accuracy of approximation to the velocity estimate on it, since the velocity is influenced by the length of the “source-receiver” line segments.
- this method works under the assumption that the wave path is straight from the source to the receiver.

Estimating the accuracy of the algorithm is reduced to comparing the theoretical time-travel curve from formula (1) with the vector of seismic wave arrival times obtained in the experiment. Denote the theoretical time-travel curve as $\vec{t}^*$:

$$\vec{\eta}(X, \theta) = \vec{t}^* . \quad (4)$$

Each element of the theoretical time-travel vector is calculated by the formula:

$$\vec{t}_i^* = \sum_{k=1}^L \frac{L_{ijk}}{\vec{v}_k} . \quad (5)$$

RESULTS AND DISCUSSION

The map of the area of the Mount Karabetova mud volcano in experiments on its vibration seismic sounding along profiles I and II is shown in Fig. 2.

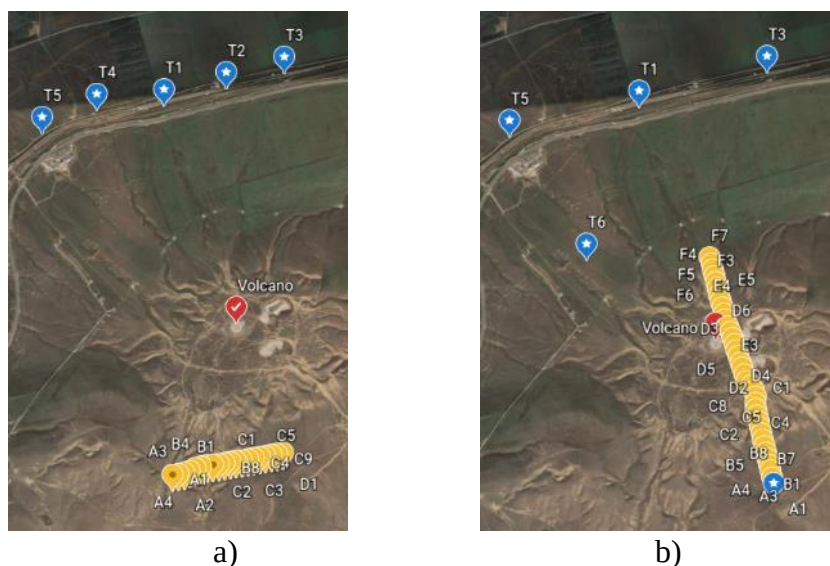


Fig. 2 Map of the area of the Mount Karabetova mud volcano in experiments on its vibration seismic sounding: a — on profile I, b — on profile II. The position of the receivers is indicated by yellow flags, seismic sources — by blue flags, the volcano area — by a red flag.

To determine the local velocities of P-waves along the sections of each profile, a square grid with a uniform number of nodes (60x60) along both axes of the Cartesian plane was chosen. The grid spacing for profile I was 42.7 m along the x axis and 47 m along the y axis, and for profile II, 31.5 m and 48.1 m, respectively. The results of determining the local velocities for both profiles are shown in Fig. 3. After the transformation of geodetic coordinates into Cartesian [10], the map of the location of sources and receivers turned almost 180 degrees counterclockwise. However, this does not interfere with the interpretation of the data. The range of local velocities for both profiles is from 1.191 to 1.474 km / sec. Fig. 3 shows that in the right area for both profiles, higher velocities prevail, which may be caused by the presence of an anticlinal flexure in this area, which is characterized by a denser geological structure [11, p. 231].

The estimation of the algorithm accuracy according to formula (5) for profile I is shown in Fig. 4. It can be seen from the figure that for the T4 and T5 sources, the error in determining the P-wave arrival times is higher in the region of 11-th, 15-20-th receivers. This may be due to the fact that local velocities in the region of the T4 and T5 sources are higher than in the rest of the region. Also, the contribution of each of the sources to the determination of local velocities is significant in the region close to the receivers due to the large number of crossings of the "source-receiver" lines in this region.

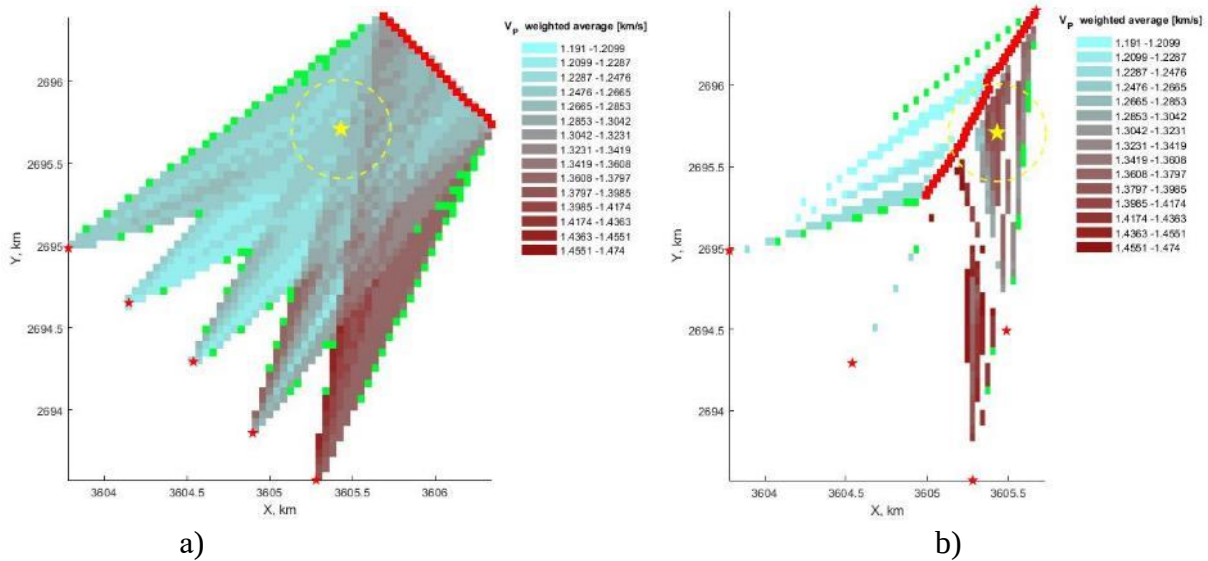


Fig. 3 Distribution of local P-wave velocities on the day surface in the volcano area for profiles: a) I, b) II. Red stars indicate the position of seismic sources, red diamonds — the position of receivers. The area of the Mount Karabetova mud volcano is highlighted in yellow. Areas are highlighted in green, where local velocities are calculated only along one “source-receiver” line.

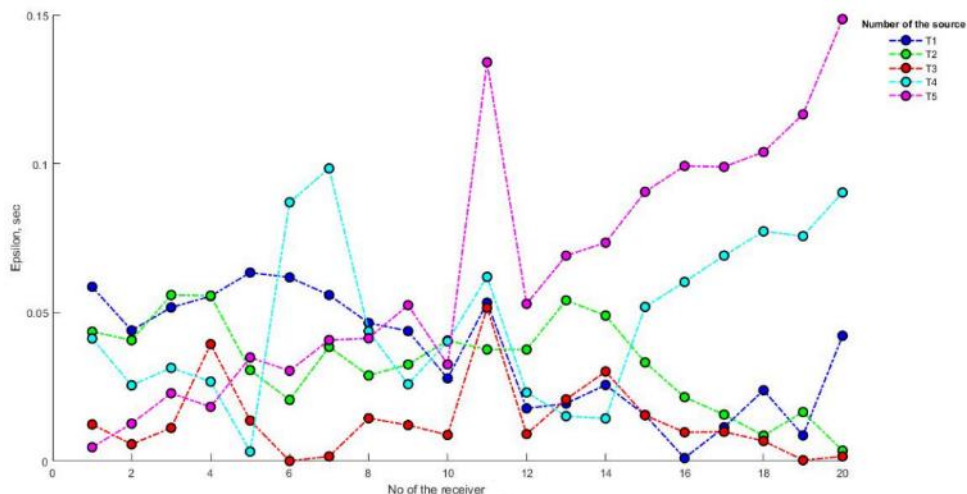


Fig. 4 Distribution of errors in calculating the theoretical time-travel curve for all seismic sources for receivers No 1-20 along profile I

CONCLUSION

This paper presents a heuristic approach to constructing local velocity characteristics of complex mediums, such as areas of mud volcanoes, based on experimentally obtained vibration seismic sounding data. The developed algorithm is tested on the data on the experimentally obtained arrival times of waves from vibration sources of the mud volcano Mount Karabetova along two profiles. It is shown that the obtained results of the distribution of local velocities are consistent with the data on the geological structure of the considered area.

ACKNOWLEDGMENTS

This work was supported by RFBR (grant № № 20-07-00861A).

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CONSTRUCTION OF A STRENGTH MODEL OF A STRAPDOWN INERTIAL BLOCK OF A SPACE ORBITER

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Annotation – Increasingly stringent requirements are imposed on modern onboard spacecraft equipment in terms of functionality, mass and size parameters, reliability and manufacturability. The cause of this demands is the acceleration of scientific and technological progress, the growing ambitions of mankind to explore outer space. The current trend is to miniaturize electronic devices maintaining the output characteristics, hence the need to modernize the design and technology of both the spacecrafts and the onboard equipment.

In this article the development of a strength model of a strapdown inertial unit, an integral part of a strapdown inertial navigation system is presented.

At the design stage we performed calculations to determine the system strength. All calculations were performed in the SolidWorks CAD environment. The two cases: linear acceleration and impact effect were taken into consideration.

Calculations of linear acceleration and mechanical shock effects produced the following observation: stresses cover the main structure volume do not exceed the main materials yield stress.

Test results detected no malfunctions in the design of the overall-weight model with the exception of minor scratches and abrasions. This allows us to evaluate the system reliability and persistence as sufficient.

The performed calculations and tests allow us to state the following conclusions:

- the unit is resistant to linear acceleration with an amplitude of 15g;
- the unit strength is sufficient to withstand impact effect up to 150g with a pulse duration of 0,65 ms.

- the performed tests confirm that CAD systems (such as SolidWorks) can be employed to determine the mechanical load parameters at the design development stage.

Keywords: system, impact effect, linear acceleration, tests, model, unit, telemetry.

Increasingly stringent requirements are imposed on modern onboard spacecraft systems (equipment) in terms of functionality, mass and size parameters, reliability and manufacturability. The cause of this demands is the acceleration of scientific and technological progress, the growing ambitions of mankind to explore outer space. The current trend is to miniaturize electronic devices maintaining the output characteristics, hence the need to modernize the design and technology of both the spacecrafts and the onboard equipment.

In this article the development of a strength model of strapdown inertial unit, an integral part of a strapdown inertial navigation system is presented.

The unit is intended for measuring, forming and transmitting an array of information parameters. This array includes measuring information represented by increments of integrals of the angular velocity vector projections onto the measuring axes of sensitive elements rigidly connected with the mounting elements of the unit attachment points.

The developed unit is designed as a lightweight body in the form a truncated hexagonal pyramid with electronic modular units of several cells non-orthogonally placed on it. Such structure design complexity results from the stringent requirements for the location of the fiber-optic gyroscopes sensitivity axes.

At the design stage we performed calculations to determine the system strength. All calculations were performed in the SolidWorks Simulation CAD environment. Two cases: linear acceleration and impact effect were taken into consideration.

To speed up the calculation we used a simplified unit model with the same strength, mass and size parameters and inertia characteristics as the original model.

The boundary conditions for the research of the linear acceleration effect are:

- rigid fixation of the mounting holes and the base geometry;
- acceleration of 147 m/s^2 (15g) applied sequentially along every unit axis for 5 minutes;
- gravity of 9.81 m/s^2 (1g) applied in the direction opposite to acceleration to simulate and analyze the effects of Earth gravity.

Figure 1 shows a model of a node stress diagram with the effects of 15g acceleration applied along the unit X-axis. The maximum stress (300 seconds analyzed) is 0.049 MPa or 0.499 kgf /cm². Stresses occur on the unit body at the gyroscope unit joints.

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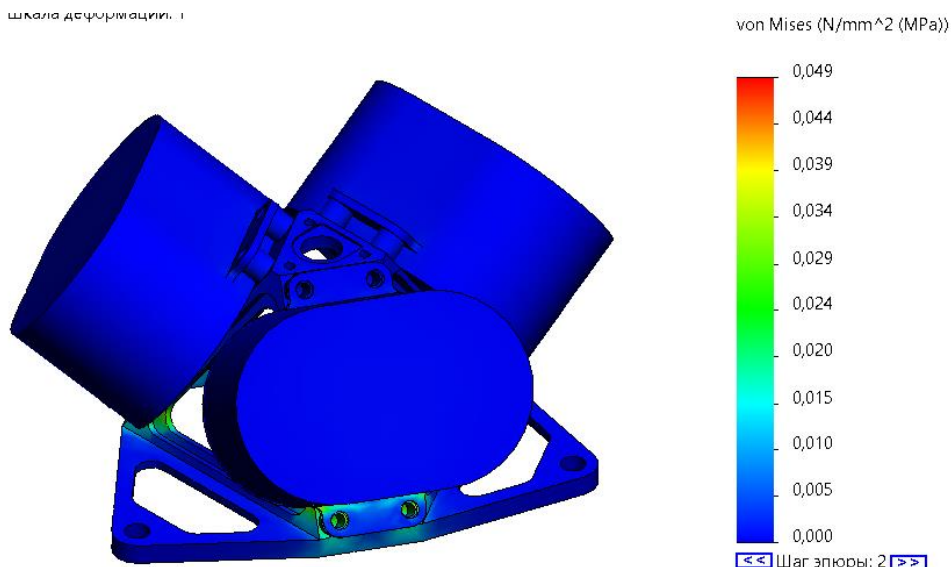


Fig. 1 Node stress diagram with the effects of 15g acceleration applied along the unit X-axis

The maximum resulting displacement in this model is 0.006 microns. It does not affect the unit performance and the sensitive elements readings. The diagram of the resulting displacement is shown in Figure 2.

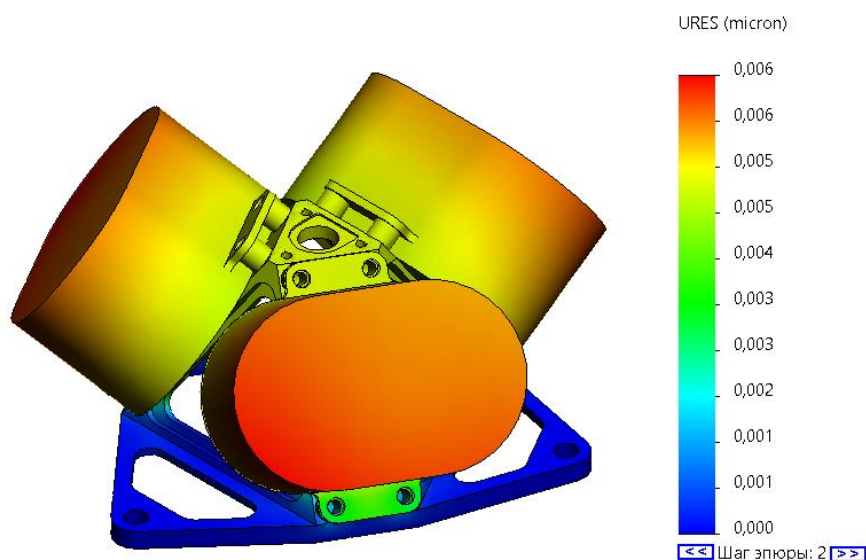


Fig. 2 Resulting displacement diagram with the effects of 15g acceleration applied along the unit X-axis

Figure 3 shows a model of a node stress diagram with the effects of 15g acceleration applied along the unit Z-axis. The maximum stress (300 seconds analyzed) is 0.175 MPa or 1.78 kgf /cm². Stresses occur on the unit body at the gyroscope unit joints.

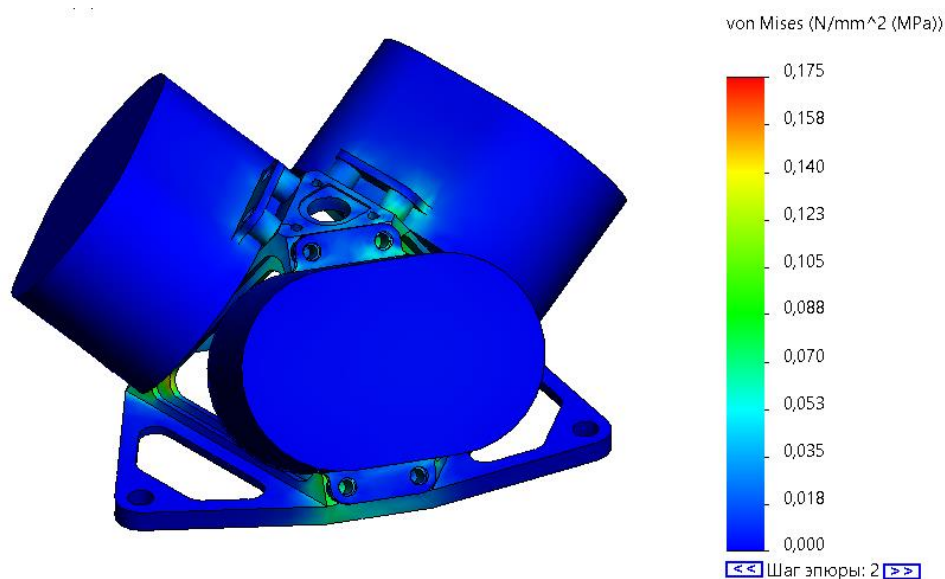


Fig. 3 Node stress diagram with the effects of 15g acceleration applied along the unit Z-axis

The maximum resulting displacement in this model is 0.093 microns. It does not affect the device performance and the sensitive elements readings. The diagram of the resulting displacement is shown in Figure 4.

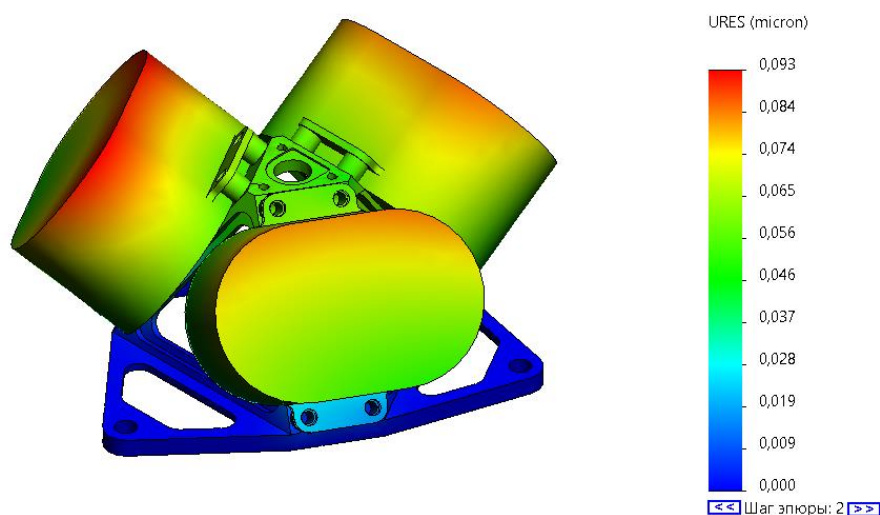


Fig. 4 Resulting displacement diagram with the effects of 15g acceleration applied along the unit Z-axis

Figure 5 shows a model of a node stress diagram with the effects of 15g acceleration applied along the unit Y-axis. The maximum stress (300 seconds analyzed) is 0.179 MPa or 1.79 kgf /cm². Stresses occur on the unit stiffening ribs.

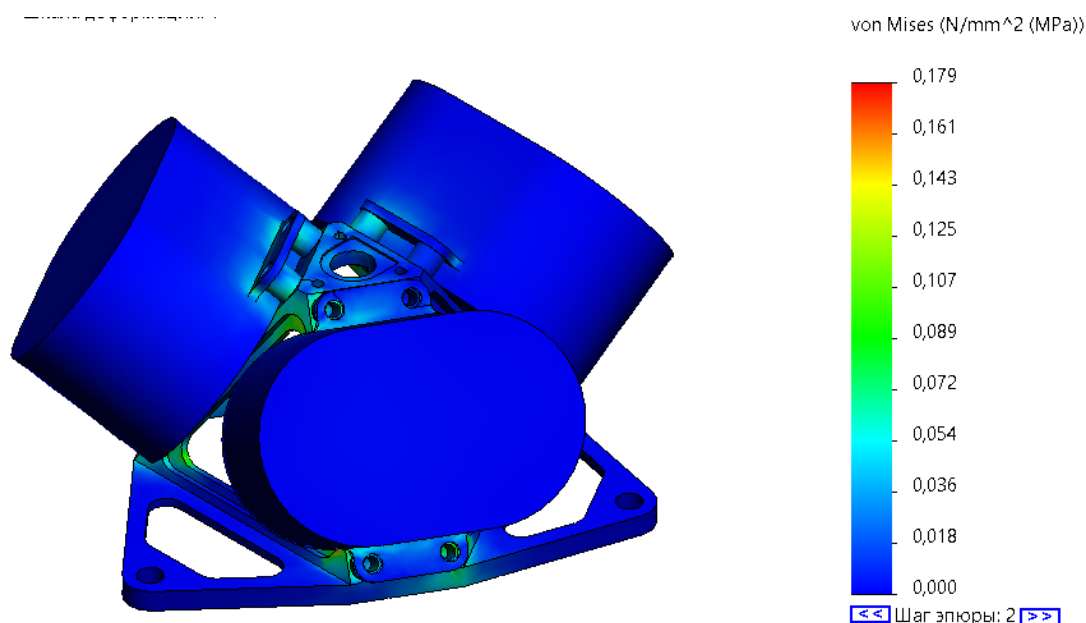


Fig. 5 Node stress diagram with the effects of 15g acceleration applied along the unit Y-axis

The maximum resulting displacement in this model is 0.093 microns. It does not affect the device performance and the sensitive elements readings. The diagram of the resulting displacement is shown in Figure 6.

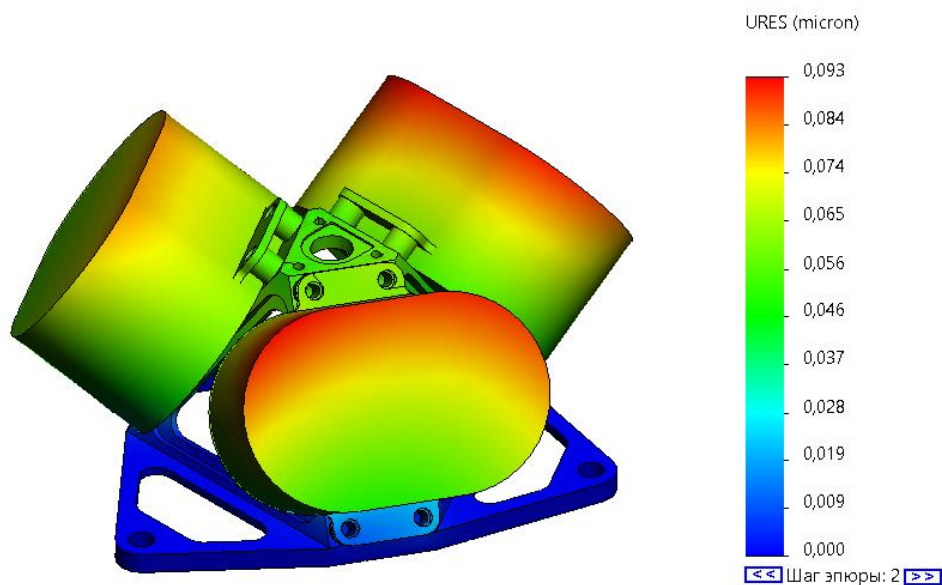


Fig. 6 Resulting displacement diagram with the effects of 15g acceleration applied along the unit Y-axis

Requirements for resistance to impact effects may be established by impact effect tests with a peak acceleration of 1471,5 m/s² (150 g), pulse duration of 0,65 ms, 5 impacts in both directions for each of the three mutually perpendicular axes (with a total of 30 shocks).

The boundary conditions for studying the impact load affects are:

- rigid fixation of the mounting holes and the base geometry simulating a unit installation on an attachment point in a spacecraft structure or a test bench;

- acceleration of 1471.5 m/s^2 (150 g), pulse length of 0,65 ms, 5 shocks in both directions for each of the three mutually perpendicular axes (with a total of 30 shocks);
- force of gravity of 9.81 m/s^2 (1g) along the unit X-axis in the direction of the unit mounting plane, to simulate and analyze the effect of Earth gravity during spacecraft launching into orbit as part of the carrier or during bench tests.

Figure 7 shows a model of a node stress diagram with the effects of given impact effects.

The maximum stress occurs at the 30th step in the diagram (0.0195 seconds of testing), which is the last impact effect of the 30 test shocks, and is equal to 0,051 MPa or 0,52 kgf /cm². Stresses occur on the unit body at the gyroscope unit joints.

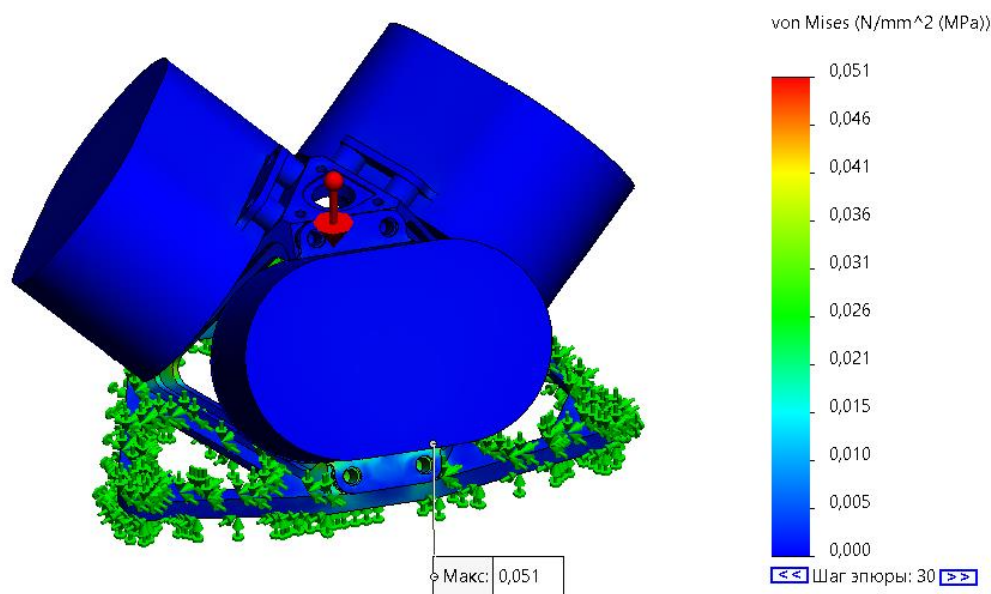


Fig. 7 Node stress diagram at the step 30 of the analysis

The maximum nonlinear resulting displacement in this model is 0,007 microns. It does not affect the device performance and the sensitive elements readings. The diagram of the resulting displacement is shown in Figure 8.

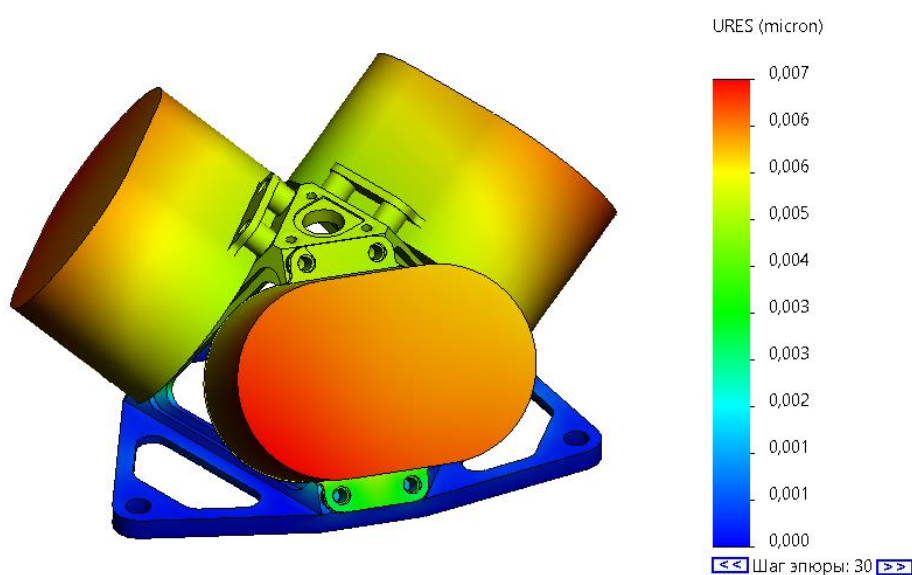


Fig. 8 Diagram of the resulting displacement

In the next experiment stage, the unit overall weight model was implemented and subjected to mechanical tests. Two types of tests were carried out: a test of linear acceleration effects resistance and a test of impact effects resistance in an impact spectrum format.

Test results detected no malfunctions in the design of the overall weight model with the exception of minor scratches and abrasions. This allows us to evaluate the system reliability and persistence as sufficient.

The performed calculations and tests allow us to state the following conclusions:

- the unit is resistant to linear acceleration with an amplitude of 15g;
- the unit strength is sufficient to withstand impact effect up to 150g with a pulse duration of 0,65 ms.

- the performed tests confirm that CAD systems (such as SolidWorks) are applicable in determination of the mechanical load parameters at the design development stage.

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ANALYSIS THE RESULT OF DECONVOLUTION OF A DISTORTED AUDIO SIGNAL

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Abstract – The paper describes the process of restoring a one-dimensional audio signal, gives examples of restoring various distorted signals, including speech signal, by using deconvolution operation with known and unknown convolution kernel, indicates the advantages and disadvantages of restoring a distorted audio signal methods that are analyzed in this work.

Keywords: audio signal; speech signal; deconvolution; digital filter; spectrum; convolution.

INTRODUCTION

In recent years, in various applied problems, occurs necessity of restoring various types of audio signals [1]: speech messages, sounds of natural origin, melodies and other signals. The most popular approach for solving such problems is spectral analysis, in particular, signal reverse

convolution or deconvolution. In this paper, we will consider the deconvolution of audio signals with a known convolution kernel [2,3].

PROBLEM STATEMENT

We will consider an audio signal as a data stream of limited or infinite size. The signal, for the convenience of processing, will be described by a time function, the values of which are represented by a set of values of the signal amplitude at given points in time.

If the input data of the task are signals in analog form, that are continuous in time, they are sampled. The frequency with which the signal amplitude will be fixed is called the sampling rate. To avoid overlapping, indistinguishability of analog signals during their sampling (aliasing), the sampling frequency of the audio signal is chosen to be equal to 44100 Hz [2].

One of the most used operations in signal processing is the convolution operation. For two finite sequences $x(n)$ and $h(n)$ with length N_1 and N_2 , respectively, their convolution is defined as follows

$$y(n) = h(n) * x(n) = \sum_{k=-\infty}^{\infty} h(k)x(n-k) = \sum_{k=0}^{\infty} h(k)x(n-k), n = 0, 1, \dots, M-1, \quad (1)$$

where $M = N_1 + N_2 - 1$ and symbol $*$ denotes the convolution operation. The function $h(n)$ is called the convolution kernel or impulse response of the linear system through which the audio signal passes. A convolution has the properties of commutativity, associativity, and distributivity.

Considering that the signal is described by a discrete function of time, it can be recommended to go to the discrete Fourier transform corresponding to the signal. Discrete Fourier Transform is a useful tool for studying the signal spectrum and analyzing the signal in the frequency domain. It also should be in mind that in the frequency domain, the description of an audio signal is a function of frequency. The main goal of moving to the frequency domain instead of the time domain is to simplify a number of audio signal processing operations such as filtering, smoothing, and noise suppression.

Summarizing what has been said, we can define convolution as follows

$$h(x) * f(x) = H(u)F(u), \quad (2)$$

where $H(u), F(u)$ – Fourier transforms of the corresponding functions.

The transition from the time domain to the frequency domain during signal processing, and then back, generally reduces the amount of computation, but is a low-speed process due to the discrete transform, and therefore the Fourier transform is usually implemented using the fast Fourier transform (FFT) algorithm. FFT allows you to reduce the number of operations to $O(N \log(N))$ in comparison with a discrete transformation, which is calculated in $O(N^2)$ operations.

Signal distortion can obey different laws, including linear. This means that the signal $x(t)$ has passed through some linear system, at the output of which the signal $y(t)$ is generated, moreover, if $x_1(t) \rightarrow y_1(t), x_2(t) \rightarrow y_2(t)$ then $\alpha x_1(t) + \beta y_1(t) \rightarrow \alpha x_2(t) + \beta y_2(t)$ (linear property). In this case, it is said that the convolution of the input signal $x(t)$ with the impulse response $h(k), k = 0, 1, \dots$, of the linear system is realized, which ultimately gives a new signal $y(t)$.

METHODS OF RECOVERY THE AUDIO SIGNAL

As mentioned above, restoring the original signal from convolution is called deconvolution. To perform deconvolution, it is necessary to build a filter with a frequency response inverse to the distorting filter and convolve the distorted signal with this filter.

In the general case, the filter changes in the signal spectrum not only the amplitudes of the harmonics, but also their phases. The objective of the research is to design filters in such a way that the phase of the signal does not change, that is, the so-called linear phase filters. This means that if the filter affects in some way the phase of the signal, then this leads to a time shift of the harmonics of the signal by the same amount.

Thus, the filter is determined by the frequency and phase characteristics, which, in turn, make it possible to evaluate the effect of the filter on the phase and amplitude of the harmonics of the processed signal. For filters with a linear phase, only the frequency response of this filter is considered [2].

In this case, the use of a filter with a linear phase is not always advisable. If the filter completely suppresses a number of signal frequencies, it will not be possible to restore these frequencies. In addition, the reconstruction significantly amplifies noise at the suppressed frequencies of the input signal. That is, it is not always possible to completely restore the original signal from the convolved one, as a rule, we are talking about obtaining some approximation of the original signal.

To analyze the results of deconvolution of audio signals of various types, a convolution kernel will be formed for model signal distortion. The kernel is modeled from a sample of random variables belonging to the general population with a normal distribution.

In Fig. 1a shows the original signal (melody) and the result of reconstruction (Fig. 1b) in the time and frequency domains, respectively.

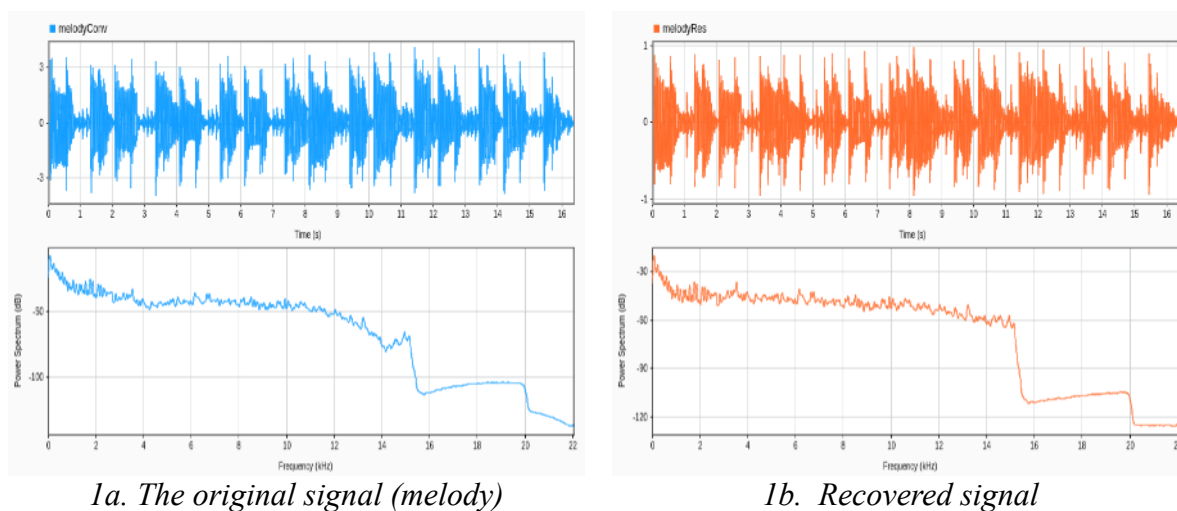


Fig. 1 The result of deconvolution of a distorted melody in the time and frequency domains

It should be noted that the shape of the corresponding signals in Fig. 1 is similar, while the amplitude is different, which is also established when the reconstructed signal is reproduced.

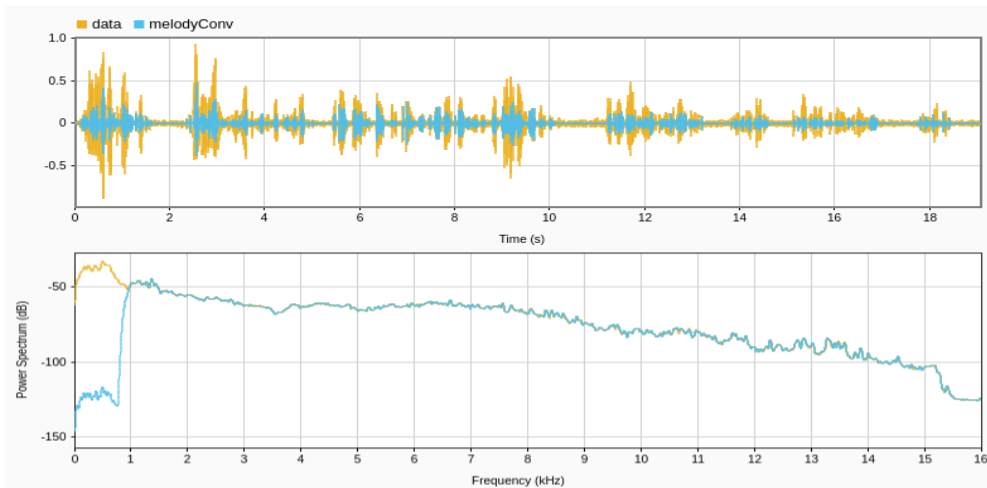


Fig. 2 Superposition of the results of deconvolution and the original distorted speech message

Figure 2 shows the superposition of the results of deconvolution of the distorted speech signal, respectively, in the time and frequency domains. The speech message has been distorted with a high-pass filter that only allows frequencies above 1000 Hz to pass. We know the impulse response of the high-pass filter, therefore, using the deconvolution operation, we will try to restore the original signal with virtually no loss.

In case of distortion of another sound signal, recording of birds singing, a band-pass filter, in the range from 1000Hz to 2000Hz, the result demonstrates a slight change in the signal in the frequency domain, which in general makes it possible to adequately perceive the reproduced reconstructed signal.

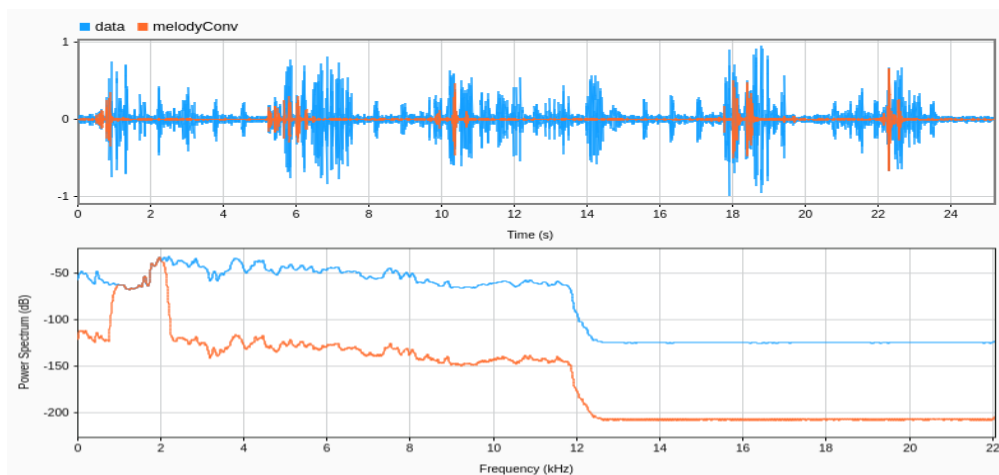


Fig. 3 Superposition of deconvolution results and the original distorted recording of the bird singing

A similar result can be obtained when selecting a melody from its overlay on the background sound (noise). In the case of signal recovery with an unknown distorting kernel, the so-called "blind" deconvolution problem is formulated, the solution of which turns out to be nontrivial.

It may be recommended to replace the original problem with the problem of filtering the noisy signal by using the low-pass filter (Figure 4) that will distinguish the original signal. This will keep signals of frequencies below the lower threshold, and signals of frequencies above the threshold will be suppressed.

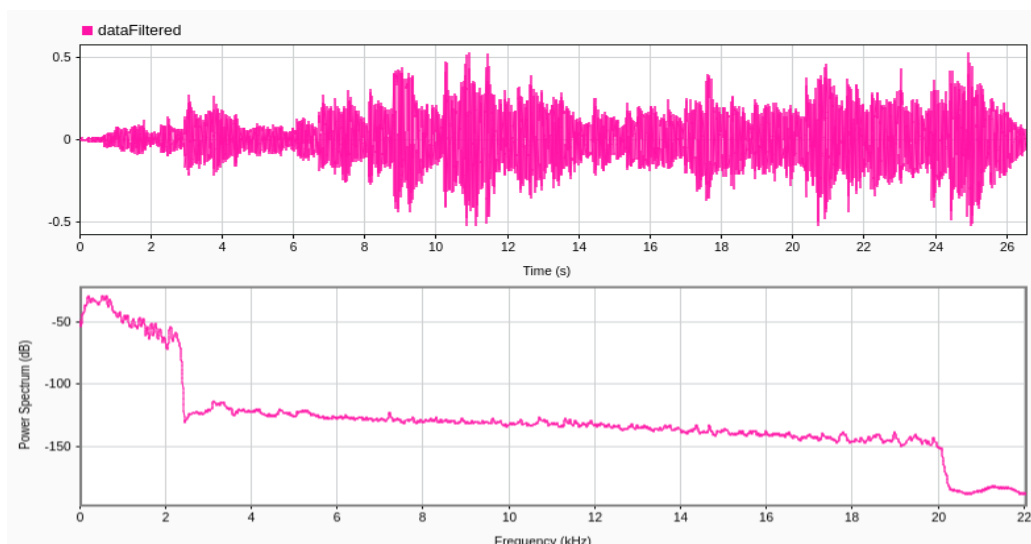


Fig. 4 The result of filtering a signal with an unknown distorting kernel

CONCLUSION

Based on this work, it can be assumed that the deconvolution method for reconstructing an audio signal, operates stably at a known convolution kernel, allowing to perceive the reproduced sound signal restored. For an unknown impulse response, the problem is reduced to the choice of the convolution kernel and turns out to be nontrivial. In this case, the original problem for the problem of filtering a noisy signal using a low-pass filter.

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THE ASSESSMENT OF THE IMPACT OF CONTACT RADIO INTERFERENCE ON A COMMUNICATION RADIO ENGINEERING SYSTEM

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Abstract — This article deals about the analysis of works devoted to the issue of contact radio interference and the assessment of their impact on the device was carried out. This analysis was carried out as a preparatory stage for conducting a study to assess the impact of contact radio interference on a communication radio engineering system. An interface has been developed that allows the calculation of the module and phase of the electric contact transmission coefficient model for the inductive, capacitive branch and the full transmission coefficient model.

Keywords: contact radio interference; communication radio engineering system; user interface.

INTRODUCTION

Currently, much attention is paid to the issues of electromagnetic compatibility of radio-electronic means and the analysis of the interference situation. In particular, this applies to various radio-electronic communication systems. A radio-technical communication system is a complex system consisting of a large number of radio-electronic means located in a limited space. This system contains a large number of metal connections that form a system of non-removable electrical split contact connections. This, in turn, leads to the formation of broadband radiated contact radio interference when organizing two-way radio communications in motion.

With the development and improvement of radio-electronic equipment, there is a tendency to reduce the weight and size parameters and increase the number of emitting and transmitting equipment in a limited space. This, in turn, leads to an increase in interference caused by re-radiation from the conductive contacts. Therefore, there is a need to take into account the impact of this type of interference on a communication radio engineering system and apply measures to reduce their impact.

MAIN CONTENT

Currently, there are a large number of works on this topic. In [1] the basics of the theory of contact radio interference and general recommendations on ways to combat contact radio interference are discussed such as conducting device shielding, using welding and soldering to connect contacts, maximum antenna spacing.

In [2] the main designs of contact pairs of electrical connectors of radio-electronic equipment for various purposes are considered and the main requirements for them, methods of calculation and design are set out.

In [3] the issues of creating models of electric current passing through detachable contact connections, models of fluctuating linear and nonlinear contact radio interference from structures containing detachable contact connections in the near and far radiation zones are considered.

In [4] the main mechanisms of the influence of electromagnetic fields on the basis of visual model representations and measures to reduce this influence are discussed.

In [5] the influence of modulating phase and amplitude distortions that occur during the generation, propagation, and reception of signals are discussed.

The analysis of the considered literature sources showed, that despite the large number of works on this topic, the currently existing works, do not accurately describe the parameters of connections from the point of view of the needs of modern radio electronics, and there are no detailed models of various types of connections, which makes it impossible to accurately predict contact interference on certain connections that are part of a communication radio engineering system. In addition, the currently existing classical models of radio engineering systems, in principle, do not take into account the influence of contact radio interference. As a result, there is a need to conduct research on this topic.

It is assumed that the work on this topic will include the following stages: analysis of mathematical and physical (circuit) linear and nonlinear contact models under various conditions, development of improved linear and nonlinear contact models under various conditions, determination of the strength of the secondary electromagnetic field from the mobile contact connection in the near and far zones, development of improved methods for predicting fluctuating linear and nonlinear contact radio interference, development of methods for designing communication radio engineering systems, taking into account the influence of contact radio interference.

The structure scheme of a communication radio-electronic system under the influence of contact radio interference is shown in (Fig. 1).

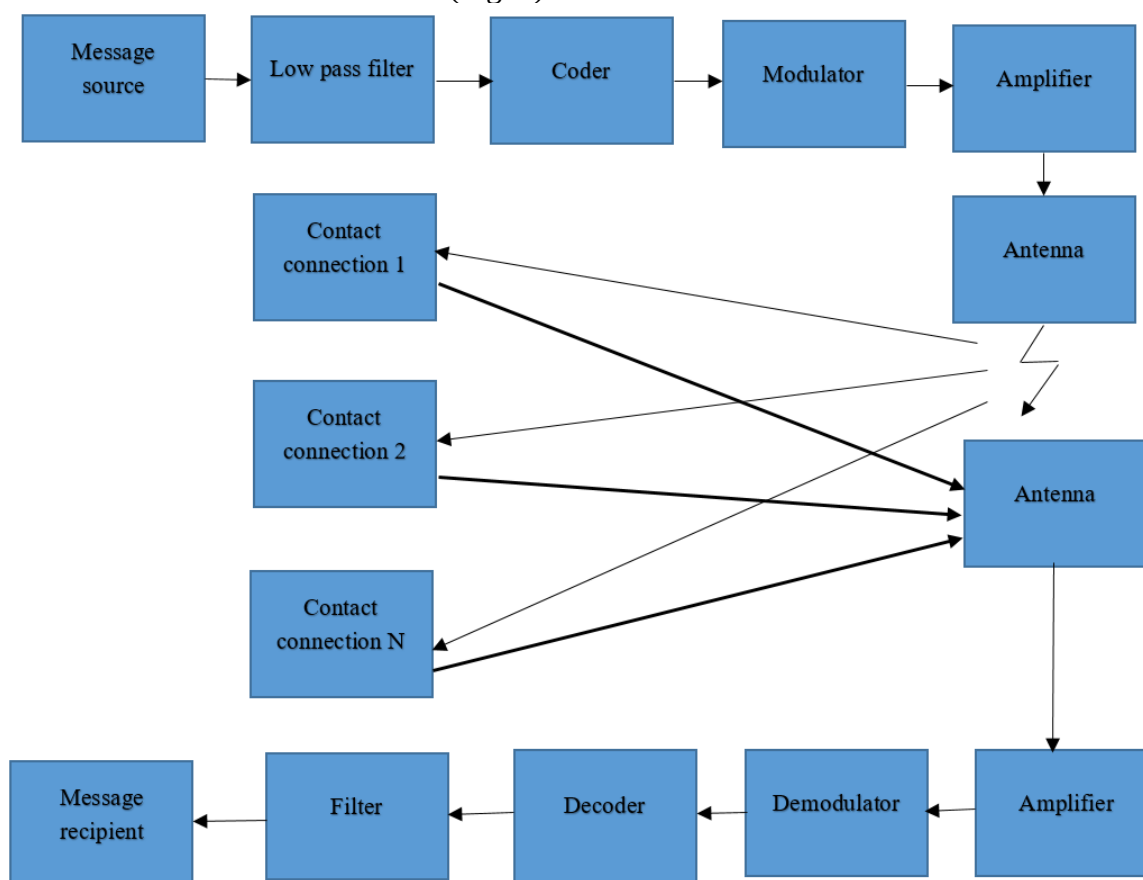


Fig. 1 The structure scheme of a communication radio-electronic system under the influence of contact radio interference

As can be seen from the scheme the signal emitted by the antenna of the transmitter of the radio communication system falls into the antenna of the receiver and this signal also falls on the mobile contact connections and, re-radiating into the open space, falls into the transmitting and receiving antennas. Thus, the receiving antenna receives two types of signals: a direct signal from the transmitting antenna and a re-radiated mobile contact connection.

Currently, there are two main types of contacts that are the source of contact radio interference: linear and nonlinear contacts. In this article the models of linear contacts are discussed in more detail.

There are conditions under which a movable contact joint can be considered as a linear inertial device with parameters. These parameters are controlled by some random modulating process, such as switching, vibration, shaking. This process changes the amplitude and frequency-phase relations of the high-frequency conduction current induced by an external electromagnetic field.

Consideration of the effect of an electromagnetic field on a variable linear contact can be reduced with some assumptions to the analysis of the passage of this field through a four-pole with a complex transfer function $K(j\omega)$ [6].

A change in the contact resistance according to the periodic law leads to a change in the complex transfer function according to the same law. By decomposing this function into a Fourier series and performing some transformations, one can conclude that the strength of the secondary field re-radiated from the variable contact can be written as the sum of two components. The first component will look like:

$$e'_2(t) = E_{1m} K_0(\omega) \cos(\omega_0 t + \phi_0). \quad (1)$$

That is, this component represents the intensity of the irradiating electromagnetic field with an amplitude reduced by $H_0(\omega)$ times and has undergone a shift of ϕ_0 .

The second component can be represented by the expression:

$$e''_2(t) = E_{1m} \left\{ \sum_{n>1} K_n(\omega) [\cos < (\omega_0 + n\Omega)t + \phi_n + \varphi_n > + \cos < (\omega_0 - n\Omega)t - \phi_n + \varphi_n >] \right\}. \quad (2)$$

Thus, this component represents a distortion of the electromagnetic field strength when irradiated with a periodically changing contact and characterizes the contact interference that occurs in this case. In this case, the spectrum of the electromagnetic field of secondary radiation contains a component at the frequency of the irradiating field and additional components at the frequencies $\omega_0 \pm n\Omega$.

The spectrum of contact interference is always wider than the spectrum of the irradiating electromagnetic field, and the frequency band occupied by contact interference expands with an increase in the switching frequency of the alternating contact [6].

In [7], it was considered an equivalent circuit of the total resistance of an electrical contact was considered for the high frequencies of the transmitted signal under the action of mechanical influences on the contact. According to this scheme, the model of the complex current transfer coefficient in the inductive branch can be presented in the following form:

$$\dot{K}_L(\omega, R, L, C) = \frac{R^2 + (\omega L)^2 - \omega^2 R^2 CL - \omega^4 CL^3 + j(-\omega CR^3 - \omega^3 CL^2 R)}{((1 - \omega^2 C_k L_k)^2 + \omega^2 R_k^2 C_k^2) \cdot (R^2 + (\omega L)^2)}. \quad (3)$$

where R – resistance in the model of the complex current transfer coefficient in the inductive branch;

L – inductance;

C – capacity.

The model of the complex current transfer coefficient in the capacitive branch can be presented in the following form:

$$\dot{K}_C(\omega, R, L, C) = \frac{\omega^4 C^2 L^2 + \omega^2 C^2 R^2 - \omega^2 LC + j\omega CR}{(1 - \omega^2 C_k L_k)^2 + \omega^2 R_k^2 C_k^2}. \quad (4)$$

The model of the total current transfer coefficient of the electrical contact can be presented in the following form:

$$\dot{K}(\omega, R, L, C) = \dot{K}_L(\omega, R, L, C) + \dot{K}_C(\omega, R, L, C). \quad (5)$$

To simplify the analysis during the preliminary stage of the study, a user interface was developed that allows you to plot the dependence of the models of the module and phase of the electric contact transmission coefficient for the inductive, capacitive branch and the model of the total transmission coefficient. The user interface program was written in C++ in the Qt Creator environment. The user interface is a dialog box in which you select the type of graph that you want to build, the contact parameters, and the frequency range in which you want to build the graph. As a result of the user clicking the "Plot" button, a graph is drawn. The user can add a graph with new parameters for visual comparison. To delete the charts, the user must click the "Erase" button. Examples of calculating the modulus and phase of the electric contact transfer

coefficient for the inductive branch with the parameters $R=2 \cdot 10^{-3} \Omega$, $L=9 \cdot 10^{-11} \text{ H}$, $C=8 \cdot 10^{-10} \text{ F}$ shown in (Fig. 2).

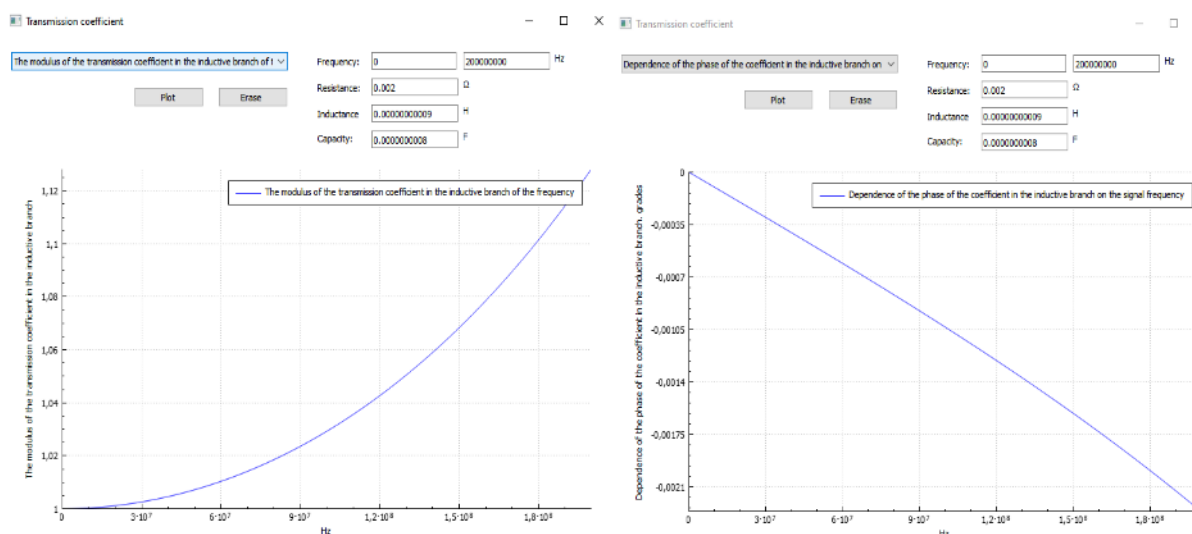


Fig. 2 Examples of calculating the modulus and phase of the electric contact transfer coefficient for the inductive branch

CONCLUSION

Within the framework of this article, an analysis of works devoted to the issue of contact radio interference and the assessment of their impact on the device was carried out. This analysis was carried out as a preparatory stage for conducting a study to assess the impact of contact radio interference on a communication radio engineering system. As part of this stage, an interface was also developed that allows the calculation of the module and phase of the electric contact transmission coefficient model for the inductive, capacitive branch and the full transmission coefficient model. The results obtained using the interface correspond to the results presented in one of the analyzed articles.

The analysis also allows us to conclude that the analysis of the influence of contact radio interference on a communication radio engineering system is a more complex process than the influence of these interferences on a separate device, because it will be necessary to study the effects of electromagnetic radiation from a large number of secondary sources, as well as the result of the addition of these fields to each other and with the primary electromagnetic field in different phase ratios.

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INTELLIGENT ADAPTATION OF TRAFFIC LIGHT CONTROLLERS

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Abstract – The creation of collective intelligent traffic light controllers integrated with automated traffic management systems Scada using advanced process simulation in the AnyLogic environment will be a new direction in the digitalization of the country's road traffic.

In the development environments of VMware Workstation Pro, TIA Portal V13, Logo!Soft Comfort there are developments in the creation of adaptive self-adjusting digital traffic light controllers based on Siemens microcontrollers in the network version. In the technical literature and practice, there are no examples of creating traffic light controllers as IoT devices.

The article discusses solutions to the problem of traffic management and road safety in the city of Almaty. Digitalization within the framework of the "Smart city" concept requires the development of technical solutions, without significant changes in the electrical circuits of traffic lights. It is proposed to use Siemens Simatic7-300 microcontrollers with TIA Portal v 13. The article offers hardware and software that contributes to the transition to digital traffic light management. The results are visualized using the HMI operator's touch screen and demonstrate the advantages of a digital traffic light based on the developed software . The results obtained contribute to solving the situation of problematic intersections using intelligent adaptive traffic lights that are programmed with time intervals and changes in operating time, taking into account traffic jams and speed.

Keywords: Traffic Light Controller, Smart City, Digital Traffic Light Controller, Smart Traffic Light Hardware And Software.

1. INTRODUCTION

Organizing road traffic is an important component of safety and efficiency of traffic within the roadway infrastructure of the whole country and populated settlements. In recent years, the increase in the vehicle-to-population ratio has led to the sharp rise in vehicle density. In major cities of the Republic, there are numerous traffic jams and congestions in the rush hours, which result in adverse environmental impact. In the city of Almaty, due to the complex terrain and small road infrastructure, harmful car emissions have led to the critical deterioration of the air.

The small number of belt routes without any traffic lights caused the existence of numerous traffic lights when crossing the Almaty city in the east-west and north-south directions. Similar situation, but on a different scale, is in the capital of the Republic, Nur-Sultan and in all Regional centers of the country.

The administration of the city of Almaty gives priority to the development of the roadway network and effective management of the morning traffic from bedroom community to the city center and vice versa in the evening. One of the radical solutions to the problem became the use of manual traffic regulation. At the same time, ‘Sergek’ sensors, speedometers and video cameras were installed on the highways of the city, there is a situation center for operational traffic management. The Smart City concept has been proposed, within which the problem of traffic jams and congestions in the city center is considered as a task of the highest priority.

One of the ways to increase the throughput capacity of busy highways is the rational use of traffic lights as active devices for traffic control. In practice, traffic light controllers are installed based on the designed throughput capacity of the highway [1]. For instance, the traffic lights in the city of Almaty have only two operating modes: regular mode and that for traffic jams [2].

The creation of adaptive multimode smart traffic lights operating on the digital principle is an important and essential task for increasing the efficiency of traffic organization in megalopolises [3,4].

2. MATERIALS AND RESEARCH METHODS

The review of Existing traffic light controllers reveals the trends of improving the design and logic of a programming unit. There was a transition from the analog principle of controlling time intervals of traffic lights to a hybrid one. In fact, the mechanical timer has been replaced with a digital one. The traffic control logic has become more complicated due to the use of modern integrated circuits. Traffic lights controlled by microcontrollers with corresponding network options are not used in Almaty.

There is a Russian traffic light that proposes an adaptive selection of time intervals for turning red or green lights on and off. There is a sensor used as a source of information about traffic intensity that is connected to a standard analog road controller. A digital traffic control system is not used [5].

In the Moscow Region, there are twenty stationary adaptive traffic light zones that display current information on the recommended speed modes on each of three lanes. Traffic lights and digital displays are highly specialized and cannot be used to display other important information for traffic control.

Similar stationary traffic lights are used in many developed countries of the world.

On online forums and in the technical literature there are articles and papers that describe the fundamental approaches to creating traffic light control algorithms for various single-chip and industrial microcontrollers. The disadvantage of these works is the lack of approaches to adapting existing analog and hybrid traffic light controllers to the capabilities of industrial microcontrollers.

The most popular in Kazakhstan road controller DK 2 (made in Russia) is based on a modular architecture using modern hardware components. It is able to operate with all the main communication channels: GSM, Ethernet and fiber-optic communication lines (FOCL).

The main feature of this road controller is the availability of an external control panel that provides for manual control of a traffic light [5]. DK 2 has no special device that would connect microcontrollers and graphic reprogrammable interfaces for displaying current traffic information. The proposed program codes for this controller are “closed-source” and cannot be reprogrammed according to the requirements of the Smart City [6].

The proposed technical solution ensures the improvement of the traffic control in the country to the level of Industry 4.0 technologies.

3. RESEARCH RESULTS AND DISCUSSION

Controlling a traffic light in terms of the information process is a cyclic, pulse-time algorithm with a coordinated change in the traffic light's output information depending on the traffic situation [7, 8].

Figure 1 represents the algorithm of the concurrent operation of traffic lights at a cross-shaped intersection.

Направление движения – Traffic direction, Пешеходный переход – Pedestrian crossing, Север-юг – North-south, Восток-запад – East-west, Дополнительная секция налево – additional signal showing left.

Abay Avenue in Almaty is one of the busiest six-lane highways of the city. The throughput capacity of the avenue is 220 thousand cars per day. The load distribution in the avenue is uneven during the week and time of day. The maximum load on Abay Avenue falls on working days in the west to east direction from 8 a.m. to 10 a.m. and in the opposite direction from 5p.m. to 8p.m. A particularity of the Abay-Tlendiyev intersection is the low throughput capacity of the leftmost lane when turning from west to north.



Fig. 1 Algorithm of the operation of traffic light at the cross-shaped intersection of Abay Avenue and Tlendiyev Street

The mode of operation of traffic lights during all days is programmed as follows:

- 90 seconds of green light on Abay Avenue from west to east, and 70 seconds from east to west. The leftmost lane is intended for the left turn. The additional section of the light lasts for 20 seconds;

- At this section of Tlendiyev Street the south-north traffic is one-way, and the green light lasts for only 20 seconds.

As a result, in the evening rush hours on Abay Avenue, there are 10-point traffic jams along the entire highway. Traffic optimization is hampered by two bus lanes that reduce the throughput of the avenue. Manual regulation in this direction is not used, although this highway is central and divides the city in half.

In fact, this avenue is a dividing line for the north-south traffic. People in the city even talk about so-called “pond” streets that prevent traffic jams in uphill central streets.

A heuristic and contemplative approach to traffic management results in the adequate increase in congestions and traffic jams in the city and its suburbs depending on the cost of construction of bridges and interchanges [9, 10].

The scientific framework of the traffic management in Almaty requires experimental studies using the LO@RA technology. The data collected from the LO@RA mobile sensors will ensure a system analysis of a vehicle location in the form of a closed Smart-City information-mathematical model using artificial intelligence [11,12].

This approach was further developed within the transport system of Thessaloniki (Greece) in the framework of the project “SMART CITY: Innovative Approach Towards a Master Program on Smart Cities Technologies.”

The most promising way of implementing Smart City technologies in traffic management is the digitalization of traffic lights. To build an automated traffic management system within the Industry 4.0 technologies, it is necessary to create and put into use a digital smart traffic microcontroller traffic light.

With the view of creating a digital prototype of the road controller, let us consider features of the Siemens S7-314 C-2 PN/DP microcontroller of the Simatic family. This device has the following characteristics:

- Programmable logic controller (PLC) Siemens Simatic S7 314C-2PN/DP CPU (6ES7314-6EH04-0AB0);
- Working memory: 192 Kb;
- Main memory (MMC): 8 MB;
- Logical operations time: 0.06 μ s;
- Number of flags/ timers /counters:2048/256/256;
- Number of input-output channels, discrete/analog, not more than 16,048/1,006;
- Built-in interfaces: MPI / DP and ETHERNET PROFINET;
- Built-in discrete inputs/outputs: 24/16;
- Built-in analog inputs/ outputs: 4 AI (I/U)+1 AI (Pt100)/2AO+4 fast counters (60 kHz).

It is evident that the capabilities of this microcontroller suffice to control complex traffic lights. Microcontrollers SIMATIC S7-314 C2-PN/DP can be combined withan HMI TOUCH operator display and personal computer.

The PLC S7-314 C2-PN/DP programming process consists of several steps related to hardware-software configuration. The management and programming environment of the SIMATIC family automation tools has been consolidated into a single Totally Integrated Automation (TIA) PORTAL shell.

The TIA PORTAL with WinCC interfaces for the HMI TOUCH operator display and the PLC Simulation program is installed on a personal computer (PC). In this software configuration, the physical presence of the microcontroller is not necessary. The whole process of modeling of the digital controller is done inside the PC, and the final project is saved, which is ready for the use in real devices.

Step 1. Launch and creation of a new project. Figure 2 shows the TIA Portal main window at the creation of a new project as well as the result of configuring PLC S7-314 C2-PN/DP with HMI KTP 900 Basic PN. The green line informs about the virtual connection of PLC with HMI at the hardware and software levels.

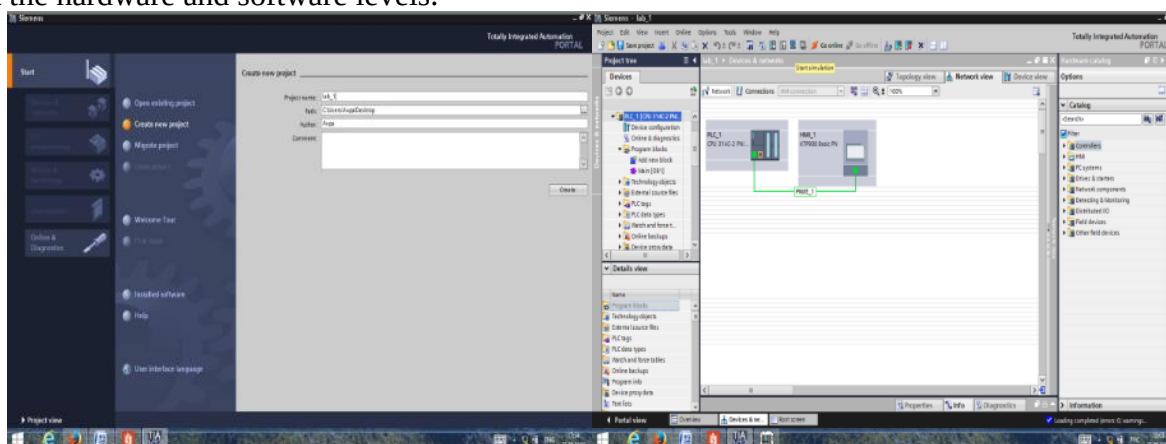


Fig. 2 View of the TIA Portal main window and network connection window

Step 2. Press  button. The data reset leads to the connection of the controller to the PC as shown in Figure 3.

Figure 3 shows that the PC works with PLC using a simulator. When connecting a real microcontroller to the PC, it is necessary to set the computer's network driver instead of the simulator.

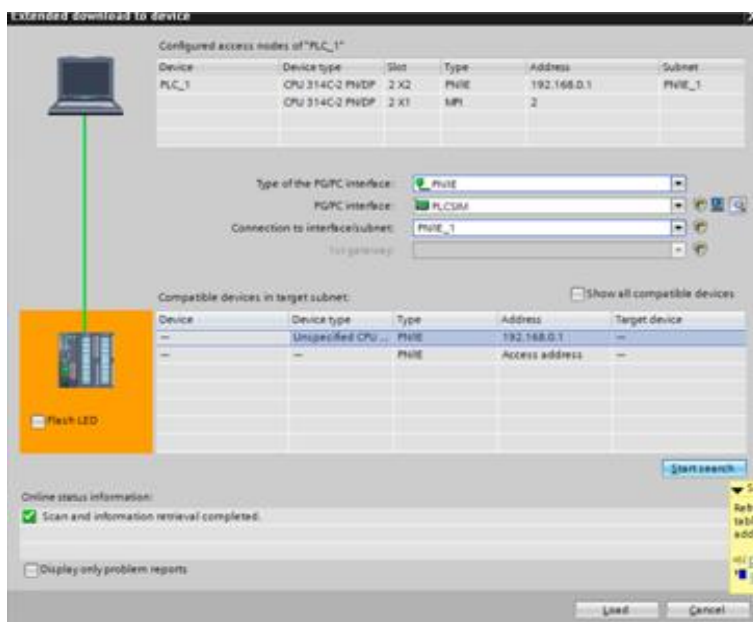


Fig. 3 A window showing connection of the PC to the microcontroller

Step 4. After running the 'PLC -> Program blocks -> Main' path, we are triggering OB1 to write the LAD code of the program (see Figure 4). The program consists of several Network blocks. Network 1 triggers Network 2,3,4 blocks for cyclic activation of traffic lights at the intersection.

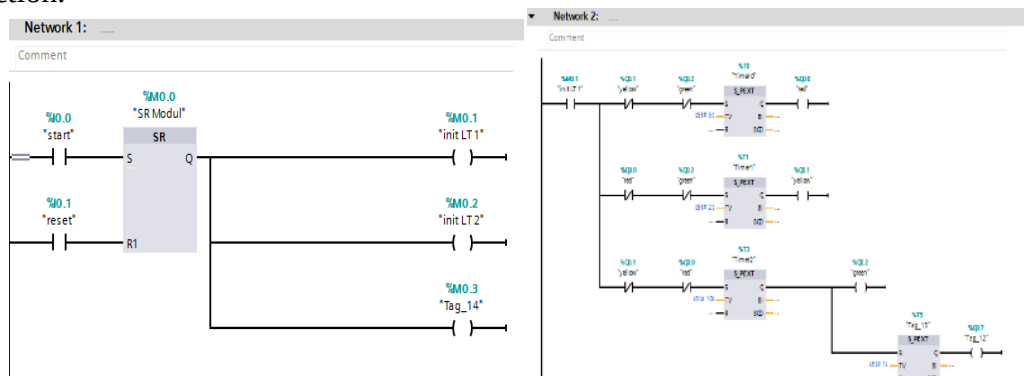


Fig. 4 Programs for the startup and reset of a digital traffic light and Network 2 with the program of cyclic activation of red, yellow and green lights and additional section controlling left turn from the western side of Abay Avenue

Step 5. After running the 'HMI -> Screens -> Root screen' path, we are drawing the intersection using the WinCC tools and adding animation and event graphics. Figure 5 depicts two event buttons and animation circumferences representing traffic lights. There is of the drawing is mere graphics and text.

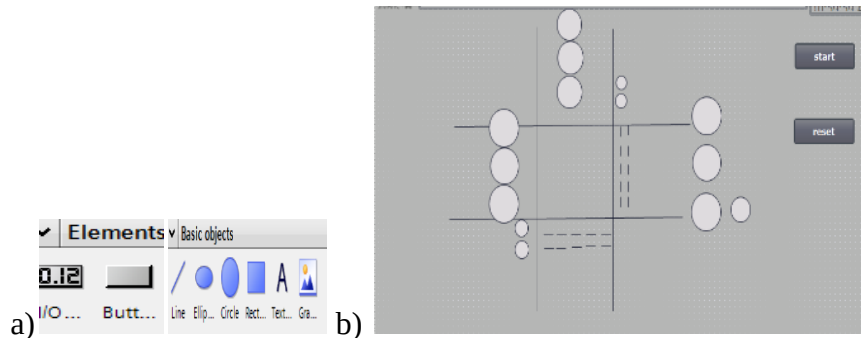


Fig. 5 a) Elements and basic object soft the WinCC graphic tools; b) Drawing of the Abay/Tlendiyev intersection with traffic lights

Step 6. The graphical interface has event and animation properties. Events were processed as the bitinverse of the corresponding tag, the animation will require the actions shown in Figure 6.

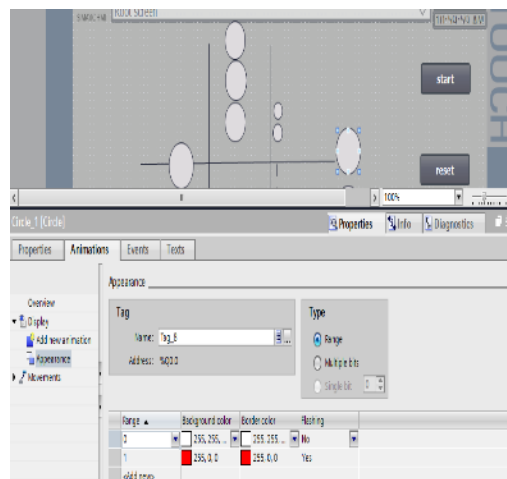


Fig. 6 Color adjustment of the selected animation object depending on the state of the tag bit of the traffic light

Step 7. After adjusting the WinCC graphic interface, it is necessary to go to the microcontroller folder and press  button to reset programs in the simulator's memory.

Step 8. After successful completion of Step 7, it is necessary to select the HMI folder and start up the simulator. As a result, the following animation will appear on the TOUCH screen (see Figure 7).

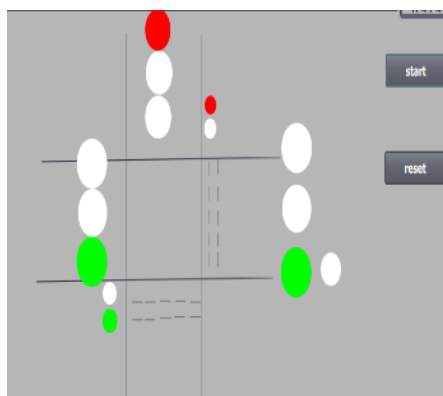


Fig. 7 Screen shot of the animation of the traffic lights operation at the Abay/Tlendiyev intersection

The obtained hardware and software system based on the S7-314 C-2 PN/DP microcontroller with the HMI TOUCH operator display adequately displays the change of traffic signals at the intersection. The software code for traffic light control and its graphic pattern can be reprogrammed. It can be adapted to any intersection with due account for traffic characteristics.

4. CONCLUSION

The performed works resulted in the creation of a prototype of the digital smart traffic light controller based on the S7-314 C-2 PN/DP microcontroller and HMI KTP 900 Basic PN display. The test animated pictures adequately reflect the information exchange between traffic lights in all time cycles. The intersection of the Almaty city was taken as a prototype. It was shown that it is more effective to use a computer device instead of a manual control panel of the DK-2 serial road controller. Information accumulated at the digital smart traffic light is saved and transferred to servers with the purpose of building an information-mathematical model for the traffic optimization in the framework of the Smart City concept.

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FEATURES OF SPACE EQUIPMENT FOR SENSING THE EARTH'S SURFACE

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Abstract— The article is devoted to the description of the features of space equipment for remote sensing of the Earth's surface. The classification of platforms for sensing the Earth's surface is also given, and the characteristic features of space equipment used to obtain various types of information are considered. The article considers the specifics of constructing systems for remote sensing of the Earth's surface.

Keywords: earth surface sensing, monitoring, earth surface research, space equipment, remote sensing, satellite equipment.

INTRODUCTION

Since ancient times, people have tried to satisfy not only physiological needs, but also spiritual, moral, and cultural ones. Human curiosity has developed exponentially. Even without realizing that the Earth is actually spherical, people were interested in its origin, composition, as well as the processes occurring on it. They were looking for answers to their questions, although they often came to a dead end. Without noticing it, people raised even more questions than they found answers. This curiosity gave rise to the totality of Earth sciences. These sciences do not subside even now, rapidly developing in the wake of technology. The development of technology is an integral process on the path of intelligent civilization. And in the 20th century, a person discovers a new environment for research, and then visits it himself. With the launch into space, new opportunities opened up for man. One of them is remote sensing of our home-planet Earth.

The term "remote sensing" means the process of collecting various information about an object, phenomenon or territory without direct contact with them [7]. This process allows us to study the properties and determine the parameters of our planet. When determining parameters, the key feature of the remote sensing method is indirection. That is, in fact, not the parameters that we are interested in are measured, but only the values that are associated with them. To decipher such parameters, it is necessary to conduct preliminary studies. These studies include various experiments and experiments on the study of the object of interest by contact methods.

Thus, the study of our home-the planet Earth from space is attributed to high technology. This is happening not only in connection with the use of high-tech technology, rocket science, complex optoelectronic devices, computers, but also with a new approach to obtaining and interpreting the results of the obtained measurements. Yes, time-consuming and resource-intensive subsatellite studies are carried out on a small area, but they make it possible to collect, analyze and generalize data over vast areas and even over the entire globe.

THE MAIN PART

Remote sensing information, as shown in Figure 1, can be obtained from various platforms. These include: aircraft, spacecraft, submarines, ships, and ground stations. Each of these platforms, of course, has its own disadvantages and advantages. I would like to immediately note some of the advantages of remote sensing of the Earth's surface with the help of space aircraft. These include: instant coverage of extremely large territories (compared to aircraft, which in turn are located at relatively low altitudes from units to tens of kilometers), the ability to track frequently changing parameters and characteristics in almost any corner of our planet, the lack of binding to state graces, the presence of geostationary devices that allow you to observe the same area throughout the entire life of the satellite and receive data at intervals of 2-10 minutes, which allows, for example, observe volcanoes and seismically active zones [1]. It is also an undeniable advantage to get information on the occurrence of natural resources and minerals that our country is rich in.

The principle of operation of remote methods is based on the fact that there is an interpretation of the results of measuring electromagnetic radiation, which is reflected or radiated by an object and recorded at a certain distance from it. Electromagnetic radiation is a disturbance of electric and magnetic fields propagating in space. In nature, electromagnetic radiation

manifests itself not only as light that we can see, but also as heat that we can feel, as well as radio waves that can be received with the help of special receivers. The propagation velocity of electromagnetic radiation is about 3×10^8 m/s².

According to the type of radiation, active and passive methods of remote sensing of the earth's surface are distinguished. Passive is a method that uses the secondary or natural radiation of the object under study. This method is often used to obtain images in the visible range, when making maps, monitoring forests [6], monitoring ships and ships [3].

The passive method refers to the method when the satellite receives a signal reflected from the Earth, but radiated by the Sun (fig. 2, b). If the satellite receives a signal of natural origin (for example, natural radiation from the Earth), then this method is also referred to as passive (fig. 2, c). A big plus is the lack of its own radiation source, because it reduces the cost of radiation and, as a result, reduces the size of batteries and solar panels. When using active methods (fig. 2, a), the equipment sends its own probing signal to the object under study, and then records its reflection from this object. The advantage of this method is that it is possible to work independently of secondary or natural radiation.

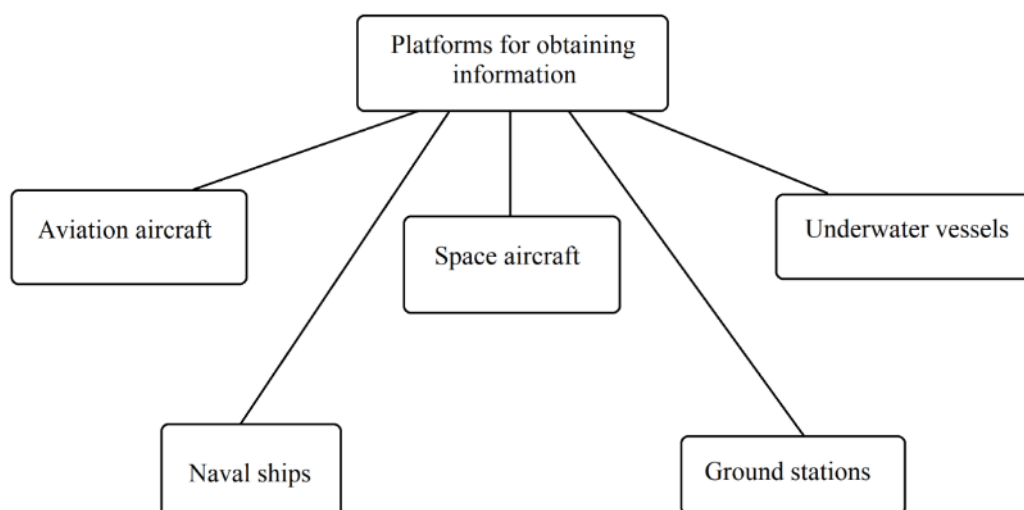


Fig. 1 Platforms for obtaining information

Many areas of life are tied to the use of satellites. Putting spacecraft into orbit is no longer a rarity, but rather an everyday occurrence. Therefore, at present, remote sensing of the earth's surface is actively engaged with the help of various types of aircraft and artificial Earth satellites [8].

In comparison with other types of equipment, space equipment for sensing the Earth's surface has some differences. The main feature can be distinguished by being in outer space. In this regard, the equipment has strict requirements for the autonomy of the power supply. Currently, this difficulty is solved by installing storage batteries, as well as installing solar panels. But this, of course, leads to significant changes in the design of the spacecraft, as well as to the complexity of the design and deployment of the spacecraft itself in orbit, which indirectly affects the reliability of the entire device.

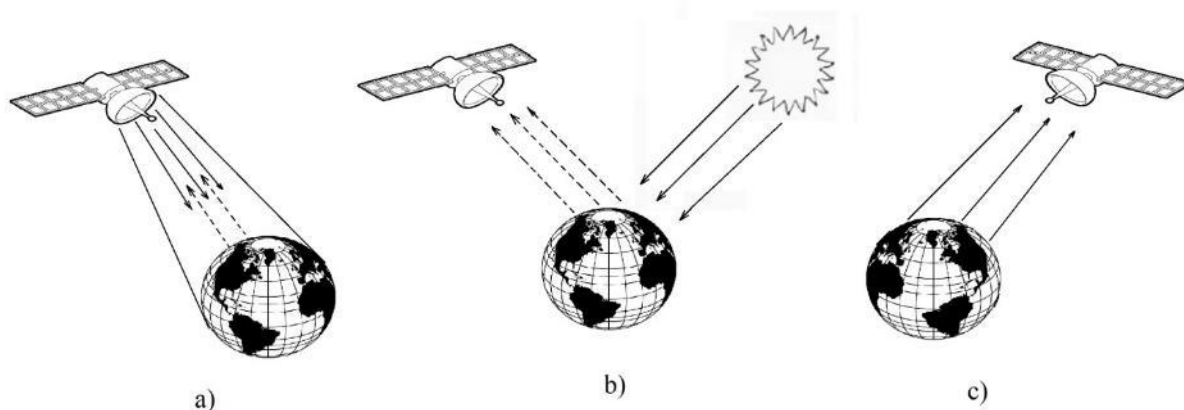


Fig. 2 Active and passive remote sensing methods

Planning, developing and launching an artificial Earth satellite into orbit is a colossal and time-consuming process of well-coordinated work of numerous groups of specially trained personnel. As a result, the cost of the equipment itself and its launch is so expensive that not all states can afford it. It is sometimes more profitable for small countries to pay for the information or data they need for research or other purposes than to put their satellites into orbit.

The high cost of development and launch imposes a limit on the minimum period of operation of an artificial Earth satellite. Depending on the purposes and accessories to different countries, the service life of satellites ranges from several units to tens of years. Because of this, there is another requirement – reliability and uptime. The requirement for the reliability of the sensing equipment is also imposed due to the fact that repairs in space are impractical, and most often impossible. In addition, outer space is an aggressive environment for the current generation of electronics. Radio-electronic means must be resistant to solar radiation, mechanical shaking and shock effects, as well as to sudden climate changes. To all this, it is also worth adding that the longer the service life of satellites, the fewer satellites of this type need to be launched into orbit per unit of time. A large number of launches negatively affects the complexity of controlling the movement of spacecraft in near-Earth space. This also creates the problem of space debris, because it is not always possible to launch a failed satellite to the surface of the planet. In addition, do not miss the fact of the formation of ozone holes in the atmosphere of our planet due to the launch of launch vehicles, which entails a deadly danger to living organisms through direct exposure to solar radiation. Thus, the issues of reliability of equipment in outer space are taken very seriously and demanding.

There are quite a lot of working and non-working objects in the Earth's orbits. They can both prevent the withdrawal of new equipment, and obscure or, even worse, be the cause of a collision of spacecraft. In this regard, there are situations when it is necessary to change the height of the satellite location. This also leads to another requirement – access to the movement control and adjustment of the aircraft.

Remote sensing systems of the earth's surface should transmit the accumulated information to ground-based data collection points in a timely manner (and sometimes even exchange data in real time)[5]. For this purpose, special radio communication channels are used. But the further away from the ground point the satellite is, the greater the loss in signal power due to the attenuation of radio waves. Thus, engineers are forced to develop equipment with high sensitivity of the receiving paths, as well as with sufficiently powerful transmitters, while observing all the requirements for electromagnetic compatibility.

Space systems for remote sensing of the earth's surface operate on the principle of interpreting measurements of electromagnetic radiation. That is, as mentioned earlier, the characteristics that need to be known are not measured directly [2], but as a result of the analysis

of the received electromagnetic signal. Depending on the frequencies at which electromagnetic waves are received, the equipment can be sensitive to various obstacles and obstacles in different ways [4]. For example, the most frequent obstacle for space equipment for remote sensing of the Earth's surface is the atmosphere of our planet. Accordingly, considerable attention should be paid to this factor when developing equipment. This also leaves an indelible mark on the list of requirements for Earth sensing systems, imposing additional requirements for line of sight. Such restrictions often apply, for example, to equipment operating in the optical range.

CONCLUSION

This article presents and discusses the main features of space equipment for sensing the Earth's surface, such as: autonomous power supply, high cost of design, launch and operation, high requirements for service life, reliability, resistance to radiation, mechanical shaking, shock, sudden temperature changes, the ability to adjust the trajectory, high sensitivity of the receiving path, transmitter power, compliance with electromagnetic compatibility, direct visibility (for systems operating in the optical range). The classification of Earth surface sensing systems based on location is also considered. The paper demonstrates some requirements for space sensing equipment.

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IMPLEMENTATION OF RECEPTION OF BROADBAND COMMUNICATION SYSTEMS WITH CORRELATORS AND MATCHED FILTERS

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Abstract— This article describes the reception of broadband signals, which is carried out with the help of optimal receivers that minimize the probability of error. It is worth noting that

the reception of broadband signals performs additional demodulation from the expanding code (pseudo-random sequence) in order to highlight the transmitted information. This is the main difference between a receiver designed to receive broadband signals from a receiver of narrow-band signals.

Keywords: telecommunication system; noise-shaped signal; synchronizer; ACF.

The main feature, noise-like signals are assigned to a separate class as signals (signals with a noise-like spectrum), lies in the fact that the spectral power of such signals in a busy band over a long observation interval is comparable to the noise power in this band or below. Although this fact in itself does not say anything about the possible complexity of detecting such signals, since the spectral power density of a signal can be quite high, it allows to separate signals as noise into a separate class. As will be shown below, noise-like signals have a number of "remarkable" properties, which, in turn, can significantly complicate their detection and recognition by conventional radio surveillance equipment based on spectral signal analysis, namely, structural energy and secrecy. In addition, as a rule, such noise-like signals have a fairly wide space, significantly exceeding the width of the message spectrum they transmit and often the bandwidth of search receivers, which also reduces the quality of their detection. The task of searching for noise-like signals consists of two interrelated parts: signal detection and signal recognition. In general, problem solving is a method that detects the presence or absence of a noise-like signal and distinguishes it from real noise in the analyzed sample. In this case, "detection" means fixing with a given probability of the presence of signs of the desired signal against the background of additive noise for a certain feature. For noise-like signals, the detection stage is necessary, but cannot be considered sufficient. Another search for noise-like signals is a "discrimination" of the detected signal. As the name of noise-like signals implies, when they are detected, false results are possible, associated with the detection of noise signals or interference similar in characteristics to the desired one. Therefore, at the discrimination stage, the detection result should be subjected to additional verification by examining the properties of the detected signal and comparing them with the properties of known noise-like signals.

The optimal is defined as the receiver that selects the most plausible sequence of characters from the received signal. The implementation of such devices is possible on the basis of correlators, or on the basis of consistent filters. The structure of the optimal receiver depends on the type of information transmitted (phase or frequency manipulation) and on the degree of "awareness" of the signal at the receiving point (coherent or non-coherent reception). But in any case, the optimal receiver includes a matched filter or correlator and a resolver. The matched filter and correlator serve for optimal reception of SHPS, and the resolver determines the symbol of the transmitted information.

First, consider processing the received signal using matched filter.

RECEIVING NOISE-LIKE SIGNALS USING A MATCHED FILTER

As an example, consider the case of receiving binary information using opposite signals (phase manipulation-BPSK). The optimal receiver (Figure 1) consists of a matched filter, a solver, and a synchronizer.

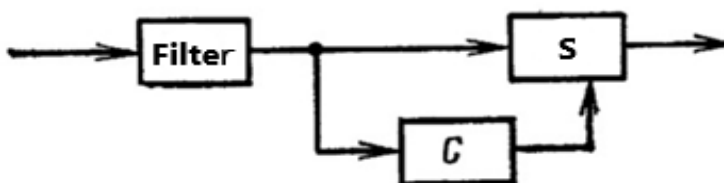


Fig. 1 Receiver structure on a matched filter

The filter is matched to a noise-like signal that carries the information. If a noise-like signal $u(t)$ is used, the pulse response of the matched filter is:

$$h(t) = au(t - T) \quad 1.1$$

a – constant, T is the duration of the noise-like signal.

For the transmission of "1" the signal $u(t)$ is used, for the transmission of "0" the reverse (opposite signal) $-u(t)$ is used. The voltage at the output of the matched filter is the autocorrelation function (ACF) of the noise-like signal with which the filter is matched. The maximum of the autocorrelation function at the output of the matched filter is:

$$V_{mf} = aE \quad 1.2$$

E is the energy of the noise-like signal.

The maximum occurs at the end of the noise-like signal. At the moment of the end of the signal, the deciding device must make a decision: which signal was transmitted $u(t)$ or $-u(t)$, that is, give a decision which information symbol was transmitted "1" or "0". But in order to make a decision at the moment of the end of the signal, you need to know the moment of arrival of the signal and the moment of its end.

In real conditions, at the beginning of a communication session, the delay time is signal is unknown, it must be measured and entered into the solver, for which the synchronizer is responsible.

The figure shows diagrams that explain the decision-making process.

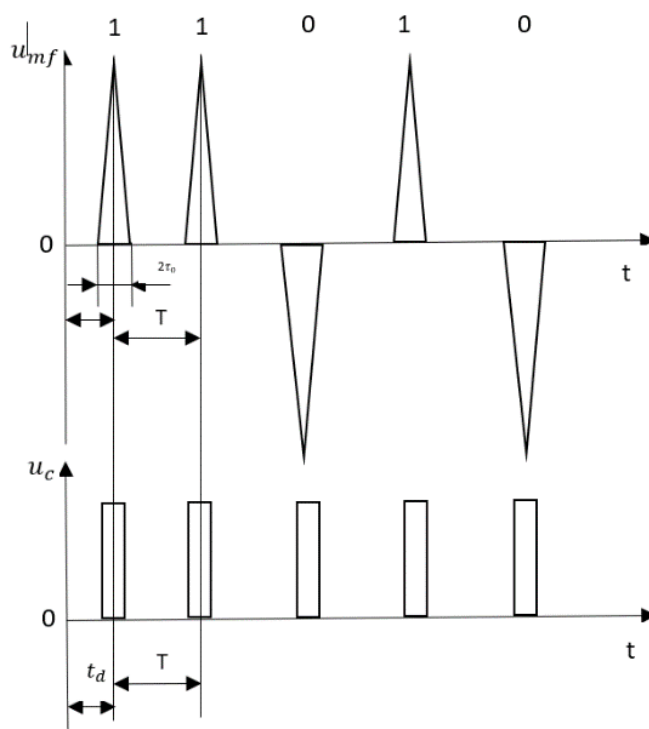


Fig. 2 Diagrams explaining the decision-making process

The voltage at the output of the matched filter is presented; it represents the sequence of the ACF signal $u(t)$ in Figure 2a. For ease of analysis, ideal ACFs are shown in the form of triangular impulses; in real conditions, the ACF will have side lobes that depend on the code sequence with which "0" or "1" are transmitted.

Since the duration of the noise-like signal is equal to T , the ACFs follow with an interval equal to T . The first ACF is delayed relative to the origin by time t_d . Therefore, the deciding

device must make a decision at times t_d , $T + t_d$, $2T + t_d$, etc. The delay time and times are measured by the synchronizer and transmitted to the solver using sync pulses (Figure 2b).

The duration of the sync pulses should be much less than the duration of the ACF peak, and the middle of these pulses should fall at the maximum of the ACF, which allows us to make a decision about the transmitted information symbol at the end of the noise-like signal.

RECEIVING A NOISE-LIKE SIGNAL USING A CORRELATOR

Now consider the correlation processing of a noise-like signal. Correlation processing is carried out in two stages:

1) Broadband modulation is eliminated. In this case, a narrow-band signal is formed, the width of the spectrum of which is determined by the modulating information message.

2) The information contained in the signal is highlighted. In this case, the usual demodulators are used.

Correlator output voltage:

$$V_{cor} = a \int_{t_0}^{T+t_0} u(t - t_d)u(t - t_0)dt \quad 1.3$$

t_d is the delay time of the noise-like signal at the receiver input;

t_0 - delay time of the reference noise-like signal in the generator relative to the origin;

a – constant;

If $t_0 = t_d$ the voltage at the output of the correlator coincides with the maximum that occurs at the output of the matched filter. But, if $t_0 \neq t_d$, then $V_{cor} \approx 0$, on the output of the correlator will no longer have a maximum. Therefore, in the correlator with an unknown delay time, it is necessary to measure it.

Figure 3 shows a diagram of the optimal receiver for receiving binary phase shift key (BPSK). It consists of multiplier, integrator, noise-like signal generator, solver and synchronizer.

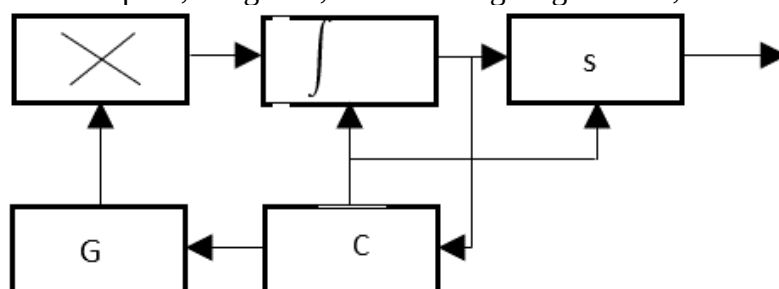


Fig. 3 The structure of the receiver on the correlator

The multiplier, integrator and generator are all correlators. The voltage at the input of the synchronizer comes from the integrator. If the measured delay time does not coincide with the true ones (the voltage at the output of the integrator does not exceed a predetermined threshold), then the synchronizer measures the delay time of the noise-like signal in the generator.

In addition, the synchronizer must ensure that the integrator is turned on and off (time point t_0 and $T+t_0$), as well as provide the supply of reference pulses to the decision device.

If the duration of the noise-like signal is T , and the duration of the central peak of the ACF is $\tau_0 = T/B$, then there are $B = T/\tau_0$ intervals of uncertainty in the delay. Therefore, in the process of receiving a noise-like signal, the synchronizer must ensure that the delay of the noise-like signal in the generator is adjusted from zero to $T-\tau_0$ with an interval of τ_0 . As soon as the delay of the noise-like signal at the input coincides with the delay of the noise-like signal in the generator, the voltage at the output of the integrator exceeds the set threshold and the synchronizer stops the process of searching for the noise-like signal and proceeds to the process of synchronizing the reference points with the moments of the end of the noise-like signal, and the resolver begins to make decisions about the symbols of the transmitted information.

It is also worth noting that according to the method of technical implementation, the correlators of the first stage of processing are divided into direct conversion correlators and frequency conversion correlators.

A feature of the matched filter is that they are invariant to the signal delay. That is, at any delay, the CA works the same way and will respond to the signal with the only difference that the moment when the signal voltage reaches the maximum at the filter output will change accordingly.

In conclusion, we can say that both receivers require a synchronizer. The main difference between the synchronizers of the two receivers is that the synchronizer of the correlation receiver must change the delay of the noise-like signal in the generator, and the search process in the correlation receiver is carried out by viewing all the uncertainty intervals. Therefore, the search time for a noise-like signal in the correlation receiver can be B times longer than the search time when using a matched filter. With large noise-like signal bases, such an increase in the search time for a noise-like signal may be excessive, and therefore it is necessary to apply faster search methods. At the same time, consistent filters on large databases are very complex devices and their implementation is difficult. Therefore, in practice, combined methods of reception are used.

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METHOD AND MEANS OF OPTIMIZING THE LAYOUT OF ELEMENTS IN ELECTRONIC MEDIA

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This paper describes the process of analyzing thermal research and creating an optimization algorithm based on the method of branches and boundaries of the layout of elements in electronic means. Optimization of the layout will improve the quality and reliability of the designed electronic devices.

Keywords: electronic means, temperature regime, optimization solutions, optimization method, optimization algorithm, means of optimizing the layout of elements.

INTRODUCTION

Due to the great complexity of modern electronic means (EM), it is necessary to automate the tasks of placing, tracing, calculating thermal modes, and electromagnetic interaction of components on a printed circuit board (PCB). Along with the increase in the volume of the designed schemes, the requirements for their quality also increase. The quality problem has been around for a long time, but only in recent decades have solutions appeared that allow us to implement it more effectively.

The designs of modern electronic devices are subject to quite high requirements for technological efficiency and operational characteristics. These are: the maximum density of the installation of elements, strict restrictions on weight and dimensions, ensuring high specific heat

generation, a high degree of stability of the characteristics [1]. The correct solution to this problem will ensure the high reliability of the designed electronic means.

The optimal design solution is called, in which the best values of the technical and economic indicators of interest are achieved. The indicator, the value of which allows us to conclude that the solution is optimal, is called the optimization criterion. As optimization criterion in this work has been selected temperature regime, which is characterized with a set temperature of individual points on the temperature field and is generated as an external thermal environment and thermal energy, emitted by the elements most PCB [2]. The temperature regime affects the reliability of the ES. Reliability refers to the property of electronic devices to keep the values of all parameters in time and perform the required functions under the specified application conditions. An increase in temperature increases the failure rate of electronic components and causes accelerated aging of structural materials [3, 4].

METHOD FOR OPTIMIZING THE LAYOUT OF ELEMENTS ON A PRINTED CIRCUIT BOARD OF ELECTRONIC DEVICES

The problem of element placement is one of the main tasks of the design stage of electronic devices and consists in determining the optimal spatial arrangement of elements on the switching field. The models used for optimization contain characteristics that need to be changed to achieve the goal. Improper placement of electrical components on the printed circuit board can lead to hot spots and damage to the electrical assembly. To avoid this, it is necessary to calculate all the characteristics of the radio components connected to each other on the printed circuit board, study the actual temperature values and compare them with the maximum permissible values. In particular, it is necessary to create and use methods to optimize the components on the printed circuit board in order to guarantee the durability of the electrical components and achieve maximum reliability. The block diagram of the proposed method for optimizing the layout of elements on a printed circuit board of electronic devices is shown in Figure 1 [5].

Figure 1 shows the procedure for developing a method for optimizing the placement of elements on printed circuit boards of electronic devices. When implementing the individual stages of the proposed method, specialized computer-aided design systems are used to synthesize the schematic diagram of the device and calculate the parameters of the elements, simulate the various modes of the developed PCB node and calculate the output characteristics. The next step is to develop an algorithm for finding the optimal layout of thermal elements, taking into account their output characteristics, for evaluating and solving layout optimization problems.

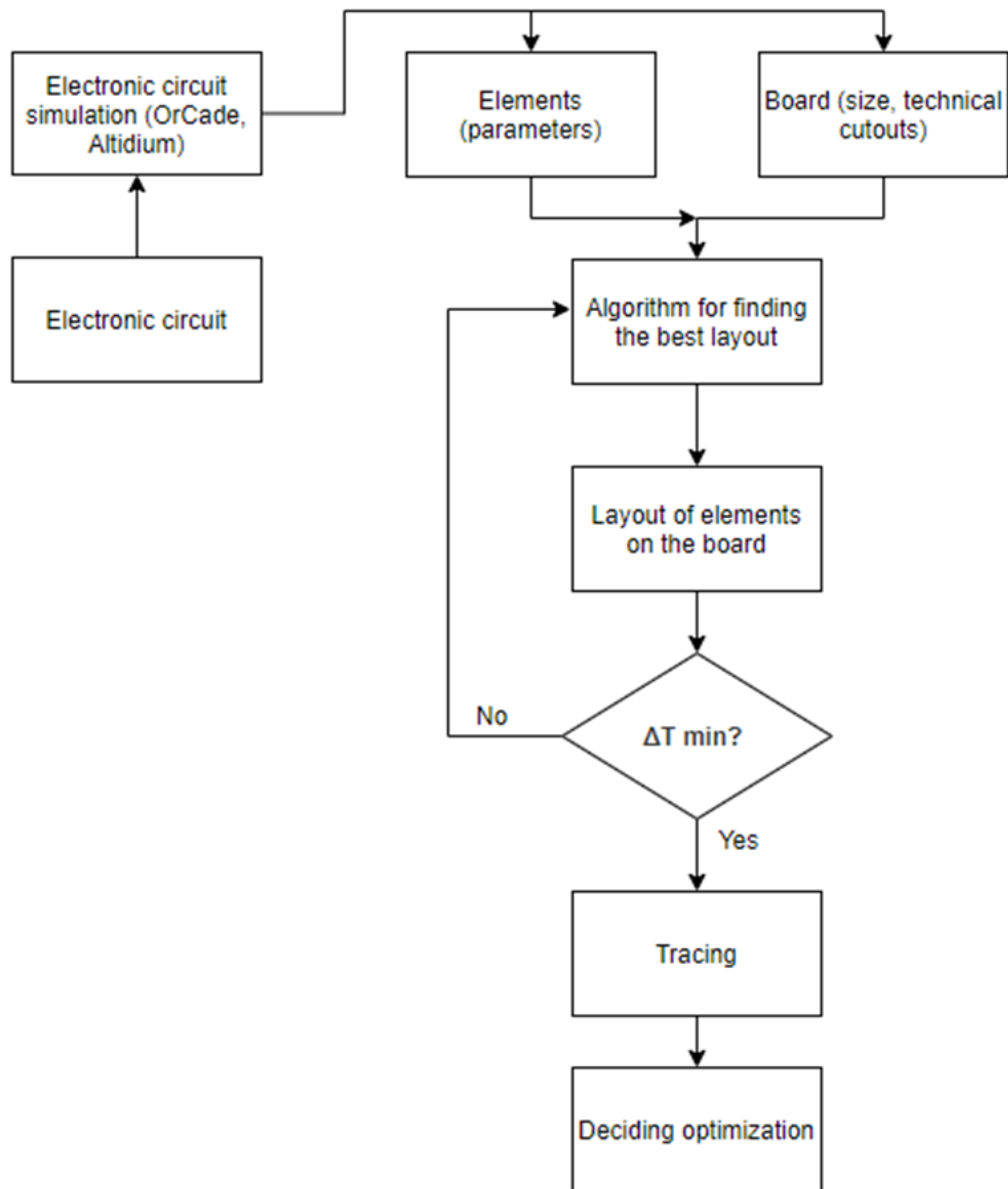


Fig. 1 Block diagram of the method for optimizing the layout of elements on the PCB EM

The main tasks of design are the tasks of layout (breakdown), placement and tracing, which are solved based on the results of circuit design. The entire set of placement algorithms can be divided into the following main groups, shown in Figure 2.

The groups of constructive and iterative algorithms include approximation algorithms, mainly designed to optimize the placement of elements in a fixed set of positions.

Iterative algorithms use the general ideas of sequential approximation methods, which are combinatorial analogues of gradient optimization methods. For these algorithms, you must specify the initial placement option. Iterative algorithms are used to solve the placement problem with different optimality criteria $F(p)$: total length of connections, total number of intersections of connections, etc.

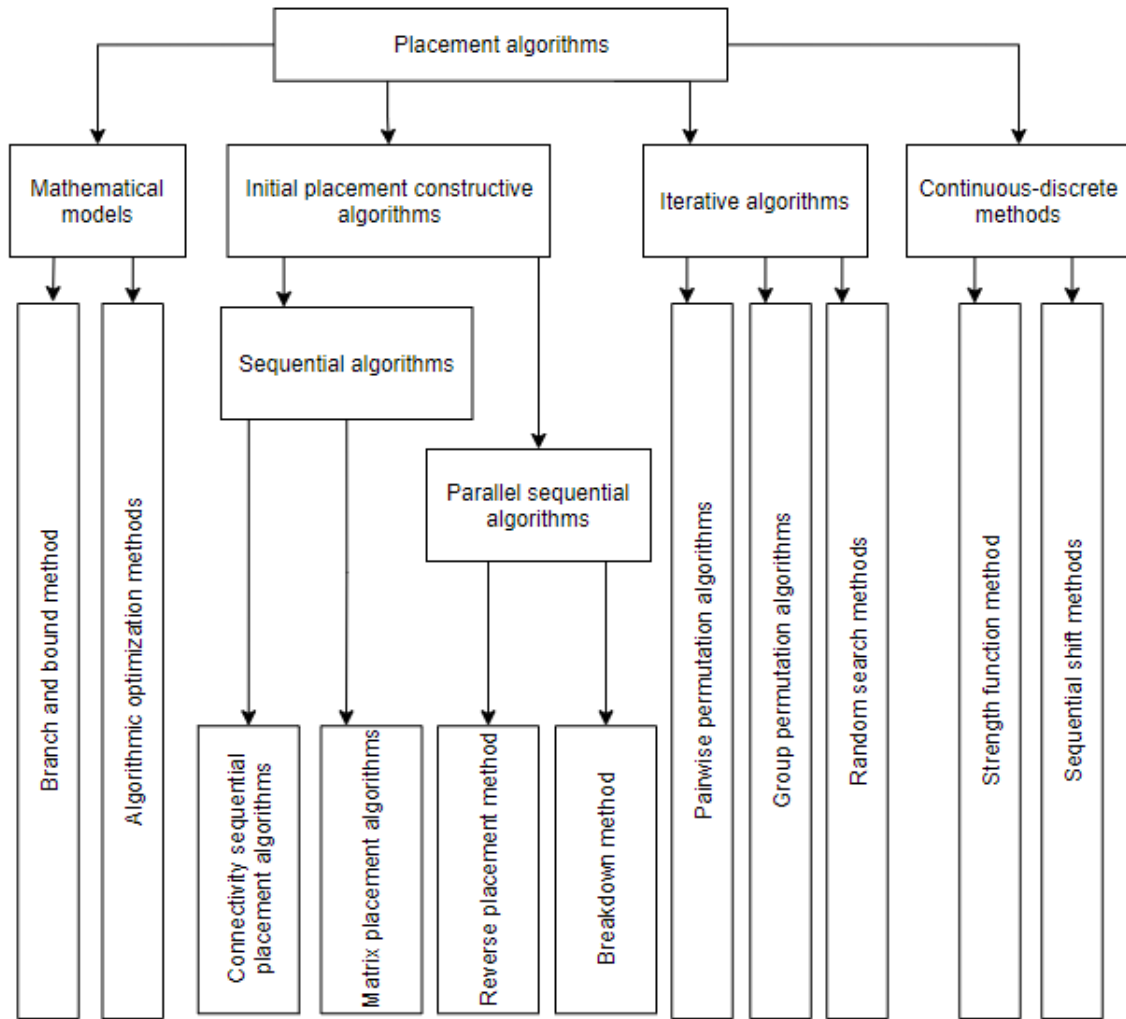


Fig. 2 EM placement algorithms

For continuous-discrete placement methods, the definition of a fixed set of positions is optional: the elements are placed on a continuous plane. This solution is of the greatest interest for a structure containing elements of different sizes. Examples are solid-state and hybrid integrated circuits, single-sided printed circuit boards with mounted elements, etc. At the same time, these methods can be used to solve placement problems in which the positions of the elements are fixed. In this case, the solution obtained by the continuous method is considered as an approximation to the solution of the corresponding discrete problem.

The process of placing elements usually involves two steps:

- the solution of the continuous problem;
- transformation of this solution to a discrete set of positions.

The group of mathematical models is included, primarily, the method of branch and bound for quadratic assignment, which simplistically reduced location problem: a set of position is fixed, the elements are treated as geometric points, the scheme of connections are given a weighted graph.

STATEMENT OF THE PROBLEM OF THERMAL ANALYSIS

The temperature rise of the elements of the printed circuit Board is connected, on the one hand, with the increase of ambient temperature, and on the other by heat due to power dissipation

elements in their work. If in devices based on electronic lamps and semiconductors, 1cm^2 of the area dissipates power of 0,03-0.5W under certain conditions, then in modern microelectronic technology this dissipation usually reaches 6 - 60W/cm². Therefore, the placement of the elements should only take into account the thermal analysis of the printed circuit board.

To calculate the thermal models of the PCB elements, we assume that the air temperature in the channels between which the PCB is located is known. The PCB elements exchange radiant energy with neighboring elements located on the PCB. The P elements are also cooled by convection in the air in the channels between the boards. Part of the heat generated by the PCB element heats it up.

The heat released by the PCB element is carried away by the air and the radiant flow, and is also transmitted to other elements of the printed circuit board through the thermal conductivity of the material. Therefore, to find the parameters of the thermal coupling between the PCB elements, it is necessary to take into account: conduction (thermal conductivity), convection and radiation (radiation) [6].

For an arbitrarily selected PCB element, we can write the heat calculation equation (1):

$$P = P_{cond} + P_{luch} + P_{conv}, \quad (1)$$

where P_{cond} – is the amount of heat transmitted through the PCB, P_{conv} – is the amount of heat dissipated by convection, P_{luch} – is the amount of heat radiated by one PCB element relative to another.

BUILDING A MODEL OF AN ALGORITHM FOR OPTIMIZING THE LAYOUT OF ELEMENTS USING THE BRANCH AND BOUNDARY METHOD

The use of the branch and boundary method in solving the problems of placing electronic components on the PCB allows us to find the global extremum. To formulate an exhaustive optimality criterion, we combine the considered thermal models of elements.

The main idea of the method is based on the sequential partitioning of the set of possible solutions into subsets. At each step of the method, the partitioning elements are checked to find out whether a given subset contains the optimal solution or not. The check is performed by calculating the lower bound of the objective function on a given subset. If the lower estimate is not less than the record of the best of the solutions found, then the subset can be discarded. The subset under test can also be discarded if a better solution can be found in it. If the value of the objective function on the found solution is less than the record, then the record is changed. At the end of the algorithm, the record is the result of its operation [7].

Methods for calculating the lower bounds of the functional for partial placements of q . The first term in equation (2) is expressed in terms of $w(p)$, the second in terms of $v(p)$:

$$F(p) = w(p) + v(p), \quad (2)$$

A particular placement q , we will call the assignment of the elements of the set $E_k = \{e_1, \dots, e_i, \dots, e_k\}$ in the position of the set $L_k = \{l_1, \dots, l_j, \dots, l_k\}$ in accordance with the rule $j=q(i)$, $k \leq n$.

The lower bound for $F(p)$ is obtained by summing the lower bounds for $w(p)$ and $v(p)$.

The formula for calculating the lower bound of $F(p)$ based on the branch and bound method, with the added calculation of the thermal coefficient, will look like this (3):

$$F(p) = F(q) + w_q(q) + v_q(p) + u_q(p) + K_{ij}, \quad (3)$$

where K_{ij} - is the thermal coefficient.

The thermal coefficient is obtained by adding all the types of heat exchange of the p_{ij} element with neighboring elements of the printed circuit board. The basic formula for calculating the thermal coefficient of a printed circuit board element will look like this (4):

$$K_{ij} = k \times \sum_{i=i-1}^{i=i+1} \sum_{j=j-1}^{j=j+1} Q_{cond} + Q_{luch} + Q_{conv}, \quad (4)$$

where k - is the weighting factor of heat in the calculation of the lower limit (0 – 100%), necessary to adjust the influence of the thermal coefficient for the lower bound (3).

The use of an optimization algorithm layout of elements on the basis of the method of branches and borders taking into account the thermal coefficient will improve the reliability of electronic tools, and avoid overheating.

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EVALUATION OF THE DEPENDABILITY INDICATORS OF THE RESTORED EQUIPMENT BY THE SIMULATION METHOD

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Abstract - The report discusses the application of simulation modeling to dependability prediction of the restored equipment. A formal model is described that allows forming time diagrams of the states of both the components and the equipment as a whole. It is shown that the use of such a model allows us to estimate the availability function and the mean restoration time of the equipment if the law of the distribution of the restoration time of the components differs from the exponential one.

Keywords - equipment, dependability, availability function, mean operating time between failure, mean restoration time, statistical modeling.

INTRODUCTION

Consider the of the dependability prediction of the restored equipment under the following conditions, assumptions and restrictions:

- RBD - "Serial connection of the Component Part (CP)";
- failures and recoveries of the CP - independent events;
- when restoring one CP, the remaining CP remain in loaded mode;
- the time-to-failure distribution law of the CP (t_{Fi}) is exponential with the parameter λ_i ;
- the law of the distribution of the recovery time of the CP (t_{Ri}) - exponential with the parameter

μ_i .

In this case, the Mean Time To Restoration (MTTR) of the equipment (T_R) is calculated according to the standard formula [1]:

$$T_R = T_F \cdot \frac{1 - K_A}{K_A}, \quad (1)$$

where

$$T_F = \frac{1}{\sum_{i=1}^I \lambda_{O_i}}, \quad K_A = \prod_{i=1}^I K_{A_i},$$

where

$$K_{A_i} = \frac{T_{F_i}}{T_{F_i} + T_{R_i}}, \quad T_{F_i} = \frac{1}{\lambda_{O_i}}, \quad T_{R_i} = \frac{1}{\mu_i},$$

where T_F is the Mean Time To Failure (MTTF) of the equipment; K_A is stationary availability function; λ_{O_i} is operational failure rate of the i -th CP; I is the number of CP in the RBD; K_{A_i} is stationary availability function of the i -th CP; T_{F_i} is MTTF of the i -th CP; T_{R_i} is MTTR of the i -th CP; μ_i is the restoration time of the i -th CP.

PROBLEM STATEMENT

However, Data Sheet for CP lead maximum allowable restoration time (T_{Rmax}) - deterministic value, mean time to repair CP (T_{Ri}), including tolerance to it ($T_{Ri} \pm \delta_i$) or the time interval [T_{Rie} , T_{Riu}]. In the last two cases, the standard [2] recommends using a truncated normal distribution to calculate the probability of recovery of parts (P_{Ri}):

$$P_{R_i} = \frac{C_i}{\sqrt{2 \cdot \pi}} \cdot \int_{T_{R_{iE}}}^{T_{R_{iU}}} e^{-\frac{[t_{B_i} - m(t_{R_i})]^2}{2 \cdot \sigma(t_{R_i})^2}} dt_{R_i} \quad (2)$$

where C_i is the normalizing coefficient; $m(t_{Ri})$ and $\sigma(t_{Ri})$ are the distribution parameters.

Obviously, if the distribution of t_{B_i} differs significantly from the exponential one, then the use of the standard [1] for calculating T_B can lead to an error, the value of which is difficult to estimate.

SOLUTION OF THE PROBLEM

At the same time, the standard [3] states that "The universal method of calculation ... is the method of statistical modeling". Therefore, we will consider the possibility of using this method to calculate the T_R , or rather, a formal model for obtaining the implementation of the process of functioning of the restored equipment during the time t_F for the above RBD with independent restoration of CP during which the remaining CP remain in operation [4, 5]. As the value of t_E , we take the service life of the equipment.

It is obvious that at $t_E=0$, the probability of failure-free operation of each CP (P_i) is equal to 1, and, consequently, $K_{A_i}=1$. However, let's assume that for $t_E=0$ $K_{A_i} \neq 1$, and their values are calculated by the formula:

$$K_{A_i} = \frac{T_{F_i}}{T_{F_i} + T_{R_i}}. \quad (3)$$

Note: it is possible to perform the calculation even if $K_{A_i} = 1$.

As a result, you can form an array of $K_{Acp} = [K_{A1}, K_{A2}, \dots, K_{Ai}, \dots, K_{AI}]$, which is necessary to determine the states of the CP at the initial time (running or recovering) for each simulation experiment, which is determined from the condition:

$$l_i = \begin{cases} 0 & \text{by } x > K_{A_i} - \text{mode of restored} \\ 1 & \text{by } x \leq K_{A_i} - \text{operating mode} \end{cases}, \quad (4)$$

where x is the implementation of the Base Random Variable (BRV).

Next, the implementation of its Time State Diagram (TSD) is calculated for each CP.

If at $t_E=0$ $l=1$, then the implementation of the operating time (t_O) is calculated. For example, for an exponential distribution:

$$t_O = -\frac{\ln y}{\lambda}, \quad (5)$$

where y is the implementation of the BRV.

Then the total time $t_\Sigma=t_O$ is calculated and the condition is checked:

$$t_\Sigma \geq t_O \quad (6)$$

If condition (6) is satisfied, then the implementation of the TSD has the form shown in Fig. 1.



Fig. 1 Implementation of the TSD CP

If condition (6) is not met, the implementation of the recovery time (t_R) is calculated. For example, for an exponential distribution:

$$t_R = -\frac{\ln z}{\mu}, \quad (7)$$

where z is the implementation of the BRV.

Then the total time $t_\Sigma=t_O+t_R$ is calculated and condition (6) is checked. If condition (6) is satisfied, the implementation of the TSD has the form shown in Fig. 2.



Fig. 2 Implementation of the TSD CP

If condition (6) is not met, then a new implementation of the operating time is calculated, t_Σ is calculated, condition (6) is checked, and so on, until condition (6) is met. In this case, the implementation of the TSD will have the form shown in Fig. 3.

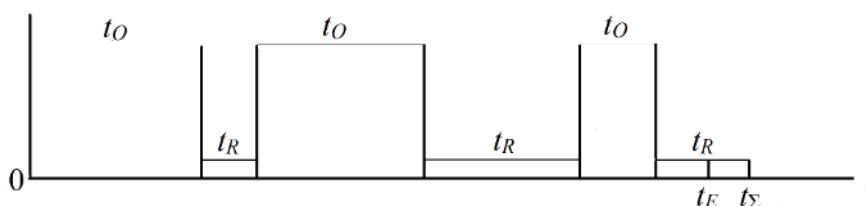


Fig. 3 Implementation of the TSD CP

If at $t_E=0$ $l=0$, then the implementation of the recovery time (t_R) is first calculated, and then the TSD of the midrange is constructed in the way discussed above.

After calculating the TSD implementations for all CP, the TSD implementation for the equipment is calculated by sequentially "superimposing" the TSD (see Fig. 4).

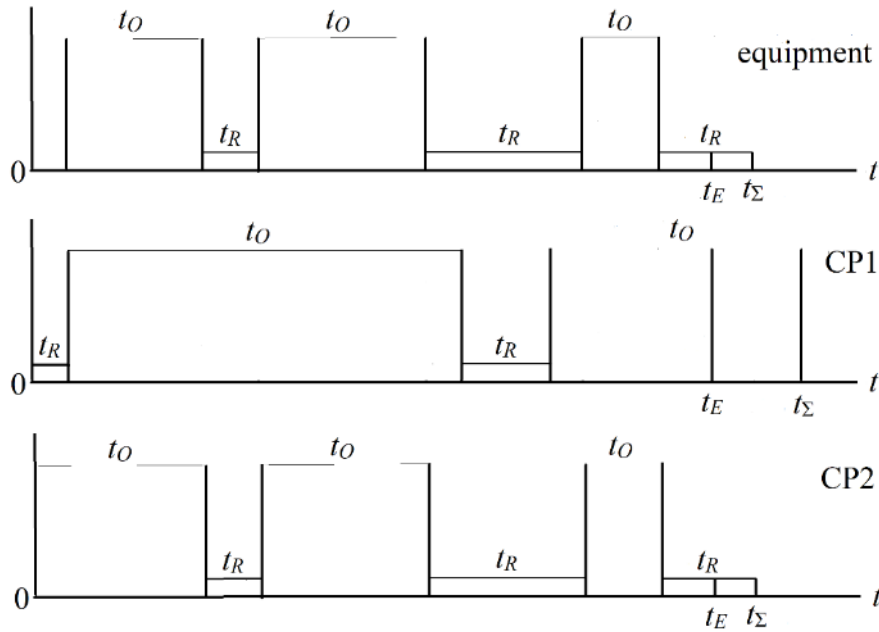


Fig. 4 Implementation of the TSD equipment

As can be seen from Fig. 4, t_{Σ} of the equipment is equal to the minimum value of t_{Σ} of the TSD of the midrange.

After calculating the implementation of the TSD of the equipment, the MTTF of the equipment (T_{Fn}) in this simulation experiment is calculated:

$$T_{Fn} = \frac{1}{J_n} \cdot \sum_{j=1}^{J_n} t_{O_{n,j}}, \quad (8)$$

where J_n is the number of intervals in which the equipment is in operation (see Fig. 4); n is the number of the simulation experiment.

And also the value of R is calculated:

$$R = \begin{cases} R, & \text{if } T_{Fn} = 0 \\ R+1, & \text{if } T_{Fn} > 0 \end{cases} \quad (9)$$

Similarly, the MTTR of the equipment (T_{Rn}) in this simulation experiment is calculated:

$$T_{Rn} = \frac{1}{K_n} \cdot \sum_{k=1}^{K_n} t_{R_{n,k}}, \quad (10)$$

where K_n is the number of intervals in which the equipment is in recovery mode (see Fig. 4); n is the number of the simulation experiment.

The value of S is calculated:

$$S = \begin{cases} S, & \text{if } T_{Rn} = 0 \\ S+1, & \text{if } T_{Rn} > 0 \end{cases} \quad (11)$$

In addition, the value of m is calculated:

$$m = \begin{cases} m, & \text{if at } t = t_E \text{ the equipment is being restored} \\ m+1, & \text{if at } t = t_E \text{ the equipment is working} \end{cases} \quad (12)$$

After performing all simulation experiments, the MTTR of the equipment is calculated:

$$T_R = \frac{1}{S} \cdot \sum_{s=1}^S T_{R_s}, \quad (13)$$

The MTTF of the equipment is calculated in the same way:

$$T_F = \frac{1}{R} \cdot \sum_{r=1}^R T_{F_r}. \quad (14)$$

The equipment availability function is calculated:

$$K_A(t = t_E) = \frac{m}{N}. \quad (15)$$

The stationary availability function of the equipment is calculated by the formula:

$$K_A = \frac{T_F}{T_F + T_R}. \quad (16)$$

CONCLUSION

Thus, the above is a formal model for the formation of TSD implementations of CP and equipment as a whole, which allows you to calculate the reliability indicators of the restored equipment with a "sequential" RBD, in which failures and recovery of CP are independent events and when restoring one CP, the remaining CP remain in the loaded mode.

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DIGITAL ENVIRONMENT OF THE UNIVERSITY

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Annotation – The article examines the features and issues of organizing distance learning for students in Russian universities based on the use of the digital environment. In the context of a viral pandemic and a general transition of distance learning students, the administration and university professors design the most optimal technical and software solutions that contribute to the development of network, telecommunication forms of organizing education with limited opportunities for movement. The main problems arising in distance learning are considered. The efficiency of using the digital environment at St. Petersburg State University is shown.

Keywords: organization of distance learning, digital environment, students, Internet services

Today, the concepts of «digital society», «network learning», «electronic educational environment» have become integral parts of our life. The digital environment of the university in the context of universal distance learning associated with the spread of coronavirus infection is an important link between sources of information services and consumers of educational resources. The digital environment includes organizational and methodological support, computer technology, educational models [1], telecommunications and information technologies [2].

The viral pandemic, which began in early 2020, accelerated the transition of Russian universities to the use of new forms of distance learning for students [3], based on the use of secure online and electronic forms of implementation of educational programs using educational content management systems (LMS platforms) based on subject databases and information and telecommunication networks [4]. According to the recommendations of the Ministry of Science and Higher Education of the Russian Federation, in 2020 most universities of the Russian Federation quickly and painlessly switched to a fully networked and distance learning regime.

The key properties of the digital society are:

- 1) widespread use and promotion of electronic (digital) services [5];
- 2) operational implementation of models of business ideas in various subject areas [6];
- 3) high-quality communication between organizations, companies, authorities and citizens in electronic form;
- 4) the use of network platforms for organizing distance learning and independent work of students [7].

In the context of universal distance education, it is necessary to master all elements of digital educational technologies of the digital environment:

- 1) educational methodological system, considering the formation of learning objectives [8];
- 2) digital educational resources;
- 3) technical implementation of the learning environment;
- 4) specialized training and development of the teaching staff;
- 5) automation of management of an educational organization.

Currently, the following are in demand: 1) training simulators with remote access, especially relevant for students of medical and technical specialties [9];

2) educational tools based on geographic information systems, useful for students of logistics, transport specialties;

3) complex expert training systems and knowledge bases with remote access for complex specific specialties;

4) training systems based on virtual reality for students in creative areas of training.

The technical implementation of the learning environment is regulated by methodological recommendations [10] for updating the material and technical base, including the basic requirements:

1) the availability of modern computer technology, the necessary licensed software, equipment for the demonstration of training videos and presentations in the computer classes of general educational organizations;

2) provision of educational organizations with information and telecommunications infrastructure, video surveillance systems, local area networks, structured cable systems.

Specialized training and development of the teaching staff, considering the active introduction of distance educational technologies, presupposes advanced training in the creation and management of methodological, substantive, technological provision of an electronic educational environment for the full-fledged remote implementation of educational programs.

The organization of remote classes with students online using distance learning technologies includes the use of:

1) platforms for organizing video conferencing (Moodle, Discord, Google Hangout, Google Meet, Hangouts, Zoom);

2) programs for preparing presentations, cutting videos, creating collages and infographics (Canva, Snapseed, PicsArt, YouCut);

3) services for organizing discussions using instant messengers and social networks;

4) tools for general use and editing of performed tasks and reports.

In this regard, there is a need to find out the degree of teachers' readiness to work with distance learning technologies, the availability of knowledge and skills in the field of practical distance learning, which includes the experience of using modern gadgets, electronic communications, software and Internet resources.

To increase the efficiency of the knowledge transfer process and the level of their reliability in each university, it is necessary to use an automated system for managing the educational process. Automation of management of an educational organization allows you to solve a number of problems:

- 1) creation of a unified database of the teaching staff of the university and the contingent of students;
- 2) automation, standardization of workflow, transition to electronic office work;
- 3) prompt open access to up-to-date information of all participants in the educational process;
- 4) a qualitative and comprehensive analysis of the state of the educational process.

At St. Petersburg University, the digital environment includes:

- 1) an automated educational process management system;
- 2) official sites, official communities, pages on social networks, through which you can get access to up-to-date information, personal account, portfolio, electronic libraries, electronic educational resources, work programs and teaching materials for all disciplines taught at the university.

Due to the full provision of the digital environment and the necessary material and technical base, the university quickly switched to a distance learning format back in March 2020. With the transition to blended learning, the functions and capabilities of the teacher's and student's personal account have been expanded:

- 1) attaching a link to a service (platform) for conducting video lectures;
- 2) adding additional teaching material for students of the entire group or course;
- 3) exchange of operational messages with the ability to attach files by students to check and evaluate the work performed;
- 4) self-notice by students about attending classes in an electronic journal;
- 5) students' requests for retaking disciplines, re-examinations, filling out and closing the electronic statement by the teacher;
- 6) close communication with the curators of study groups; 7) online participation in various conferences, seminars, Olympiads, asset schools, open days, creative events.

The system makes it possible to simplify the transition to distance learning for students and teachers, to ensure control by the administration over the quality of teaching by teachers, to increase the transparency and comfort of training. In the course of working with students in the context of distance learning, the online service Slack is actively used, which helps to organize operational communication between all participants in the educational process in the form of group conversations with the ability to connect many additional online tools and the ability to synchronize with all connected devices.

Before the start of the practical lesson, students take questionnaires in a playful way with a competitive effect in the Kahoot! Program, which motivates students to repeat the material they have covered and receive additional points and bonuses.

The services Miro and Google.com are used to structure teaching materials and store them in the cloud. The distance learning system of St. Petersburg University provides full access to work programs and educational and methodological materials, however, the Miro service, as a large virtual canvas, inside which various teaching materials are located, is convenient to use online to organize joint work with students. In addition, the Internet tool Miro includes the functions of tracking the activity of students, which ensures the collection of a "digital footprint" on the changes made by them on a common board in real time (fig. 1).



Fig. 1 Board Miro

For the joint implementation of project work [11], which ends the semester, the Yougile program is used, in which all project activities are presented on familiar boards for acquaintance with urgent tasks, as in Trello and by connecting a chat, as in Telegram. The finished report can be displayed in the form of a Gantt chart, which allows you to see the general progress of the process (start and end dates of tasks, work sequence) performed by team members and manage them through clarity.

In the context of the universal transition of university students to distance learning, the importance of the development of digital educational technologies is increasing dramatically. This is the use of a variety of educational models [12], elements of gamification, methods of collecting a digital footprint, the introduction of a digital environment, including an educational methodological system, digital educational resources, technical implementation of the learning environment, specialized training of teaching staff and, accordingly, automation of educational organization management.

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ELECTRONIC EDUCATIONAL RESOURCES FOR STUDENT DENTISTS

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Annotation – An approach to the formation and uses of educational resources in the context of distance learning for dental students of a medical university, based on the use of modern software solutions

Keywords: distance learning, Course Designer, electronic educational resources, dental students, electronic testing, software solutions

Teachers and students of universities in the context of the transition to mixed and distance learning in connection with the spread of viral infection [1] faced the need to revise some of the forms, methods and tools used in the educational process in the formation and use of electronic educational resources, which are actively used by all participants in the educational process:

- 1) teachers;
- 2) specialists of educational authorities;
- 3) students in classroom / online classes and in self-preparation;
- 4) tutors;
- 5) mentors;
- 6) developers of teaching materials [2].

Collections of electronic educational resources include a variety of teaching materials (text laboratory workshops, presentations, audio and video lectures), thematic encyclopedias, software for supporting educational activities and organizing the educational process.

At the Department of Dentistry, in the context of distance learning, the development of educational modules and monitoring the effectiveness of the educational process for dental students, graduate students and staff who improve their qualifications is carried out using the software «1C: E-learning. Course Designer».

Constantly improving training system «1C: E-learning. Course Designer» together with the «teacher's and student's web office», developed on the «1C: Enterprise 8» software platform for control and learning, covers several levels of knowledge and makes it possible to create collections of electronic educational resources. The developed methodological training materials, formed by modules, allow you to constantly update the training material, maintaining the organization of the educational process in an updated state with the ability to conduct the necessary control of knowledge and competencies.

The teachers of the department have developed training courses:

- «Dental literacy and oral hygiene» [3];
- «Comprehensive diagnostics and prevention of the state of oral hygiene» [4];
- «The use of additive technologies in the medical field» [5].

Multi-user access to the electronic educational resource gives the teacher the opportunity, through his personal account, to develop multivariate scenarios for the formation of scientific material.

In the Course Builder, tests have been developed with the ability to mix questions from several topics in random order with multimedia inserts, illustrations, diagrams and pictures. When compiling tests of the entrance control of knowledge, popular types of questions are used according to the principle of choosing the correct sequence, choosing one of many or many of many, the principle of correspondence with the setting of time and a certain number of attempts.

The current control of students of dentistry with a list of the implementation of certain actions using 3D graphic models makes it possible to test the skills and abilities of their implementation. This is possible when developing a simulation script using the extended content of the question form in the "Advanced" tab, as well as when developing interactive questions using HTML, JavaScript tools.

For students - future dentists, the very process of modeling the movement of teeth is of interest. For example, 3D Smile is an aligner system that combines the functionality of braces and ultra-precise 3D modeling and 3D printing technologies. It consists of a series of orthodontic transparent aligners, made for each person according to individual measurements. 3D aligners gradually, comfortably and imperceptibly align the teeth. Each of them is a copy of the teeth, but with a more even position. In the classroom, students study technologies for manufacturing aligners using various innovative technologies (fig. 1).

Upon completion of testing, the teacher will be able to automate the testing of students' practical skills and assess the correctness and sequence of performing certain actions in specialized graphic programs, for example, 3D modeling of aligners [6].

Created courses and tests, if necessary, can be published according to the SCORM-2004 standard for transfer to a third-party DO system, in *.html format for viewing in a browser or in *.xml format for placement in the «Examiner» or «Corporate University» systems.

Implementation of new forms of education and control in the context of distance learning with «1C: E-learning. Course Designer» allowed teachers to collectively develop courses, thereby reducing the time of their creation, forming a unified creative learning environment for both students and teachers in connection with the transition from the traditional learning model to multilevel educational models of learning [7], [8].

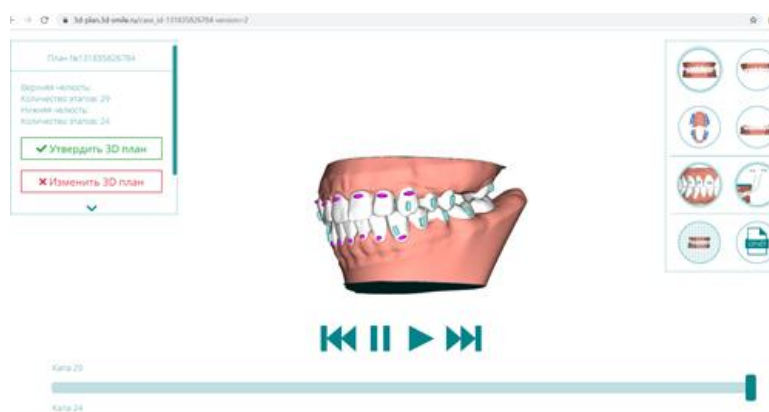


Fig. 1 3d-smile program window

The criterion for assessing the effectiveness of distance learning among dental students is the competent use of information technologies in the educational process, which affect the development of search and creative activities, activates the ability to self-organize when studying the material, the ability to independently make management decisions in future professional activities.

Future dentists, using a remote team form of work, carry out project activities [9], namely, the search for the necessary text information, video materials, scientific articles, on the basis of which they develop presentations and create their own mini-video films on the given topics: «Programs for 3D modeling in orthodontics and other branches of dentistry», «3D diagnostic methods in orthodontics», «Modern orthodontic appliances», «Scanning tools for the manufacture of aligners», «Equipment for the full cycle of manufacturing orthodontic aligners», «Digital dentistry». The material, competently developed by teams of students, under the guidance of the teachers of the department, is entered into the electronic library of the department. To manage teamwork remotely, students use software solutions such as Redbooth, Basecamp, Trello, YouGile, Asana, Podio, Microsoft Teams, Slack, Wrike, Roadmunk and others.

Surveys and questionnaires of students at the end of each module show the effectiveness of using this form of training, in which students independently create demonstration training materials for each module of the discipline being studied.

In addition, in the context of distance learning, the use of specialized software systems in the educational process is of particular importance. In particular, the BIT. Management of the medical center of the «1C» company is designed to automate the financial, operational accounting of medical activities of commercial medical centers, multidisciplinary, specialized medical institutions (dental, ophthalmological clinics, narcology) and other healthcare organizations. Using this software solution, students work with a scheduling calendar, registering potential patients for appointments, selecting and calculating the necessary dental services, drawing up work schedules for employees, and studying marketing tools.

Electronic educational resources created on the «1C: E-learning platform. Course Designer» provide the opportunity to continuously update the methodological support of the educational process with relevant information, improve the quality of training for future dentists based on a combination of innovative pedagogical, medical and information technologies, provide prompt open access to relevant information for all participants in the educational process with the possibility of a qualitative and versatile analysis of the state of the educational process in the context of distance learning.

Using information technology in practice, students, when creating electronic educational resources, gain skills in working with software solutions for image processing and video cutting (Snapseed, PicsArt, YouCut), creating presentations (Prezi, MS Power Point), mind maps

(MindMeister, Coggle) , advertising products (Canva, MS Publisher), websites (Wix, WordPress).

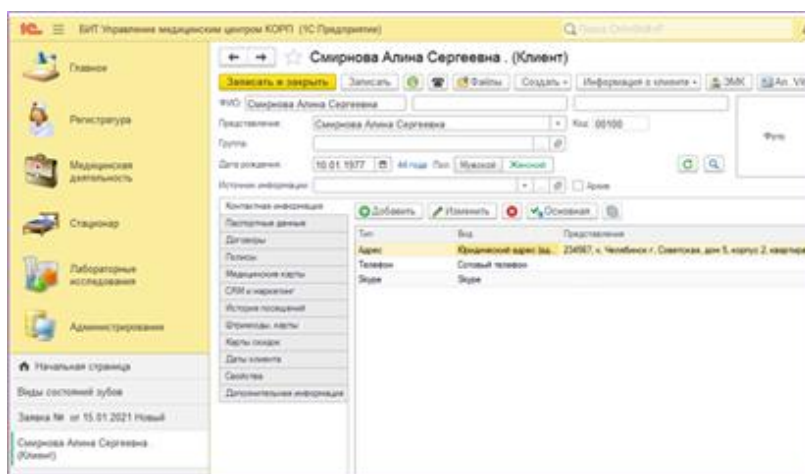


Fig. 2 Window of the program «Management of the medical center»

As a result, productivity, motivation and interest in studying various disciplines increase, and the share of participation of each dental student in collecting data on topics of classes from alternative sources increases.

The specialized applied solutions in the medical field used in educational practice make it possible to reduce the possible negative consequences of the transition to partially or completely distance learning, to optimize the organization of distance learning with limited opportunities for the movement of students and teachers in the context of a viral pandemic.

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CONTROL DEVICE FOR AUTOMATIC FIRE EXTINGUISHING IN GROUND PUBLIC TRANSPORT

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Abstract - This article is devoted to the development of an automatic fire extinguishing control device in ground public transport. The development of this project began after the presidential decree on the creation of an integrated system for ensuring the safety of the population in transport. The proposed control system is designed for the interaction of the driver with the fire extinguishing system. The driver himself will be able to decide when one or the other module needs to be switched on. The system provides for the connection of modules and sensors of various types and functionality.

Keywords: design, public transport, fire fighting, control system.

INTRODUCTION

The number of fires in public transport is increasing every year. The reasons for this may be different: the driver's negligence, which led to an accident and fire, faulty equipment or wiring in transport, hooliganism of passengers, a terrorist attack. Fires occur, both in unused public transport and crowded with passengers during peak hours. Human casualties cannot be avoided either.

The government decided to equip public transport with fire extinguishing systems. Various types of fire extinguishing modules have been developed and implemented. These modules provide fire suppression in the engine compartment and in the control panel. But they work by themselves, there are no tracking devices, no indication of the operation of these modules. The driver simply does not know whether they are in working order or not, and in most cases cannot control the operation of these modules.

PROBLEM STATEMENT

This article proposes a system designed for interaction between the driver and the fire extinguishing system. The driver himself will be able to decide when one or the other module needs to be switched on. It is also possible to install a driver's dashboard, a panel with a fire system navigation, thus, he will see which modules are in operation, and which are out of order, which have worked and which have not yet.

The system that is proposed in this article provides for the connection of modules and sensors of various types and functionality. These can be modules with aerosol sprays to extinguish the fire. Modules that include interior ventilation to remove carbon monoxide to the outside. Various sensors, such as temperature, carbon dioxide, which determine the level of smoke.

SOLVING THE PROBLEM

The development of fire extinguishing and safety equipment in public transport began after a presidential decree. In accordance with the Decree of the President of the Russian Federation dated March 31, 2010 No. 403 "On the creation of an integrated system for ensuring public safety in transport" and the Order of the Government of the Russian Federation dated July 30, 2010 No. 1285-r, the "Comprehensive program for ensuring public safety on transport " [1].

The urgency of this issue has increased after numerous terrorist attacks in the metro and airports. It has also led to the development of a large number of fires following accidents involving public transport, with numerous casualties.

Security systems of varying degrees and for different purposes were developed, but there was no comprehensive solution that would affect all aspects of security and be able to be installed on any public transport.

The considered and developed fire extinguishing device is not just a device that eliminates the source of ignition, but also prevents it, and also launches a whole chain of actions to eliminate the consequences of a fire and ensure the safety of passengers' lives. There are no such devices on the market yet, so there are no full-fledged analogues. We can give examples of analogs of those devices that can be equipped with vehicles that have been developed and partly adopted for use, as well as individual execution units and mechanisms.

Consider the existing fire extinguishing systems and their individual modules as possible components of the system being developed. Their advantages and disadvantages in comparison with the developed system.

Analogue 1 - AGS fire-extinguishing aerosol generator. This is a module that is responsible for the distribution of a gas-aerosol mixture in the fire site. Such a module is used mainly in an enclosed space such as an engine compartment or a compartment with fuses and high voltage wires. This module itself generates and distributes a gas-aerosol mixture through a closed space of the required volume to the required concentration, which is necessary to extinguish and stop the flame combustion process.

By itself, the module is a small cylindrical-type metal case. Along the perimeter of which, there is a nozzle slot through which the aerosol is sprayed. The dimensions of the module depend on the volume of the compartment in which it is installed. The largest module in this family is capable of protecting a compartment with a volume of up to 28 cubic meters. It is also subdivided into many types of fasteners and the direction of spraying of the gas-aerosol jet.

This module is started by applying an electrical impulse or heat to it. Simply put, it contains a NO-type thermal contact, it can be closed either electrically (the driver presses a button in the cabin), or the plate bends from heating and closes the contact itself.

The advantages of the module include small overall dimensions, the ability to start in 2 ways, the ability to automatically start when the case heats up. The disadvantages are installation only in confined spaces and the inability to diagnose performance.

Analog 2 - Grant-Salamander. Automatic fire extinguishing system. The set of such a system includes the fire extinguishing module itself, an alarm about temperature excess and a start button, which is located in the driver's cab. Includes 2 temperature contacts. The first contact is triggered at temperatures above 130 degrees. It turns on the sounder for the driver and then, at the discretion of the driver, whether or not the system is manually started. If the driver cannot do this (he is unconscious or he is injured as a result of an accident), then when the temperature threshold of 180 degrees is reached, a second contact is triggered, which starts the process of generating a fire extinguishing aerosol.

This system is capable of extinguishing a fire in the engine compartment and in the box with fuses and relays. If the fire occurred in the bus, then there is another module for this case. It is necessary to take all passengers out of the passenger compartment and pulling the check on the fire extinguishing module, throw it into the passenger compartment. After a few seconds, the module is activated and fills the interior with aerosol, which lowers the temperature and

extinguishes the fire. Complete volatilization of the aerosol occurs in 10-15 minutes. therefore, there is no possibility of re-ignition [2].

The advantages of the system include small overall dimensions, the ability to start in 2 ways, the ability to automatically start when the case heats up. The disadvantages include the installation only in a limited space and the impossibility of diagnostics of performance.

Analogue 3 - Intellect fire extinguishing system. The system is designed to fight fires in vehicles, including passenger ones. Consists of a device for starting fire extinguishing equipment, a linear fire detector or an autonomous detector, and an automatic fire detection and extinguishing system.

The fire extinguishing device launcher is used for fire extinguishing in manual mode, when the driver himself decides to extinguish. The linear fire detector sends a signal to the driver when the temperature in the protected compartment reaches over 138 degrees. An autonomous detector combines not only a temperature meter, but also an autonomous electric pulse generator. This detector is used together with powder fire extinguishing modules and aerosol type. The automatic fire detection and extinguishing system is designed for manual or automatic fire extinguishing. He also diagnoses the performance of fire extinguishing modules. An example of the location of control units and fire extinguishing modules is shown in Fig. 1.

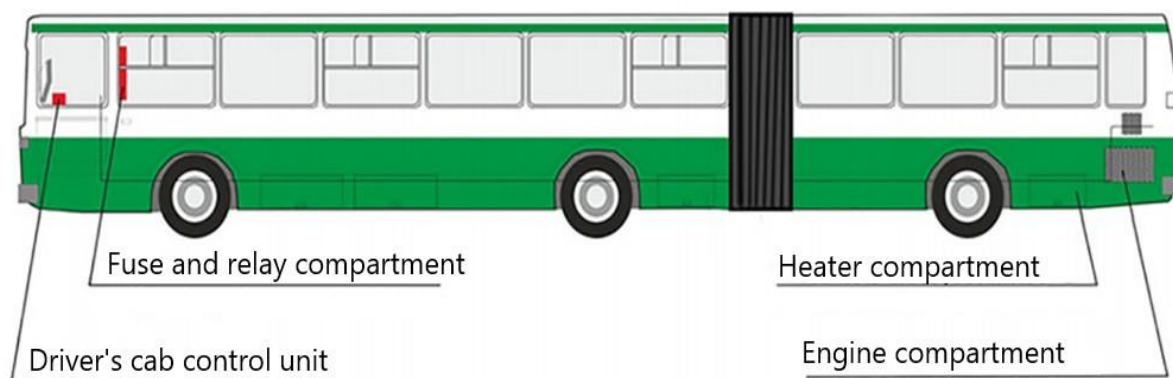


Fig. 1 Layout of blocks and fire extinguishing modules

The developed control device for the fire extinguishing system is designed to control, prevent and prevent fires in public transport. The system consists of a control unit and sensors and modules connected to it. The control unit provides control over the sensors (presence of sensors, their performance, checking the readings) and specialized modules (aerosol, powder fire extinguishing modules, exhaust fan modules, door opening modules) [3].

The system is an independent unit that is linked to the vehicle and driver control system through an information board. The device performs its functions both when the vehicle is moving and when it is parked. The system can work both in automatic mode, tracking the readings of sensors, and in manual mode, when the driver himself can turn on one or another module. Plug-in fire extinguishing modules can be powder and aerosol. Powder ones are installed in closed compartments of the vehicle and provide protection for important parts of the vehicle. Aerosol fire extinguishing modules can be installed in the passenger compartment of public transport, since the short-term exposure of the aerosol to the human body does not cause any side effects. After activation of such a module, the exhaust fans will be automatically turned on, which will remove smoke and combustion products. A self-diagnostic system of the device is also provided, which will detect the presence of internal errors in the control unit. The control unit also has a self-recovery mode after power surges. The basis of the device is a control board, on which

elements of domestic production and foreign ones are installed, selected by price category and their availability on the market. This provides the device with low cost and maintainability.

Comparative characteristics of analogs. Let's carry out a comparative analysis of the given analogs and the device under development. Based on the results of comparing analogs with our device, several factors were identified that do not meet our requirements, namely:

- lack of an automatic control unit,
- lack of self-recovery during power surges,
- high price,
- work only with fire extinguishing modules.

All presented analogs for comparison and the companies producing them were taken solely for informational purposes, for comparison with this development.

From the above analogs and the device under development, it is clearly seen that the device under development is superior to the above analogs. We will consider the principle of operation of the device using the example of the structural diagram in Fig. 2.

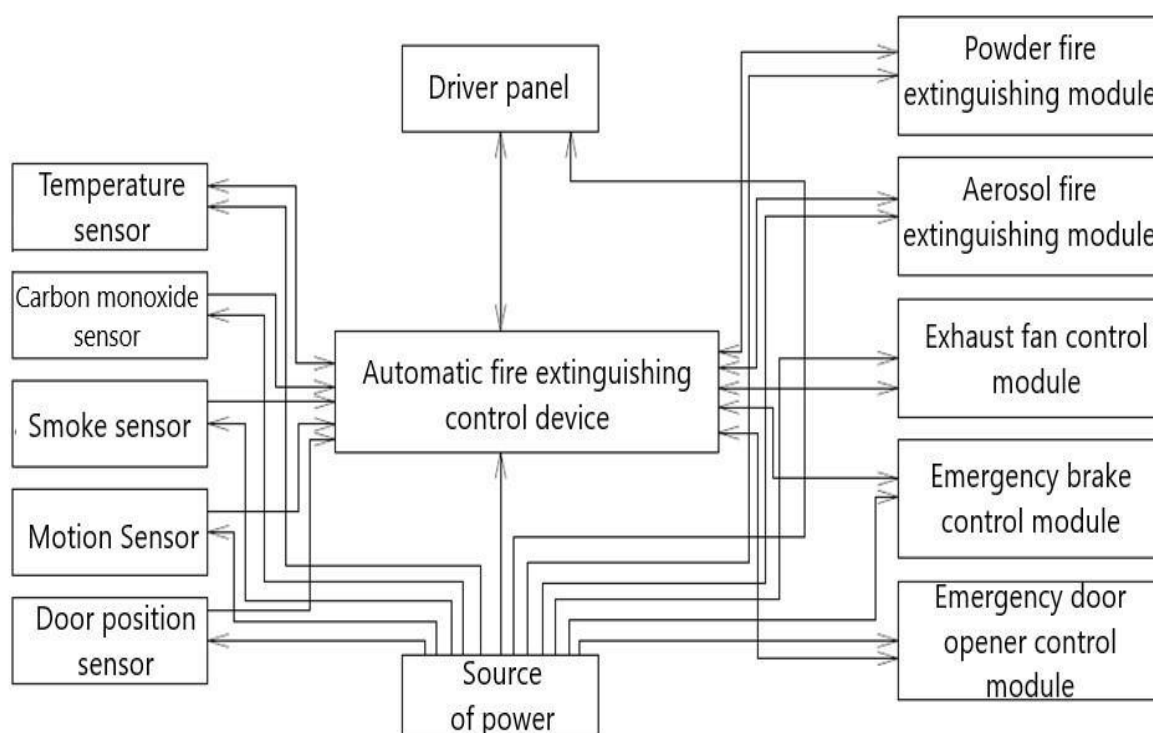


Fig. 2 Electrical structural diagram

The control unit is a hardware and software device. Responsible for the software is the ATmega48A-AU microcontroller, which is part of the electrical circuit.

The principle of operation of the control unit is to collect and analyze information coming from sensors of various types, and located in critical places of public transport. The collection of information for the operation of the program is carried out from temperature sensors located in such places as the engine compartment, the compartment with the vehicle controls, the driver's cab and in the passenger compartment. In critical places, the sensors are duplicated and installed from different sides. This helps to determine if one of the sensors is out of order or incorrect readings. The program also cyclically checks the operability of all connected modules and sensor readings. If it is found that one or more modules are out of order, then a signal about a malfunction is sent to the driver's console. Also, the driver in the cab indicates the temperature and the operability of the entire device as a whole. Based on these data, the driver will make a decision on further actions [4].

The program is also designed to conduct operational measures to rescue passengers, and later to extinguish a fire. For example, when the driver, for some reason, cannot control the situation in the event of an emergency, the system itself begins to operate. In the event of a critical increase in the temperature in the compartments, the system turns on the fire extinguishing modules and then a system of fans built into the roof to remove the smoke. If a fire has occurred in the passenger compartment, then according to the sensors for the concentration of carbon dioxide and smoke sensors, the system will also turn on the exhaust fans.

If public transport is in motion, then a signal is sent to turn on the braking. On different types of transport, the braking system is different. The easiest way to organize this is by electric buses, trams and trolleybuses. At the same time, a signal is sent to the fire extinguishing module in the cabin. The module in the cabin is aerosol, and with short-term contact with people, it is safe. After stopping, the automatics will open the doors for passengers to leave the cabin.

Structurally, the control device has a rectangular parallelepiped forks with body dimensions of 150mm by 190mm and a height of 43mm. The body of the control unit is made of ABS \ PC plastic, the maximum operating temperatures of which are 130-140 degrees. The body consists of a base and a cover for easy maintenance and repair. There is a USB connector on the case for connecting modules and sensors. Inside the case, on six dielectric racks, there is a printed circuit board with dimensions of 102x147x2 mm. Such printed circuit boards are the simplest in execution, reliable in operation and have a low cost. Six attachment points provide mechanical resistance to the PCB assembly. On the base of the body there are six holes for attaching it to the walls of the vehicle body.

CONCLUSION

The presented fire extinguishing control system surpasses the previous ones in basic parameters and, at the same time, the developed unit takes up smaller dimensions and surpasses the previous ones in terms of functionality. The new block is more versatile and has better maintainability. Its design, taking into account additional functions, consists of parts of a higher degree of integration and is more technologically advanced. In addition, the new unit consumes less power from the power supplies and allows remote automatic control of additional modules and sensors.

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PORTABLE HARDWARE AND SOFTWARE DEVICE FOR AUTOMATED CONTROL OF THE INTEGRITY OF CABLE PRODUCTS

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Abstract – The article proposes a method for monitoring the integrity of cable products by means of a new circuit design and design solution. The analysis of information sources is carried out. The method includes the structure of a portable hardware and software control

device, its circuitry and design solution. The principle of operation and functioning of the developed device is described and a brief overview of its capabilities is provided

Keywords: design, development, integrity control, cable products.

INTRODUCTION

Checking cable products for compliance with the electrical characteristics specified in the relevant regulatory and technical documents for the product is an integral and extremely important part of the life cycle of a cable product. In this regard, it is customary to test cable products according to certain methods. These tests are extremely important, especially for products that belong to a high safety class or require high accuracy of the measured characteristics. These tests are carried out by measuring devices and special testers. At the same time, it seems quite relevant to have a small-sized device for conducting the necessary checks instead of the currently used large-sized electronic equipment cabinets.

PROBLEM STATEMENT

Various cable products are installed at nuclear power plants of the water-water power reactor type in Russia and other countries. The loops provide the transmission of electrical signals and power supply to the equipment of control systems and control systems in the area from the assemblies of in-reactor detectors to the concrete fence of the reactor. And in the section from the communication line of the in-reactor control system or the reactor coolant level control system outside the concrete enclosure of the reactor to the sealed penetration, cable routes run.

In this regard, it became necessary to develop a portable device for checking these cable products during acceptance tests, input control and other checks during the production and operation of cable products at the installation facilities. The objects of the installation are nuclear power plants in Russia and partners abroad.

The portable device must provide:

- measurement of the electrical resistance R , Ω of conductive cores and shields under normal climatic conditions with an instrumental error of no more than 0.2%;
- checking the addresses of the external connections of the cable terminals and monitoring the integrity of the electrical circuits;
- measurement of the electrical resistance of insulation R_{isol} , Ω under normal climatic conditions with an instrumental error of no more than 20%;
- check the electrical strength of the insulation with a breakdown voltage of $U_{\text{bd}} = 125\text{V}$;
- storage of measurement results on a removable storage medium with the date and time of the test;
- the ability to connect connectors 2RM, 2 RM T, 2 RMD, 2 RMDT, IP50 (Lemo), IP68 (Lemo) with a total number of switched contacts of at least 50 on each side;
- automated testing process;
- connecting to a service workstation (SWS);
- portability and have autonomous power supply.

SOLVING THE PROBLEM

A device has been developed that allows monitoring the main electrical characteristics of cable products. The developed device provides:

- checking the addresses of external connections of cable terminals and monitoring the integrity of electrical circuits;
- control of electrical resistance parameters R , Ω of conducting wires according to 2 and 4 clamp connection schemes in normal climatic conditions with an instrumental error of no more than 2%;

- control of the electrical resistance of the insulation R_{isol} , Ω under normal climatic conditions with an instrumental error of no more than 20%;
- control of the electrical strength of insulation with a breakdown voltage of U_{bd} to 150 V;
- the ability to connect connectors 2RM, 2RMT, 2RMD, 2RMDT, IP50 (Lemo), IP68 (Lemo) with a total number of switched contacts – 64 on each side;
- the presence of removable switching modules, which increases maintainability and reduces the weight and size of the device;
- drive separation. The first drive contains data for checking (types of cable products, parameter tables, etc.), and the second one records the results of the check with the time and date fixed;
- built-in real-time clock that allows you to record the time and date of the test;
- Connecting to a service computer via USB Type-C;
- Availability of autonomous power supply: Li-ion battery;
- The presence of an LCD display with a keyboard.

Development of a block diagram:

The design of the device for automated control of the integrity of cable products is an electronic equipment unit that includes several functional units inside the housing, with removable switching modules. The block diagram of this device is shown in Fig. 1.

The core of the circuit is a microcontroller of the AVR ATmega1280-16AU family from Atmel, 2 microSD slots, a keyboard, a 20x4 LCD display, UART-USB and UART-RS-232 adapters, as well as a standalone power source (3.7 V li-ion battery) [1].

The microcontroller communicates with the peripherals by means of buses, namely:

- 2 microSD are connected to the three SPI buses and the output to the sets of switching modules is carried out (the CS - Chip Select bus selects the modules);
- The DS3232 real-time clock is connected to the I2C bus;
- The LCD display is connected via an eight-bit parallel data bus and a three-bit control bus;
- A keyboard is also connected via an eight-bit parallel data bus;
- the uart0 and uart1 buses communicate with the UART – USB and UART – RS-232 adapters.

The measuring device is connected to the sets of switching modules using a 4-wire circuit. Two wires go to the set of modules 1 and two more wires-to the set of modules 2. The tested cable products are connected to the corresponding switching modules. Switching modules consist of shift registers and relay sets that close the necessary contacts.

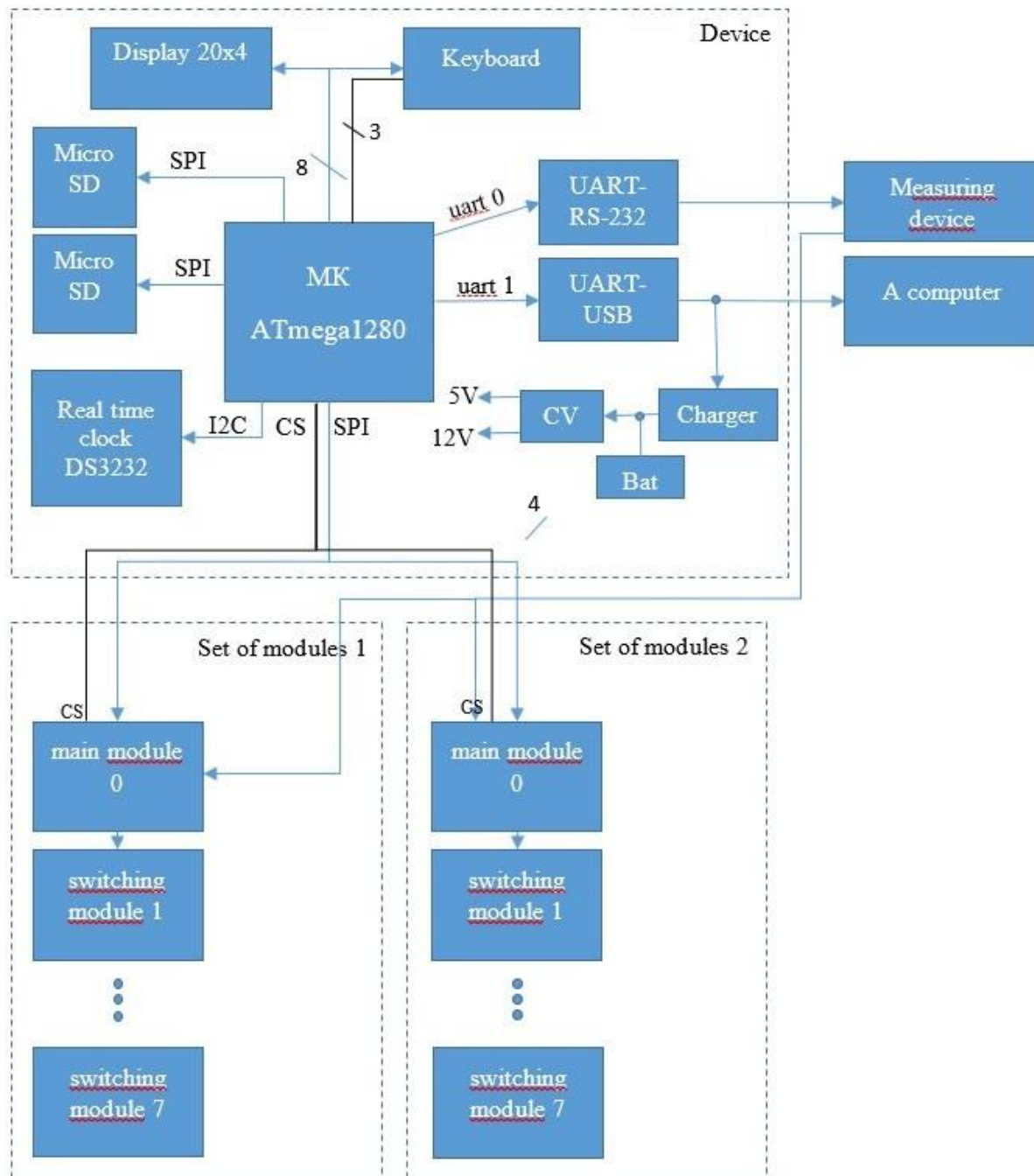


Fig. 1 Block diagram of the device for automated control of the integrity of cable products

The first microSD card contains a table of parameters (with an acceptable range of electrical characteristics) for checking, as well as individual codes of the adapters connected to the modules. The test results are recorded in the second microSD card. Each test has a date and time of the test, thanks to the built-in real-time clock.

The introduction of switching modules solves most of the design problems that arise when designing devices. This design has a number of advantages, such as:

- reduced power consumption and heat dissipation of the device. By placing the relay (and other elements with increased power consumption and heat dissipation) in a separate module.
- maintainability. Maintenance of the device is greatly facilitated by the possibility of replacing failed modules.

- portability. This device is wearable.
- versatility. The presence of removable modules with 128 contacts allows you to check most cable routes and loops.
- ease of use. The device has small dimensions, removable modules, as well as an automatic testing mode.

The principle of operation of the device: The developed device involves working together with adapter products and switching units, as well as together with trusted measuring devices that can be connected to the device via the RS-232 interface, and have sufficient measurement accuracy.

The device provides electromagnetic relays located in the switching units with a voltage of 12 V and 5 V, through the DB9-Female output connector. The 5V power bus provides operation of the 74HC595 shift registers and other chips located in the switching blocks and consuming 5V for normal operation [2].

The connection of the tested cable products is carried out by special adapters through the switching blocks. The terminals of the measuring device are connected to the main switching unit in special sockets.

The appropriate cable or loop type is selected using the navigation buttons and the visual display of the selection data on the display. After the appropriate selection, using the "OK" button, the mode of automated verification of the connected object is started.

The microcontroller sends the data of the selected cable type sequentially to the switching unit via the SPI bus. The code is loaded into the 74HC595 shift registers connected in series. A signal is generated at each output of the shift register: "1" - if the relay should close, "0" - if not. Using the Darlington ULN2004 transistor assembly, the amplified signal closes the desired relay.

Two main switching modules are connected to the device via two DB9-Female connectors, to which additional modules are connected. Depending on the number of contacts to be checked, the corresponding number of switching modules is set. An external measuring device is also connected to the modules.

The external measuring device communicates via the UART protocol via the RS-232 interface and records the measurement results on the microSD card provided for storing the results.

The necessary adapters are connected to the switching modules, which have contacts for cable products, and also have their own unique code, which is transmitted to the device via the SPI bus and identified.

To activate the automated object testing mode, you must use the keyboard to select the appropriate function, as well as the type of cable product to be measured, displayed on the device screen. After that, the device will automatically perform the specified check, display the results on the screen, and also write them to a removable media.

The data of the verification protocols can be found both on the service computer and on the screen of the device itself. On the service computer, the test results are stored in a file with the extension ".txt". For each test result, the date and time of the integrity check, as well as the type of cable product, are displayed.

The device is self-powered by a li-ion battery and is charged from USB via a USB Type – C connector.

Depending on the type of test and the object of control, the corresponding connection diagram is assembled.

All measurements are carried out in accordance with the program and method of checking the cable product.

To check the addresses of the external connections of the cable product terminals and check the integrity of the electrical circuits, connect the test object to the switching units through the transition devices. Then connect each switching unit to the corresponding socket (DB-9),

which are located on the device, according to the design drawing. Then you should select the type of cable product, set the type of test and switch the device to the test mode by pressing the " OK " key. The device compares the readings with the specified parameter table and outputs the test results. The test report is recorded on a removable media.

To measure the electrical resistance R , Ω of the conductive wires and shields, it is necessary to assemble an appropriate connection diagram with an external milliohmeter and set the required test conditions.

According to the technical specifications, the measurement accuracy of the milliohmeter should be no less than 0.2 %. For example, the gom-7804 milliohmeter from the manufacturer GW Instek. Its resistance measurement range: from 1 $\mu\Omega$ to 5 m Ω with an error of no more than $\leq \pm 0.05$ %.

If the measured electrical resistance is less than or equal to the nominal value, taking into account the error $R_{eq} = \leq R_n \pm 0.2$ %, then such a conductor is considered serviceable, otherwise, the conductor is defective. Such an accurate check allows you to detect poor-quality soldering of contacts and other manufacturing defects [2].

The device compares the readings with the specified parameter table and outputs the test results. The test report is recorded on a removable media.

When monitoring the electrical resistance of the insulation, it is necessary to assemble an appropriate connection diagram with an external megohmmeter and a DC voltage source, set the required test conditions and apply a voltage of $U_{bd} = 100V$ to the object being tested. The required measurement accuracy for a megohmmeter is not less than ± 20 %. As an example, the megohmmeter S.A. 6543 is used, with a measurement accuracy of at least $\pm (15 \% + 10 \text{ units})$. If the measured electrical resistance is greater than the nominal value $R_{eq} = > 20 \text{ M}\Omega \pm 20$ %, then such electrical insulation is considered serviceable, and in the opposite case-defective.

The device compares the readings with the specified parameter table and outputs the test results. The test report is recorded on a removable media.

To check the electrical strength of the insulation with a breakdown voltage of $U_{bd} = 125V$, assemble the appropriate connection diagram with an external DC voltage source and set the necessary test conditions. According to the technical specifications, the insulation resistance of each core should be measured within 1 second.

Criterion for evaluating the test results: no signal indicating the presence of a breakdown or surface overlap. The device compares the readings with the specified parameter table and outputs the test results. The test report is recorded on a removable media.

Development of the concept diagram:

The schematic diagram and the rest of the CD were developed in such environments as:

- Altium Designer-a comprehensive CAD system for designing electronic modules based on printed circuit boards, developed by the Australian company Altium;
- KOMPAS-3D is a CAD system based on a graphics editor. This software allows you to design REA models and draw up documentation in accordance with the standards of the ESKD and SPDS series;
- SolidWorks-a CAD software package for automating the work of an industrial enterprise at the stages of design and technological preparation of production. Allows you to simulate REA objects and simulate design and technological tests etc [3].

The core of the electrical circuit is the ATmega1280-16AU microcontroller of the AVR family from Atmel [4]. It ensures the consistent operation of the entire electrical circuit. This microcontroller has the following characteristics:

- 8 Kbytes of SRAM RAM, 4 Kbytes-EEPROM, and 128 Kbytes-flash;
- 1 SPI mode and 4 USART that have the ability to operate in SPI mode;
- it has an 8-bit data bus width.;
- number of inputs/outputs: 86;

- power supply voltage from 2.7 V to 5.5 V;
- ability to operate within the temperature range from -40°C to 85°C.

Along with the microcontroller, the important components of the circuit are:

- DS3232 real-time clock. This chip provides data on the date and time of the check;
- TSM-0505s-DC-DC converters and dual-channel digital isolators ADUM1201ARZ.

The UART–USB and UART–RS-232 adapters are galvanically isolated. This solution allows you to ensure the independence of the signal circuit, which increases noise immunity, and electrical safety when working with equipment;

- the ADM232 is a multi-channel RS-232 interface transceiver and the FT120X is a USB to BASIC UART converter. These components are necessary in order to transform interfaces. In the first case, the ADM232 converts the signal transmitted over the uart0 bus to the RS-232 interface and goes to the X1(DB9) connector to the external meter. In the second case, the FT120X converts the signal over the uart1 bus to the USB interface and goes to the X4 (Type-C) connector.

Such a circuit solution is acceptable from the point of view of rational design and makes it possible to significantly reduce the dimensions of the device when developing its design.

The structurally developed device is a block of electronic equipment in the form of a rectangular parallelepiped with overall dimensions of 225×165×40. On the front panel of the device there are connectors for connecting the cables under study, external measuring devices that provide the necessary measurement accuracy and can be located remotely. On the upper panel of the case, there is a liquid crystal display and a keyboard that provides operational control of the process of measuring the characteristics of cables. The device is powered from a 230V AC power supply (via an adapter with an output voltage of 5V and an output current of 1A) or from a built-in Li-Ion battery Li26650/4000 with a capacity of 4000 mAh and a voltage of 3.7 V. The voltage in the circuit is converted using step-up DC-DC converters based on LTC4002 chips with output voltages of 5V and 12V. Inside the case, the printing unit of the device has a rigid mechanical attachment to the base of the device case. Intra-block connections are made by volumetric installation.

The use of external measuring devices brings a number of significant advantages:

- eliminates the need to verify the device as a measuring instrument. The developed device monitors the integrity using the readings of pre-verified devices recorded in the register. This design solution determines the economic advantage and simplifies the design process of the device;

- significantly reduce the size of the device;
- reduces the power consumption and heat generation of the system by dividing the design into separate modules, which also greatly simplifies repairs in the event of a failure or damage to the device's peripherals (you just need to replace the failed module);
- the measurement limits are flexible, as the measurement range is determined by the connected measuring device.

Communication with the computer is carried out via the USB protocol via a 24-pin USB Type-C connector by means of a galvanically isolated UART–USB adapter.

CONCLUSION

The developed device allows not only to exclude errors of the human factor, but also to significantly reduce the time for testing cable products. The functionality and design of such a device provides flexibility and scalability of applications in the nuclear industry, as well as in other areas of electronics and instrumentation.

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ON THE DEVELOPMENT OF SOFTWARE WITH A GRAPHICAL INTERFACE THAT SIMULATES THE ASSEMBLY OF THE CONSTRUCTOR

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Abstract — The paper describes basic algorithms of computer graphics that can be used for creating a realistic model of mutually overlapping objects. The most suitable methods are picked for solving the problem. A software is described which allows users to create a three-dimensional object from a set of three-dimensional primitives and to visualize a scene containing such 3D objects. A user can add elements of a given house constructor, the mutual position of elements is limited with a set of non-intersection rules. The simulation results in an image representing a house constructor.

Keywords: z-buffering, surface model, method of constant rendering, simple shading, Gouraud shading, Fong shading.

INTRODUCTION

The main goal of computer graphics is to process and synthesize images, so that the human eye doesn't detect the difference between the generated picture and reality. Displays show raster images, therefore there is a need to develop algorithms to achieve such realism while generating raster images out of 3D models. Every year, as the performance of modern devices is growing, the demands for the realism of the simulated 3D image is also growing. Such models are used in graphics, computer games, stage effects, virtual and augmented reality.

PROBLEM STATEMENT

There is a need to develop a program that allows users to create a three-dimensional complex object from a set of three-dimensional primitives. The program should allow users to create an object from a set of three-dimensional primitives and to edit and manipulate the resulting object. The object should be modeled using the transfer, zoom, and rotate operations. Objects can be stacked on top of each other or side by side. A tube can only be installed on the roof.

SOLUTION OF THE PROBLEM

There are several types of geometric models [1].

1. Wireframe model.
2. Surface model.
3. Volumetric model.

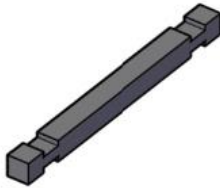
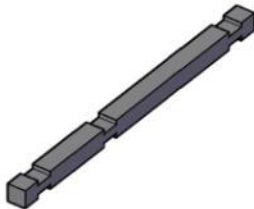
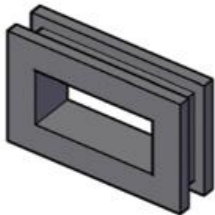
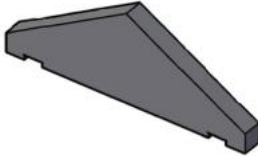
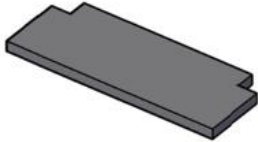
Scene objects are best described through the surface models. Wireframe models don't have sufficient realism, volumetric models are too informative, which will complicate

calculations and will be more memory-intensive [1]. Geometric primitives such as point and triangle are used to represent objects.

The scene can consist objects such as:

- a set of elements (primitives based on polygons made up of triangles) (table 1);
- a launch pad made up of rectangles;
- a light source – a material point from which rays of light emanate in all directions.

TABLE I. SET OF ELEMENTS FROM WHICH USER CAN BUILD A HOUSE MODEL.

Element name	Graphic explanation
Small timber (L=120)	
Middle timber (L=520)	
Large timber (L=720)	
Window (L=320)	
Fronton (L = 520)	
Flat roof element (L=360)	
Tube (L=70)	

DESCRIPTION OF METHODS

Z-buffer algorithm

This algorithm for removing invisible surfaces is one of the simplest and most widely used. It uses two buffers: frame buffer and depth buffer called Z-buffer. The frame buffer is used to store the intensity of each pixel in image space [1]. The depth buffer stores the Z-coordinate (depth) value of each visible pixel in image space. The depth value of each new pixel which

entered into the frame buffer is compared to the depth of the pixel that has already entered into the Z-buffer. If this comparison shows that the new pixel is closer to the viewer than the previous pixel in the frame buffer, the new pixel is entered into the frame buffer and the Z-buffer is adjusted: the depth of the new pixel is entered into it. If the depth value of the new pixel is less than that stored in the buffer, the transition to the next point is performed.

The advantages of the algorithm are simplicity of its implementation, correct processing of cases of mutual intersections of objects, linear dependence of inversed computational effectiveness on the number of objects on the scene, as well as the absence of the need for preliminary sorting of objects by depth.

The disadvantage is the need to allocate memory for two buffers, both of which have a size equal to the number of pixels on the screen.

Shading algorithms

To select the most suitable algorithm for solving the problem at hand, one should analyze the existing algorithms: simple shading, Gouraud shading, Fong shading.

Simple shading

The essence of this algorithm is that for each edge of the object a normal vector is found. Using this value and in accordance with the selected lighting model, the intensity value is calculated, and the entire edge is painted over with this intensity [2].

Advantages of the algorithm are simplicity in implementation and low requirements for computational resources.

Disadvantages: the color of the entire edge is the same, so the scene looks unrealistic. Other disadvantages include poorly accounted reflected light.

Gouraud shading

This method differs from the simple shading, as different points of the edge are shaded with different intensity values. A normal vector is found at each vertex of the edge and the intensity value is calculated. Then the calculated intensity values are interpolated over all points of the edge.

Advantages of the algorithm: it is suitable for smooth surfaces. The Gouraud method is one of the ways to eliminate the discreteness of the paint intensity and, therefore, the image looks quite realistic, but it seems opaque.

Disadvantages of the algorithm: less high-quality image of local effects, in particular reflected light, Mach effect (Figure 1), or edge contrast effect, which prevents the eye from creating a smoothed image of the scene.

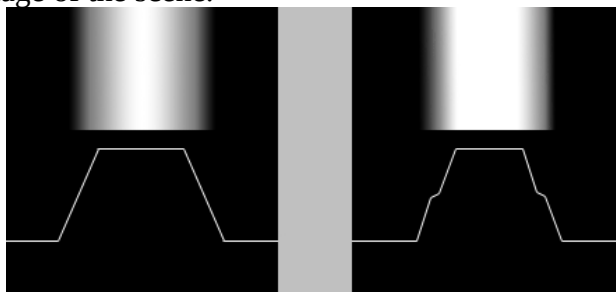


Fig. 1 Mach effect

The effect of Mach bands is observed when the slope of the intensity curve changes sharply. If the intensity curve is concave, then at this point the surface appears lighter, or darker in case it is convex.

Fong shading

The Fong shading is similar to the Gouraud shade, but its difference is that in the Gouraud method intensity values are interpolated across all points of the polygon, while in the Fong method the vectors of normal are interpolated, and then intensity value for each point is calculated.

This shading requires more computational resources than the Gouraud shading. However, it enables the user to achieve a better local approximation of the curvature of the surface and therefore to form a more realistic image. The Fong shading is well at mirror reflection.

Advantages of the algorithm: good image of reflected light and shadows, suitable for smooth surfaces; the image looks more realistic.

Disadvantages of the algorithm: it requires quite a lot of computational resources.

Figure 2 shows the differences in the considered paint methods.

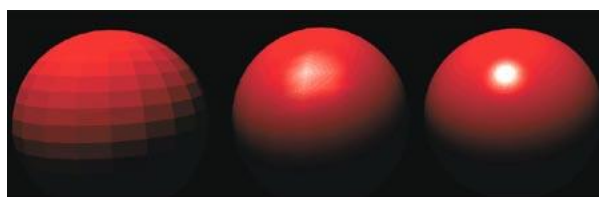


Fig. 2 Paint methods (Simple, Gouraud, Fong)

Summing up the advantages and disadvantages of the algorithms, the simple shading algorithm was chosen to solve the problem, since it is easy to implement, has a high speed of operation and doesn't require optimization.

ALGORITHMS FOR LIGHTING MODELS

There are global and local lighting models. Global models take into account the reflection and refraction of light from objects that are not direct light sources, so they require significant computational costs.

There are simpler, local lighting models that take into account only the light from the light source. This type of model is used in this work.

The Lambert Model

This model is the simplest lightning model, since it takes into account only the ideal diffuse reflection of light from the body [2]. Figure 3 shows that according to this model, the lighting at a point is determined only by the light density at the point of the surface, and it depends linearly on the cosine of the angle of incidence. In this case, the position of the observer does not count, because diffusely reflected light is scattered evenly in all directions.

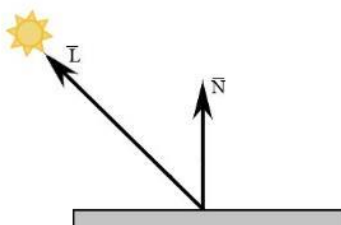


Fig. 3 The Lambert Model of lighting

In this model, the intensity should be calculated with the following values:

$\vec{L}$ – vector from point to source,

$\vec{N}$ – normal vector,

I – resulting intensity of light at a point,

I_0 – source intensity,

K_d – diffuse illumination factor.

The formula for calculating the intensity is as follows:

$$I = I_0 \cdot k_d \cdot (\bar{L}, \bar{N}) \quad (1)$$

From formula 1 follows the main drawback of the Lambert model: the same intensity at all points belonging to the same edge.

SOFTWARE IMPLEMENTATION

A software was implemented in C++ basing on a combination of selected algorithms of computer graphics. The following figures show examples of models that can be constructed using the program (Figure 5-6).

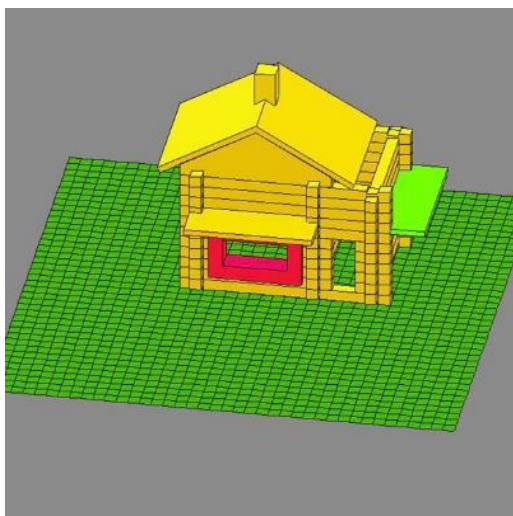


Fig. 5 Example of model 1

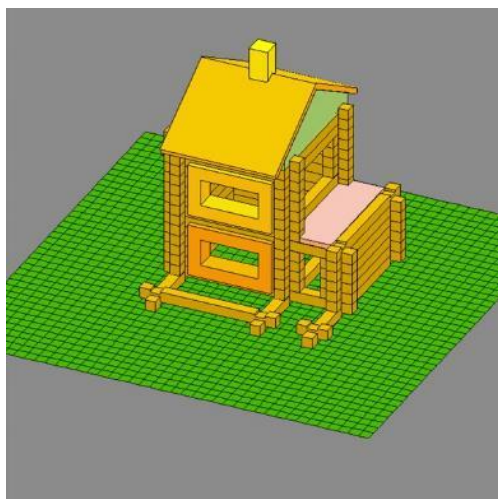


Fig. 6 Example of model 2

CONCLUSION

Existing algorithms for removing invisible lines and surfaces, shading and lighting were analyzed, their advantages and disadvantages were indicated. The existing data structures and algorithms necessary to solve the problem have been adapted in order to create a software enabling users to assemble a module home constructor with its 3D visualization. For solving the problem of modeling the creation of a three-dimensional object from a set of three-dimensional

primitives, the z-buffer algorithm, simple shading and Lambert's lighting model were considered as the most suitable. A software with 3D graphics was designed and implemented, it simulates assembling a constructor in real-time.

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ANALYSIS OF POLYMODAL INTERACTION IN APPLIED INFOCOMMUNICATION SYSTEMS

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Annotation – The development of infocommunication technologies is a priority task of the XXI century. Infocommunications are widely used in applied fields, where an important role is assigned to information processes that play a large role in the transportation and transformation of data, and are fundamental and integral elements of applied infocommunication systems. To describe the information processes involved in infocommunications, the domain model of infocommunications is widely used. Education involves the use of polymodal systems and the domain model of infocommunications to describe them. The application of the domain model of infocommunications and the comparative analysis of modalities was carried out on the example of the St. Petersburg State University of Telecommunications named after prof. M.A. Bonch-Bruyevich during the Covid-19 period.

Keywords: infocommunications, cyber-physical systems, polymodality

The development of infocommunication technologies is viewed as a priority task of socio-economic development and is one of the most important factors influencing the formation of society in the XXI century.

Global changes associated with the informatization of Russian society accelerated the use of new opportunities by organizations through the use of infocommunication systems, direct digital signals from the external environment, improved the quality of customer service, expanded the possibilities for optimizing business processes, and increased the geographical coverage of organizations through the use of various digital communication channels. In the era of building the digital economy, the time and spatial boundaries of economic activity have been erased, ensuring the transfer of information in real time.

The role of infocommunications has increased, which makes it possible to combine the processes of information transfer, digitalization and dissemination of information services into a single whole. With the transition to the digital economy, the list of provided communication and data transmission services is expanding, the production and social infrastructure is improving due to the introduction of mobile broadband access, and an increase in the bandwidth of channels. In this regard, infocommunications have a significant impact on the processes of communication

between a student and a teacher, a buyer and a consumer, a musician and a listener, making them effective and more open.

Therefore, today new trends and directions in the creation of intelligent communication systems are being formed, and the development of technologies for wireless access to global networks, the Internet of things, and optical technologies is becoming relevant. With the active development of infocommunications, the services provided to end users are improving.

The effectiveness of the implementation of infocommunication infrastructure is assessed by the following indicators:

- 1) the coverage of socio-economic activities of information and communication technologies and the electronic environment;
- 2) accessibility of users to the Internet;
- 3) technical possibilities of using infocommunication networks and information and communication technologies by the population;
- 4) the ability to connect audiovisual and multimedia information, content using wireless broadband access.

The digital economy is characterized by an increase in the volume of transmitted information, the intensity of the connection of electronic devices to communication networks, the provision of services to the population by the business sector, e-commerce, government and educational structures, including distance education, individual learning paths, social networks [1].

The «digital transformation» of all types of activity leads to the fact that information and telecommunication systems are becoming an integral, key element of applied systems. Practically any systems for various purposes - transport, educational, medical, etc. - are referred to as «applied» systems. The concept of «cyber-physical systems» is widely used, which are a variant of infocommunication systems considered in a specific aspect. The interaction of participants (users - sources and consumers of information) is a process of exchange of meaningful data - an information process. The processes of information interaction are truly fundamental and integral in any application system, from whatever angle they are considered. It turns out that the information processes themselves do not have sufficiently strictly formalized methods of their description and quantitative assessment useful for further use [2].

The fundamental basis that provides a general basis for solving the problems of infocommunications and in the particular case of cyberphysical systems is the Domain model of infocommunications, which acts as a universal tool for describing information interaction.

To describe complex interdisciplinary infocommunication systems, it can be effective to use the «Domain model of infocommunications» [3] or its development of the «polymodal multidomain model of infocommunications».

In the general case, the process of information interaction in the system, consisting of several information sources - entities of the cognitive and physical domains and several recipients of information will be described by the expression

$$\langle A \rangle^{\xi_A} \xrightarrow{Q_1} \langle \langle A \rangle^{\xi_A} \rangle^{\xi_B} \xrightarrow{Q_2} \langle \langle \langle A \rangle^{\xi_A} \rangle^{\xi_B} \rangle^{\xi_C} \quad (1)$$

Expression (1) describes the process of information interaction typical for applied systems of various types and purposes, such as medical, educational, etc. The domain model of infocommunications (DMI) distinguishes three domains, where three relatively independent, albeit closely related, types of activity are concentrated, namely: physical, informational and cognitive domains.

Educational activity, as a set of educational and methodological activities (lectures, laboratory work, practices), takes place in the «real world», which corresponds to the physical domain. Intellectual activity, such as data analysis, selection, comprehension and evaluation of

options, the product of which is decision-making, on the contrary, is the product of mental and mental activity occurring in the sphere of the «ideal» represented in the cognitive domain.

Based on the principles of the domain model of infocommunications and the platform-oriented model of mental activity, the analysis of classes held at SPbSUT using distance technologies based on the Google Meet platform was carried out. An essential feature of a complexly organized multidimensional activity, such as, for example, education, is polymodality, use of different types of data and different modes of their use. An example of the same type, but polymodal data is music, speech, synthesized sound. Presenting the same type – «acoustic» data, they differ significantly in processing methods. It is easy to see that «polymodality» is an extension and refinement of the concept of «multimedia». Information-rich interfaces of modern cyber-physical systems represent a wide field for studying the principles of organization and effective use of polymodal systems.

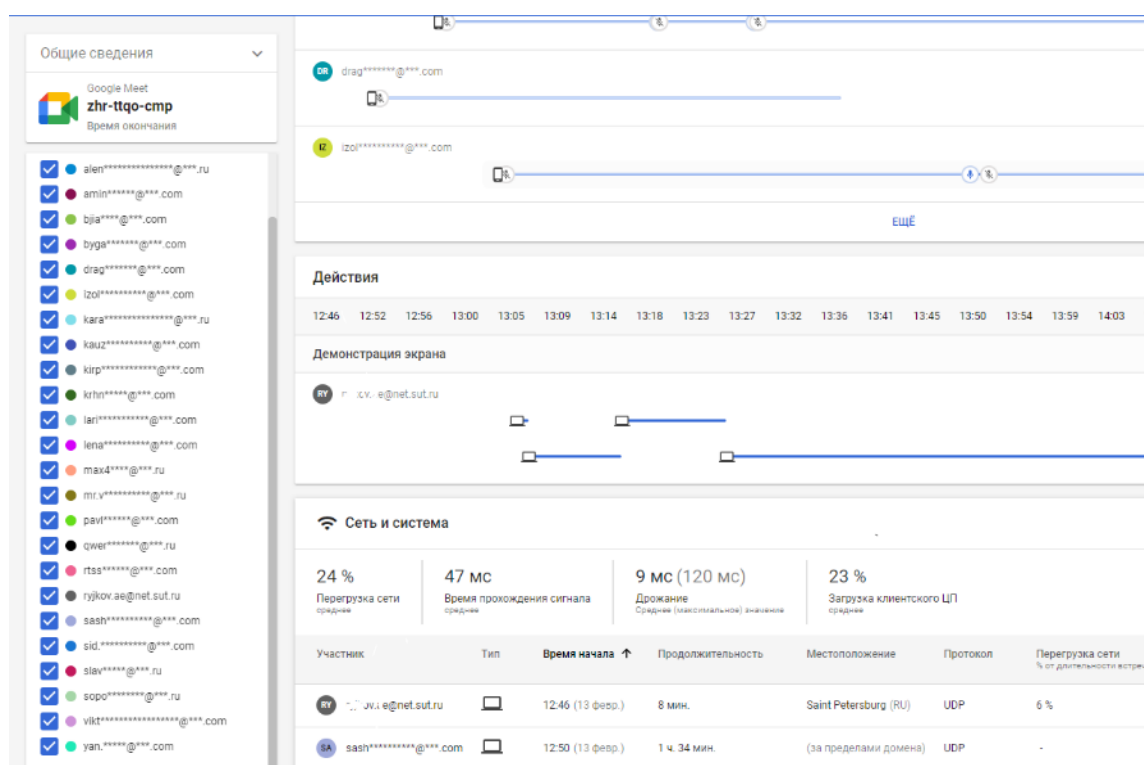


Fig. 1 Analysis of statistical data in the Google Meet system

Estimates of the characteristics of the flows of various data in the system were obtained for various modalities of information interaction during distance learning with students (fig. 2, table 1). The table shows the average values typical for video conferencing sessions in the Google Meet system used for lectures in distance learning mode at SPbSUT during the COVID-19 period. The four used modalities and values of the actual bit stream rate and the «allowable» - selected as the maximum allowable value based on the external requirements for the system are considered.

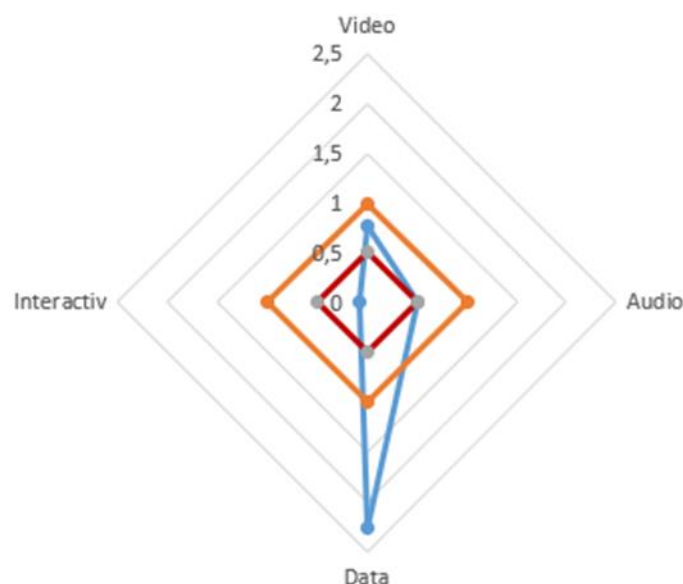


Fig. 2 Modalities of communication

TABLE 1. VARIANTS OF MODALITY OF (INFORMATIONAL) INTERACTION

Modality	Actual speed	Permissible speed	Normalized	Demand 1	Demand 2
Video	328 κб/с	500 κб/с	0,764	1	0,5
Audio	2 κб/с	4 κб/с	0,5	1	0,5
Data	225 κб/с	100 κб/с	2,25	1	0,5
Interactiv	0,04 (1/20)	0,5	0,08	1	0,5

Thus, it seems possible to draw reasonable conclusions about the ranges of technical requirements for applied ICS and the feasibility of using certain technologies.

The domain model provides a good basis for the description and analysis of information flows in the system and the construction of quantitatively-oriented concretized models that can be used in the design of IP in socially oriented areas of education and healthcare.

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MICROPROCESSOR CONTROL OF THE OPTIMIZED CHARGE OF STORAGE
BATTERIES FOR A SOLAR POWER PLANT ON Si-PHOTO-ELECTRIC CONVERTERS

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The article presents a deductive-analytical analysis of existing systems for controlling the charge of storage batteries for power systems based on photoelectric converters and algorithms for the operation of a solar power plant. The relevance of this direction is due to the general trend of energy saving. The aim of the work is to study the possibilities of increasing the efficiency of power systems based on photoelectric converters due to the operational control above the battery charging mode. The object of the research is microprocessor systems for controlling the charge of storage batteries at a solar power plant. The principles of constructing power systems based on photoelectric converters have been investigated. An example of an optimized control system is given.

Key words: photoelectric converter, solar battery, solar power plant, charge controller, storage battery, inverter.

INTRODUCTION

Currently, the urgent task is the development of alternative energy sources. The energy of solar radiation is 81000×10^6 MW; 27000×10^6 MW falls on the continents. To store this energy, it is necessary to use storage batteries (STB), which need to be used correctly. The article shows the circuitry of STB charge controllers. The practical significance of the article lies in the study of the operation of the equipment of a solar power plant and the development of circuits for measuring voltage and current for its effective use. A photoelectric converter (PEC) is an electronic device that converts photon energy into electrical energy. Its efficiency is 16-25 %. The solar battery (SB) includes some PECs. Types of modern SB are distinguished by material [1]:

- Monocrystalline SBs are created on the basis of a sawn Si single crystal grown from a melt of polycrystalline Si. Productivity of 1 kW is 190 W/h ($S = 7 \text{ m}^2$).
- Polycrystalline SBs are created on the basis of sawn polycrystalline Si obtained by directional crystallization. The productivity of 1 kW of the system is 160 W/h ($S = 8.3 \text{ m}^2$).
- Thin-film photovoltaic modules are the most productive SBs, their efficiency is 25 %. The capacity of a 10 kW system is 2.5 kW / h ($S = 183 \text{ m}^2$).

COMPONENTS OF SOLAR POWER PLANTS

The main types of solar power plants are self-contained; they work without connecting to the network and generate only direct current. The main element of power system control is the controller, which does not allow system overload or reverse current. The inverter converts direct current from the SB into alternating current to power electrical appliances. The automatic input device is used to switch the power supply of the object. The scheme of autonomous power supply of the facility with STB is shown in Fig. 1 [2].



Fig. 1 Self-contained provision of the object

Any self-contained power supply system containing STB must have means of charge and discharge control. This is especially true for systems with lead-acid storage batteries. Therefore, load shedding devices are introduced into the system. Charge controllers are built into inverters

or uninterruptible power supplies. They differ in the charging algorithm, in the control methods, and in the possibility of observing the maximum power point (MPP). Simple controllers turn off the SB when they reach 14 V, more complex ones use pulse width modulation (PWM) and provide 100 % battery charge. The most sophisticated controllers monitor the MPP and are called “Maximum power point tracking” (MPPT).

CHARGE CONTROLLERS MPPT

Charge controllers turn off the solar battery when the battery voltage reaches approximately 14.4 V (for a lead-acid battery with a nominal voltage of 12V). When the voltage on the storage battery drops to the 12.5 V range, the SB is connected to it again, and the charge resumes. In this case, the maximum storage battery charge level is 60-70 %. [3]. More advanced controllers use PWM in the active stage of the charging process. They support temperature compensation of the current using external sensors. MPPT controllers themselves choose the optimal voltage / current ratio, remove the high voltage of the SB and convert it into the optimal voltage for charging the STB. For a standard 12 V storage battery, it is necessary to withstand a charge with a voltage of 14.4 V for 2-4 hours. This stage is called absorption. When the voltage on the SB is lower than the STB voltage, the MPPT controllers stabilize it. The use of MRPT controllers allows receiving 15-30 % more electricity from the SB in comparison with other controllers. Fig. 2 shows the Volt-ampere characteristic of the SB [3; 4].

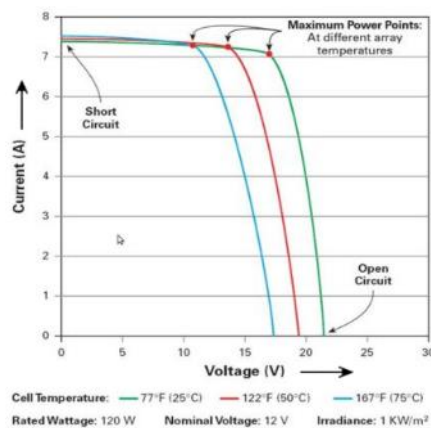


Fig. 2 Volt-ampere characteristic of SB

The MPPT controller monitors the current and voltage on the SB, multiplies their values to MPP, it reduces the voltage from the no-load point to the voltage on the STB. The main advantages of MPPT controllers are an absence of losses during battery charging; increased recoil in low light; the ability to use a higher input voltage of SB. The controller performs the following functions: tracking MPP; storage battery charge control and protection against overcharge; load protection against overloads; connection of system parameters with external systems. Table 1 shows the technical characteristics of the MPPT charge controller [5].

TABLE 1. TECHNICAL CHARACTERISTICS OF MRPT CHARGE CONTROLLER

№	Parameter	Value
1	PEC rated voltage	12V
2	Maximum PV voltage	27V
3	Maximum PV power	100W
4	Nominal voltage RB	12V
5	Maximum RB charge current	6A
6	Maximum load current	8A

The MPT612 integrated circuit is designed for MPP tracking devices. It provides up to 15 kW of built-in high-speed flash memory and operates at 70 MHz. It implements serial interfaces: UART, SPI, SSP. The JTAG/UART board is used for service and provides battery charging current (Fig. 3).



Fig. 3 JTAG/UART controller board

The circuit for measuring the voltage and current of the SB is shown in Fig. 4. A resistor divider R3, R5 is located at the input of the circuit. The current controller integrated circuit U14 is used to measure current [6].

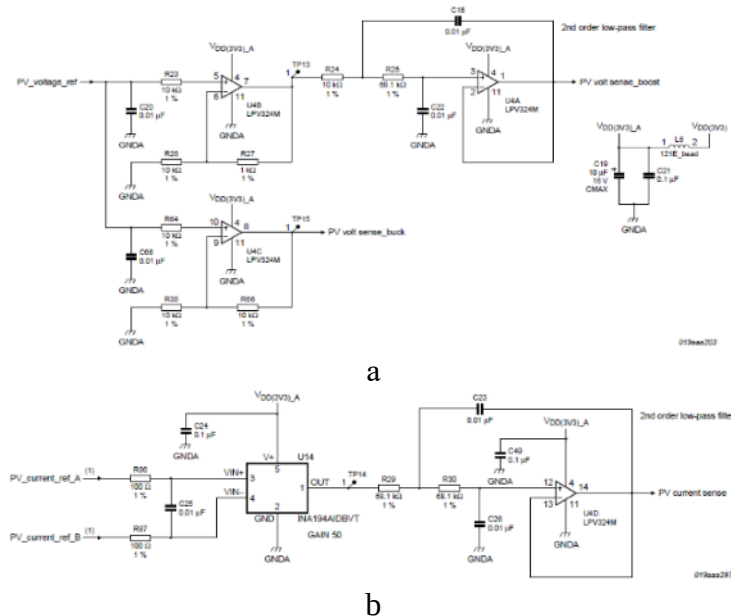
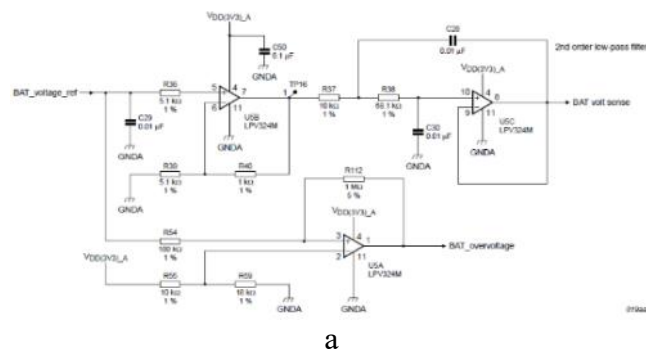


Fig. 4 Voltage measurement circuits (a) and current (b) SB

The STB voltage and current measurement circuit is shown in Fig. 5. The input of the STB voltage measurement circuit is built on a resistor divider R4 and R7. U6A and U6B perform STB current sensing.



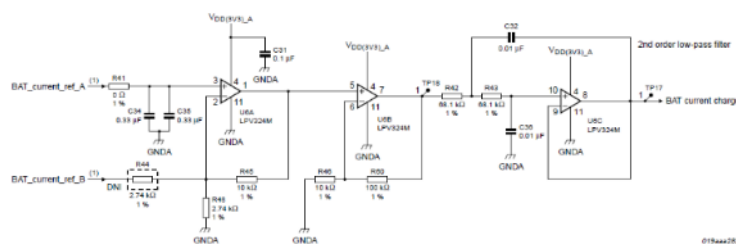


Fig. 5 Voltage measurement circuits (a) and current (b) STB

DETERMINATION OF INVERTER POWER

The power supply system is planned for a house with power consumption $W = 72$ kWh per week. The house is connected to a common power grid. When the SB power is insufficient, the energy will be consumed from the power grid. DC energy, taking into account losses in the inverter, will be required [7]

$$W_{in} = W_k = 72 \times 1.2 = 86.4 \text{ kWh.} \quad (1)$$

Divide the value W_{in} by the number of hours per week

$$P_{in} = \frac{W_{in}}{168} = \frac{86.4 \times 10^3}{168} = 514.28 \text{ W.} \quad (2)$$

We select the Power Master PM-800-12 (24) SLU ($U_n = 24\text{V}$; $P_n = 800\text{W}$) inverter. To cover the AC load, it is necessary

$$q \approx \frac{W_{in}}{U_n} = \frac{86.4 \times 10^3}{24} = 3600 \text{ Ah.} \quad (3)$$

DETERMINING THE VALUE OF THE STORAGE BATTERY CAPACITY

We assume that the maximum number of days when the battery can be recharged at any time of the day is $N = 1$. The total capacity of STB, taking into account the number of days without the Sun [8] is

$$q_N = q_{day} N = 514.28 \text{ Ah.} \quad (4)$$

We set the value of the depth of the permissible discharge of the battery as 70%, the utilization rate of the battery charge as $\gamma = 0.7$. STB charge taking into account the depth of discharge is

$$q_\gamma = \frac{q_N}{\gamma} = \frac{514.28}{0.7} = 734.69 \text{ Ah.} \quad (5)$$

We choose a coefficient taking into account the environment temperature. At 15.6°C – $\alpha = 1.11$. Total STB capacity is

$$q_{gen} = q_\gamma \alpha = 734.69 \times 1.11 = 815.5 \text{ Ah.} \quad (6)$$

STB Altek 6FM200EVX/J quantity is

$$N_{par}^{RB} = \frac{q_{gen}}{q_n} = \frac{815.5}{200} \approx 4 \text{ pieces; } N_{ser}^{RB} = \frac{U_{in}}{U_n} = \frac{24}{12} = 2 \text{ pieces.} \quad (7)$$

$$N^{RB} = N_{par}^{RB} N_{ser}^{RB} = 4 \times 2 = 8 \text{ pieces.} \quad (8)$$

DETERMINING THE REQUIRED AMOUNT OF SOLAR BATTERIES

To ensure the stability of the power system, we choose the following SBs TSM-190P: $P_n^{SB} = 190\text{W}$; $U_{MPP}^{SB} = 24\text{V}$; $I_{MPP} = 5.43\text{A}$; $S = 1.3\text{m}^2$. We take into account the charge-discharge losses of the STB [9]

$$q_{ch-dis} = q_{day} \zeta = 514.28 \times 1.2 = 617.13 \text{ Ah.} \quad (9)$$

Current value to be generated by the SB is

$$I^{SB} = \frac{q_{ch-dis}}{i} = \frac{617.13}{5.43} = 113.65A. \quad (10)$$

The total number of required SB is

$$N^{SB} = \frac{I^{SB}U_{in}}{P_n^{SB}} = \frac{113.65 \times 24}{190} = 15 \text{ pieces}; \quad N_{ser}^{SB} = \frac{U_{in}}{U_{min}^{CB}} = 1 \text{ pieces}; \quad N_{par}^{SB} = \frac{N^{SB}}{N_{ser}^{SB}} = 15 \text{ pieces}. \quad (11)$$

We calculate the area of the SB

$$S^{SB} = N^{SB}S^{SB} = 15 \times 1.3 = 19.5 \text{ m}^2. \quad (12)$$

CONCLUSION

In the scientific article, the calculation and analysis of the structure of a solar power plant based on a PEC transformer is made. It has been established that the most effective are SBs based on a PEC made of single-crystal Si. To obtain maximum power from the SB and provide the necessary conditions for charge-discharge, it is advisable to use controllers with monitoring of MPP MPPT. To accumulate energy received from the SB, it is advisable to use STB of type GEL. A prerequisite for the operation of a solar power plant is the receipt of a sinusoidal signal at the output of the inverter. The article developed a methodology for calculating solar power plants and a study of the principle of operation of a controller with MPPT.

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PROBABILITY OF FAILURE-FREE OPERATION OF DIODE ASSEMBLIES IN THE CONTROL UNIT OF MICROWAVE SIGNALS PARAMETERS

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This article discusses a unit for monitoring the parameters of microwave signals, during the operation of which failures of electrical radio elements occur. The mechanical impact exerted on the unit leads to disruption of the functioning of the ERE. The paper describes the results of modeling the mechanical and thermal effects on the diode assembly fastening bar, as the most vulnerable to failure. A design was chosen to improve vibration strength and heat dissipation.

Modeling the influencing factors will provide a justification for the correct choice of design and the probability of failure-free operation of diode assemblies.

Reliability of electrical radioelements, thermal conditions, mechanical modes.

INTRODUCTION

During the operation of various electronic devices, electrical and radioelement failures are possible in them, which arise as a result of exposure to both external and internal factors. These include: mechanical (vibration, shock) and thermal. The performance of the unit depends on the total action of the above factors. So, during its operation, failures occur at the place of attachment of the diode assemblies. Due to the mechanical effect, the legs of the fasteners, soldered to the wires, break off, as a result of which the integrity of the circuit and the functioning of the unit are violated. The unit for controlling the parameters of microwave signals is a device for switching with other units. Its overall dimensions are 248x190x120 mm. The external view of the device is shown in Figure 1.



Fig. 1 External view of the unit for monitoring the parameters of microwave signals

The housing contains a printed circuit board and separately fixed radioelements, which determine its functioning and trouble-free operation. This article presents an analysis of the diode array mounting bar to improve it from external / internal factors and increase the likelihood of failure-free operation.

MAIN PART

The probability of failure-free operation is the probability that a failure of an object does not occur within a given time interval. The value is calculated using the formula:

$$P(t) = e^{-\lambda_i \cdot t} \quad (1)$$

Where λ_i – average failure rate of circuit elements, t is the operating time of the system (based on the technical specifications of 10,000 hours);

So one of the determining factors for the value of the average failure rate of an element is temperature. We will simulate the fixing bar for diode assemblies with installed ERE in CAD SolidWorks and set the parameters for analysis in the Simulation extension. The simulation results are presented in Figures 2 and 3.

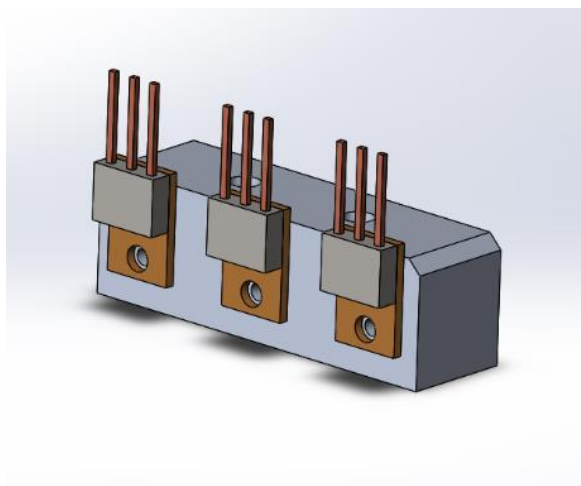


Fig. 2 Fixing bar for diode assemblies with installed ERE

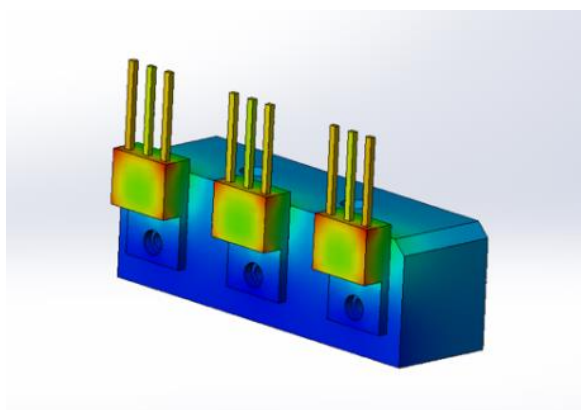


Fig. 3 Thermal analysis of the diode assembly mounting bar with installed ERE

The bar and diode assemblies are modeled based on the materials from which they are made. Based on the simulation results, we see that the heating of radioelements allows their operation, however, local places arise where the temperature reaches high values (47°C). For further analysis and ensuring the failure-free probability of the unit operation, it is necessary to calculate the convective heat transfer coefficient. The calculation of the convective heat transfer coefficient of the diode assembly taking into account natural convection is presented in Table 1.

TABLE 1 - CALCULATION OF THE COEFFICIENT OF CONVECTIVE HEAT
TRANSFER OF THE ERE WALLS

Indicators	Designation / dimension	Side surface	Side surface	Bottom surface	Top surface
Air velocity along the heat transfer boundary	$w = (\text{m/s})$	0	0	0	0
Ambient temperature	$t_b = (^{\circ}\text{C})$	20	20	20	20

Surface temperature	$t_n = (C)$	47	47	47	47
Surface blackness	$\varepsilon =$	0,9	0,9	0,9	0,9
Surface width	$B = (m)$	0,008	0,00333	0,00333	0,00333
Surface length	$L = (m)$	0,0103	0,0103	0,008	0,008
Determining temperature	$t_o = (C)$	33,5	33,5	33,5	33,5
Determining the size of the surface	$I_o = (m)$	0,0103	0,0103	0,5	0,5
Air density	$\rho = (kg/m^3)$	1,151439752	1,151439752	1,151439752	1,151439752
Dynamic coefficient of air viscosity	$\mu = (Pa \cdot s)$	1,87534E-05	1,87534E-05	1,87534E-05	1,87534E-05
Specific isobaric heat capacity of air	$C_p = (Gj/(kg \cdot K))$	1006,516296	1006,516296	1006,516296	1006,516296
Coefficient of thermal conductivity of air	$\lambda = (W/(m \cdot K))$	0,026609097	0,026609097	0,026609097	0,026609097
Kinematic coefficient of air viscosity	$\nu = (m^2/s)$	1,62869E-05	1,62869E-05	1,62869E-05	1,62869E-05
Volumetric expansion coefficient of air	$\beta = (1/K)$	0,003262643	0,003262643	0,003262643	0,003262643
Prandthal number	$Pr =$	0,709366793	0,709366793	0,709366793	0,709366793
Reynolds number	$Re =$	0,00	0,00	0,00	0,00
Grashof number	$Gr =$	417,8382982	417,8382982	47797654,2	47797654,2
Rayleigh number	$Ra =$	296,4006137	296,4006137	33906068,68	33906068,68
Nusselt number	$Nu =$	2,813518666	2,813518666	20,60312624	48,5493856
Convective heat transfer coefficient	$a_k = (W/(m^2 \cdot K))$	7,268465248	7,268465248	1,096461183	2,583710654

The following table shows the formulas:

– Determining temperature

$$t_o = (t_e + t_n) / 2 \quad (2)$$

Where t_b – ambient temperature, t_n – surface temperature;

- Determining the size of the surface

$$I_0 = L \quad \text{– for horizontal surface} \quad (3)$$

$$I_0 = (B * L) / (2 * (B * L)) \quad \text{– for vertical surfaces} \quad (4)$$

Where B – surface width, L – surface length;

- Prandthl number

$$Pr = \mu * C_p / \lambda \quad (5)$$

where μ – dynamic air viscosity (at t_0), C_p – specific isobaric heat capacity of air (at t_0), λ – air thermal conductivity coefficient (at t_0);

- Reynolds number

$$Re = w * I_0 / \nu \quad (6)$$

where w – air velocity along the surface boundary, I_0 – determining the size of the surface, ν – kinematic coefficient of air viscosity (at t_0);

- Grashof number

$$Gr = \rho * \beta * |t_n - t_a| * I_0^3 / \nu^3 \quad (7)$$

where ρ – air density (at t_0), β – volumetric expansion coefficient of air (at t_0);

- Rayleigh number

$$Ra = Gr * Pr \quad (8)$$

- Nusselt number

$$Nu = 0,664 * Re^{1/2} * Pr^{1/3} \quad \text{limitation } Re \leq 5 * 10^5; \quad (9)$$

$$Nu = 0,037 * Re^{0,8} * Pr^{0,43} \quad \text{limitation } 5 * 10^5 < Re \leq 3 * 10^7; \quad (10)$$

for horizontal surface;

$$Nu = 0,68 + 0,67 * Ra^{1/4} / (1 + (0,492 / Pr)^{9/16})^{4/9} \quad \text{limitation } Ra \leq 10^9; \quad (11)$$

$$Nu = (0,825 + 0,387 * Ra^{1/6} / (1 + (0,492 / Pr)^{9/16})^{8/27})^2 \quad \text{limitation } 10^9 < Re \leq 10^{12}; \quad (12)$$

for vertical surfaces;

- Coefficient of convective heat transfer

$$\alpha_k = Nu * \lambda / I_0 \quad (13)$$

Also, in the Simulation extension, it was possible to simulate the mechanical effect (vibration) of the diode assembly mounting bars with the EREs attached to them. Based on the operating conditions (UHL 4 in accordance with GOST 15150) and the REA classification (ground transportable), the parameters for calculating the mechanical analysis were set, which are presented in Figure 4.

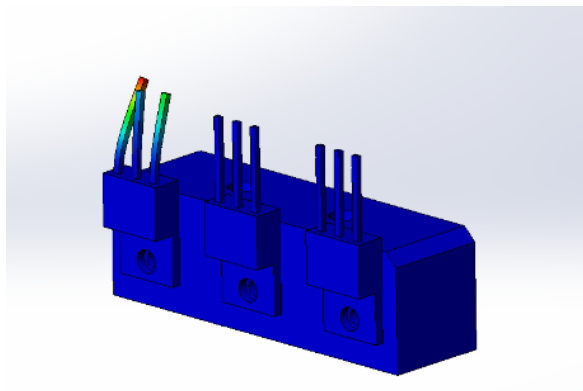


Fig. 4 Vibration analysis of the diode assembly mounting bar with installed ERE

According to the results of the analysis, it was revealed that the deviation of the leg of the diode assembly from the nominal value is 3.8 mm. To achieve vibration strength, better heat dissipation from the ERE and fixing of the wires, the design was changed – Figure 5.

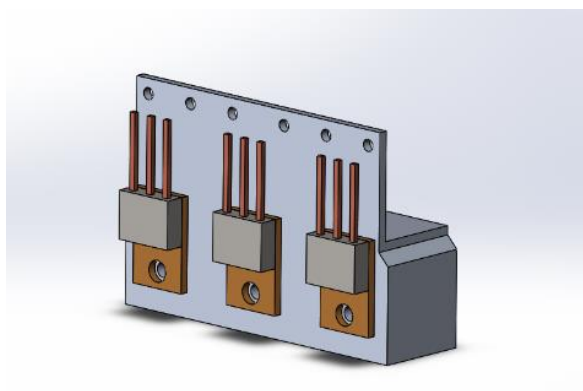


Fig. 5 Modified mounting plate for diode assemblies

The wires that go to the fastening bar are fixed with clamps on the corner with dimensions 52x20x16 and thickness 1.5 in accordance with GOST R 50571.5.52-2011. The analysis of the new design showed that changing the wire fastening reduced the vibration load, and also managed to increase the heat dissipation between the diode assemblies and the fastening strips. The simulation results are presented in Figures 6 and 7.

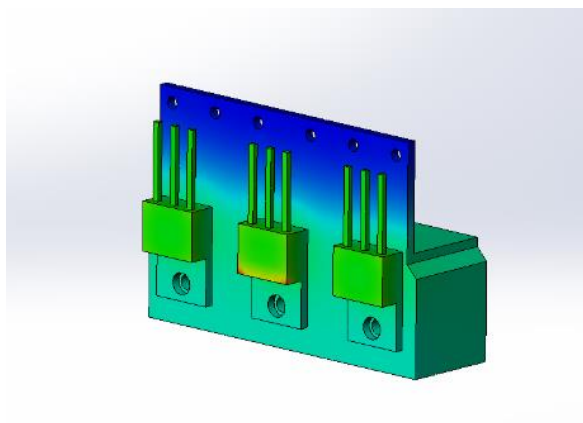


Fig. 6 Thermal analysis of the modified diode assembly mounting bar with installed ERE

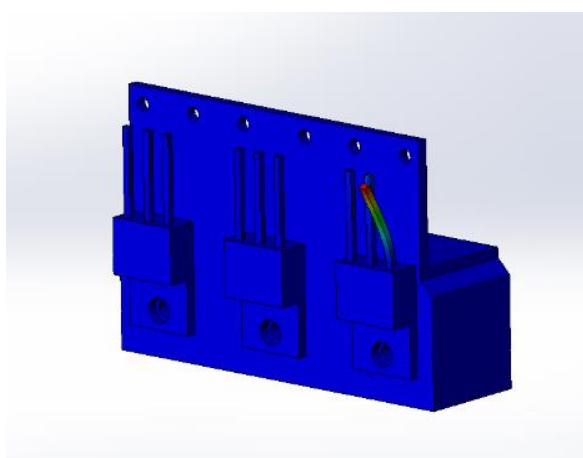


Fig. 7 Vibration analysis of the modified mounting plate of the diode assembly with installed ERE

It can be seen from the simulation result that the temperature value decreased from 47°C to 42°C, and the deflection of the legs was 1.2 mm.

From the above it follows that the value of the probability of failure-free operation (1) depends on the average failure rate, the indicator of which is due to various factors that appear on the ERE. For this, correction factors are introduced. This analysis considers the correction factor α , which depends on the temperature of the ERE and the load factor $K_H=0,26$ (from technical specifications).

$$\lambda_i = \alpha * \lambda_0 \quad (14)$$

where λ_i – the failure rate of the element, taking into account the load and temperature,

λ_0 – failure rate in nominal operating modes

($\lambda_0 = 9,10 \cdot 10^{-9}$ reference data);

The dependence of α on temperature and load factor is shown in Figure 8.

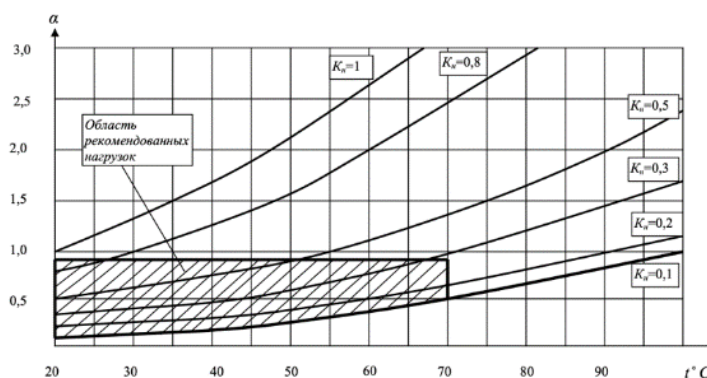


Fig. 8 Typical dependence of α on temperature t and load factor K_n

Substituting all known data on two structures into formula (14), and then in (1), the analysis of the data obtained was carried out.

Based on the above thermal analyzes, the temperature of the diode assemblies decreased and the correction factor decreased from 0.41 to 0.32. At the same time, the probability of failure-free operation increased by 0.00219972, the new design for fastening the wires provided protection against breaking the legs of the diode assemblies, the leads began to deviate from 3.8 to 1.2 mm, and the resonant frequency increased from 2800 Hz to 2900 Hz, which provided better functioning of the unit for monitoring the parameters of microwave signals.

OUTPUT

Thus, we can conclude that if it is more efficient to remove heat from the heating elements, the more they will have the likelihood of failure-free operation. To ensure reliability from vibration factors in the considered variant, the method of increasing the rigidity of the system is chosen. Simultaneously with the task of increasing the rigidity, the problem with heat removal from the ERE was partially solved, which led to a visible result, based on the calculations performed above. These and many other factors contribute to the likelihood of system uptime, which can be improved by rational design.

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CREATION OF ELECTRONICAL MODEL OF THE PRODUCT FOR THE DESIGN OF
ROCKET AND SPACE TECHNOLOGY PRODUCTS

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Abstract – The paper describes the mechanism of filling the electronic layout of the product of the rocket and space industry, which will increase the efficiency of the design processes and the quality of the products.

Keywords: EMP; electronic model of the product; rocket and space technology products.

INTRODUCTION

The design of rocket and space technology is a complex and knowledge-intensive process, during which huge amounts of information concerning the stages of the life cycle (LC) are accumulated. The use of outdated data management methods leads to the fact that specialists do not navigate the accumulated information, and the threat of losing important information increases. In the design process, an important role is played by the interaction of the participants of the LC participants and the transfer of relevant information between them, which in the case of using only paper media is not always quickly implemented.

PROBLEM STATEMENT

A modern industrial product, especially a product of the rocket and space industry, should consist of two equivalent components: the physical embodiment and the information embodiment or the electronic model of the product (EMP), i.e., data about the product. In this case, the final product begins to appear only at the production stage and ends its existence at the disposal stage of the product. At the same time, the EMP begins to exist together with the beginning of the LC of the product and can continue to exist even after the end of the LC of the product. At the initial stages of the product LC (design, process development) EMP is equivalent to the product itself, since the physical product does not yet exist.

Creating an EMP at the enterprise allows to save the information that occurs at each stage of product design, and use it at other stages, that allows to centrally contain the information needed at different stages, and eliminating the possibility of duplication. To work with data, the principle of user rights differentiation is implemented, in which each user of the system gets the right to create/change information, or only receive/read it (to prevent unauthorized changes to data), or restrict the right to receive this information if it should not be available to the user.

EMP is a kind of data storage that contains all the information created and used by all departments and services of the enterprise, participants of the product's life circle, in the course of their production activities.

SOLUTION OF THE PROBLEM

Figure 1 shows the structure of the EMP, which reflects the main components of the data obtained during the design of a prototype product of rocket and space technology. The dominant position over these data is occupied by the design technique in the notations of IDEF0 diagrams, as the main tool for filling in the EMP. The blue color indicates the main, but not the only, standards that regulate the results of the LC stages

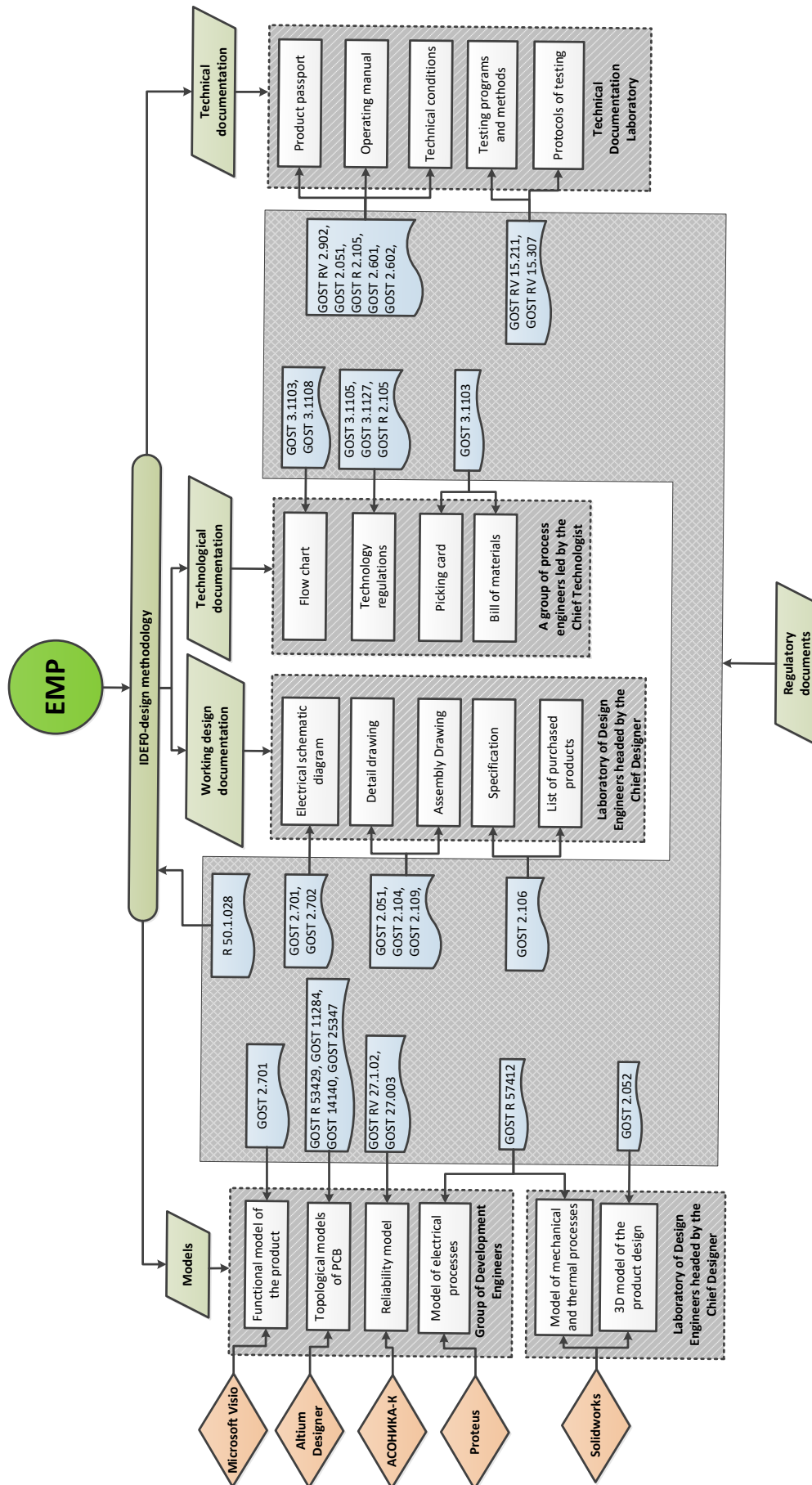


Fig. 1 EMP composition

In the process of product development, in addition to various analytical calculations, using design and technological CAD systems (examples of such CAD systems are shown in Figure 1 in orange), models are created that describe the structure of the product, its composition and its components: parts, components, components, materials, etc.

Also, the results of computer modeling are mathematical models containing information about the geometry of the product, the interface with different parts, thermal conductivity, etc. On the basis of computer mathematical models in specialized CAD systems, data is obtained, for example, on the sensitivity of circuit components to changes in parameters or on the reliability of the product.

All these models must contain sufficient information to create technical and operational design documentation at the stages of the product life cycle.

CONCLUSION

As a result, the creation of EMP allows you to avoid unnecessary time spent on searching, copying and archiving data, which with paper data can take up to 30% of the total work time. Due to the fact that information is available at all stages of the LC, it becomes possible to simultaneously and jointly design specialists from different industries (technologists, designers, developers, etc.). With the introduction of an additional data management system (PDM system), you can reduce the development time of new products by searching for suitable parts or very similar ones from already created, rather than creating from scratch.

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DEVELOPMENT AND TESTING OF THE LASER SYSTEM CASE FOR MONITORING DEFORMATIONS IN LONG BUILDINGS AND BRIDGES

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Abstract — The article discusses a new system for monitoring deformations in structures. The main part is devoted to the development of a laser system housing for observing deformations in extended buildings and bridges and conducting tests for resistance to sediment and dirt. Several options for constructing the corpus are also considered, on the basis of which the final option is selected. The article contains the results of tests and measurements of the size of falling precipitation, software processing and image analysis.

Keywords: deformation monitoring system, laser system housing, deformations in extended buildings, deformations in bridges, deformation monitoring.

INTRODUCTION

In 2020, the total mass of objects created by humans exceeded the mass of the entire biosphere [1]. The number and complexity of buildings is growing every year. Skyscrapers, huge buildings, high-rise and extended structures, bridges are being erected. Over time, the deformation of the entire structure or its individual parts occurs [2]. For example, in 2018 about 100 bridges collapsed in Russia [3]. In 2020, the number of collapsed bridges decreased, but collapses still continue.

In order to notice deformations in time and prevent emergencies, it is necessary to carry out regular monitoring of objects. Currently, a total station [4] or its improved version - a laser scanner is used for this. The disadvantages of geodetic monitoring is the lack of information about the state of the object between the periods of monitoring. The automated monitoring system allows you to collect and process data on the deformation processes of the controlled object at any frequency, as well as to provide emergency notification of emergency situations.

DEFORMATION MONITORING SYSTEM

A monitoring system is a complex hardware and software complex that includes high-precision measuring equipment (sensors), equipment of the monitoring center and communication channels, as well as software for control, collection and processing of data [5].

The main idea of the system for monitoring deformations is the use of a laser transmitter as a signal source [6,7], as well as the use of a photosensitive matrix to receive [8,9] a signal and determine deviations from the normal position. At the beginning of the extended object, a transmitter is attached (Fig. 1 (1)), which emits a laser beam in the direction of the receiver (Fig. 1 (2)). The receiver receives the laser signal, transmits the data to the monitoring center, the data is processed and analyzed, after which it is sent to the application, where it can be viewed.



Fig. 1 Location of the transmitter and receiver of the strain monitoring system

One of the main components of the monitoring system is considered to be specialized software (software) installed on the server of the monitoring center. This software should provide the following functions: control of measuring sensors, collection, processing and storage of measured parameters in a local database, visualization, generation of alerts in emergency and critical situations (via SMS, in an application on a smartphone). The customer will be able to view all collected data in the application on a smartphone or on a personal computer.

Due to the fact that the receiver and transmitter are mounted outside a building or bridge, requirements are imposed on the deformation monitoring system equipment to be maintained in various weather conditions. Climatic conditions [10,11] in different regions impose restrictions on the use of such devices without enclosures. Accordingly, the placement of equipment without

a case is impossible, since after unfavorable weather the equipment will fail [12]. Rain, snow, mud - all of these can affect the correct operation of the system. Thus, it is an important challenge to design the housing for the transmitter and receiver.

The receiver housing must have at least one hole for the laser beam to hit the sensor (matrix). It is impossible to close this hole with a lens, as it will soon become dirty. It would be possible to create a special group of one or two people who, at a certain period of time, would come and clean the body of dirt. But this is not a very rational decision, since cleaning would have to be done very often. And this leads to unnecessary financial costs and is not always feasible. Therefore, in this work, the question of the implementation of the case and the study of the effects of precipitation and dirt on the device are solved.

DEVELOPMENT OF THE CASE AND RESEARCH OF THE EFFECTS OF SEDIMENT AND DIRT ON THE DEVICE

The housing is an important part of the device because various weather conditions can damage the system. At the beginning of the study, a model was developed in the form of a cube with a hole in the center for the passage of a laser beam (Fig. 2). Behind the front wall there is another wall with a hole in order to weed out rain drops when passing through the first hole. There are also two holes in the side walls to prevent condensation from forming. There are holes in the bottom wall through which water will flow. The model was designed in the Russian CAD "Compass-3D v19".

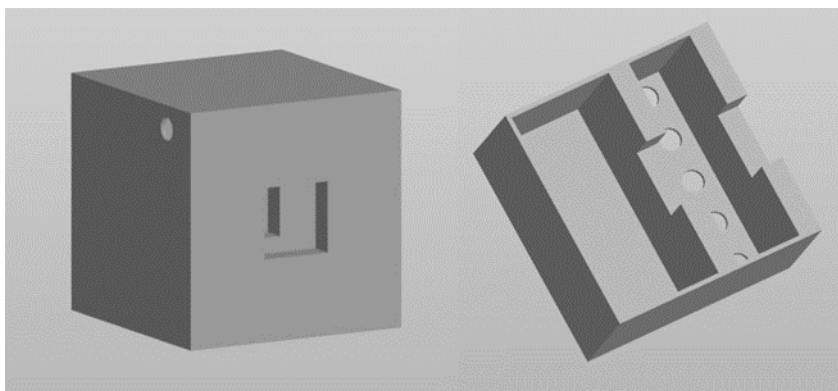


Fig. 2 3D model of the receiver body

For testing, a plastic test piece was printed on a MakerBot Replicator + 3D printer. The receiver body is planned to be disassembled for research and simplified assembly and disassembly. The study of the influence of precipitation and dirt on the device is proposed to be carried out by replacing real precipitation and dirt with paint. The consistency of this paint is chosen close to rain and dirt. The test is supposed to be evaluated by measuring the size and number of droplets that fall inside the receiver housing. Due to the fact that the receiver (sensor) itself will be located on the rear inside of the case, it is important to investigate the effect of precipitation and dirt on this area of the case. The test procedure was as follows. Within a minute, swinging movements with a paint brush were applied to the sample at different angles in order to examine and estimate the number and size of drops that fall on the device (Fig. 3).



Fig. 3 View of the device after testing

Then, using the EVOTIS Lynx VS9 visual control system, the drops that fell on the rear inner wall were measured (Fig. 4). A white sheet of paper is used for research purposes as an indicator of dirt and sediment that gets inside the case.

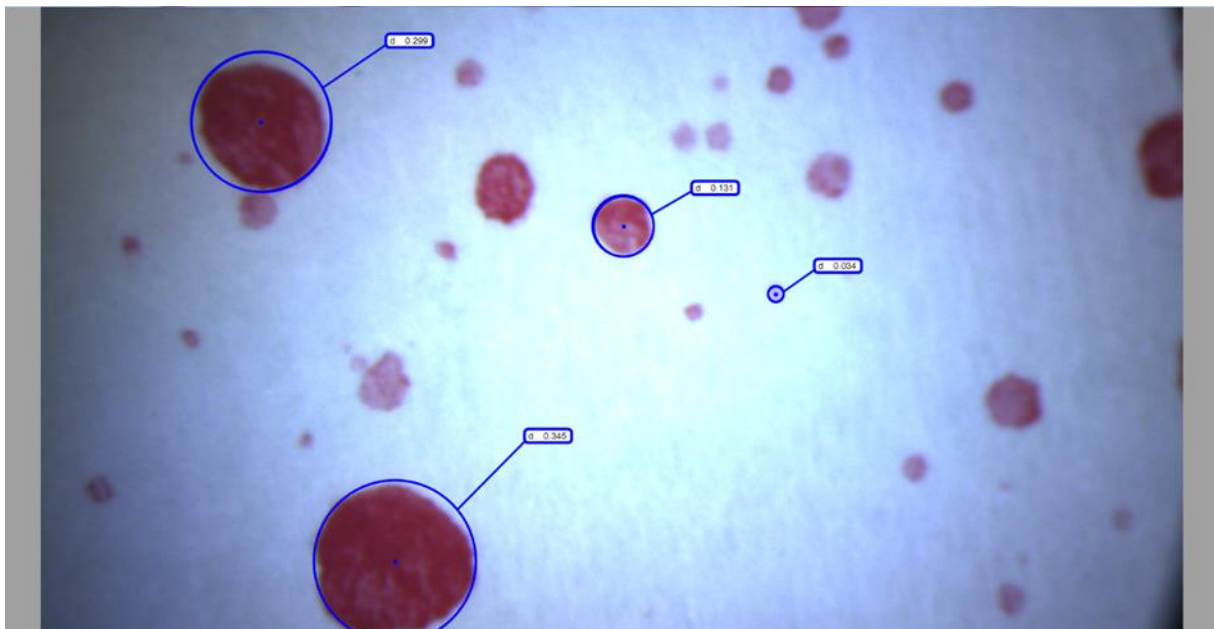


Fig. 4 Measurement of the dropped drops

The results of the first test showed that this case in this form is not entirely successful. Conclusions were made, as well as a modification of the front walls of the case was proposed. Namely, it was decided to move the walls out in the form of a pyramid (Fig. 5) so that fewer drops of dirt and precipitation could get inside.

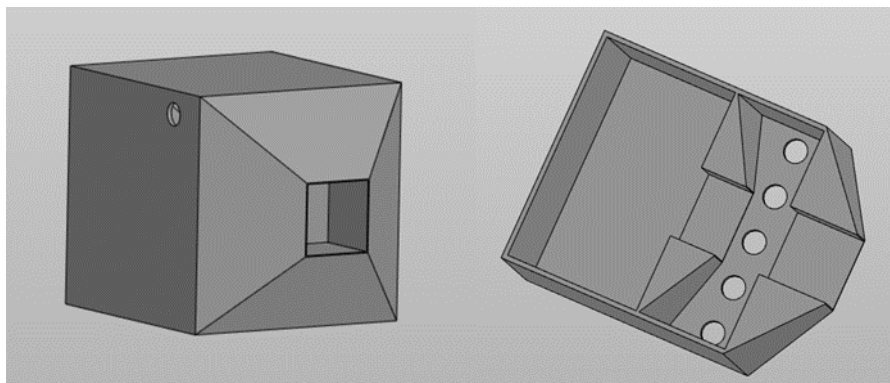


Fig. 5 Receiver body with elongated walls

The second test piece was tested using the same procedure, and the measurement results are shown in Figure 6. The test showed that in comparison with the first model, droplets of a smaller diameter reached the rear wall. Drops also accumulated at the bottom of the case. To solve this problem, it was decided to place the bottom of the model at an angle so that the drops flow into specially created holes. Also, the distance to the rear wall was increased by 2 cm to reduce the likelihood of drops falling on the indicator (Fig. 7).

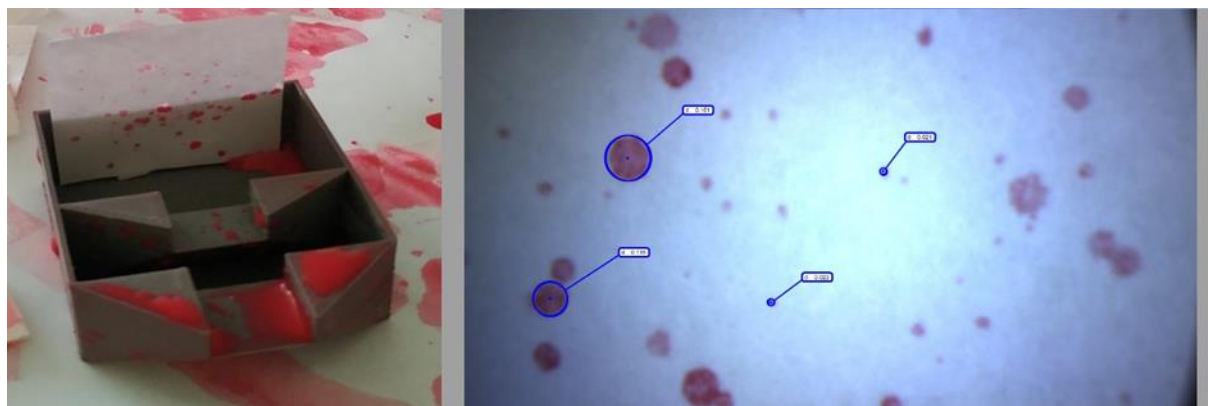


Fig. 6 Body after testing and measurement results

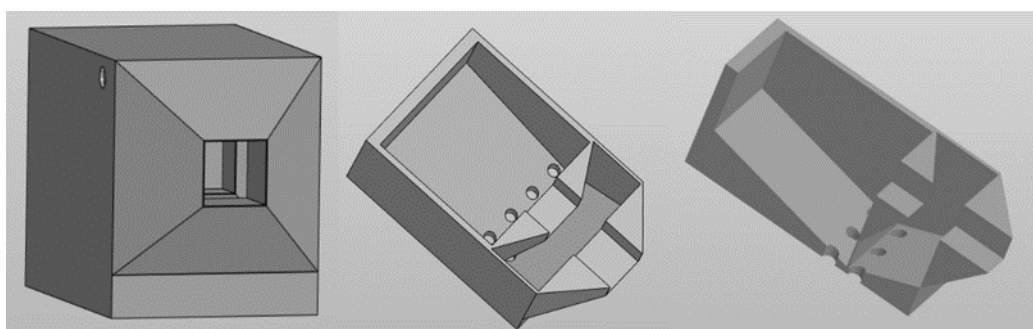


Fig. 7 The receiver body is elongated

The test results show (Fig. 8) that the number of drops reaching the rear wall of the housing has decreased. But the droplet diameters have increased.

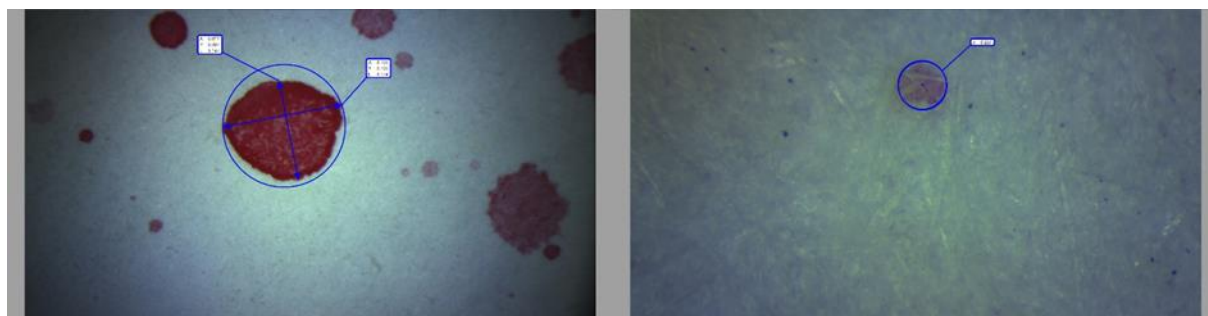


Fig. 8 Measurement of entrained drops

The increase in the diameter of the droplets is due to the fact that the droplet, entering the body, ricochets from the lower short thick wall and immediately falls on the back wall. Therefore, it was concluded that it is necessary to reduce the thickness of the bottom wall, as well as to make

chamfers near the inlet holes. After making decisions, an improved version of the test case was developed (Fig. 9), as well as the results of its testing (Fig. 10).

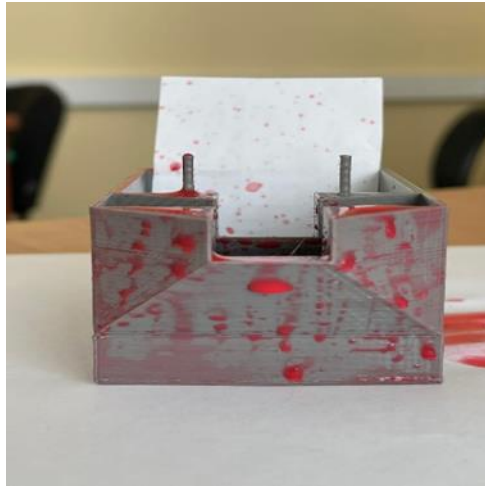


Fig. 9 Improved receiver housing

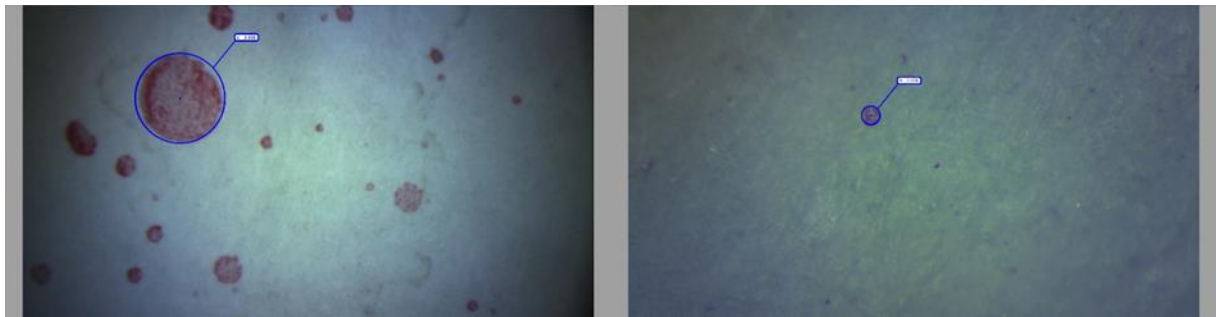


Fig. 10 Measurement results

The test showed that a large number of droplets still fall on the back wall. By increasing the length of the case by one more centimeter, the final version of the test case was obtained (Fig. 11), and the results of its tests are also presented (Fig. 12).

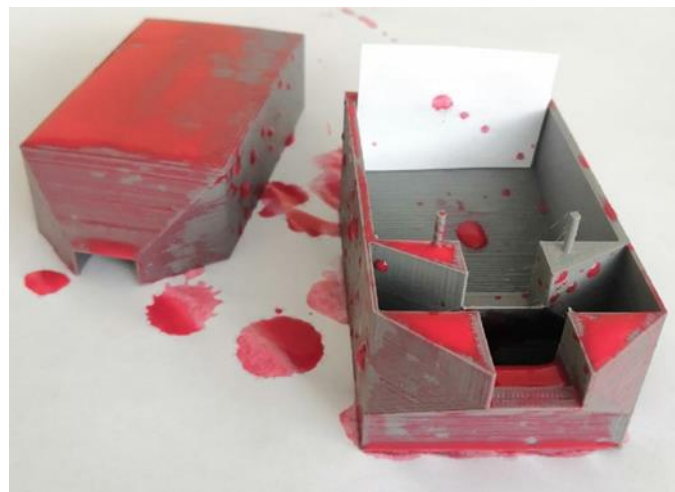


Fig. 11 The final version of the receiver housing



Fig. 12 Measurement results

CONCLUSION

At the beginning of the work, the task was set, the back wall of the case should be filled with paint to a maximum of 1.25-1.5% of the entire wall area. With each new body, the fill percentage decreased, reaching 1.1%, which does not exceed the threshold and is an excellent result (Fig. 13).

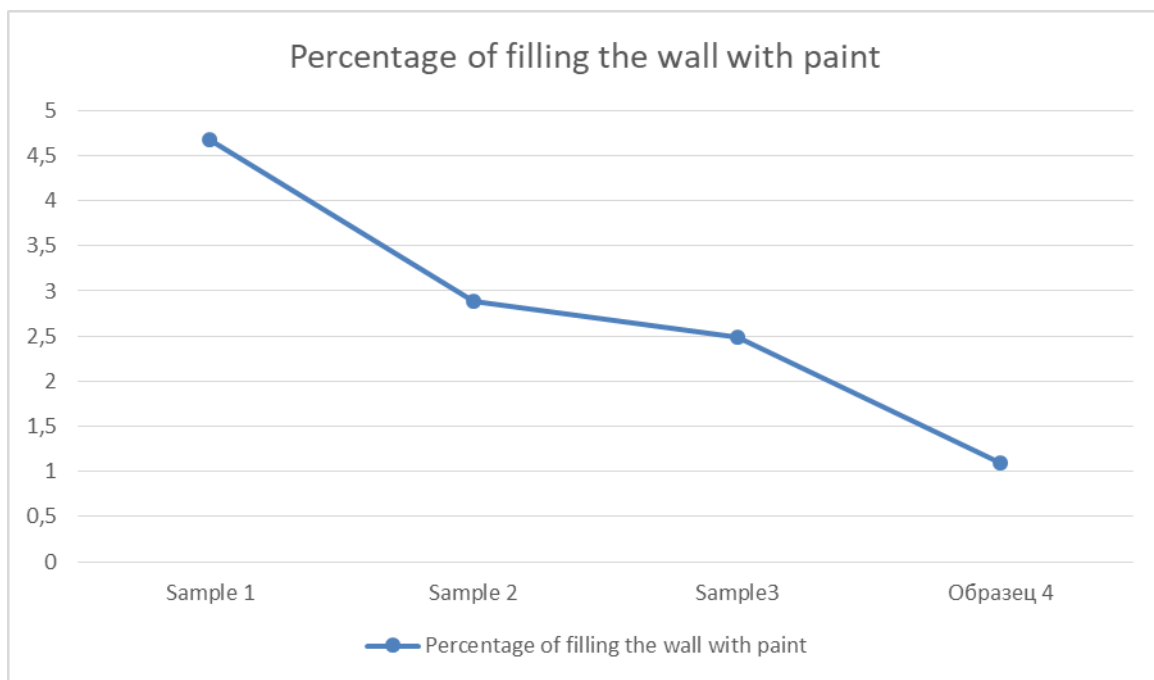


Fig. 13 Paint filling the back of the enclosure

This paper presents the key ideas in the construction and use of a laser system for observing deformations in extended buildings and bridges. The stages of the implementation of the body of this system from the development of a 3D model in the Russian CAD "Compass-3D v19" to implementation using 3D printing are demonstrated. The method of testing the device resistance to precipitation and dirt is presented. The main emphasis in the article is made on testing, studying the dependence of the shape and size of the receiver body of a laser system for monitoring deformations in extended buildings and bridges. Conclusions are made about the optimal shape of the receiver body.

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CONSTRUCTION OF THE PRINTING UNIT FOR CONTROL AND CONTROL OF THE LASER GYROSCOPE UNIT

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Abstract – With the development of aircraft technology of various types, increasingly stringent requirements are imposed on their control and navigation systems in terms of expanding functionality, improving weight and dimensions, increasing reliability and manufacturability. The general trend towards miniaturization of both the aircraft themselves and the onboard equipment, along with the expansion of their capabilities, leads to a constant improvement in the design and technology of their manufacture. One of the important directions for improving onboard aviation equipment is the creation and improvement of high-precision inertial navigation systems. The task of such systems, built on the basis of accelerometers and optical gyroscopes

based on the Sagnac effect, is to determine the angular velocities, accelerations of a moving object, and, in general, the orientation of the object in three-dimensional space.

Keywords: control and management unit, gyroscope, strapdown inertial navigation system, Sagnac effect, thermal model of a printed circuit board.

INTRODUCTION

The development is associated with the improvement of the unit of laser gyroscopes and, in particular, the design of the printed circuit unit for monitoring and controlling the unmanned aerial vehicle of the aviation navigation system (Fig. 1). This report presents the results of the layout and construction of the thermal model of the printed circuit assembly.

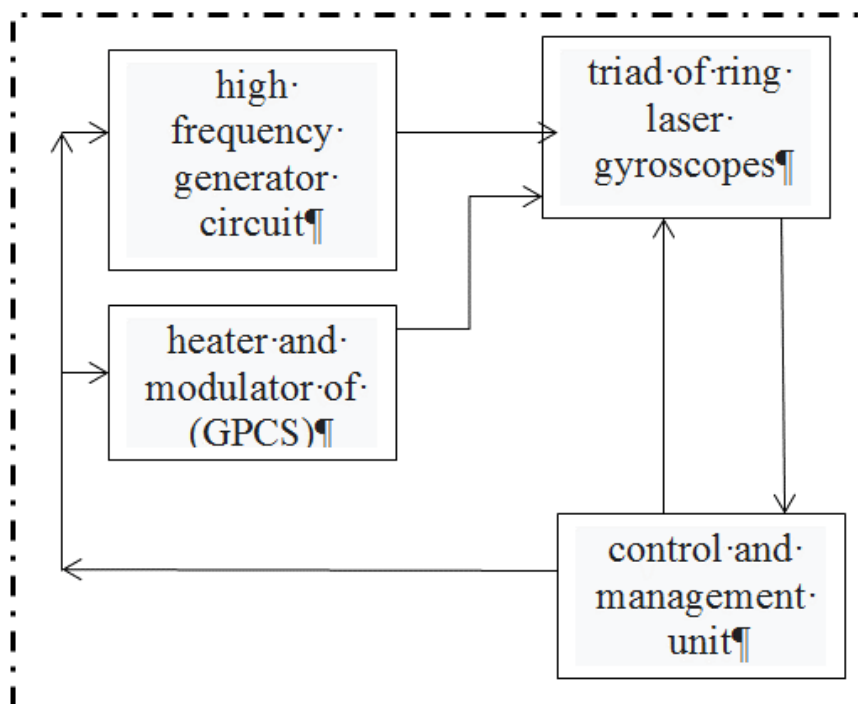


Fig. 1 Block diagram of the unit of laser gyroscopes

The main element of the unit of laser gyroscopes is a triad of ring laser gyroscopes. Their principle of operation is based on the Sagnac effect: the phase difference (Sagnac phase) of two light waves propagating along the fiber circuit in opposite directions is proportional to the angular speed of rotation, which is measured by the LG sensors.

The ring laser gyroscope is an active interferometer - a closed-loop laser (Fig. 2).



Fig. 2 Appearance of ring laser gyroscope

Used as a generator, a helium-neon laser excites in a closed system of mirrors - a ring resonator - two beams moving towards each other. When the resonator rotates with a high frequency around the axis of the system, the propagation velocities of the rays become different. This difference is proportional to the rotation speed and is indicated in the form of a phase difference or resonant frequencies in a closed beam propagation system. The difference frequency, as a result of the superposition of two opposing waves, is read using a photodetector. The output characteristic depends not only on the rotational speed of the optical system, but also on thermal effects, which are minimized using the automation system of the monitoring and control unit. In general, the functions of a node are reduced to controlling all systems of the block:

- high frequency generator circuit;
- heater and modulator of the gyroscope perimeter control system;
- by igniting the laser;
- vibration drive gyroscope;
- formation and transmission of information about temperatures, orientation angles (roll, pitch).

PROBLEM STATEMENT

The purpose of the node development is: increasing the weight and size characteristics by rearranging and combining two printed circuit assemblies previously used in the design, both schematically and functionally; increasing the resistance of the assembly to the effects of external factors; an increase in the processing speed of the received information due to the use of a more powerful processor.

At the design stage, a preliminary thermal calculation of the unit was carried out in order to select the optimal arrangement of radioelements on the surface of the printed circuit board to ensure the thermal regime; ensuring the required characteristics with an increase in installation density. The calculations were performed in the CAD environment SOLIDWORKS.

SOLUTION OF THE PROBLEM

1 Design requirements for the assembly

The dimensions of the seat of the designed assembly must correspond to the seat of its prototype.

The dimensions of the designed unit should not exceed 80.5 mm x 57.0 mm.

It is not allowed to use forced air / liquid cooling to ensure the thermal regime, since it can lead to an increase in the mass-dimensional parameters of both the unit itself and the the unit of laser gyroscopes.

The values of the maximum temperatures of the elements of the printed circuit assembly should not exceed the values specified in the technical documentation for electrical radio product.

The projected board of the node must belong to the third class of accuracy.

The base material of the assembly's printed circuit board must ensure the dimensional stability of the printed circuit board when exposed to temperature and humidity.

Limit deviations for the mating dimensions of the PCB contour should be no higher than 12 grade.

2 Technical requirements for resistance from the effects of external factors

Strapdown navigation systems are used in various types of special equipment: aviation, sea, land. The designed Strapdown navigation systems refers to the object of aviation equipment, therefore, the designed unit must meet the requirements for resistance to the following types of (TABLE 1).

TABLE 1 – CHARACTERISTICS OF INFLUENCING FACTORS AND THEIR MEANINGS

Influencing factor	Characteristics of the influencing factor	Value
Linear acceleration	The value of the linear acceleration, m/s ²	100
Repeated mechanical shock	Peak shock acceleration, m/s ²	80
	Duration of action, s	15
Resonance	Frequency, Hz	400
Increased ambient temperature	Operating, °C	55
Reduced ambient temperature	Operating, °C	-55

3 Reliability requirements for a node

Mean time between failures - at least 10,000 hours.

4 Preliminary heat calculation of the node

This section is devoted to the preliminary thermal design of the node in the Solidworks FlowSimulation environment in order to select the optimal layout of the electrical radio product along the surface of the printed circuit board to ensure the thermal regime; ensuring the required characteristics with an increase in installation density.

4.1 Initial data for calculation

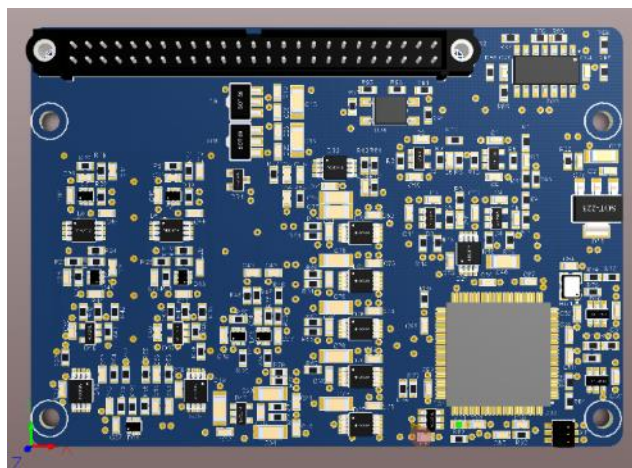


Fig. 3 Preliminary assembly of the node

PCB size: 80.5 mm x 57.0 mm.

Material of the PCB of the assembly: FR-4 fiberglass was chosen for the design of the PCB of the assembly.

Placement of components on the surface of the printed circuit board: the printed circuit board is multi-layer, one-sided mounting.

4.2 Results of preliminary thermal calculations

Based on the results of thermal modeling of the preliminary assembly of the assembly, it turned out that for nine elements the maximum temperature reached as a result of the study exceeds the value of the limiting temperature specified in the technical documentation. With this arrangement, it is necessary to use forced air cooling, which does not meet the requirements of clause 1.1 of this work.

4.3 Basic methods for arranging electrical radio products on the surface of a printed circuit board

Equalize the power dissipation on both sides of the PCB by moving the functionally related components to the opposite side.

The arrangement of elements on the surface of the printed circuit board in accordance with the requirements of GOST for the third class of accuracy.

Place the most stressed components at the edges of the printed circuit board to ensure heat dissipation.

Place the least loaded components closer to the center.

4.4 Results of the thermal calculation of the modified printed circuit board

Based on the results of thermal modeling of the modified printed circuit board (Fig. 4), the following conclusions can be drawn:

- the maximum temperature of all overheated components has leveled off;
- the maximum temperature of the most heated component reaches 39 °C, which fully meets the limit value for technical documentation;
- the dimensions of the board do not exceed those specified in clause 1.1;
- to ensure the thermal regime, the use of forced cooling is not required.

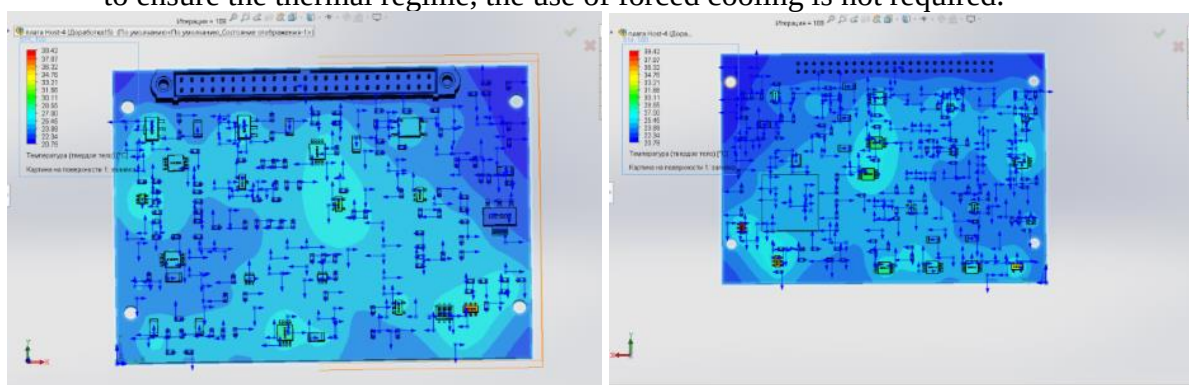


Fig. 4 Results of thermal modeling of a node in a CAD environment

CONCLUSION

As a result of the research, the following works were performed:

- the optimal layout of the electrical radio product was selected in accordance with the requirements of GOST;
- selected material for the base of the printed circuit board;
- the dimensions of the resulting printed circuit assembly do not exceed 80.5 mm x 57.0 mm;
- the resulting printed circuit board is multilayer with double-sided assembly of the electrical radio product;
- built a thermal model of the unit;
- modeling of thermal processes of the thermal model of the unit was carried out;
- according to the research results, the optimal temperature values were achieved for each of the unit elements

Considering the above, we can conclude that the selected design solutions fully comply with the requirements specified in clause 1.1.

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INFLUENCE OF PERFORATION ON THE TEMPERATURE REGIME OF THE BLOCK

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Abstract - At this stage of development, humanity is using various electronic equipment everywhere. During operation, the question often arises about the organization of thermal modes to ensure the proper functioning of the device, in our case, it will be the interface block of peripheral equipment. In this article, we will consider the influence of different types of perforations on the temperature inside the block, what is the relationship between the heat in the corpus and the area of the perforation.

Keywords: interface block; perforation; perforated block; thermal mode; thermal analysis; block temperature.

Electronic equipment plays an important role in human life, and its failures and failure can lead to sad consequences. One of the main tasks of the designer is to ensure the thermal regime in the device under development.

The reliability of the REA depends very much on the temperature regime. When exposed to both high and low temperatures, the probability of failure of the device increases dramatically. But where does the "extra warm" come from, the main problem is that the electric radio elements do not use all the energy received, only a part is given to the payload, and the rest is released as heat to the environment.

The interface block consists of many elements and each of them releases unspent energy outside, enhancing the effect of thermal impact, which is still limited by the corpse of the device.

There are many methods for reducing the temperature of electronic equipment. The most popular in electronic equipment is natural air cooling, with the use of forced ventilation, as well as the use of heat sinks.

For the developed interface unit, I suggest considering natural air cooling, which is also convective. Convective heat transfer is the transfer of energy in the form of heat in an unevenly heated medium due to the convective motion of the medium.

The heat calculation will be performed in the SolidWorks program.

Basic block data:

- Dimensions of the unit 198x120x70 mm (LxWxH);
- The unit uses two boards with a total heat output of 8.46 W.
- Maximum operating temperature +55°C.

To begin with, we will conduct a thermal analysis of the block without using cooling means. Figure 1 shows the result of the simulation in the program. According to this picture, we can conclude that the unit is overheating and we need to somehow reduce the temperature in it to +85°C, since when the heat value is higher, some EREs begin to fail.

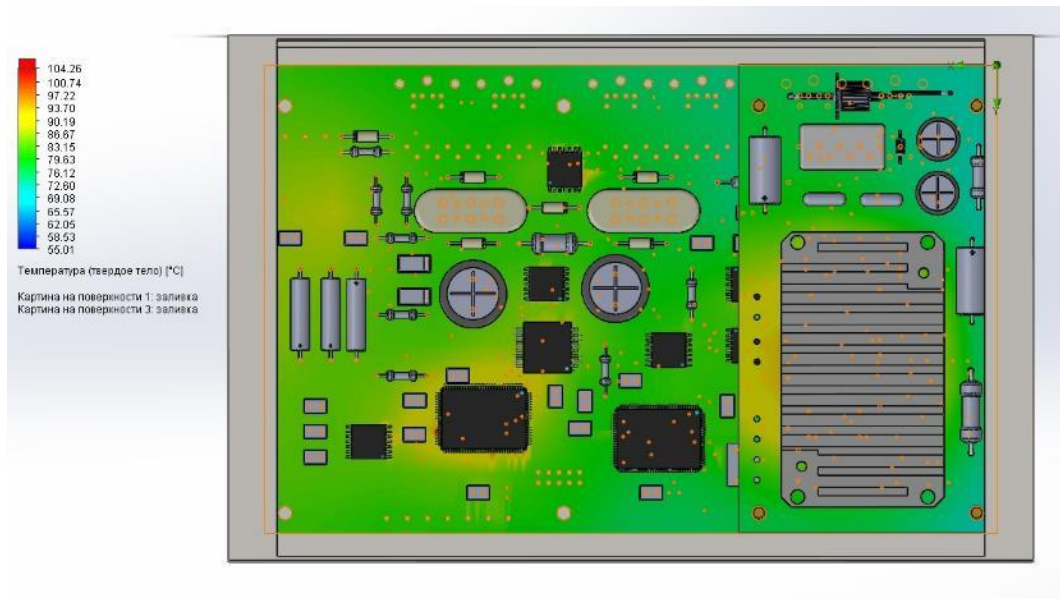


Fig. 1 The result of modeling the heat of the interface block in the Solidworks program

The simplest and cheapest way to ensure the thermal regime inside the unit is perforation. It ensures the flow of cold air inside the corpus, and also allows better heat dissipation in the environment. There are many types of perforation, each of them performs its own function, but you need to determine which will be most effective for the block being developed. With the help of perforation, the temperature value in the unit and on the cases of electric radio elements can be reduced by up to 30%.

For thermal analysis analysis, we use the holes of type 1a according to GOST R 58602-2019, shown in Figure 2, and the holes of type 3 according to GOST 16841-79, shown in Figure 4. The perforation of type 4 according to the OST of the manufacturer of the block will also be used, an example is shown in Figure 7. The simulation result is shown in Figures 3, 5, and 8.

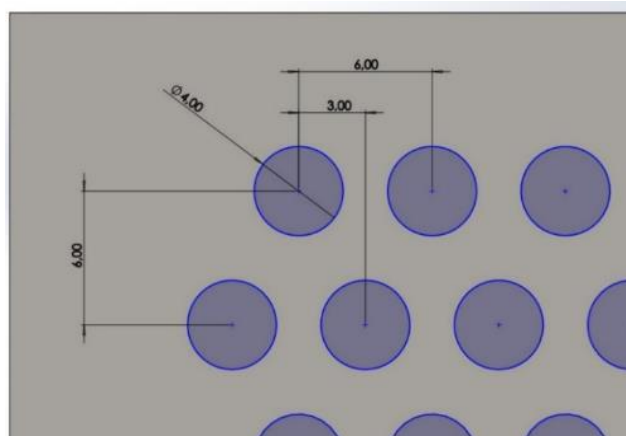


Fig. 2 Type 1a perforation according to GOST R 58602-2019

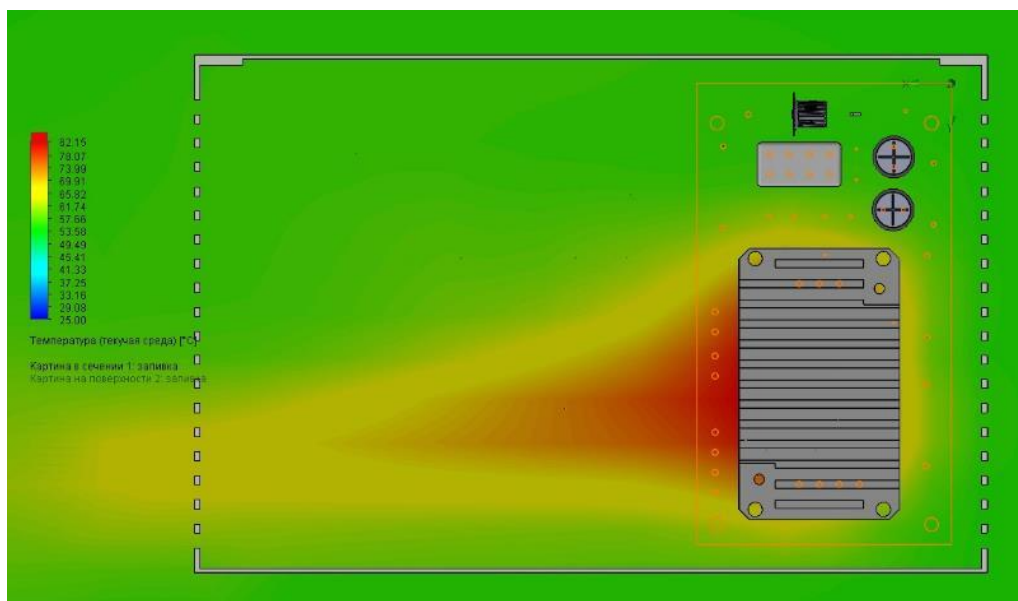


Fig. 3 Result of heat simulation with allowance for perforation 1a in the Solidworks program

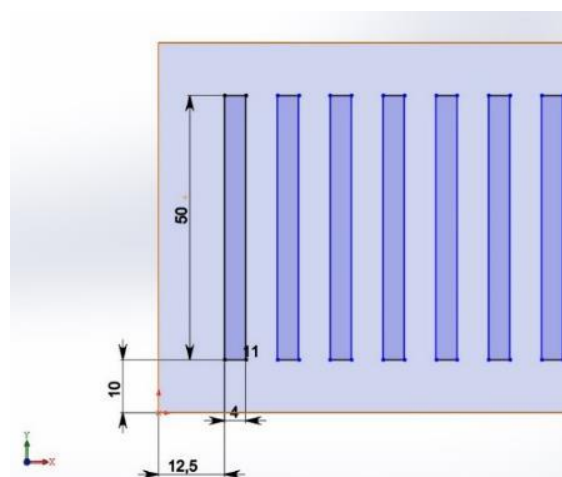


Fig. 4 Type 3 perforation according to GOST 16841-79

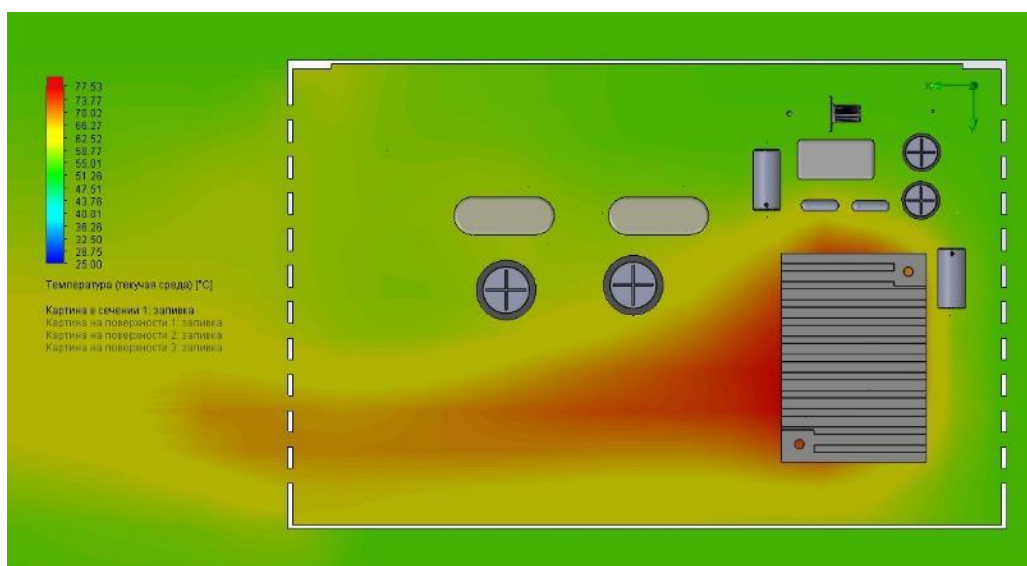


Fig. 5 Result of heat simulation with allowance for perforation 2a in the Solidworks program

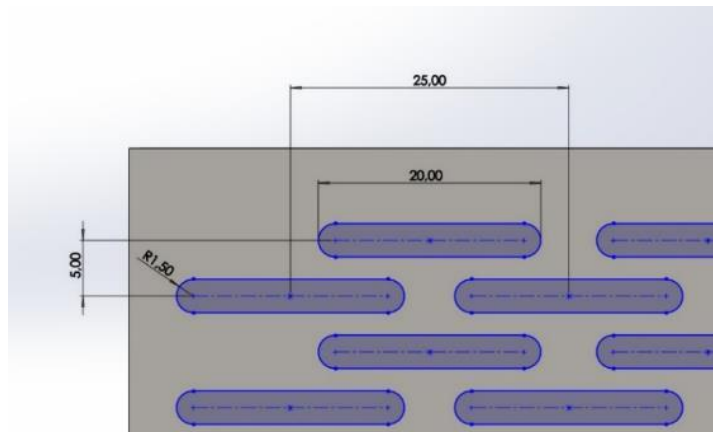


Fig. 6 Type 4 perforation according to the manufacturer's OST

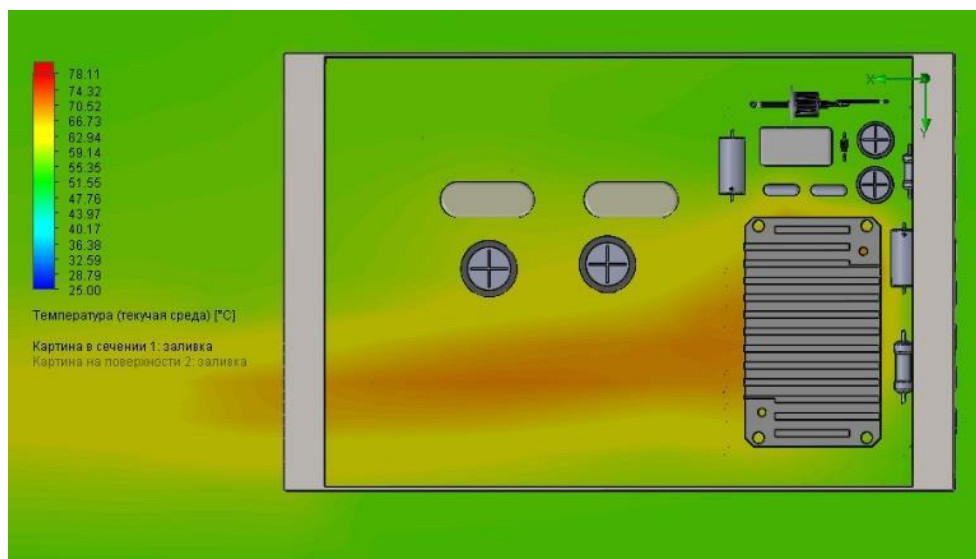


Fig. 7 Result of heat simulation with type 4 perforation in the Solidworks software

CONCLUSION

The best result was obtained when using a type 3 perforation, the temperature decreased to $+77^{\circ}\text{C}$, a close result for type 4 holes to $+78^{\circ}\text{C}$, and the worst of the simulated ones – for round holes 1a. if we compare the areas of the perforated faces, we get a result of 24.3%, 23.5% and 22%, respectively. From this, it can be concluded that the perforation area significantly affects the ability to remove heat by natural ventilation.

It is necessary to observe a certain line between the amount of perforated holes and the required thermal regime, a lot is not always better. If you only pursue the thermal parameters, you can critically reduce the strength of the structure. The case may deform, which naturally leads to a malfunction of the device.

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GOST R 58602-2019 Sheets perforated. Technical conditions
GOST 16841-79 Ventilation instrumentation openings for electronic and electrical devices

ON THE TASK OF MODELING A SOFTWARE LIFECYCLE BASING ON PETRI NETS

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Abstract — The paper describes problems in the field of project planning, shows the shortcomings of existing planning systems. The necessity of modeling the progress of the project is substantiated. An overview of design modeling methods using Petri nets is presented.

Keywords — Gantt chart; Petri Net; software project management.

INTRODUCTION

Software development has been and remains one of the most risky businesses. The percentage of unsuccessful projects, including those that did not meet the deadline or the budget, is the highest in the field of information technology and especially among projects related to software development. The success of any project largely depends on the preparatory work done during the planning stage.

It is also important to choose a model according to which the project will develop. Currently, the most common life cycle models are as follows: cascade, incremental (staged model with intermediate control) and spiral. However, with any of these, project planning in the field of software development is always associated with a high degree of uncertainty, which is a consequence of the novelty of the goals and objectives of each project. The result is a frequent change in requirements, growing the duration of tasks and emergence of various unforeseen situations.

PROBLEM STATEMENT

In modern project management systems such as Microsoft Project, the logical relationship of tasks is determined by a Gantt chart or PERT chart. Such diagrams allow visualizing the list of works, dependency relationships between activities and their durations, but they cannot be used to model the dynamics of the project. At the same time, the task is relevant to forecast the performance of project work with various combinations of external and internal factors of a probabilistic nature.

SOLUTION TO THE PROBLEM

There are a number of methodologies and tools for discrete event modeling in application to such systems. The process of software development and support refers to parallel-sequential processes, therefore, Petri nets are the most effective tool for modeling such projects.

Petri Net. Petri net is a mathematical abstraction focused on the analysis and synthesis of discrete dynamical systems. This formalism is used to find blockages, deadlocks, bottlenecks in the modeled system.

Mathematically, a Petri net is a tuple $PN = (\theta, P, T, F, M_0)$, where

- $\theta = (0, 1, 2, \dots)$ is the set of discrete times,
- $P = (p_1, p_2, \dots, p_n)$ is a finite set of network elements called places,
- $T = (t_1, t_2, \dots, t_m)$ is a finite set of network elements called transitions, $P \cap T = \emptyset$,
- $F = (P \times T) \times (T \times P) \rightarrow (0, 1, 2, \dots, k, \dots)$ is the incidence function, where k is the arc multiplicity,
- $M_0 \rightarrow P (0, 1, \dots)$ - initial position marking.

The graph-theoretic representation of a Petri net is a bipartite oriented multigraph. This graph contains: positions (places) - circles; transitions - vertical strips, oriented arcs - arrows connecting positions with transitions and vice versa. An example of such a network is shown on Fig. 1.

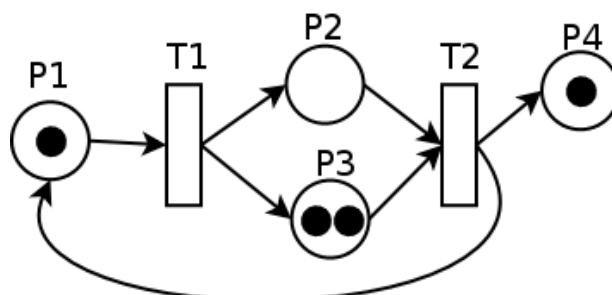


Fig.1 Petri net graph

WorkFlow net. There are a number of approaches for modeling the project life cycle using Petri nets. Thus, in the article [1], a formalism for modeling workflows called WF-network (WorkFlow network) is proposed.

Petri net $PN = (P; T; F)$ is a WF-net if and only if:

- 1) PN has two special places: i and o . Place i is a source place: $\bullet i = \emptyset$. Place o is a sink place: $o \bullet = \emptyset$.
- 2) If we add a transition t^* to PN which connects place o with i (i.e. $\bullet t^* = \{o\}$ and $t^* \bullet = \{i\}$), then the resulting Petri net is strongly connected.

WF networks are used to check workflow graphs for structural conflicts such as deadlocks and lack of synchronization. There are no structural conflicts if the WF network is defect-free. This paper also provides examples of networks for workflows of a different nature - sequential, parallel, iterative and conditional.

Passage from the Gantt Chart to Petri networks. Suppose that as a result of work in the project planning system, a Gantt chart G has been built. In paper [2] it's proposed to determine the rules for the transition of the problem $z_i \in G$ to an element of the Petri net.

First of all, it's necessary to formalize the task from the Gantt chart. Every task has its duration τ_i , parameters $\tau_{i \text{ ear}}^b, \tau_{i \text{ lat}}^b, \tau_{i \text{ ear}}^e, \tau_{i \text{ lat}}^e$ which characterize early and late start and end, and links with other tasks, which can be one of four types:

- end - beginning,
- beginning - beginning,
- end - end,
- beginning - end.

Let's mean t_i as transition that simulates the process of executing the task i with the duration of operation τ_i and t_i^B and t_i^E as initial and final transitions, for which the durations of actuation are either equal to zero, or depend on one of the values $\tau_{i \text{ ear}}^b, \tau_{i \text{ lat}}^b, \tau_{i \text{ ear}}^e, \tau_{i \text{ lat}}^e$. Then the Petri network for end-beginning connection would be as shown on Fig. 2.

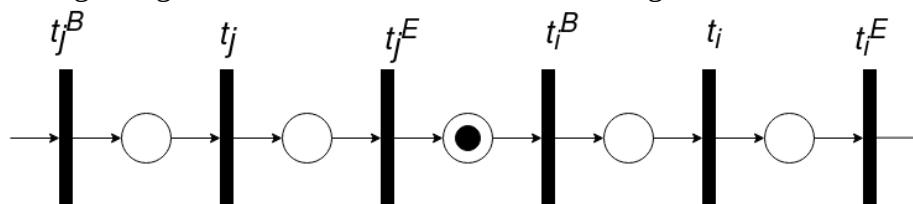


Fig 2. Petri net for end-beginning connection type.

Using the presented methods alone or in combination in a hierarchical Petri net can be a good solution for large projects with complex relationships. For example, using the rules for

iterative Petri nets from [1] can be useful when planning projects with an incremental life cycle model, while the rules for moving from Gantt to Petri nets from [2] are suitable for small projects with a waterfall model.

CONCLUSION

The problem of modeling the software life cycle is considered. Factors indicating the need for life cycle modeling are listed. Methods of modeling software lifecycle projects using Petri nets are overviewed. Petri nets are considered to be applicable to the task of modeling the software life cycle.

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GRADER CONSTRUCTOR

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Abstract – Modern education follows the main trend - using technologies for safe and convenient learning in a distant format. There are a lot of online educational platforms with special features such as auto-generated tests, interactive auto-grading tasks and so on. But the majority of exercises and material are not automated at all, tests are graded manually, lecturers spend heaps of time to create test tasks for their students. Our main aim is to develop software that will be helpful for teachers and students in the context of distance learning. In particular, service should create auto-graded personal tasks, manage all of the integrated educational services, provide the unified user interface for all educational utility services and manage student's grades automatically between graders and Learning Management Systems (LMS). Our service has its own name - "Graders Constructor". As a special feature, we extended the functionality with Learning Tools Interoperability (LTI) standard support to interact with different LMS. To conclude the mentioned features, "Graders Constructor" helps tutors to avoid manual tests creating and grading, giving free time that can be used for communication with students.

INTRODUCTION

Distance learning usually demands use of information technologies to test students' knowledge online. Tutors get confused by the wide range of online educational platforms, they must choose the one with personally required functionality. In case of user convenience, it would be better to have all required tools for course managing and tests graders in the one website. This service was created to respond the following aims:

- allow users to manage courses and create personal assignments;
- provide the functionality of forms creation to allow tutors include different tasks with videos or puzzles;
- give a single point of access to all integrated educational services.

Graders Constructor is not represented as a worldbreaker in distance learning, this service is a convenient and helpful solution for internal university educational needs, it provides a minimal package of tools to create assignments, manage courses.

This paper includes the following structure: section *Related work* views analogues of our service, section *Method* represents the architecture of service and the process of development, results are represented in section *Results*, and *Conclusions* section concludes the findings and describes our future goals.

RELATED WORK

Autograding systems are being broadly launched to meet the challenge of teaching students online. Here is an overview of the related work in the distance education area.

In the context of distance learning, there is an urgent need to introduce mass online courses in training in Russian universities [1]. There is a need to develop a digital educational environment focused on e-learning and distance learning [2]-[4].

When teaching online, teachers still have to grade students' assignments, so the problem with the increase of the number of students who take online courses arises. Danutama [5] suggests a possible solution to it. The study explains that now it is almost impossible to grade all the students' works in time. In the circumstances of the current educational online systems and disproportionate ratio of students to teachers the authors propose a scalable autograder and Learning Management System integration. The proposed LMS is powerful and secure to cope with many submissions in a sufficient number of courses. Moreover, the authors reason that an autograder enriches LMS functionality allowing teachers to grade assignments automatically and, besides, is an essential part of judging programming contests.

[6] mentions that nowadays autogradors in computer science courses are expanding their opportunities by new features, such as dealing with human feedback, gamification of the process, remote code execution and test coverage analysis, to name but a few. Although, the authors claim that challenges and practical benefits of exploitation of these features are not provided with enough attention.

The increase in the number of undergraduate students in technical education programs is overloading teachers, assistants, laboratories, and other resources. To cope with resource challenges, many universities have automated key processes, such as evaluating papers. Before replacing the manual process with an automated tool, it is necessary to answer two questions [7]. First, does the proposed automation contribute to or detract students from learning? Second, do the benefits outweigh the costs of automation? In the article, the authors present an analysis of the introductory course on programming, where a high level of automation was used. The study found that a carefully designed and managed automation system can improve student performance while significantly saving limited learning resources.

The analysis of data from online learning systems offers the potential to improve student performance by identifying the characteristics of their behavior and habits and their relationship to grades [8]. In particular, it can help identify underperforming students in the early stages of the course. In the study, the authors use methods to analyze the behavior of students during the semester. The experiment revealed that the introduction of more frequent control elements and the presence of additional attempts to pass tasks motivate students not to give up and increase their chances of good academic performance.

Studies of massive open online courses (MOOCs) have shown that prior knowledge of the basics required to complete a course and measures to engage students in the course (for example, multiple attempts to submit assignments when the initial submission is incorrect) dramatically affect student performance, but little is known about what factors predict student retention [9]. When applying the analysis to a sample of more than 20,000 participants in one popular computer science MOOC, the authors found that the same criteria that affect academic performance are useful in predicting whether students will complete the course. In addition, it

was found that prior knowledge of the course topic, programming experience, and gender-traits previously considered constant predictors of whether students would stay until the end of the course - have effects that weaken as the course progresses. This finding proves that MOOC teachers should consider the prospect of possible growth in terms of student perseverance: as students overcome obstacles, their resilience becomes stronger.

Automatic code testing is often used in programming courses [10]. However, the usual methods of writing tests are not able to generate detailed and reasonable feedback about the reason for the failure of the test, which novice students need. The authors present a technique for using reflection to create test suites to quickly determine the cause of each failure in testing a solution.

Haldeman [11] offers a method that extends autograders' opportunities by providing helpful feedback for incorrect programs which the students have submitted. The teacher defines key concepts of each assignment and designs a comprehensive test set that enables classifiers to classify common errors and categorize students' errors in future submissions. Later the teacher studies these classes of errors and provides students with additional hints based on most common mistakes. Tentative results illustrate that the hints were helpful in 96% of the cases with erroneous submissions.

The manual assessment process has many problems, including increased labor intensity and pressure on teachers due to the presence of deadlines for verification [12]. These problems suggest that the educational community is in dire need of grader systems. Automatic assessment systems are widely used around the world, as they play a crucial role in educational technologies. The study compares various algorithms (raw processing, tokenization, use of stop words, stemming) used in automatic essay evaluation systems. The results prove that an automatic grading system can benefit teachers and save a lot of time.

It is argued that automatic grading has become a necessity in computer science and programming courses, helping teachers to reduce the time of grading and the time spent on the course as a whole [13]. However, novice programmers are disappointed with the automatic evaluation tools, because they often give minimal feedback, or the questions are too high a level of complexity. The authors suggest using Bloom's Taxonomy to gradually increase the complexity of a programming question in an automatic evaluation tool. The simplest questions are based on knowledge and understanding, and subsequent questions require application and analysis. The most difficult questions test your creative skills. The system of testing programming knowledge developed by the authors corresponds to these categories. For example, for debugging, students need to understand and analyze the code. However, to write a program with more complex logic, students must have creative abilities. The main goal is to teach novice programmers to learn more effectively and efficiently. The article presents examples of developed programming problems with automatic verification, based on Bloom's Taxonomy, and the results of a pilot study in the framework of an optional course, proving that this system is quite effective in training.

The Department of Automation and Computer Engineering of Vologda State University has developed a remote workshop on programming and databases [14]. The system contains graders for the course disciplines and more than 2000 tasks. When returning a verified solution, the student is sent not only a verdict, but also a comment about possible mistakes made. After successful completion, other people's solutions to this task become available to the participant, so that he can get acquainted with alternative solutions. The best solutions are selected based on the speed of operation and the cost of memory. These criteria, as well as the analysis of the algorithm architecture, are key in solving Olympiad programming problems [15]. Thus, the rating table further motivates students to improve their decisions by competing with others. The system selects the best solutions in terms of speed and memory usage. This further encourages students to solve problems in the most effective ways. The grader automatically checks the work for

plagiarism, so that the student can not send a decommissioned solution. Implemented the formation of statistics for teachers by groups and individual students. This system facilitates the work of teachers, allowing them to free themselves from manual verification of decisions and logging in favor of individual work with students, as well as generally facilitates the organization of distance learning. Students can expect to get the skills of accurate programming and high-quality verification of their decisions at the beginning of the course. The successful experience of using the system in courses on programming and databases caused the teachers of the department to want to use it in other disciplines.

Graders significantly improve the quality of student learning, especially in programming courses, bringing distance education to a whole new level [16].

One of the most advanced distance learning systems is Moodle. This system has expanded functionality and is suitable even for such an extraordinary task as organizing control events in the process of professional retraining and advanced training of music teachers [17]. LMS Moodle has the ability to expand functionality through built-in solutions, including an automatic task verification system. Adding features is done by using existing user interfaces for answers or creating new ones, developing new types of questions, with different answer interfaces, programming languages for verification, templates, and evaluation types [18]. Our Grader Builder system integrates with Smart LMS based on LMS Moodle via LTI.

An interactive web system with universal access and independence from third-party platforms, used to visualize the operation of algorithms, is described [19]. This tool allows you to check the developed algorithms and monitor their progress step by step.

A lightweight open-source cross-platform computer environment for conducting exams has been developed, which uses graders in programming courses [20]. Unlike normal paper-based exam testing, in this environment students can type programming tasks on their laptops in an environment similar to their usual programming environment (for example, with syntax highlighting), but the system purposefully does not allow them to compile and/or run their code. The study found that students do better when they are given the opportunity to print their program, rather than writing on paper by hand. In addition, grades are automatically collected in an electronic journal, freeing up free time for teachers.

[21] claims that autograding in embedded systems courses is impossible without personal contact between the teacher and the student because of setups available only in laboratory facilities. The problem is to provide simultaneous remote code execution for all students. [6] has a solution for this aspect for simple programs, although as for embedded systems code, the issue remains open. Moreover, Li et al. [21] emphasized another drawback - the time-consuming process of manual grading. This deprives students of the opportunity of training by making multiple assignments. [6] proposes an autograder that can be used with a number of experimental setups and MOOC courses and also supports embedded systems tasks.

Mehta et al. [22] introduces another approach that enables 3D-modelling assignments to be autograded. The authors propose an automatic grading system which attaches labels to assignments and uses them later during the evaluation, similarly to Haldeman's [11] method with classification of common errors. This autograding tool compares students' submissions to an ideal one by 4 parameters: an additional parameter set by the teacher, the number of polygons, objects and placement of those objects. Every graded submission provides personal feedback automatically.

[23] suggests that techniques of program reparation could be used to provide students with automatically generated feedback on their programming submissions. The idea is to use real submissions with the highest rating to repair the erroneous ones. The model automatically divides the correct solutions into classes based on a notion of dynamic equivalence. There is a repair 'candidate' from every class for every erroneous submission. Then the algorithm selects a

minimal repair solution from them. Gulwani et al. [23] conducted an experiment repairing 4,293 submissions to validate the result.

Currently, the problem of choosing a programming language and system for teaching programming from scratch is quite relevant [24]. Because if the system and language are too complex, students will face difficulties and spend extra time learning programming features in an inconvenient environment. The same time can be spent on solving more interesting problems. The authors have developed a system that allows you to automatically check tasks in Pascal using 455 templates with a visual view of all data types [25]. However, this system uses a limited set of tasks and does not involve adding tasks by the teacher independently, and also checks solutions exclusively in one programming language.

One of the studies describes an electronic textbook in Excel using the Visual Basic for Applications programming language [26]. The textbook has the means of self-checking, the possibility of modeling with a visual demonstration, automatic display of the student's progress on the topic by built-in MS Excel tools. This system, in contrast to the one presented [25], allows teachers to dynamically add tasks to the list, but has one significant drawback, as well as a larger number of similar developments considered – compatibility with only one technology or programming language. An online system was also developed to automatically test the knowledge of Windows OS tools (Microsoft Word, Excel, PowerPoint, and others) [27].

A system has been developed for the automatic evaluation of student programs based on the templates used in the exams [28]. The development automates a particularly time-consuming aspect of the grading process: the partial assignment of points based on grading criteria. The input data is a list of criteria and an exam task template, as well as a set of programs for grading. Operating the system on exams in a course of 1,500 students demonstrates that in less than two minutes, the developed program automates 43.1% of the grading work, achieving 95.8% completeness and 100% accuracy (performance evaluation characteristics used in machine learning).

There is a system of automatic testing and grading called "CODE", it is integrated with Canvas LMS [29]. The article discusses the experience of implementing this system in the course on programming in C++ by teachers and students. The experiment had some important features, and here are some of them:

- Teachers and students had no previous experience working with courses using automatic grading systems (graders);
- The students had almost no knowledge in this area, especially about programming using the Linux OS;
- The course program included complex concepts of operating systems, multithreading, and computer systems and networks.

The experiment used 3,300 tasks (for 54 students) and an analysis of a survey conducted at the end of the course. The findings from the statistics clearly support the use of automatic assessment systems in training programs to improve learning in programming-oriented courses. We can partially agree with the authors, but it is even more rational to use graders in disciplines of any nature. In another project, the authors clearly proved that this is possible [17].

Jupyter Notebooks are being increasingly used over the last few years. Manzoor et al. [30] offered an automatic grading system for Jupyter Notebooks. In light of ubiquitous Jupyter Notebooks exploitation, this system solves the problem of students not getting feedback shortly after assignment completion. The proposed system represents a combination of Web-CAT autograder and Jupyter Notebook. This autograder reduces teachers' workload crucially. The authors state that 80% of students in the test group believe in connection between instant feedback on the submitted assignments and students' performance improvement.

A flexible tool for creating and automatically checking tasks in the Jupyter Notebook environment is presented in [31]. The developed system allows teachers to create a single

reference master copy of the task, including tests and canonical solutions. From the master copy, a non-solution version is created for the student, which saves the teacher from having to maintain two separate versions of the assignment. The system also automatically evaluates submitted tasks, performing grading and storing test results in a database. After the automatic assessment, teachers can manually evaluate failed responses and assign partial scores using the Form Validation Tool (Jupyter Notebook extension). Teachers can leave individual feedback about each student's work, including comments, as well as detailed comments about errors. When used with JupyterHub, the system opens up additional functionality. After creating a task, teachers can send it to students directly through the Jupyter Notebook server interface. Students can submit completed assignments via the same interface. After students submit their solutions, teachers can collect them with a single command in the terminal and use the automatic evaluation function as usual. Since its introduction in September 2014, the system has been used in a number of educational programs, including courses at the University of California at Berkeley, California Polytechnic University, the University of Pretoria, the University of Edinburgh, and many others. As of May 2018, there were already more than 10,000 jobs based on this system on GitHub. In addition to the core functionality, the development has been expanded to support a number of new features, including the following:

- the ability to process multiple courses in a single JupyterHub instance,
- the ability to enable or hide automatically graded tests,
- configurable delay penalties,
- support for importing task files downloaded from the LMS.

All of the above facts suggest that automatic assessment systems are useful in training courses for both teachers and students.

Our autograding system combines the benefits of some of the aforementioned projects, enabling teachers to create assignments of different types and students to submit their works multiple times and obtain instant feedback.

METHOD

A system was developed that allows you to create tests (control and measurement materials) with automatic generation of options from pre-prepared tasks, as well as tasks using other automatic verification tools (graders). The system provides integration with LMSes for transferring the student score after completing tasks with automatic verification. The tests provide not only the possibility of simple automatic verification of students' answers like in Google Forms and similar platforms, but also more complex checks provided by the author of the task (for example, regular expressions). We developed a tool for creating graders and control measuring materials in the form of tests to distribute them to students in the form of personal tasks at a specific time and rate them in the LMS after they are completed. The technical solution of the problem is the use of a suitable LMS and its built-in tools (API, etc.). The verification of student's answers can be carried out either by a simple comparison or by a detailed analysis of the answer. In the first case, the student's answer is compared with the correct one: single choice, multiple choice, number, string, etc. In the second case, the student's response is a string, for example, a text command to invoke the program with the appropriate arguments, which will then be checked according to the rules that are set by the instructor, or according to a specified regular expression.

Initially, the work was to develop a system for creating tests with individual variants (random distribution of a set of tasks) using Google Forms and Google Classroom, where the score was automatically transmitted to the Google Classroom thanks to the built-in support for tests created using Google Forms. During development, many difficulties arose due to the very poor integration and automation capabilities provided by Google Classroom and Google Forms, as well as the lack of versatility (for example, support for other LMS). There was also a need to

develop a centralized portal for convenient creation of both tests and tasks with automatic verification, which were developed in other projects opened on the basis of the faculty. Therefore, it was decided to abandon the original plans and not use these platforms as the basis for the system. Currently, integration with the following projects has been partially or completely carried out (the given identifiers are internal numbers of the faculty's projects):

- #19101 Solvers - a project that allows the teacher to create additional questions for students that will be asked after completing the main task, for example, laboratory work;
- #238 Integration of external platforms - a project to automate interaction with video conferencing services, including automatic creation of scheduled events and recording of lectures and seminars;
- #589 CI / CD Graders - a tool for automatically checking programming tasks, as well as complex tests of laboratory work on FFmpeg, ImageMagick, ONVIF and GStreamer using CI/CD tools built into GitLab;
- #553 Draw.IO graders - a tool for automatically checking tasks that are based on diagrams and created in an open source graphical editor (app.diagrams.net);
- #590 Google Documents Workbook - a tool for automatically checking tasks that are completed in Google Documents;

The developed system allowed the projects described above not to create their own separate web interfaces and provided teachers with unified access to the creation of different graders and other features, for example, choosing the preferred platform for lectures and seminars, as well as integration with various LMSes. Our project also solves the problems associated with authorization and obtaining user data by integrating with the API of various university systems. This includes determining the status (student, teacher, employee), study group, and many other data that is used in different projects.

Integration with various LMS is provided by the IMS LTI 1.1/1.3 protocol. It also allows Higher School of Economics lecturers to embed assignments in SmartLMS, the university's LMS, which is built on top of the LMS Moodle that supports this protocol. In addition, the architecture allows developers to add modules for other LMS that do not support LTI integration, but have their own API.

There is also a component that allows users to create error reports, the answers to which will be sent by email, and the reports themselves will be available to developers in an external system-tracker (taiga.io).

ARCHITECTURE

Since the system includes many modules, which often have little common functionality, it was decided to use a microservice architecture. This type of architecture allows you to separately develop and test different components of the system (which is important in a project with several developers) and quickly integrate new modules if necessary. At the moment, the system has 5 modules: an authorization service, a test creation service, a system selection service for conducting online lectures and seminars, and a service for interacting with various LMS, which provides graders from different projects with a single way to transfer grades to the LMS after the student completes the task. Users interact with all services through a monolithic client side (frontend). The chosen architecture also allows you to flexibly integrate services and graders from other projects with the authorization system, as well as services that are not directly related to the main purpose of the project, but which also require an authorization system and user information.

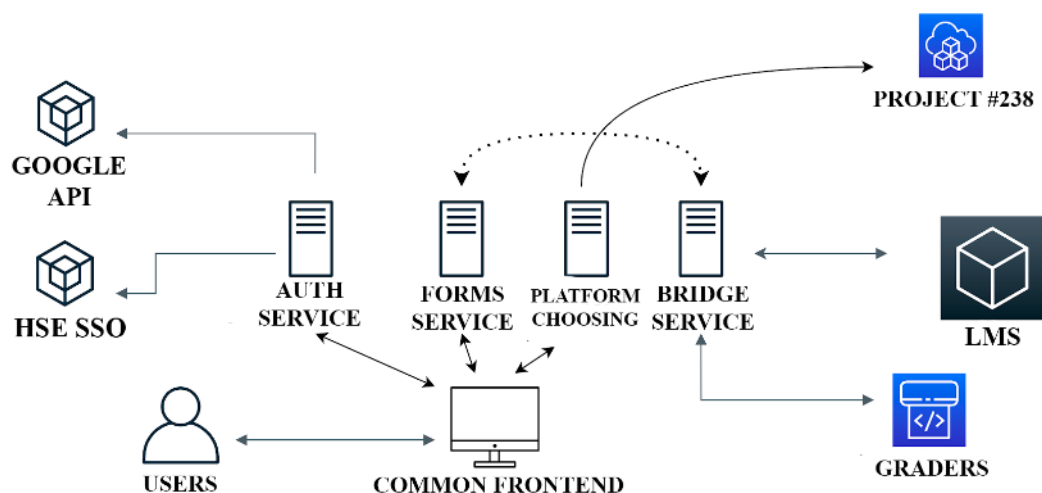


Fig. 1 Grader constructor's architecture

RESULTS

To get feedback from real students and find the most common problems, we decided to test service in the real conditions. There was a computer graphics subject test, made with a task generator service and graded with an auto-grader service. All students in google classroom service got an assignment at the appointed time, they completed the corresponding tasks and submitted their solutions. Autograder checked solutions and then returned grades list into general assignment in google classroom. There were few students, who were late because of technical problems, got their assignments privately. After a successful experiment the exam was performed in the same way. The experiment proves some of our guesses about google services, for example, long delay during the responses to the google API.

CONCLUSION

This paper represents the process of creating a web application with the following functionality: creation of personal tasks for students, unified user interface for managing auto-grading services. This work continues one of the previous research in the field of students' works grading in online courses. The previous research allows us to say that automatic grading is helpful for both students and tutors, our service shows an important step forward in this field, allowing teachers to create tests from different types of interactive tasks.

The main advantages of our grading system are automatic transfer of grades into LMS, different types of tasks including "choose one option", "choose several options", and other text answers, but also interactive test forms with videos, matching tasks. New features can be easily added to graders systems, it means service flexibility and simplicity. The project is helpful for both teachers and students, teachers can reduce unnecessary workload, students can solve tasks from any device they want to.

In the future plans, we could expand the system with more types of graders, extend the number of supported LMS. Further direction of the research highly depends on students' and tutors' feedback, so it would be better to test our service in more cases.

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PSEUDORANDOM NUMBER GENERATOR BASED ON CELLULAR AUTOMATA AND THE GAME "LIFE"

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Abstract — Neural networks are one of the key classes of methods, widely used in computing for recognition and data analysis. One auxiliary task is initializing coefficients at the very beginning of machine learning. There is a range of pseudo-random numbers generators (PRNG), and this article is dedicated to one prospective class of PRNG -- the cellular automata-based PRNGs. Pseudorandom number generators are widely used in a lot of fields of science: mathematics, cryptography, neural networks, modeling, medicine. A method for generating random numbers based on a cellular automaton, the rules of behavior in which are determined by the game "Life", is proposed. The developed algorithm was tested in several tests, a comparative test was performed with the linear-congruent random number generation method and another random number generator, also based on cellular automata technology. In all tests, the algorithm showed excellent results. The simplicity of implementation and the features of cellular automata technology hide a great potential in the development of this method

Keywords: Pseudorandom number generator, cellular automaton, cell, sequence.

INTRODUCTION

Pseudorandom number generators (RNG) are a technology for creating random number sequences and are widely used in various fields, such as cryptography, modeling, medicine, neural networks, and testing. In view of this, the creation of high-quality RNG is an urgent task of modern science and requires deep and high-quality study.

Significant progress has been made in the direction of linear-congruent generators [8, 9] and vortex algorithmic generators [10-13]. Nevertheless, the questions of the completeness of the sets of elements and the repeatability of the elements of the resulting sequence remain open.

RANDOM NUMER GENERATOR

A random number generator (RNG) is a device or algorithm a rhythm that produces a sequence of statistically independent numbers.

Random number generators by the method of obtaining numbers are divided into:

1. hardware;
2. tabular data;
3. algorithmic ones.

Table generators as a source of random numbers use pre-prepared tables containing verified uncorrelated numbers and are not generators in the strict sense of this concept. The disadvantages of this method are obvious: the use of an external resource for storing numbers, the limited sequence, the predefined values.

Hardware generators of (true) random sequences must have a source of entropy. The development of generators that use entropy sources and generate uncorrelated and statistically independent numbers is quite a difficult task. In addition, for most cryptographic applications, such a RNG should not be the subject of study and the effects of the opposite party.

An algorithmic generator is a combination of a physical generator-torus and deterministic algorithm. Such a generator uses a limited set of data obtained from the output of the physical generator to create a long sequence of numbers by transformations of the original numbers. This type of generator is of the greatest interest because of its obvious advantages over other types of random number generators.

CELLULAR AUTOMATA

Cellular automata are discrete dynamical systems whose behavior is completely defined in terms of local dependencies, much to a large extent the same is true for a large class of continuous dynamical systems defined by partial differential equations. [2] It includes a regular lattice of cells, each of which can be in one of a finite set of states.

The state of each cell depends on the state of the cells around it – its surroundings. There are usually two types of neighborhoods: The Moore neighborhood and the von Neumann neighborhood [5] (Figure 1).

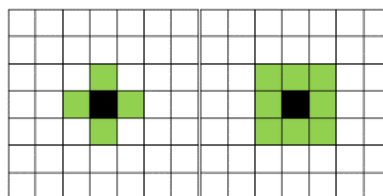


Fig. 1 Neighborhoods of von Neumann (left) and Moore (right)

GAME “LIFE”

Life is a cellular automaton invented by mathematician John Horton Conway in 1970. In creating the game, he was inspired by the problem proposed by John von Neumann - a self-

replicating machine. Conway tried to simplify von Neumann's solution and through research was able to determine the rules of the game. [8]

The rules of the game are as follows:

1. Survivals. Every counter with two or three neighboring counters survives for the next generation.
2. Deaths. Each counter with four or more neighbors dies (is removed) from overpopulation. Every counter with one neighbor or none dies from isolation.
3. Births. Each empty cell adjacent to exactly three neighbors--no more, no fewer--is a birth cell. A counter is placed on it at the next move[7].

THE METHOD OF GENERATING PSEUDORANDOM NUMBERS

It is required to solve several problems in the presented method for generating pseudorandom numbers. The first is a modification of the rules of the game "Life". The second is to solve the problem of choosing an initial configuration. This task includes the choice of the size of the cellular automaton matrix, the initial filling of the matrix, and the number of generations. When choosing an initial configuration, it is important to determine all the parameters so that not only does not "kill" all the cells, but also achieve sufficient completeness of the matrix.

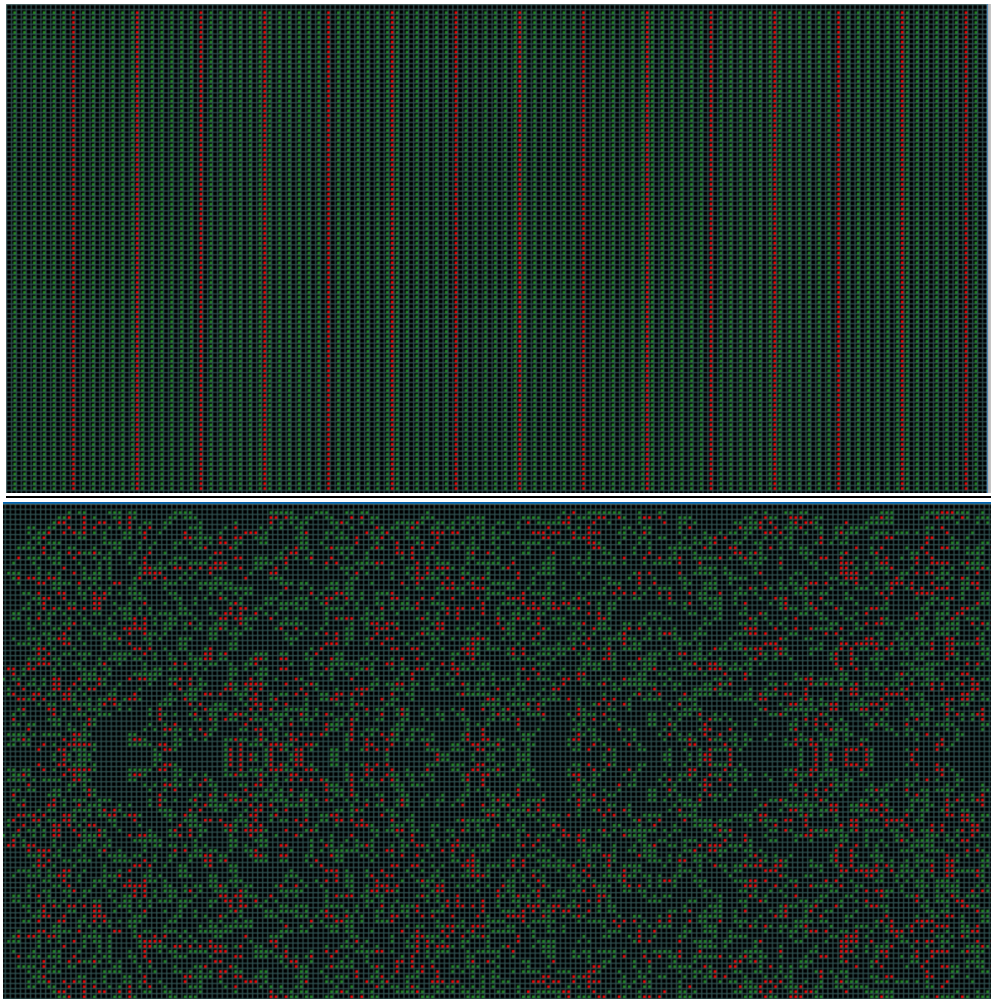


Fig. 2 “Life” in the first generation (top) and in the last (bottom).

PRNG TESTS AND COMPARISSON

There are many different tests that determine whether the sequences of values are sufficiently random. Thanks to these tests, the quality of a random number generator is determined. Several tests from the NIST suite were selected.

Below are the results of testing the pseudo-random number generation, as well as its comparison with other generators.

TABLE I. PASSING TESTS

Monobit test	0.7324398999038725	PASS
Frequency Block Test	0.3954669433496319	PASS
Serial test	0.9145182387620326	PASS
Spectral test	0.3740525925192202	PASS
Non-overlapping template matching test	0.6993018720649098	PASS
Run test	0.8022450936184753	PASS
Approximate Entropy test	0.46960616243661973	PASS
Cumulative Sums Test	0.6059354934001464	PASS
Random excursion test	0.3302969563320579	PASS
Random_excursion_variant test	0.21231716077296492	PASS

For comparison, the test results are presented in comparison with other generators, namely, linear-congruent and the generator, which is also based on a cellular automaton [3].

A linear congruential generator (LCG) is an algorithm that yields a sequence of pseudo-randomized numbers calculated with a discontinuous piecewise linear equation. The method represents one of the oldest and best-known pseudorandom number generator algorithms. The theory behind them is relatively easy to understand, and they are easily implemented and fast, especially on computer hardware which can provide modular arithmetic by storage-bit truncation.

The generator is defined by recurrence relation:

$$X_{n+1} = (aX_n + c) \bmod m$$

where X is the sequence of pseudorandom values, and

$m, 0 < m$ — the "modulus"

$a, 0 < a < m$ — the "multiplier"

$c, 0 \leq c \leq m$ — the "increment"

$X_0, 0 \leq X_0 < m$ — the "seed" or "start value"

are integer constants that specify the generator. If $c = 0$, the generator is often called a multiplicative congruential generator (MCG), or Lehmer RNG. If $c \neq 0$, the method is called a mixed congruential generator [1].

Another PRNG based on cellular automaton gets pseudorandom numbers are generated by means of rules of transitions in cells of the cellular automaton depending on templates of the neighborhood and the output data of cells of "neighbors". Through several transitions at the choice of a generation technique the sequence of pseudorandom numbers turns out from zeroes and units.

TABLE II. COMPARISSON WITH OTHER PRNG'S

Test name	Based on game "Life"	Another PRNG based on cellular automaton	Linear congruent
Monobit test	0.7324398999038 725	0,744146	0,739918
Frequency Block Test	0.3954669433496 319	0,380537	0,122325
Serial test	0.9145182387620 326	0,428244	0,213309
Spectral test	0.3740525925192 202	0,650637	0,639918
Non-overlapping template matching test	0.6993018720649 098	0,578346	0,578346
Run test	0.8022450936184 753	0,651956	0,615983
Approximate Entropy test	0.4696061624366 197	0,778903	0,791468
Cumulative Sums Test	0.6059354934001 464	0,734146	0,689918
Random excursion test	0.3302969563320 579	0,610977	0,534146
Random_excursion_var iant test	0.2123171607729 649	0,633388	0,468312

We can conclude that the generator really works, works successfully, produces random sequences and it is not inferior to the classical method of generating pseudo-random numbers (linear-congruent method), but also surpasses it. It can also be observed that the second generator, also based on the cellular automaton technology, is superior to the classical method of generating pseudo-random numbers.

CONCLUSION

In this paper, the method for generating random numbers based on cellular automata and the game "Life" was proposed. The results of the tests are presented, as well as a comparative analysis with other generators. As a result of the tests, the proposed RNG not only showed excellent results, but also due to comparative analysis, it allowed us to observe an interesting fact: the RNG based on cellular automata gives a better result than the classical linear-congruent one – one of the most popular. This suggests that this method of generating random sequences hides a great potential in the development of technologies for creating high-quality RNGs. After all, in addition to the obvious advantages in the resulting result, the technology of cellular automata allows you to use multithreading and parallel programming, thereby significantly increasing the speed of the generator, which is especially important when working with supercomputers. Also, should be said that this approach is applicable for coefficients initialization in neural networks or for Cohonen self-organizing maps. Furthermore, the generator can be used in cryptography, for example, when creating an encryption key.

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THEORY OF 3-D SPHERICAL RESONANCE GYROSCOPE. TECHNICAL APPLICATIONS IN MICROMECHANICAL SYSTEMS

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The article is devoted to the presentation of the foundations of the fundamental theory of the "generalized" Foucault pendulum, implemented on the basis of a fundamentally new 3-D spherical resonant gyroscope (SRG / SRG), the basic sensitive element of which is a miniature high-Q spherical quartz resonator. The physical effect underlying the functioning of a fundamentally new 3-D gyroscope, which is part of the considered class of gyroscopes, is described, and general principles for constructing the laws of control of its phase state are formulated. The issues of stability of functioning of the main operating mode of the new inertial attitude sensor are studied. The applied aspects of the implementation of the fundamental theory of the "generalized" Foucault pendulum in high-precision three-dimensional micromechanical inertial sensors of the SRG / SRG type are considered. The main engineering and design and technological solutions based on modern approaches to the practical design implementation of spherical wave solid-state gyroscopes of a new generation based on miniature 3-D spherical resonators made of modern amorphous materials for low-dynamic and high-dynamic objects of aerospace are presented.

Key words - classical Foucault pendulum, "generalized" Foucault pendulum, hemispherical quartz resonator (2-D wave solid-state gyroscope), spherical quartz resonator (3-D spherical solid-state gyroscope), theory of inertial sensors.

Introduction

Experiments carried out in 1851 by the French mechanic and astronomer Leon Foucault [1,2], as well as the experiments of his numerous followers, gave qualitative results confirming the fact of the Earth's rotation. A quantitative study of the errors of the classical Foucault pendulum and a new analytical proof of the Earth's rotation were given in his doctoral dissertation in 1879 by the Dutch experimental physicist Haykes Kammerling-Onnes [2]. It is known that an isotropic oscillator with two degrees of freedom, which plays the role of a Foucault pendulum in

modern gyroscopes, is implemented in the form of one of the modes of natural vibrations of an elastic medium with axial symmetry. In this case, in contrast to the classical Foucault pendulum, the rotation of the elastic medium around the axis of symmetry of the sensor involves the realized form of natural vibrations in rotation relative to the absolute (inertial) space. In the proper subspace of the chosen form of oscillations, the fundamental questions of the theory of the new sensor of inertial information can be considered within the framework of the same equations, analogous to the equations of the classical Foucault pendulum. For this reason, this entire class of gyroscopes can be called new inertial sensors of the “generalized” Foucault pendulum family [2]. In the modern practice of world gyroscopy, a whole class of new gyroscopic devices has appeared, in which the idea of a “generalized” Foucault pendulum is actually implemented: a string gyroscope [2], a ring gyroscope [3,4], a hemispherical quartz resonator (wave solid-state gyroscope) [4], VTG with a metal cylindrical resonator [2], quapazon [2], spherical quartz resonator [5]. The indicated inertial orientation sensors very successfully compete with the well-known classical gyroscopes, but their theory differs significantly from the fundamental theory of symmetric and asymmetric mechanical gyroscopes.

For example, the angular momentum, which mechanical gyroscopes tend to make as large as possible, should be zero in the above inertial orientation sensors [2,4]. The “generalized” Foucault pendulum is a mathematical pendulum, homeomorphic to a real physical pendulum, the oscillation plane of which slowly turns relative to the earth's surface in the direction opposite to the direction of the earth's rotation. Many researchers assume that the Earth does not involve the plane of oscillation of the pendulum in rotation around the local vertical. Meanwhile, due to nonlinear effects, the Foucault pendulum has its own rate of precession around the local vertical, so that, without controlling this precession, it is impossible to make reliable measurements of the angular velocity of the Earth's rotation.

I. Effect of inertia of elastic waves

The proposed scientific research examines the fundamental issues of the fundamental theory of promising gyroscopic inertial sensors of orientation of the family of “generalized” Foucault pendulum. A new local control theory is proposed for the “generalized” Foucault pendulum [2]. The general principles of controlling mechanical standing waves, which are excited in high-Q axisymmetric quartz resonators and other materials, are considered in detail. Practical aspects of the implementation of the necessary laws for controlling electrical signals in a new generation of high-quality hemispherical quartz resonators for aerospace purposes are proposed, the design of which excludes the use of a traditional annular excitation electrode to maintain the required working forms of resonant oscillations of the pendulum [2]. An isotropic oscillator with two degrees of freedom, which plays the role of a “generalized” Foucault pendulum in new devices, is implemented in the form of one of the modes of natural vibrations of an elastic medium with axial symmetry. In this case, in contrast to the classical Foucault pendulum [2], the rotation of the elastic medium around the axis of symmetry of the sensor involves the realized form of natural vibrations in rotation relative to inertial space (the exception is the string gyroscope), but the ratio of the angular velocity of the vibration mode relative to the elastic body to the angular velocity of the body relative to space is a strictly constant value (constant), depending on the number of the working vibration mode and almost independent of the properties of the material. This constant is called the scale factor of the inertial sensor, or Brian's coefficient, after the first researcher of vibrations of a thin elastic ring [1,2].

The phenomenon of precession of mechanical standing waves in a thin elastic ring rotating at a constant angular velocity was first discovered by Brian [3,4]. He showed that the coordinate system in which a mechanical standing wave of elastic vibrations can be observed rotates with a constant angular velocity Ω relative to the absolute (inertial) space:

$$\Omega = -\frac{k^2-1}{k^2+1}\omega, \quad (1)$$

where: k - is the number of the vibration form (mode). In the proper subspace of the chosen form of oscillations, all the fundamental questions of the theory of such a high-precision sensor of inertial information can be considered within the framework of the same equations, similar to the equations of the classical Foucault pendulum. For this reason, this entire class of devices can be called a "generalized" Foucault pendulum. Of course, not all questions of the theory can be solved within the above framework [2]. Mainly, these are issues related to taking into account the nonlinear properties of the oscillatory system. However, the question of how to control such a pendulum and how to identify its defects in order to make the extracted information the most reliable are solved within the framework of equations common to the entire class of new inertial sensors. The Brian effect, as the effect of the precession of a standing wave when the resonator rotates with a constant angular velocity, is the effect of the splitting of two frequencies; therefore, this effect has little to do with what was experimentally discovered by Scott [2,4] in 1982 and used in the same year. in the famous Lynch patent. Although the authors of the patent erroneously referred to Brian's formula [4], in fact, in support of their idea, they cited the result of an experiment in which a standing wave of elastic vibrations was excited in an initially immobile elastic shell, corresponding to the main (second) form with four nodes and four antinodes on a circle (hemisphere edge). Then the shell was rotated around its axis of symmetry at an angle of 90 degrees and stopped. At the same time, the authors of the experiment noticed that the standing wave also turned without changing its basic shape (like a rigid body) and stopped. Rotation of the initially motionless vibrating hemispherical resonator through an angle of 90 degrees caused a rotation of the standing wave relative to the hemispherical resonator by 30 degrees without any changes in the very shape of the standing wave. In this case, the angle of rotation of the wave relative to the base of the device was 70 degrees. Thus, in fact, an experimental formula, which is very important for the purposes of practical application in gyroscopy, was established:

$$\varphi_B = -1/3 (\varphi) \quad (2)$$

The formula obtained in the experiment no longer relates the constant rotation rates of the resonator, but the rotation angles themselves at clearly variable angular velocities. The foregoing can be summed up in the form of a theorem [2]: Whatever the dependence of the angular velocity of a thin elastic ring on time (in the class of functions differentiable on an infinite half-interval), there is also a unique coordinate system rotating with respect to the ring in which, under certain initial conditions, the oscillations of the ring are mechanical standing waves. The speed of this coordinate system is expressed by the formula

$$\Omega(t) = -\frac{k^2-1}{k^2+1} \omega(t) \quad (3)$$

A particular case from formula (3) follows the well-known result of Brian [2,4], which he established only for a constant angular velocity ($\dot{\omega} = 0$) of a resonator in the form of a thin elastic ring:

$$\omega_B = -\frac{2}{1+k^2} \omega \quad (4)$$

Note that an expression that is true for a stationary case, as a rule, is not true for a nonstationary one. Formula (3) describes a new physical effect, not noticed by Brian, and was first established experimentally by the authors of the famous patent "Vibratory rotation sensor" [2,4]. If both sides of relation (3) are integrated, then we will obtain a similar relation (2) for the rotation of the body and the standing wave, which explains the essence of the Lynch-Scott experiment [3,4]. Formula (3), due to its exact nature, can be analytically differentiated as many times as desired. In particular, it can be noted that the acceleration of a mechanical standing wave is proportional to the acceleration of an elastic vibrating ring:

$$\left(\frac{d\Omega}{dt}\right) = -\frac{k^2-1}{k^2+1}\left(\frac{d\omega}{dt}\right) \quad (5)$$

Since the acceleration of the elastic ring is proportional to the moment of external forces applied to it $I\ddot{\omega} = M$, then it can be shown that this moment causes not only the acceleration of the ring, but also the acceleration of the precessing standing wave. This allows us to define the physical effect discussed here in an unevenly rotating ring as a new physical effect of the inertia of elastic waves in it.

II. Problem Statement

Recently, a class of new gyroscopic devices has appeared, in which the idea of a Foucault pendulum is realized. This class of sensors includes: string gyroscope, ring gyroscope, “quapazone”, hemispherical quartz resonator (HRG), or wave solid gyroscope. In all cases, playing the role of a Foucault pendulum, an oscillator with two degrees of freedom is realized as one of the working modes of natural vibrations of an elastic medium with axial symmetry. Unlike the classical Foucault pendulum, the rotation of an elastic medium around the axis of symmetry presupposes a realized form of natural vibrations when rotating relative to inertial space (the exception is a string gyroscope), however, the ratio of the form of rotation relative to an elastic body to the angular velocity of a body relative to space is a constant value depending on the number forms and practically independent of material properties. This factor is called the scale factor, or Brian's factor, after the first researcher of vibrations of an elastic body, taking into account its continuous rotation in absolute space with a constant angular velocity. In the eigenspace corresponding to the chosen mode of vibration, all fundamental questions of the theory of such an inertial information sensor can be considered within the framework of the same equations as the equations of the classical Foucault pendulum. For this reason, this whole class of new instruments is called the "generalized" Foucault pendulum.

In modern studies [1,2], the problem is being solved of how to effectively control such a pendulum in order to make it a high-precision integrating gyroscope. It should be noted that in the case of an elastic ring and in the case of an elastic hemispherical shell, the physical effect of inertia of standing waves has a one-dimensional character: the angular velocity $\omega(t)$ is a scalar characterizing the rotation of an elastic solid around a stationary axis of sensitivity of the device in space. It is proposed to consider the generalization of this effect to an arbitrary spatial case. For example, in a stationary three-dimensional elastic solid (quartz spherical hollow elastic resonator), a standing wave of oscillations with some known operating tone is excited. After that, we will bring a three-dimensional rigid body into rotation with an arbitrary angular velocity $\omega(t)$ and determine the angular velocity of a spatial standing wave excited on the surface of a spherical resonator (for example, an ellipse of revolution).

Such an ellipse of rotation will rotate relative to the body, lagging behind its movement strictly according to a certain law. In this study, differential equations are obtained that determine the evolution of the m-wave oscillation mode of a free spherical rigid body due to the presence of arbitrary rotation. The analysis of the obtained equations confirms that the vector of the angular velocity of rotation of the spatial standing wave relative to the rigid body is proportional to the vector of the angular velocity of the body relative to the inertial space itself: $\Omega(t) = -k\omega(t)$, or the vector of the angular velocity of the wave relative to the inertial space: $\Omega(t) = (1-k)\omega(t)$. For a full thin spherical shell, the Brian coefficient is $k = 0.25$, which is less than its known values for an elastic ring, cylinder, and hemisphere. It should be emphasized that for a full spherical shell, the Brian scale factor has a three-dimensional value. It determines the proportionality of the angular velocity vectors to each other, in contrast to the case of a ring (cylinder, hemisphere), when the angular velocities of plane rotation are taken into account. In three-dimensional space, a three-dimensional mechanical standing wave in the form of, for example, an ellipse of revolution moves relative to the body with an angular velocity vector

proportional to the rotation vector of the most elastic rigid body relative to absolute (inertial) space.

III. Solving the problem of spatial precession of standing waves on a sphere

III.I Equation of vibrations of an elastic spherically symmetric body

Let us proceed to consider the vibrations of a thin spherical shell. Let's take an elastic spherically symmetric rigid body $X=X_1 X_2 X_3$ with a free boundary, which is acted upon by mass density forces f . The main vector of forces acting on such an elastic body, $\int_V f dm$ without loss of generality, will be assumed to be zero. Under the influence of the main moment $\int_V r \times f dm$, the body changes its orientation in space (r - radius c – vector of an arbitrary point of the body, dm - mass element, V - the area occupied by the body). To describe the elastic deformations of a thin spherical shell, we introduce a coordinate system $X_1 X_2 X_3$, associated with the elastic body under consideration so that the conditions:

$$\int_V X dm = 0, \quad \int_V r \times X dm = 0, \quad (6)$$

where: $X=X_1 X_2 X_3$ - the elastic displacement of the point that occupied the position in the undeformed state r . Conditions (6.1) characterize a coordinate trihedron relative to which the body, on the average (over all particles), does not move or rotate. The following problem is posed: knowing the absolute angular velocity of the trihedron $X=X_1 X_2 X_3$ in projections on its axis $\omega(t)$, determine how the waves of elastic deformations behave. Let us write down the d'Alembert-Lagrange principle for the considered body following the monograph [3]:

$$\int_V \left[\ddot{x} + \omega \times (\omega(r+x)) + \dot{\omega} \times (r+x) + 2\omega \times \dot{x} + \frac{1}{\rho} \nabla \Pi - f \right] \delta x \times dm = 0 \quad (7)$$

Here ρ - is the density, which depends only on the modulus of the radius vector $|r|$, $\nabla \Pi$ - is the gradient of the quadratic functional of the linear theory of elasticity.

The coordinates defining the angular position of the body as a whole do not change, it is assumed that the angular velocity $\omega(t)$, is a known function of time. To select generalized coordinates, consider a special case $\omega=0$. In the publication [3], it is shown that the spectrum of natural vibrations of a free rigid body is discrete under the conditions (6) introduced above. This means that the increasing sequence of natural frequencies $\nu_1 \leq \nu_2 \leq \dots$ is unbounded, and the natural elements $h_1(r), h_2(r), \dots$ corresponding to these sequences of frequencies form an orthonormal system of functions, complete in the configuration space of the problem under consideration:

$$\int_V h_n(r) h_1(r) dm = \delta_n^l \quad (8)$$

This allows one to introduce independent Lagrangian coordinates describing all degrees of freedom during deformation of the body, in the general case $\omega(t) \neq 0$, as follows:

$$x = \sum_{n=1}^{\infty} q_n(t) h_n(r) \quad (9)$$

The problem of natural vibrations of a spherically symmetric free body admits the SO (3) group; therefore, the spectrum of natural frequencies is degenerate and consists of a sequence of at least threefold frequencies:

$$\nu_1 = \nu_2 = \nu_3 \leq \nu_4 = \nu_5 = \nu_6 \leq \dots$$

In this case, the configuration space is a direct product of three-dimensional eigen subspaces:

$$\{h_1, h_2, h_3\} \times \{h_4, h_5, h_6\} \times \dots$$

We fix the number m of an arbitrary proper subspace and introduce designations for the corresponding generalized coordinates: $q_{3m-1} = u, q_{3m-2} = v, q_{3m-1} = w, (m=1,2,\dots)$.

Substituting (9), as well as the expression $\delta x = \sum_{n=1}^{\infty} \delta q_n h_n(r)$ in the original identities (63.1) and equating to zero the coefficients of independent variations δq_n , we obtain an infinite system of ordinary differential equations of the second order with respect to q_n :

$$\begin{aligned} & \ddot{u} + au + bv + cw - v(\dot{\omega}, k_3) + w(\dot{\omega}, k_2) - \\ & - 2\dot{v}(\omega, k_3) + 2\dot{w}(\omega, k_2) + F_1 + L_1 = 0, \quad (10) \\ & \ddot{v} + bu + bv + ew + u(\dot{\omega}, k_3) - w(\dot{\omega}, k_1) + \\ & + 2\dot{u}(\omega, k_3) - 2\dot{w}(\omega, k_1) + F_2 + L_2 = 0, \\ & \ddot{w} + cu + ev + fw - u(\dot{\omega}, k_2) + v(\dot{\omega}, k_1) - \\ & - 2\dot{u}(\omega, k_2) + 2\dot{v}(\omega, k_1) + F_3 + L_3 = 0 \end{aligned}$$

In the system of differential equations (10), the scalar coefficients have the form:

$$\begin{aligned} a &= \int_V (h_{3m-2}, \omega)^2 dm - \omega^2, \\ b &= \int_V (h_{3m-2}, \omega)(h_{3m-1}, \omega) dm, \\ c &= \int_V (h_{3m-2}, \omega)(h_{3m}, \omega) dm, \end{aligned}$$

$$\begin{aligned} d &= \int_V (h_{3m-1}, \omega)^2 dm - \omega^2, \\ e &= \int_V (h_{3m-1}, \omega)(h_{3m}, \omega) dm, \end{aligned}$$

$$f = \int_V (h_{3m}, \omega)^2 dm - \omega^2,$$

$$\begin{aligned} F_1 &= \int_V (\nabla \Pi, h_{3m-2}) dV, \\ F_2 &= \int_V (\nabla \Pi, h_{3m-1}) dV, \\ F_3 &= \int_V (\nabla \Pi, h_{3m}) dV \end{aligned}$$

L_1, L_2, L_3 - are linear functions of generalized coordinates corresponding to other eigen subspaces. The presence of these terms characterizes the fact that systems of type (10) for different subspaces are not independent of each other.

When deriving equations (10), it was assumed for simplicity that the mass forces f are orthogonal to all eigen functions:

$$\int_V f h_n(r) dm = 0$$

This means that there is only a constant component in the forces ($\int_V r \times f dm \neq 0$), which ensures the rotation of the body with speed $\omega(t)$. In (10) the vector coefficients k_1, k_2, k_3 have the form:

$$\begin{aligned} k_1 &= \int_V h_{3m-1} \times h_{3m} dm, \\ k_2 &= \int_V h_{3m} \times h_{3m-2} dm, \\ k_3 &= \int_V h_{3m-2} \times h_{3m-1} dm \end{aligned}$$

Due to the spherical symmetry, the choice of the eigen vectors $(h_{3m-2}, h_{3m-1}, h_{3m})$ can be carried out so that the following identities hold:

$$k_1 = k(1,0,0), k_2 = k(0,1,0), k_3 = k(0,0,1), \quad \text{where:}$$

$$k_1 = k(1,0,0), k_2 = k(0,1,0), k_3 = k(0,0,1) \quad (11)$$

Using the Cauchy-Bunyakovsky inequality for (11), we obtain $0 \leq k \leq 1$. If we now introduce the notation:

$$z = \begin{pmatrix} u \\ v \\ w \end{pmatrix}, \quad \omega = \begin{pmatrix} p \\ q \\ r \end{pmatrix},$$

$$L \begin{pmatrix} L_1 \\ L_2 \\ L_3 \end{pmatrix}, G = \begin{pmatrix} 0 & -r & q \\ r & 0 & -p \\ -q & p & 0 \end{pmatrix},$$

then equations (10) can be rewritten in the following compact vector form:

$$\ddot{z} + Az + k\dot{G}z + 2kG\dot{z} + L = 0, \quad (12)$$

where: A - is the symmetric matrix of positional forces, consisting of the coefficients of elastic forces F1, F2, F3 and, accordingly, a, b, c, d, e, f - scalar coefficients.

III.II Spatial precession of a standing wave on the surface of an elastic sphere

The vector equation (12) determines the spatial evolution of the m-th mode of vibration of a free spherical elastic rigid body, caused by the presence of rotation. This evolution is determined by two circumstances. First, the mode of vibration itself reacts directly to the rotation of the body, which is determined by the presence of terms G and $\dot{G}$ in (12). Secondly, the considered mode of vibration is influenced by other modes. We note right away that this effect is insignificant, because, for example, when solving equations (12) by the averaging method, all the terms determined by linear functions of generalized coordinates L disappear in the first approximation.

In addition, the following fact takes place. There is such a coordinate system: $z \rightarrow y$: $z = My$, where M - is the time-dependent orthogonal coordinate transformation matrix, in which equation (12), when the identity is satisfied $L=0$, has a self-adjoint form. In this coordinate system, equation (12) admits a standing wave solution. Let's show it. Substituting the equation $z = My$ into (12) obtained above, we find:

$$\ddot{y} + 2M^T(\dot{M} + kGM)y + M^T(\ddot{M} + 2kG\dot{M} + k\dot{G}M + AM)y = 0 \quad (13)$$

We require the following first-order differential equation to be satisfied, which is obtained from equation (13):

$$\dot{M} = -kGM \quad (14)$$

As a result, we obtain a second-order differential equation of the form:

$$\ddot{M} = -k\dot{G}M + k^2G^2M$$

and substituting it into (13), we find the following second-order equation:

$$\ddot{y} + M^T(A - k^2G^2)My = 0$$

Thus, if a mechanical standing wave of oscillations with some pure tone is excited in a motionless elastic spherical body and then the body is brought into rotation with an angular velocity arbitrarily varying in time, then the standing wave will rotate relative to the body itself according to the law (14). It should be noted that the first-order differential equation (14) is the well-known kinematic Poisson equation. Let us compare equation (14) with the well-known Poisson equation for the rigid body itself, in which the orthogonal matrix determines the orientation of the rigid body in absolute (inertial) space. Whence it can be seen that the angular velocity of the standing wave relative to the body is proportional to the angular velocity of the body relative to space:

$$\Omega_0(t) = -k\omega(t), \quad (15)$$

or for the speed of a mechanical standing wave relative to absolute space, we have

$$\Omega(t) = (1 - k)\omega(t) \quad (16)$$

Relation (15) is a generalization of the introduced scalar relation (3) to the spatial case. We emphasize that for a complete spherical shell, the Brian coefficient is spatial in nature. It determines the proportionality to each other of the angular velocity vectors (15), in contrast to the case of a ring, when the angular velocities of plane rotation were considered. A standing wave in the form of, for example, an ellipsoid, precesses relative to the body with an angular

velocity vector proportional to the angular velocity vector of the body itself relative to absolute space.

IV. Micromechanical spatial integrating wave solid state gyroscope

Micromechanical spatial integrating solid-state wave gyroscope containing a resonator in the form of an axisymmetric thin-walled element capable of vibration, one resonator electrode, a plurality of sensor electrodes, control electrodes, an electronic control unit containing devices for calculating the angle, stabilizing the oscillation amplitude, suppressing quadrature oscillations and connected to the electrodes resonator, sensor electrodes, control electrodes, in which the electronic control unit contains a comparator with hysteresis, a phase-locked loop device, a modulator, an adder, an analog-to-digital converter, a microcontroller, while the outputs of the angle calculating devices are connected through an analog-to-digital converter with a microcontroller, and also through a device for suppressing quadrature oscillations with a device for stabilizing the amplitude of oscillations, and the output of the suppressor for quadrature oscillations is connected to the input of the adder, the output of one of the devices is

The angle measurement is connected in series with a comparator with hysteresis and a phase-locked loop, the output of which is connected to an adder through the modulator, characterized in that the resonator is made in the form of a spatial evacuated small-sized module, consisting of concentrically placed one inside the other outer and inner hollow spheres with a diameter of 10 mm from a magnetic material with a mutually opposite direction of magnetization, and the power source, electromagnetic centering coils and a control unit are located in the inner sphere, and control electrodes and an auxiliary electrode are located on the outer side of the inner sphere; on the inner side of the outer sphere there are sensors for measuring the position of the standing wave and on the outside of the outer sphere there are electromagnetic centering coils, and the spatial standing wave is excited in a thin-walled sphere made of material with low internal friction parameters, covering the outside of the inner sphere through non-magnetic bushings.

Conclusion

For a full spherical elastic shell, the Brian scale factor is approximately one quarter. This value of the scale factor turns out to be slightly less than it was previously obtained for a ring (or cylinder) equal to, or for a hemisphere.

We emphasize especially that for a full spherical shell, the Brian coefficient is spatial in nature. It determines the proportionality of the angular velocity vectors to each other, in contrast to the case of a ring (cylinder, hemisphere), when the angular velocities of plane rotation are taken into account. In three-dimensional space, a three-dimensional mechanical standing wave, realized in the form of, for example, an ellipsoid of revolution moves relative to an elastic rigid body with an angular velocity vector proportional to the Brian coefficient (the vector of rotation of the most elastic body relative to absolute space. In this case, a spatial mechanical standing wave implemented on the surface An elastic two-dimensional sphere in the form of, for example, an ellipsoid of revolution, moves relative to the body with an angular velocity vector proportional to (the vector of the angular velocity of the body itself relative to absolute space. The acceleration of a spatial standing wave relative to an elastic sphere is the same certain fraction of the acceleration of the sphere relative to inertial space. Thus, for numerous practical applications, we have in one gyroscopic device a very compact, accurate three-dimensional inertial angular velocity sensor, which can be technically implemented in a modern micromechanical design and allows you to simultaneously measure the increments of three quasi-coordinates - pseudo-orientation angles included in the kinematic differential equations, integrating which we solve the classical Darboux problem of the spatial orientation of a moving object in three-dimensional space using the angular velocities of the body known from the measurements of the 3-D SRG /

SRG sensor. These results are confirmed by mathematical modeling, and experimental testing is planned in the future.

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TOWARDS A BOOK RECOMMENDER SYSTEM

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Annotation – This work is devoted to the development of a recommendation system that will allow parametric selection of books in Russian, basing on the analysis of books texts and books attributes. The classification of recommendation systems is given and an approach to the construction of the recommendation system is chosen. The main steps of text processing are analyzed along with methods and algorithms for vectorization, determining the weight of a word in a document and measures of similarity. A set of abovementioned methods is chosen for natural language-based text analysis for feature extraction from books texts.

Key words – Recommender system, natural language text analysis, vectorization, measure of similarity.

INTRODUCTION

A book contains a lot of useful knowledge, its author shares his experience through it. The book helps to understand human kind and the world, shows the greatness of humanity and opens a large and beautiful world in front of us.

The development and spread of the Internet have led to greater availability of books. Books can now be read not only in paper, but also in electronic format. However, in such a variety [1], it is difficult to make a choice of an interesting book. Glancing through thousands of covers, one can hardly find a good book. A few phrases read on a randomly opened page or in the annotation make it possible to reject completely mediocre texts. One can use one of the book forums [2], but "there is no accounting for taste". In regard, methods of automating the selection (or as it is called recommendation systems) have become popular. First of all, recommendation systems have emerged as a way to assist users in their decision-making process because they suggest the most appropriate choice for a specific user.

Mathematical methods and algorithms for text analysis make it possible to automate the assessment of alternatives, excluding the human factor from the decision-making system. There is a demand for the service that helps to choose a book precisely according to the user's preferences and books, unlike short articles, are voluminous enough to compose their portraits, which can then be compared.

THE COMPARISON OF RECOMMENDER SYSTEMS TYPES

1. Collaborative filtering

Within such system, recommendations are formed for each user based on the preferences of similar users: from the set of U , those users are selected that are similar to the user U_i . Next, ratings of books are considered to select from ratings by similar users those items which weren't yet read by this user. The recommendation is based on the estimates obtained. For example, given a table of ratings for books by several users (Table 1).

Table 1 – Example of user book ratings

Book title	War and peace	Pride and prejudice	Crime and punishment	Fathers and sons
John	5	4	1	2
Sam		5	2	?
Kate			3	5
Mary	4		4	5
Jack				4
Andrew		5	3	3

The task in this case is to fill in the cells in which there is no estimation, so that basing on full data and thus on predicted values, the system could recommend particular alternatives to users.

The major disadvantage of such systems is the problem of “cold start”, when data about a new user or a book haven't yet been accumulated.

2. Content-based recommender systems

Content-based systems use a user-preference metric that compares the alternatives with the user's preferences, derived from the survey offered to him during registration, and later also from the results of the actual user's choice [3].

To create recommendations, a vector of object features is used. The features can be divided into several groups:

- quantitative;
- qualitative;
- tags;
- keywords;
- subjects;
- styles.

In particular, the number of some constructions in the text (speech clauses, etc) can be considered as a feature of the first group.

The user should not rate all the books from the school curriculum in a row, otherwise the system may focus in its recommendations on children's literature and classics. It is recommended to choose not only bestsellers, but also include some specifics in the list of preferences in order to recommend and diversify the issuance of the system. [3]

3. Precedent (case-oriented) recommendation system

To solve the “cold start” problem, some pragmatic-driven behavior scenarios are often defined for a user or a group of users. For example, it can be one of following cases: "children's literature", "literature in the steampunk setting", "literature for Francophiles". This will allow to assign a user to one or several of the groups predefined with the involvement of experts in order to make recommendations in accordance with the case. The disadvantage of this approach is the necessity to involve experts.

4. Hybrid recommender system

A recommender system can be developed as a hybrid of collaborative and content-based systems. Cases of collaborative system can be modeled by a set of tags or groups of tags. If it implements an open set of tags assigned to objects, it could probably lead to the appearance of noise, so moderation of tags is desirable [3].

CONCLUSION ON A COMPARISON OF RECOMMENDATION SYSTEMS

Thus, the main disadvantage of collaborative filtering is the “cold start”. To avoid it, it's possible to develop a content-based recommendation system. With selection data accumulation, it's possible to apply a collaborative filtering, by shifting towards a hybrid recommendation system. If necessary, application of the case-oriented approach is prospective.

To develop the content-based part of the recommender system, we consider it necessary to analyze the text. Extracted text features would allow thorough text analysis, as semantic features extraction are still rarely applied in recommender systems.

DOCUMENT PRESENTATION

To compare two texts, the primary task is to select a set of features from the text. The set of features includes, for example, rare literary words, sayings, proverbs, Latin words or phrases, abbreviations, stylistic, thematic or specialized speech, etc.

The first stage of text processing is to split the stream of characters into tokens. Thus, documents are splitted into paragraphs, paragraphs into sentences, sentences into separate words. This stage is called tokenization.

Part of this step is normalization. At this stage, words are reduced to a common form: words are transformed to one register, abbreviations are deciphered, numbers are transformed into text. This stage is necessary for further unification of text processing methods [4].

This is followed by the stage of morphological analysis: the reduction of words to the initial form. This stage is necessary in order to focus only on the start form and not on all possible word forms. There are two key methods for this stage.

- Stemming is a process during which endings are discarded from a word in the expectation that in most cases it will justify itself. The advantage of this method is the speed of work. The disadvantage is the possible loss of the meaning of the word after processing.

- Lemmatization is a precise process using lexicon and morphological analysis of words, which removes only inflectional endings and returns the basic form of the word. An obvious advantage of this method is its accuracy, but a ready-made dictionary or a library (e.g., pymorphy) is required to use it [5].

The third stage of text analysis is syntactic analysis, which will make it possible to compile (in one of the readings) a tree of syntactic dependencies for each sentence. It is possible to determine the features of the formation of a sentence from such a tree, as well as the peculiarities of branching of the tree.

The fourth stage is semantic analysis. This is a group of methods that extract elements of sense (semantics) from a text, e.g. named entities, topics, locations, etc.

At an additional stage, it is possible to filter the text tokens: to remove stop-words that may not be considered as important in relation to the problem being solved, for example, articles,

interjections, conjunctions, prepositions, etc. At the same time, for certain genres or authors, frequently used particles, which are considered as noise in other problems, may be important.

VECTORIZATION

As soon as the text is converted into a normalized sequence of words, the process of its vectorization starts with conversion into numerical graphic sequences. There are several models for this.

- “The bag of words” is a model that ignores the order of words in the text. The task of this model is to determine for each word entry its quantity in the text [3]. In practice, this model is implemented as a dictionary structure, where the key is the word itself and the value is a word entry quantity. The advantage of the model is simplicity of implementation, but ignoring the word order leads to a disadvantage: possible loss of meaning in the text.

- An N-gram is a sequence of n elements in a row in some text. A sequence of two elements is called a bigram, of three – a trigram. Sentence boundaries can be used as boundaries for accounting for N-grams. Using N-grams, it is possible to calculate, for example, set expressions or author’s phrases [6].

- Word2Vec is a set of models developed by Google in 2013 to analyze natural languages, an algorithm based on distributive semantics and vector representation of words. The corpus of texts is used as input data. First, a dictionary is created from the training text data. Next step is to computerize the representation of words based on contextual closeness. In this case, the words that cooccur in the text, will have close numerical coordinates in the vector representation [7].

Then it’s important to determine the weight of the words in the document. There are several methods for this.

- Boolean weight – equal 1 if the term occurs in the document and 0 otherwise;
- tf (term frequency) – weight is determined as a function of the number of occurrences of a term in the document: the more often a word occurs in a document, the more important it is for the document;

- tf-idf (term frequency – inverse document frequency) – the weight is defined as the multiply of a function of the number of occurrences of a word in a document and a function of the reciprocal of the number of documents in the collection in which this word occurs [5]. Thus, it is possible to determine the importance of a word for a specific document much more accurately, relative to other methods.

After defining the set of words that are important for the texts, signs can be identified. For example:

- locations of the book;
- heroes;
- important events that take place in the book (victory, war, Reconquista, revolution, olympiad).

Basing on the analysis of a large number of books on the same topic, dictionaries can be compiled, consisting of the most important words for this topic. This will allow determining similarity between user's books and this set of dictionaries, and then to offer him a book on this topic (accompanied with a corresponding dictionary). Similarity can be determined using similarity measures (Word2Vec can also be considered as such).

TEXTS COMPARISON

Similarity measures, or similarity functions, are functions that determine the similarity of two objects. The three most popular distance measures are Euclidean and Manhattan distances, and the cosine proximity measure.

If the coordinates of some document A in N-dimensional space are equal $(x_{A_1}, x_{A_2}, \dots, x_{A_n})$, and the coordinates of some document B in N-dimensional space are equal $(x_{B_1}, x_{B_2}, \dots, x_{B_n})$, then the Euclidean distance from document A to document B is equal to (1).

$$d(A, B) = \sqrt{\sum_{i=1}^n (x_{A_i} - x_{B_i})^2} \quad (1)$$

When $n = 2$, equation (1) is reduced to the formula for city blocks, or Manhattan distance (2).

$$d(A, B) = \sum_{i=1}^n |x_{A_i} - x_{B_i}| \quad (2)$$

Manhattan distance may be preferable to Euclidean distance in case of high-dimensional data [9].

Cosine measure calculates documents similarity as the angle between document vectors. In practice, it is easier to calculate the cosine of an angle than the angle itself (3).

$$\cos(A, B) = \frac{\sum_{i=1}^n x_{A_i} x_{B_i}}{\sqrt{\sum_{i=1}^n x_{A_i}^2} \sqrt{\sum_{i=1}^n x_{B_i}^2}} \quad (3)$$

If the result obtained from formula (3) is 0, then the document vectors are orthogonal and have no correspondence [8]. The advantage of this measure is that with a large scatter of values along one axis and small scatter along the other, the contribution of values which are large in amplitude will outweigh other contributions by an order of magnitude; on the other hand, when comparing vectors by proximity in angle between them, the difference in amplitudes will be leveled out.

All three measures are subject to implementation for further selection of the most appropriate recommender system at the stage of parameterization.

CONCLUSION

When implementing a recommendation system from scratch, in case there is no database of user ratings, it's recommended to choose a content-based system. Furthermore, it's useful to shift towards a hybrid system: in cases where there are no ratings, the content-based approach would be in the lead, otherwise collaborative recommendation strategy could be used along with the content-based one in order to combine results.

Methods of natural language processing are considered to be important, for they allow extracting semantic data along with text style features. Basing on NLP methods overview, following recommendations are formed. When analyzing texts at the stage of morphological analysis, it's important to choose lemmatization, because when analyzing books, it is important not to lose the meaning of the text, which stemming can lead to. For the same reason, when choosing a vectorization method, a bag of words will turn out to be ineffective as standalone, that's the reason why it's preferable to make a choice between N-grams and word2vec.

As a result of the completed work, the main types of recommender systems were studied. The stages of text analysis are considered. Models of vectorization of a sequence of words are presented. Several methods to the analysis of the weight of a word in a document are considered. The main functions of similarity measures are presented. The direction of development for the creation of a recommendation system for the selection of books is formed and reasoned.

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TOWARDS DEVELOPING A MOBILE APPLICATION FOR AUTOMATED ASSESSMENT OF EVALUATION OF A CONVERSATIONAL ROBOT DIALOGUE STRATEGIES

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Abstract — This paper is dedicated to the task of automating user feedback assessment. The setting is assessing user experience in dialogue with a robot or a dialogue system. F-2 the communicative robot is considered. In order to allow respondents to evaluate their communication via online, developing a mobile application is suggested. Key problems are considered which should be solved during the application development. An interface is developed and described. Further work on back-end is discussed along with user experience aspects for the front-end.

Keywords — mobile application, user experience, dialogue system, communicative robot, F-2, human-machine interaction.

INTRODUCTION

As robots have become a part of everyday life, it is important to make them interact with people effectively. For this purpose, robots should process input and react correctly and adequately. A particular class of tasks interconnected with robotics is human-machine interfaces

development, especially dialogue systems development. The latter are intended to simulate robotic understanding of human natural language input, including not only commands; the reaction should be formed in natural language as well. One of the types of dialogue systems is classic artificial intelligence which ‘talks’ to a human interlocutor and is destined for prospective passing the Turing test. It is important for such software, or systems, to act as naturally as possible while communicating, so that they could create a positive opinion and so that a human could possibly forget that the robot is not a living person.

A particular dialogue systems class is affective robots. Affect is a general term relating to emotions, moods and other such states with different degrees of activation and valence [1]. Beyond Ekman’s basic emotions set, emotions can be represented as points in a continuous 2D space, with following axes: valence and activation [2]. Attitudes can be modelled as amalgamations of emotions [1]. Another approach [3] is based on mood changing basing on pleasure, arousal and dominance, the weighted combination resulting in an emotion.

For emotions modelling authors of [4] introduced such emotional primitives (referred to as control states) as plans, intentions, wishes, emotions (short-term), preferences, skills, rules and personal characteristics (long-term). The supposition is, agent’s actions are defined by concurrence in control states hierarchy, each of the state having its activation degree (changing in time). In the F-2 project [5] the approach of concurrent control states is adapted, in particular based on the corpus-based observations which allow specifying a set of more low-level control states (emotions or moods) as well.

F-2

F-2 the communicative robot is one of the most advanced Russian dialogue systems, and it has a robotic body. It analyzes human speech and forms an inner representation of its sense. Then it produces affective reactions to the extracted sense. The contrary to smart assistants, this dialogue system is intended to talk, to pretend it’s the interlocutor’s pal – and to express affective opinions to interlocutor’s phrases, sometimes sad, sometimes happy, but at every time with a personal touch. The F-2’s dialogue system has its own syntactic-semantic natural language text parser [6], and as a reply to the input text pragmatics a communicative goal is formed (to express sadness, happiness, etc.). Different possible multimodal reactions are assigned to each communicative goal. Multimodal reactions comprise text (sounded by means of Yandex SpeechKit [7, 8]), gestures (with hands and head) and/or mimics (an LCD stands for the face). The robot model is shown on Fig. 1.



Figure 1. F-2 – one of models of the robot

Each type of input is associated with a communicative goal, which means what the robot should express in his reaction. Thus, communicative goals stand for the inner representation of robot’s reactions pragmatics. To achieve one goal, one set of affective reactions is selected from a database of reactions. The more the reactions components, the more variative the F-2’s reactions (actually, it acts as variative as to overcome the typical problem of such robotic toys as Aibo or Pleo: with all the remarkable technics, the specter of their reactions is quite limited,

which leads a human to loss of interest towards a toy which behavior is predictable). F-2's reactions are copying human reactions and are based on the project's research corpus REC (Russian emotional corpus) [9], which includes annotated videos with human behavior in emotional situations (an exams subcorpus and a happy people subcorpus). Expressing reactions physically is an advantage, when comparing F-2 to another advanced Russian dialogue system – Yandex Alice [10], which has no avatar. Its advantage is using intonations, but still it is a smart assistant, its emotional reactions are pre-recorded and case-based (e.g., answering “Everybody can offend a robot” to rude words), and its variety of expressing the same meaning are quite limited, which reminds every time that it's an artificial intelligence. With more open corpora Russian AIs and affective robots will certainly step forward and advance further.

PROBLEM STATEMENT

One of the important tasks in the project and in the field is evaluating the quality of the system's answers in the dialogue, i.e. evaluating adequacy, correctness of answers along with human impression. The latter is to be aggregated in terms ‘pleasant’, ‘adequate’, ‘correct’ (further to be referred to as ‘feedback’). Only people can give such feedback, and that is the most important evaluation method for the task. In the project psychologists work with respondents and evaluate feedback on live dialogue with the robot.

In order to develop dialog strategies for F-2, their quality should be evaluated. The solution to this problem is in inviting respondents who would communicate with F-2 and assess the dialogue in whole and in part. Thus, for the development of the robot, we need live communication with it to analyze its advancements and to train it to act more and more like a human. The more people communicate with F-2, the more data we get (including sometimes most important ideas, what is missing), the better it is possible to advance F-2. But still we meet the problem of time required to provide such a flow of communication. Moreover, due to the epidemiologic situation sometimes live communication with the robot would be impossible. Therefore, to solve this problem, the task arises to automate the process of communicating with the robot and, the most important, of assessing user experience.

A MOBILE APPLICATION FOR FEEDBACK ASSESSMENT

Having studied human needs, one can conclude that almost everybody has mobile phones, and these devices people are used both for personal needs and for work. Hence, we decided to create a mobile application that would allow people to communicate with the robot at any time when it would be convenient for them, and to evaluate its work – to give feedback.

The interface is developed for the application under consideration. At this stage users can communicate with the robot only by texting in the application, but in the future the possibility of voice communication can be added. After communicating to the robot the respondents (the application users) have the opportunity to evaluate each answer and fill out a small questionnaire in special pop-up panels (available via swapping), thereby sharing their user experience. Each user dialogue session is stored to provide the user with the opportunity to give his feedback he at any time convenient (in case one can't share his opinion immediately due to time limits). The application designed has a special screen that appears at the end of the conversation and on which the user is offered to evaluate the answers of the distant robot (there is a field for plain text input as well, in case a respondent would will to offer one's answer). A user can get to this screen and to the screen of the questionnaire at any time, provided that one has correspondence without reviews.

To use the opportunity to communicate with the robot and to evaluate it, an application user should have a username and a password in order to authorize within the application. Next, the user is supposed to fill out a profile and to chat with the robot. During the communication, the user will see the emotions of the multimodal interlocutor, which are present in the physical

robot, but via recorded gifs corresponding to different reactions (in prospective a videostream broadcasting functionality might be added to the app).

The application will use the robot's backend which is under construction, and a database of pre-recorded reactions (in .gif format) is required along with a database to store feedback from respondents for further analysis. The backend functionality should be as follows.

- (1) To save and load the last chat without feedback. Feedback can be added at any time.
- (2) To register respondents as users of the system and to authorize users.
- (3) To send a dialogue system's response into the app (text and/or gif-file(s)).
- (4) To save feedback and to load the unfinished feedback session.

The UX/UI (user experience/user interface field) studies are important in mobile applications development, so preliminary evaluation shows the designed interface suits the requirements stated in [11]. In future work, more thorough analysis will be conducted, according to [12-15], in order to adjust the interface to get the highest evaluations of user interface of the application under consideration.

CONCLUSION

Dialogue systems were considered, with the focus on F-2 the affective communicative robot. The task of assessing feedback on dialogue of a human with F-2 is set. An application was introduced for automating feedback assessment: the interface development is described, and the project of a backend is discussed. The automated feedback assessing would provide the F-2 project with more data to evaluate, and it will allow setting dialogue experiments even in case of quarantine. Assessed feedback evaluation at every time allows verifying dialogue strategies of F-2 the communicative robot, and further advancements in developing the robot's behavior.

ACKNOWLEDGEMENTS

The research is supported by the grant of the Russian Science Foundation (project №19-18-00547).

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ON HUMAN FEATURES EXTRACTION FROM VIDEO FOR ENRICHING DIALOG STRATEGIES OF THE F-2 CONVERSATIONAL ROBOT

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Abstract— This paper describes a modified method for the formation of a multimodal reaction of a robot-interlocutor based on identification of signs of a person on a video. This method is intended to increase the value of assessment of the respondents' interaction with the robot and leave a person with positive emotions from the communication process, since the effect on a human interlocutor states pro or contra dialog strategies success. A module for recognizing the 5 types of objects in the image is developed, its accuracy is estimated.

Key words—multimodal reaction, F-2, affective robot, feature recognition, computer vision.

INTRODUCTION

Nowadays robotics is actively developing, but mainly modern robots are designed to replace a person in an aggressive environment or while performing complex production operations.

However, people have long dreamed of humanoids, emotional robots that can show humor, emotions, and maintain a conversation. With the advent of Tamagotchi in 1996, the Tamagotchi effect was discovered - an emotional attachment to a robot or some kind of virtual object, i.e. people tend to get attached to things that show superficial emotional phenomena. Therefore, it is important to find ways to teach robots to respond to human actions with some sentiment (behavior elements demonstrating superficial emotional phenomena).

There exist robotic interlocutors and companions, which show so-called emotional reactions using facial expressions, gestures or phrases when communicating with a person. These include the Mertz robot, developed at Massachusetts Institute of Technology [1], and agent Max, developed at the University of Bielefeld [2].

In Russia there exists project of the same nature: the communicative robot-companion F-2 [3]. It analyzes human speech by means of the project’s own semantic parser [4] and perceives

its sense via forming an inner representation of input text pragmatics – extracted facts. Each fact activates one or several communicative goals (to express sadness, happiness, etc.), and the most activated goal implies selecting and demonstrating a corresponding set of multimodal reactions [5]. The variety of reactions stored in a database allows solving the problem of loss of human interest towards a toy which behavior is predictable, no matter how wonderful the technics is. Multimodal reactions consist of text (sounded with Yandex SpeechKit [6]), gestures (with hands and head) and/or mimics (an LCD stands for the face).

This work is devoted to modification of F-2's method with forming multimodal reactions basing on recognition of human signs in the video.

LIST OF WORKS PERFORMED

The purpose of this work is to develop a module for selecting a pattern on a person's clothes in the frame. To achieve it, the following tasks were set:

- formalization of the task;
- selection of algorithms, solutions and implementation tools;
- development of a module for highlighting people's faces on the image;
- searching and marking images for training a neural network;
- training a neural network to classify patterns on clothes;
- evaluating the trained neural network accuracy.

HUMAN FEATURES RECOGNITION

For a high-quality selection of the features of the pattern on the clothes of several people in the frame, it is necessary to select the person's face and classify the pattern located below the location of the face. The following characteristics were identified as features:

- bow-tie;
- tie;
- drawing of a cat;
- striped clothes;
- plaid clothes.

It is assumed that a person is depicted full-face; several people can be in one image.

There is a huge number of existing solutions for recognizing a person's face in a frame. One of the most popular is the pretrained deep neural network in the OpenCV [7] (Open Source Computer Vision Library) library. Its main advantages are high accuracy (99.38% on the Labeled Faces in the Wild (LFW) dataset) and the ability to execute in real time.

The TensorFlow library was chosen to train the neural network [8]. TensorFlow is an open-source machine learning library developed by Google for solving problems of building and training neural networks in order to automatically find and classify patterns, reaching the quality of human perception. This library has a wide base of pre-trained models and high-quality documentation.

HIGHLIGHTING A PERSON IN THE FRAME

A module has been developed to recognize a face in the frame and highlight the area of the image below it. The area where the body should be located is the rectangle zone with a width of 3 head heights below the coordinates of the head. In the future, this area will be transferred to the neural network for classification.

Figure 1 shows the original image and its copy with highlighted areas of the face and the body – the area in which the classification of the pattern on the clothes is supposed to work.



Figure 1. Original image and highlighted areas of the face and body

SELECTION OF IMAGES FOR TRAINING THE NEURAL NETWORK

To train a neural network, it is necessary to prepare at least several hundred images. 80 images were selected and labeled from each of the categories defined above.

For each image, an xml file is generated with the coordinates of the rectangle containing the selected object and the name of the category to which it belongs. It is necessary to collect all this information into one csv file and convert it to TFRecords – a data format that will be transferred to the tensorflow model for training. Next, one needs to specify the number of classes and the number of images prepared for training the neural network, and specify the paths to the images and the map of labels – all of it in the configuration file.

NEURAL NETWORK TRAINING

Instead of training the neural network from scratch, it was decided to use the transfer learning technique. Transfer learning is the application to the solution of a problem of the knowledge extracted by a neural network when solving another problem. This makes it possible to significantly reduce the amount of data required for high-quality training of a neural network [9].

Faster-RCNN-Inception-V2, pretrained on the COCO (Common Objects in Context) dataset, containing 330 thousand images divided into 80 categories, was chosen as the neural network model.

The neural network was trained until the loss function at each training iteration was stably below 0.05. A loss function is a function that is minimized during model fitting. It represents the selected measure of disagreement between the observed data and the data "predicted" by the fitted function and is described by formula 1 [10].

$$L(p, u, t^u, v) = L_{cls}(p, u) + \lambda[u \geq 1]L_{loc}(t^u, v), \quad (1)$$

where u is the class of the transferred region of interest according to the dataset version, $v = (v_x, v_y, v_w, v_h)$ is the framing shell of the object corresponding to the transferred region of interest. $u = 0$ corresponds to the class of negatives, and in this case the second term in the loss function vanishes. λ allows balancing the influence of classification error and coordinate refinement error.

The classification error is calculated as standard: $L_{cls}(p, u) = -\log(p_u)$. In the second term, the following sum is taken as a loss function:

$$L_{loc}(t^u, v) = \sum_{i=x,y,w,h} \Psi_1(t_i^u - v_i), \quad (2)$$

where $\Psi_1(x)$ denotes the Huber function (with parameter 1):

$$\Psi_1(x) = \begin{cases} 0.5x^2, & \text{если } |x| < 1 \\ |x| - 0.5, & \text{иначе} \end{cases} \quad (3)$$

Training and features recognition can be carried out both on the central processor and on the GPU. Despite the fact that installing and configuring tensorflow to work with the central processor is much easier, because does not require installation of additional software: CUDA toolkit and cuDNN (library of primitives for deep neural networks), it was decided to use the version for working on the GPU, because its speed is much higher.

Characteristics of the system on which the training was carried out: processor Intel Core i5 2300 2.8 GHz, video card Nvidia GTX 1650 Super.

The network training carried out on the processor took about a day, the classification of objects on one image averaged 3.1 s (the average of 10 tests for 10 different images). The training carried out on the video card took 2 hours, the classification of objects in the image took an average of 0.14 s. This performance allows real-time classification.

TESTING

300 images not used in training the neural network were selected for testing (50 for each of the above mentioned categories and 50 images without classified objects), and the classification accuracy was calculated – the percentage of correctly recognized objects in the images. The overall accuracy is 82%, and 247 out of 300 test images were correctly recognized. The detailed accuracy for each category is shown in Table 1.

TABLE 1. ACCURACY FOR EACH CATEGORY

Category	Number of recognized images	Accuracy
Plaid clothes	48	96%
Striped clothes	42	84%
Drawing of a cat	43	86%
Tie	40	80%
Bow-tie	35	70%
Other (no features of interest)	48	96%

CONCLUSION

Task formalization was carried out. Algorithms, solutions and implementation tools were selected. A module was developed for detecting a person's face in the image and highlighting the area on which a person's clothing should supposedly be located. Images for training a neural network were selected and classified. Training for the classification of patterns on clothes was carried out, classification accuracy tests were carried out, which gave an overall result of 82%. This module allows enriching dialog strategies of the F-2 conversational robot, particularly with a strategy of a lector who sees a student with a raised hand but doesn't know the name. In this case a lector would possibly address to the person with a clarification, as to distinguish one from all of the close raised hands: "Would you answer? The one with a bow-tie." Saying compliments is a prospective strategy for the robot as well, and recognized clothes features would be a good reason to.

ACKNOWLEDGEMENTS

The research is supported by the grant of the Russian Science Foundation (project №19-18-00547).

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ON TWO-FOLD MEMORY ORGANIZATION FOR A CONVERSATIONAL DIALOGUE SYSTEM

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Abstract — The paper describes modeling dual-layer mechanism for the conventional agent F-2. Since the robot has a facts database with which it operates (the long-term storage), the operative memory layer introduction is discussed. The point of the research is in evaluation of the effectiveness of the suggested mechanism, which is intended for storing a selection of facts inside a short-term memory, and prospectively for standing for a storage of what should be called dialog context. The tests are performed, the results are discussed. The Redis-based short-term memory layer is shown to be applicable for dialogue systems.

Keywords — dialogue system, AI, short-term memory, long-term memory, robot F-2, Redis database.

INTRODUCTION

Dialogue systems cover a wide range of software solutions, from classic artificial intelligence based on natural text processing (SIR [1], ELIZA [2], SHRDLU [3], PARRY [4], and modern projects IBUG [5], SEMAINE [6], Greta [7], Max [8]) to modern incarnations of menus with console input, so-called chat-bots (sudden synonyms for NLP-based chat-bots, but this new misleading term usage is highly popular over last 5 years). General strategies for NLP-based dialogue systems with NLP interfaces (text input, pretty frequently aided by voice-recognizing and/or voice synthesizing converters) are as follows: question answering, free flow dialogue conduction, commands extraction and execution, business processes assistance (e.g.

following one of manager strategies of a web-shop consultant and manager). Each dialogue system requires thorough memory organization.

One particular class of dialogue systems is communicative and affective agents and robots. Expressing some kind of affective reactions is what triggers the Tamagotchi effect: people tend to attach emotionally to robots and toys which demonstrate surface emotional phenomena. In order to lead the dialogue, a robot can operate interchanging microstates associated with moods – communicative goals with different activation degrees or weights [9]. One particular Russian project is F-2 the affective robot. With a semantic parser in its basis [10], the F-2 robot mines facts from input sentences, each fact activates one or several communicative goals, e.g. to express surprise, joy, sadness and so on [11]. The communicative goal with the heaviest weight is activated, and one or several elements of reaction are selected from the reactions database (e.g., there is a bulk of joy expressions, and a random one is selected). The reaction is multimodal: a reaction frame can include text, gazes (an LCD display stands for the face), head and hands movements. Goals weights decrease over time, similar to a human getting calm. With a big reactions database formed via translation of human behavior elements into robotic behavior, a big variety of F-2's reactions is achieved, which allows overcoming the problem of loss of human interest when it comes to predictability of reactions after a week or two of using robotic toys, however admirable technics they represent. The reactions are selected from a research corpus REC (Russian Emotional Corpus) of video recordings of people in emotional contexts [12].

PROBLEM STATEMENT

Currently the conversational agent F-2 stores its data in PostgreSQL [13]. Long-term memory is good for safely storing information, but in case the database is filled with big data, it would require a significant time amount to extract data. This might possibly lead to problems in time restricted environment.

In future development, the F-2 project assumes the presence of a system for modelling dialog as well as saving its context. One of important aspects to create such a system is memory. One can organize robot's memory in different ways, for example we can divide it the very same way as in the personal computer: into short-term and long-term memory.

Since there are requirements to safely store data and to provide fast access to it, one can use two different types of databases: one that uses short-term memory for faster access and the other that uses long-term memory for safe constant storing. In this research we created an application that simulates basic dialog, using PostgreSQL as the long-term memory database and Redis [14] as the short-term one.

To compare databases different tests were performed to define the time necessary to extract data, in particular during dialog theme changing, when it comes to getting a new set of data extracted from the long-term database.

TESTS DESCRIPTION

For research software, two types of data are required: subject areas (for example, movies, books etc.) and elements of knowledge about each subject area, to be referred to as facts. Data were pre-generated via a python script in order to perform tests with large amounts of data. Different data order was considered in order to simulate straightforward load of a bunch of sorted data on one topic and to simulate selection of facts randomly located in the database (the case when they are not stored compactly nor sorted by topic). The latter order was intended for simulating a cache miss.

Tests were carried out on two system configurations, which differed only in amount of RAM. First configuration had eight gigabytes of RAM, second had sixteen gigabytes.

There were four tests on long-term memory database. The first one – extracting facts within one theme one by one, in straight order. The second one – extracting facts about random

subject area. The third one – extracting facts about subject areas in straight order, but performing requests to different tables, trying to simulate a cache-miss. The fourth one – similar to the third one, but facts about random subject areas are extracted.

For short-term memory database there was only test, an analog to the first test for long-term memory.

Two different datasets were used, with sorted and unsorted data, for checking if that would influence the tests results.

Tests were carried out on a system with two 8 gigabyte RAMs Kingston 99U5471-054.A00LF and a Terabyte HDD storage Seagate Barracuda ST2000DM001.

TESTS WITH EIGHT GIGABYTES OF RAM

I. PostgreSQL tests with sorted data

- Fetching data in straight order: 0.1296 sec.
- Fetching data about random subject area: 0.1452 sec.
- Fetching data in straight order, trying to get cache-miss: 0.1366 sec.
- Fetching data about random subject area and trying to get cache-miss: 0.1553 sec.

II. Redis test with sorted data

- Fetching data in straight order: 0.0044 sec.

III. PostgreSQL tests with unsorted data

- Fetching data in straight order: 0.1554 sec.
- Fetching data about random subject area: 0.1506 sec.
- Fetching data in straight order, trying to get cache-miss: 0.1314sec.
- Fetching data about random subject area and trying to get cache-miss: 0.1383 sec.

IV. Redis test with unsorted data

- Fetching data in straight order: 0.0037 sec.

TESTS WITH SIXTEEN GIGABYTES OF RAM

I. PostgreSQL tests with sorted data

- Fetching data in straight order: 0.1152 sec.
- Fetching data about random subject area: 0.1089 sec.
- Fetching data in straight order, trying to get cache-miss: 0.1136 sec.
- Fetching data about random subject area and trying to get cache-miss: 0.1121 sec.

II. Redis test with sorted data

- Fetching data in straight order: 0.003 sec.

III. PostgreSQL tests with unsorted data

- Fetching data in straight order: 0.1085 sec.
- Fetching data about random subject area: 0.1195 sec.
- Fetching data in straight order, trying to get cache-miss: 0.1284 sec.
- Fetching data about random subject area and trying to get cache-miss: 0.1316 sec.

MEMORY CONSUMPTION

The RAM measurements showed following results.

PostgreSQL required around 5 Megabytes.

Redis required around 600 Kilobytes when not filled with data, and around 89 Megabytes when fully loaded.

CONCLUSION

The tests showed that Redis outperforms. Redis enables performing facts selection many times faster, due to the fact that this database stores information in RAM. As the initial supposition was, fetching data that has not been sorted in advance took more time.

The two-fold memory approach proved its consistency. This work showed that in-memory (short-term memory) database usage may improve time values required to extract data from the storage. That should as well enhance the dialogue system software work with large data amounts in order to continue working in real time. Results of this paper can be implemented in F-2 the conversational agent in order to improve the dialog system when it would come to context implementation.

The suggested mechanism is intended for storing a selection of facts inside a short-term memory. The tests results show that the Redis-based short-term memory layer is applicable within dialogue systems.

ACKNOWLEDGEMENTS

The research is supported by the grant of the Russian Science Foundation (project №19-18-00547).

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ON A METHOD FOR TRANSFORMING REQUESTS FOR A QUESTION ANSWERING DIALOGUE SYSTEM

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Abstract — The paper describes modeling dual-layer mechanism for the conventional agent F-2. Since the robot has a facts database with which it operates (the long-term storage), the operative memory layer introduction is discussed. The point of the research is in evaluation of the effectiveness of the suggested mechanism, which is intended for storing a selection of facts inside a short-term memory, and prospectively for standing for a storage of what should be called dialog context. The tests are performed, the results are discussed. The Redis-based short-term memory layer is shown to be applicable for dialogue systems.

Keywords — dialogue system, question answering, natural language processing, semantic search, robot F-2.

INTRODUCTION

Dialogue systems evolved from classic artificial intelligence based on natural text processing (first natural text processing software SIR [1], Weizenbaum's ELIZA [2], Terry Winograd's SHRDLU [3]) to modern projects which generate machine representations of emotions and demonstrate surface emotional phenomena: IBug [4], SEMAINE [5], Greta [6], Max [7]. Key Russian dialogue systems are ABBYY Comprero [8], IBM Watson [9], Yandex Alice [10], and F-2 [11-12] (the robot doesn't answer questions). They mostly limit the knowledge domain (IBM Watson is adapted to medical reasoning, Yandex Alice is limited to its assistant functions and scenarios within topics) or perform semantic analysis basing on grammars and/or semantic markers dictionaries, which serves a natural limitation to their knowledge specter. Each of the abovementioned systems requires experts work in order to fulfill grammars, dictionaries, scenarios databases.

One particular Russian affective communicative robot is F-2. Its dialogue system is based on the project's syntactic-semantic parser [13] which uses formal grammar rules in order to transform each input phrase into a syntactic dependency tree, in which every node has semantic markers. A fact can be selected from a tree following one of existing facts templates, which include annotations which should be present in the nodes along with semantic roles (e.g. object + verb + subject corresponding to a fact that a living creature ingests some food, which is a real world object). Thus, a fact is a subtree of a syntactic dependency tree with semantic annotation; each of its lexemes (one lexeme is a node) is assigned a semantic valency. In this research that's the following triad: agents/subject (a), patients/object (pat), predicate/action (p). Semantic features are distributed over valencies (as in [14], around 800 features). The task of decreasing the number of cases of empty search results is solved for requests to the facts database, the solution is in reformulating requests.

TRANSFORMING REQUESTS

Natural language processing implies work with lexemes and semantic features, which, in its turn, implies processing word groups on the lexical level: synonyms, quasysynonyms (partly synonyms), hyponyms (context-dependent as well, and not considered to be universal in the task under consideration), hyperonyms, homonyms etc. A lexemes dictionary is used: for a lexem there are semantic features and closest synonyms, quasysynonyms, hyperonyms (up to 3 of each category). The facts database consists of a million rows, each fact comprising a set of rows (each lexem is mostly associated with several rows with different features). Each fact is represented

with several lexemes (each having a semantic valency), each lexem has several semantic features. The question is formulated as a fact consisting of three abovementioned valencies (the limitation of this work), one of which is filled with a wh-word, the core of the question. Simple questions are considered at this stage of research. The core fact tree node (the lexem is in its initial form) should be replaced with the most relevant search results. But in case there is no direct answer, several question transformations should be performed in order to form any close answer to the imposed question. E.g. what(pat)-eat(p)-cow(ag). The search should return a set of facts relevant to the question, so semantic search should match the question to facts in the database.

CASE-BASED INVESTIGATION

Following replacements are defined for reformulating the question, or the query (in descending priority order): synonymic, quasysynonymic, hyperonymic. In case of fail, semantic features can be replaced with close features due to partly hierarchical structure of valencies. Thus, the semantic feature 'ingest' is the parent node to two nodes: 'eat' and 'drink', all of the three might be interchanged during reformulation. For example, the latter question will be reformulated as follows: what-{eat, drink, ingest}-{cow, herbivore}, and after searching for each fact 2 answers will be found: grass and water.

This leads us to the student dilemma: what is more crucial — not to respond or to answer a close question, not exactly the imposed one. There is no evident decision for all cases. The developed approach has lead us to a human dilemma, which might be considered as an argument pro our human thinking-based approach.

The introduced method for replacements in queries was approbated within a segment of the facts knowledge database. The results demonstrate the process of investigation within the database, this process *humanum est*.

Several conclusions were made on fulfilling the replacements dictionaries.

Given a set of facts extracted from the database and concerned with verbs close to 'to look' ('смотреть'). There exist valencies of path, target, instrumentative, locative. Following verbs close to the initial one are explored: 'to watch', 'to gaze', 'to glance', 'to stare', 'to see'. The collocation 'to turn back' has a close meaning, but that's not a trivial case, since it doesn't necessary include a gaze. Following collocations are possible as well: 'to set one's eyes upon', 'to stop/move/direct the look/gaze'. Hence, in order to find relevant facts to a query comprising the initial verb, there exist a lot of different replacements. This requires expert work, and this shows that the artificial limitation of maximum 3 replacements of each type is too strict. Perhaps, there should be the first pool of replacements (the most frequent words used as replacements) and the second one (comprising less frequent cases). The latter pool could comprise collocations of verbs with following nouns: 'gaze', 'glance', 'eyes', 'eye' in the patiens valency, as well as collocations 'take a look', 'watched the sleeper narrowly' and 'with his eyes upon her face' – the latter word will have the valency of instrumentative (instrument of action), then the gaze would have a trajectory. There is an exception 'to look in the eyes': the target should be extracted from the semantic tree if it is not in the fact under consideration, or even from several previous sentences enriching the context (special rules should be introduced).

Basing on thorough examples analysis, rules should be formed which would allow semantic search within a topic, or a small domain. This leads us to the precedent approach – isn't most of the semantics precedent-based? General questions intended to find all of the possible answers should be considered separately (a verb in past tense, or with a modal word; e.g. 'what can one look at?'), as well as specific situations limited to the context of the dialogue.

CONCLUSION

Basing on thorough analysis of semantic search results, following conclusions are drawn.

- The suggested method allows decreasing the frequency of the case of lack of answer to the initial (or direct) question due to several types of replacements in the structure of the initial fact (a question containing a wh-word). Still the case when there is no answer can't be excluded.
 - The amount of answer-facts after reformulation is under the critical influence of the fulfillment of the replacement dictionaries.
 - In semantic search results mistakes can be found of the same source than the human mistakes in the learning period. This shows that the suggested approach is close to the human one, which is prospective.
 - In particular, not all of the verbs can be replaced to each other. Hence, additional rules should be introduced in order to impose the replacements correctness, in particular those connected to the context ('to play' in music or in sports').
 - Replacements rules concerning semantic features require limitations for the sake of replacements correctness.
 - The semantic search task requires thorough expert work for fulfilling a dictionary of hyponyms in order to answer special questions, such as the part-to-the-whole relations analysis (the question 'what can people do with instruments?' implies the replacement of lexems 'people', 'instruments').
 - It is possible to extract the direct pointing at semantic features (in the latter example — semantic features of the instrumentatives group).
- The described approach proved its consistency. This research is only the first stage, much expert work remains to be done. Still the goal has been achieved: there is a medicine which can help in case of absence of answers to the initial question.

ACKNOWLEDGEMENTS

The research is supported by the grant of the Russian Science Foundation (project №19-18-00547).

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NEW ASPECT IN PRODUCT QUALITY MANAGEMENT BY USING FUZZY CONTROL CHART

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Annotation. A control chart is one of the main statistical process control tools that provides information about a process. Fuzzy logic theory is especially suitable for non-measurable data. the use of fuzzy set theory is essential for control charts with data of "quality" (non-measurable, uncountable data type). For this reason, studies of fuzzy control charts are included in the literature. In most of the past literatures, fuzzy control charts are usually generated using defuzzification techniques to transform fuzzy sets corresponding to linguistic variables into crisp numbers. Based on this defuzzification, a fuzzy control chart is shown, which in turn results in the loss of basic information in the original data. Therefore, to avoid this drawback, fuzzy rules are applied in this study. First of all, within the purpose of this study, an upper control limit (UCL) and a lower control limit (LCL) will be created for fuzzy control charts. Another purpose of this study is to create fuzzy control charts using the fuzzy comparison techniques.

Key words: Quality management, fuzzy control chart, fuzzy rule, fuzzy number comparison methods.

1. INTRODUCTION

Control charts show if the process is moving between the desired levels or not. It is widely used in the process because it graphically shows the situation, whether the data is out of control or within control. Control charts have been used over time in many areas and were developed in the 1920s by Shuhart [1]. By looking at the control charts of a product or process, you can get information about the contingency and take the necessary action for this situation.

Subsequently, control charts are not limited to Shewhart control charts and have been split into CUSUM and EWMA charts. When a fuzzy logical approach began to appear in the literature, fuzzy control charts began to be mentioned. Using fuzzy numbers, especially for control charts for attributes, has the advantage of preventing data loss. There are immeasurable quality characteristics such as color, brightness, surface refraction, etc. Fuzzy numbers not only contribute to the measurement of these attribute data, but also allow you to obtain many quality characteristics using expert opinion [2].

A fuzzy control chart is more sensitive than a similar control chart. These control chart options are fuzzy. Building a fuzzy control chart has several advantages. The main contribution of fuzzy set theory is its ability to represent uncertain data. With the help of the theory of fuzzy sets, the flexibility of the system is increased. The correct classification of fuzzy control charts is important. This helps engineers select the best diagram [3]. The fuzzy approach is appropriate

for attribute management diagrams (p, np, c, and u diagrams) when the data is linguistic, categorical, indefinite, or possibly human-dependent subjective judgment. Fuzzy attribute control charts can be divided into 4 categories usually ± 3 -sigma control limits: a) p-fuzzy chart b) c-fuzzy chart c) np-fuzzy chart d) u-fuzzy chart.

2. BASICS OF THE RESEARCH METHOD

In the presence of data fuzzy, the variance of normal observations tends to increase [4], and some intermediate solutions necessarily exist between the binary classification [5]. Thus, in order to adapt to these fuzzy environments, traditional control charts with binary classifications are necessarily expanded to “fuzzy control charts” [6, 7], which are seen as an inevitable and appropriate choice for monitoring and controlling a production process with fuzzy data [6, 8,9]. Thus, several fuzzy control charts have been proposed and built, for example, by Gulbay M., Kahraman C. (2006), presented an “direct fuzzy approach (DFA)” to fuzzy control charts for attributes under vague data is proposed without using any transformation method [8]. Hungshu.M and. Hsien.C.W. (2010), used the " On comparing interval numbers," method for classifying the manufacturing process [10]. Talebs H. and Limam M. (2002), based on fuzzy and probability theory to constructing control charts for linguistic data [11], etc.

The main result of this study is to propose a method of constructing fuzzy data from real data by "Confidence intervals measure" method, from which we can determine the fuzzy limits of control chart [12]. In this section, by comparing the greater possibilities of two different fuzzy numbers (comparing two fuzzy numbers [13]) to check whether the object is within the limits of fuzzy control, we describe an algorithm for constructing a control chart. Fuzzy control charts are used to track small portions of non-matching items on a fuzzy database. The block diagram of the algorithm is shown in fig. 1.

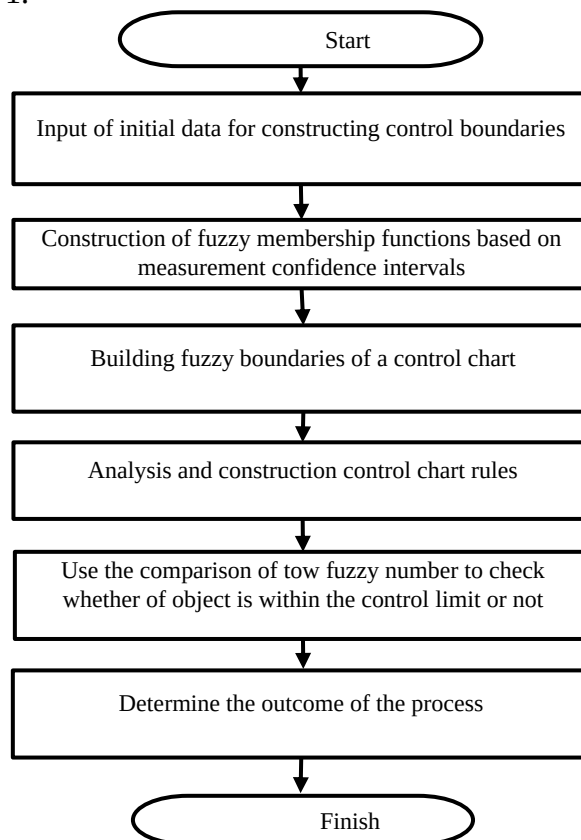


Figure: 1. Block diagram of the fuzzy control chart algorithm

Let $p_i = (l_i, k_i, u_i)$ be fuzzy observations (fuzzy data) for $i = 1, \dots, m$, where m - number of samples. In fact, fuzzy data are assumed to be fuzzy real numbers. Using these fuzzy data, it is sufficient to construct the $\widetilde{UCL}$ and $\widetilde{LCL}$ of fuzzy control charts by applying the comparing two fuzzy numbers to determine whether the fuzzy average p_i lies within the UCL and LCL. The procedure for constructing the UCL using fuzzy data is first described in this section.

Consider p a random variable with probability density function $N(\mu, \sigma^2)$, which is the normal probability density with unknown mean μ and unknown variance σ^2 . To estimate μ we obtain a random sample $p_1, \dots, p_n$ from $N(\mu, \sigma^2)$. Suppose the mean of this random sample turns out to be $\bar{p}$ and the sample variance is σ^2 . Then a $(1 - \beta)100\%$ confidence interval for μ is

$$[\theta_1(\beta), \theta_2(\beta)] = [\bar{p} - t_{\frac{\beta}{2}} \frac{\sigma}{\sqrt{m}}, \bar{p} + t_{\frac{\beta}{2}} \frac{\sigma}{\sqrt{m}}]$$

where $t_{\frac{\beta}{2}}$ comes from the t-distribution with $n - 1$ degrees of freedom, m - number of samples, so that the probability of exceeding this value is $\beta/2$. To obtain a graph of fuzzy μ . We are using β here since α , usually employed for confidence intervals, is reserved for α -cuts of fuzzy numbers. In this confidence interval one usually sets β equal to 0.10, 0.05 or 0.01 [11].

Now, for any given $\beta \in [0, 1]$, the corresponding real-valued data $k_{i\beta}$, $l_{i\beta}$ and $u_{i\beta}$ for $i = 1, \dots, m$ can be obtained by the following formula:

$$(l_{i\beta}, u_{i\beta}) = \left(k_{i\beta} - t_{\frac{\beta}{2}} \frac{\sigma}{\sqrt{m}}, k_{i\beta} + t_{\frac{\beta}{2}} \frac{\sigma}{\sqrt{m}} \right).$$

To determine if the plotted fuzzy mean c lies within $\widetilde{UCL}$ and $\widetilde{LCL}$, we propose a ranking method that is applicable to the set of all fuzzy numbers. First, we analyze the ranking method proposed by Chang [13] determining the possibility of comparing two fuzzy numbers.

$$V_i(\tilde{S}_i \geq \tilde{S}_j) = \sup_{y \geq x} [\min(\tilde{S}_j(x), \tilde{S}_i(y))].$$

In the last step, we will estimate the preferred vector $W = (W_i, W_j)$:

$$W_i = \frac{V_i(\tilde{S}_i \geq \tilde{S}_j)}{V_i(\tilde{S}_i \geq \tilde{S}_j) + V_j(\tilde{S}_j \geq \tilde{S}_i)}, \quad W_j = \frac{V_j(\tilde{S}_j \geq \tilde{S}_i)}{V_i(\tilde{S}_i \geq \tilde{S}_j) + V_j(\tilde{S}_j \geq \tilde{S}_i)}.$$

Vector $W = (W_i, W_j)$ is called a normalized weight vector characterizing the comparability of two fuzzy numbers $\tilde{S}_i \geq \tilde{S}_j$. Similarly, the vector $W' = (1 - W_i, 1 - W_j)$ is called the normalized weight vector characterizing the comparability of two fuzzy numbers $\tilde{S}_i \leq \tilde{S}_j$.

Let $W_{p_i}^1 = (a, 1 - a)$ and $W_{p_i}^2 = (b, 1 - b)$ be two normalized weight vectors, the characteristic of the ability to compare two fuzzy values $p_i \geq \widetilde{LCL}$ and $\tilde{p}_i \leq \widetilde{UCL}$. where: $0 \leq a = W_{p_i \geq \widetilde{LCL}} \leq 1$, $0 \leq b = W_{p_i \leq \widetilde{UCL}} \leq 1$.

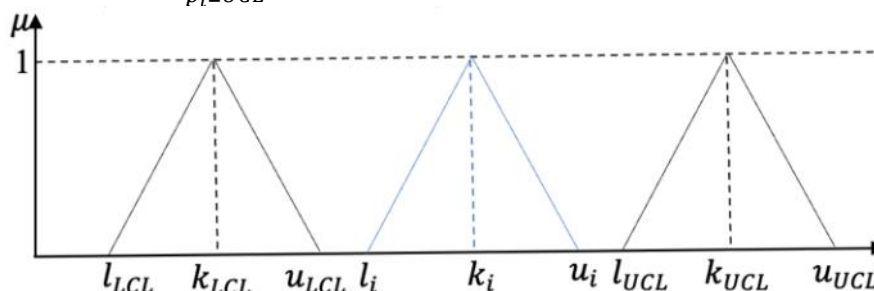


Figure: 2. Representation of fuzzy control limits

Let $P_{p_i} = \min(a, b)$ be the characteristic value for making control and monitoring decisions, P_{p_i} can be calculated using the following equation:

$$P_{pi} = \begin{cases} 1; & \text{if } (u_{LCL} < l_i) \wedge (u_i < l_{UCL}), \\ 0; & \text{if } (u_i < l_{LCL}) \vee (u_{UCL} < l_i), \\ a; & \text{if } (l_i < u_{LCL} \leq u_i) \vee (l_i < l_{LCL} < u_i), \\ b; & \text{if } (l_i \leq l_{UCL} < u_i) \vee (l_i < u_{UCL} < u_i), \\ \min(a, b); & \text{if } (l_i < u_{LCL}) \wedge (l_{UCL} \leq u_i). \end{cases}$$

From the above cases, a summary can be drawn for deciding whether the process is under control can be taken according to the percentage capability of the sample that has remained within the fuzzy control $\widetilde{LCL}$ and $\widetilde{UCL}$ defined as fuzzy sets. When fuzzy sampling is fully engaged within the fuzzy control, the process is called “controlled”. If fuzzy sampling is completely ruled out by fuzzy control limits, the process is called “out of control”. Otherwise, the sample partially falls within the limits of fuzzy control. In this case, if the percentage possibility (a, b), this is the characteristic of the possibility of comparing two fuzzy values $p_i \geq \widetilde{LCL}$ and $p_i \leq \widetilde{UCL}$, is equal to or greater than a predetermined allowable percentage (γ, γ') [14], then the process can be taken as “controlled” or “rather controlled”; otherwise, it can be said to be “rather uncontrolled” or “uncontrolled”.

Finally, a process control solution can be defined as follows:

$$\text{Process} = \begin{cases} \text{in control} & \text{if } P_{pi} \geq \gamma, \\ \text{rather in control.} & \text{if } 0,5 \leq P_{pi} < \gamma, \\ \text{rather out of control} & \text{if } \gamma' \leq P_{pi} < 0,5, \\ \text{out of control.} & \text{if } P_{pi} < \gamma'. \end{cases}$$

The intermediate levels of process control decisions are subjectively determined by the quality expert. In a binary classification (clear case), the quality expert can only know if the process is under control or out of control. These predefined levels can refer to true out of control. It can be used to track and provide valuable insight before the process gets out of hand. Despite the fact that intermediate levels are determined subjectively (determining the values of γ, γ'), they should refer to the depth of information required by the quality expert to take some preventive action.

3. CONCLUSION

In fact, the fuzzy rule method reports the level of control or out of control in four linguistic terms based on the percentage of samples that are within or out of control. When a process is “rather in control” or “rather out of control”, this should be considered a warning. In the event of any warning, depending on the severity, the process expert must take some action, such as monitoring device settings and warn operators to be more careful to correct problems.

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Section 3
INFORMATION TECHNOLOGIES IN SOCIAL-ECONOMIC SPHERE

INFORMATION TECHNOLOGIES IN POPULATION FORECASTING

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Abstract— The article examines linear and nonlinear models for forecasting the population of the Russian Federation in the period from 1946 to 2020. Comparison of the effectiveness of mathematical models for predicting the population size using information technologies is carried out. Computational experiments have shown high statistical characteristics of the studied models.

Keywords: regression analysis; prediction, information technology, population, time series.

INTRODUCTION

Population forecast for a region or a country as a whole is important for managing the socio-economic process of labor supply and employment. Based on the dynamics of demographic characteristics, educational level of the population, the development of socio-economic conditions of life, long-term trends in the quantitative and qualitative indicators of the population and labor resources are determined.

To conduct an effective socio-economic policy of the country, it is necessary to have data on the population size. This helps to look into the demographic future and predict possible demographic shifts.

In the modern world, for the effective implementation of the socio-economic concept of the country's development, it is necessary to have information on the population size. The state shows concern in solving problems related to demography, which is reflected in the Decree of the President of the Russian Federation on the approval of the Concept of the demographic policy of the Russian Federation for the period until 2025 No. 1351 dated 09.10.2007 [1].

The article examines the effectiveness of the developed mathematical models for the implementation of a retrospective forecast of the population for the period 1946 - 2020. Currently, statistical prediction models are widely used in forecasting population dynamics, among which modeling using regression and the method of moving ages stand out, which have a high area of use and an effective degree of reliability of forecasting. In the practice of forecasting the dynamics of population size (PN), nonlinear models are most often encountered [2-4].

PROBLEM STATEMENT

In work [4], a nonlinear exponential model was investigated for predicting the population of the Russian Federation for the period from 2001 to 2017. The article concludes that the model has a good predictive ability. Having carried out the appropriate calculations, we found that the coefficient of determination in this model is very small and equal to 0.016. Fisher's criterion was found to be 0.248.

When comparing the Fisher criterion with the tabular one, the above model turned out to be insignificant, which makes it impossible to use it in practice. The obtained statistical characteristics of the model are explained by the small sample size.

It is required to develop better mathematical models for predicting population size with good statistical and predictive properties, as well as to apply modern information technologies to calculate the proposed models.

SOLUTION OF THE PROBLEM

The article investigated the effectiveness of linear and nonlinear regression models for predicting the population of the Russian Federation based on experimental data from work [6], which are shown in Table I

TABLE I. POPULATION OF THE RUSSIAN FEDERATION BY YEARS

Year	PN, mln	Year	PN, mln	Year	PN, mln
1946	97,548	1971	130,252	1996	148,291638
1947	98,028	1972	130,934	1997	148,028613
1948	98,834	1973	131,687	1998	147,802133
1949	99,706	1974	132,434	1999	147,539426
1950	101,16	1975	133,217	2000	146,890128
1951	102,833	1976	134,092	2001	146,303611
1952	104,439	1977	135,026	2002	145,649334
1953	106,164	1978	135,979	2003	144,96365
1954	107,828	1979	136,922	2004	144,333586
1955	109,643	1980	137,758	2005	143,801046
1956	111,572	1981	138,483	2006	143,236582
1957	113,327	1982	139,221	2007	142,862692
1958	115,035	1983	140,067	2008	142,747535
1959	116,749	1984	141,056	2009	142,737196
1960	118,307	1985	142,061	2010	142,833502
1961	119,906	1986	143,033	2011	142,865433
1962	121,586	1987	144,156	2012	143,056383
1963	123,128	1988	145,386	2013	143,347059
1964	124,514	1989	146,505	2014	143,666931
1965	125,744	1990	147,665081	2015	146,267288
1966	126,749	1991	148,273746	2016	146,54471
1967	127,608	1992	148,514692	2017	146,804372

1968	128,361	1993	148,561694	2018	146,880432
1969	129,037	1994	148,355867	2019	146,78072
1970	129,66	1995	148,459937	2020	146,74859

A nonlinear model of the form $Y = e^{a+bt}$ was investigated. With the help of tools [5 - 6], developed on the basis of modern information technologies, the statistical characteristics of the model were calculated. The coefficients of the model are equal: $a = 4,694$; $b = 0,005$. The coefficient of determination was equal to 0.774, the Fisher criterion was equal to 249.443.

The model turned out to be significant. Indicator $MAE = 7$, indicator $MAPE = 5,348$. The forecast accuracy calculated by the formula $T = 100 - MAPE$, turned out to be 94.65%.

A linear model of the form $Y = a + bt$ was investigated. With the help of tools [5 - 6], developed on the basis of modern information technologies, the statistical characteristics of the model were calculated. The coefficients of the model are equal: $a = 109,166$; $b = 0,635$. The coefficient of determination was equal to 0,795, the Fisher criterion was equal to 283,222.

The model turned out to be significant. Indicator $MAE = 6,315$, indicator $MAPE = 4,865$. The forecast accuracy calculated by the formula $T = 100 - MAPE$, turned out to be 95,14%.

A nonlinear model of the form $Y = a + b \ln t$ was investigated. With the help of tools [5 - 6], developed on the basis of modern information technologies, the statistical characteristics of the model were calculated. The coefficients of the model are equal: $a = 78,69$; $b = 16,256$. The coefficient of determination was equal to 0,916, the Fisher criterion was equal to 799,163.

The model turned out to be significant. Indicator $MAE = 3,506$, indicator $MAPE = 2,766$. The forecast accuracy calculated by the formula $T = 100 - MAPE$, turned out to be 97.234%.

A nonlinear model of the form $Y = at^b$ was investigated. With the help of tools [5 - 6], developed on the basis of modern information technologies, the statistical characteristics of the model were calculated. The coefficients of the model are equal: $a = 85,005$; $b = 0,1317$. The coefficient of determination was equal to 0,9297, the Fisher criterion was equal to 965,407.

The model turned out to be significant. Indicator $MAE = 3,298$, indicator $MAPE = 2,533$. The forecast accuracy calculated by the formula $T = 100 - MAPE$, turned out to be 97.467%.

A nonlinear model of the form $Y = a + bt + ct^2$ was investigated. With the help of tools [5 - 6], developed on the basis of modern information technologies, the statistical characteristics of the model were calculated. The coefficients of the model are equal: $a = 93,605$; $b = 1,8473$, $c = -0,016$. The coefficient of determination was equal to 0,9833, the Fisher criterion was equal to 4298,257.

The model turned out to be significant. Indicator $MAE = 1,643$, indicator $MAPE = 1,201$. The forecast accuracy calculated by the formula $T = 100 - MAPE$, turned out to be 98.799%.

An additional set of statistical characteristics of the models is presented in Table II.

TABLE II. STATISTICAL CHARACTERISTICS OF REGRESSION MODELS

Model	MSE	$RMSE$	R^2	F	n
$Y = e^{4,694+0,005t}$	59,169	7,692	0,774	249,443	75
$Y = 109,166 + 0,635t$	48,675	6,977	0,795	283,222	75

$Y = 78,69 + 16,256 \ln t$	19,879	4,459	0,916	799,163	75
$Y = 85,005 t^{0,1317}$	16,512	4,063	0,9297	965,407	75
$Y = 93,605 + 1,8473 t - 0,016 t^2$	3,987	1,997	0,9833	4298,257	75

Of the models shown in Table II, the polynomial model has the best statistical and predictive properties.

CONCLUSION

Linear and nonlinear regression-type models showing high predictive ability are proposed and investigated. The effectiveness of the developed statistical techniques based on linear and nonlinear models is checked. Information technology-based software tools have been developed for predicting the population of the Russian Federation using the developed models. Of the models presented in the article, the polynomial model has the best statistical and predictive properties.

The relevance of the article is beyond doubt, since the developed linear and nonlinear models and methods of effective decision-making on them make it possible to conduct economic research more quickly, reliably and at lower costs when predicting the population of the Russian Federation. The paper presents mathematical linear and nonlinear models for predicting population size and tools for their implementation.

The developed linear and nonlinear regression models have demonstrated high efficiency, which allows them to be used for practical application. Population forecasting will make it possible to more effectively pursue the social and economic policy of the state.

The research results are recommended to be used in the process of studying demographic processes, which helps to look into the demographic future and predict possible demographic shifts. The conducted research does not exhaust the entire completeness of the problem under consideration, but suggests one of the ways to solve it. In our opinion, the questions of building confidence intervals for the obtained linear and nonlinear regression equations for constructing demographic forecasts and assessing their accuracy.

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STUDYING THE ISSUE OF COMBATING THE DECLINE IN COGNITIVE FUNCTIONS BY CONTROLLING THE PARAMETERS OF THE MICROCLIMATE

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Abstract - The article examines the influence of microclimate parameters on human cognitive functionality. Methods of control and regulation of such parameters as temperature, humidity, air velocity, carbon dioxide concentration are analyzed. The article analyzes the modern Russian and foreign regulatory framework related to the standardization of these parameters. Methods for improving air quality inside educational and public premises are presented.

Keywords: microclimate, cognitive functions, temperature, humidity, carbon dioxide, ventilation.

INTRODUCTION

Microclimate is a complex combination of physical parameters of the internal environment of rooms, which in one way or another affects the heat exchange of the body and human well-being. According to SanPiN 2.2.4.1294-03 [1], the following microclimate components affect the heat exchange between the human body and the environment: temperature, speed and relative humidity. These indicators must be within the optimal values at all workplaces, the permissible indicators are set separately for permanent and temporary working zones in accordance with GOST 12.1.005-88 [2].

The optimal temperature regime for working activities is considered to be the range of 18-25 °C, depending on the severity of the work. Optimal relative humidity and air velocity are in the range of 40-60% and 0.1-0.3 m / s, respectively. Control of the normalized components of the microclimate should be carried out at the beginning, middle and end of the cold and warm period of the year at least 3 times per work shift (at the beginning, middle and end). With dynamic changes in microclimate parameters, which are caused by technological and any other factors, measurements should also be carried out at the highest and lowest temperatures in the working area that occur during the entire work shift. As you can see, the procedure for monitoring the microclimate indicators specified in GOST [2] is strictly regulated.

Much less attention in the space of the working environment is paid to the control of the concentration of carbon dioxide, since it is not considered a toxic or harmful substance: according to GOST 12.1.007-76 [3], this is a relatively harmless gas that belongs to the 4th hazard class. At the same time, it should be clarified that in accordance with GOST 8050-85 [4]: "At concentrations of more than 5%, carbon dioxide has an extremely harmful effect on human health ... At the same time, the volume fraction of oxygen in the ambient air decreases, which can provoke the phenomenon of a lack of oxygen and suffocation."

But with all of the above documents in Russia there are no strict norms that would regulate the content of carbon dioxide in work and classrooms (for work premises, its permissible concentration fluctuates within extremely wide limits according to GOST [3], for ventilated non-residential buildings, the standard [5] assesses not the concentration of gas in its pure form, but its excess over the level of content in the external supply air, for residential and public premises there are simply no standards of this type), although in Europe and the USA they are actively involved in the problem of exceeding its permissible concentrations: carbon dioxide is subject to mandatory control exactly as well as other pollutants (nitrogen oxides, carbon monoxide, volatile organic compounds) [6].

There have been at least 11 independent studies by scientists from different countries [7] on the effect of carbon dioxide concentration on the physiological state of people (Figure 1). In total, more than 200 people participated in these studies.

Based on the results of these studies, it was concluded that when the concentration of carbon dioxide is above 600 ppm in the classroom, the respondents were more likely to have problems with the respiratory system, as well as weakness, headache, drowsiness, runny nose and difficulty distributing attention. As a result, people have a decrease in overall working capacity and, in particular, cognitive functions. With a longer stay in a room with an increased concentration of carbon dioxide, a certain number of subjects experienced degenerative changes in the circulatory (change in acid-base balance, hypertension, vasospasm), central nervous (impaired perception, coordination, working memory), respiratory (exacerbation of respiratory diseases, bronchospasm, asthma attacks) systems.

	CO ₂ levels (ppm)	Exposure duration (min)	Participant mean age (years)	Number participants (Paid/No)[M:F]	Participant background	Study location
Kajtar et al., 2006	600, 1500, 2500, 5000	140	22.5	10 (?) [5:5]	Students	Hungary
	600, 1500, 3000, 4000	140 @1500, 4000; 210 @600, 3000	21.3	10 (?) [4:6]		
Satish et al., 2012	600, 1000, 2500	150	25.5	22 (?) [10:12]	Students	California
Allen et al., 2016	550, 945, 1400	480 (lunch break ~45)	41	24 (Paid) [10:14]	Office workers	New York
Zhang et al., 2016	500, 5000	150	25	10 (Paid) [5:5]	Students	Denmark
Zhang et al., 2017	435, 1080, 3000	255	23	25 (Paid) [10:15]	Students	Denmark
Liu et al., 2017	380, 3000 (@ 35 °C)	180	24.8	12 (Paid)[6:6]	Students	Denmark
Rodeheffer et al., 2018	600, 2500, 15000	150	30	36*(No)[36:0]	Submariners	Connecticut
Allen et al., 2018	700, 1500, 2500	180	45	30 (No)[30:0]	Commercial airline pilots	Florida
Snow et al., 2019	830, 2700	~48	22.5	31 (Paid) [?]	Students, university employees	England
Scully et al., 2019	600,1200, 2500,5000	180	38.8	22 (No)[14:8]	Astronaut trainees	Texas
Chikamoto and Mimura, 2019	600, 1500, 3500, 5000 (with mask)	105	(?)	5(?) [5:0]	University students	Japan

Fig.1 Research information

PROBLEM STATEMENT

Microclimate parameters, namely: temperature, humidity, air velocity and carbon dioxide concentration, require constant and strict control in rooms with people staying. It is worth approaching this issue as responsibly as possible when controlling parameters within educational institutions and other public buildings. Appropriate instrumentation and technical methods are required to ensure this control and combat the overshoot of these parameters.

SOLUTION OF THE PROBLEM

If we consider the problem of controlling such parameters of the microclimate as temperature, humidity and air flow rate, then we may face the fact that the solution to this problem is quite trivial in modern realities. Warming up of cold air is carried out in the winter period of the year by special equipment - heaters, which are heated with hot water or steam. Hot water heating systems have also gained wide popularity, as they are efficient and relatively convenient. In these systems, finned and smooth pipes, as well as radiators, are used as heat transfer elements. Air cooling is carried out by passing it through a special irrigation chamber (irrigation is carried out with cold water), where, in addition, it is humidified.

Air conditioning is also actively used. It is customary to refer to air conditioning as the automatic maintenance of important suitable characteristics of the local climate in the premises, independently of the configuration of external criteria and modes from inside the building. With the provided method of maintaining the characteristics of the internal atmosphere of the building, it is possible to independently control the rate of air supply to the building, as well as its temperature and relative humidity. There are both local air conditioners - for servicing individual rooms and rooms, and central ones - for servicing whole groups of rooms, workshops and industries as a whole. A simple case is considered to be home air conditioners, which can be seen integrated into the windows and fixed from outside the walls of the premises.

For optimal operation of any air conditioning system, an objective solution is continuous monitoring of all microclimate parameters, for which there are various devices for measuring them. Of course, standard equipment can be used as such devices, which includes liquid and mechanical instruments (for example, a thermometer, a psychrometric hygrometer). But this method presupposes constant visual control over the state of the measuring instruments and manual modification of the conditioning program. In modern realities, the most optimal solution would be to use temperature and humidity sensors based on changes in the electrical properties of materials from fluctuations in the corresponding quantities. Such sensors are relatively inexpensive, and most importantly, they eliminate the need for their constant maintenance and visual control, since such sensors are easily integrated into automatic microclimate control systems. The most widespread are resistive, capacitive and semiconductor sensors due to their satisfactory accuracy of operation, excellent reliability and uncompromising ease of production on an industrial scale.

If we consider ensuring the quality of the microclimate from the side of controlling the concentration of carbon dioxide, then the task is no longer so trivial. In most non-production premises, natural air ventilation is still used, which is far from always capable of ensuring the permissible level of CO₂ content. The main advantage of this type of ventilation is the lack of energy consumption for air movement. However, the effectiveness of natural ventilation significantly depends on the seasonality and temperature of the outside air, for example, at the same temperatures outside and indoors, there will be no air draft. As you can see from Figure 2, natural ventilation does not allow you to maintain an optimal level of carbon dioxide in the room [8].

That is why, in the overwhelming number of construction projects, the design of ventilation is a reasonable decision. In this case, it is worth considering the number of people who will carry out activities in this room, as well as other possible sources of carbon dioxide. Based on this, it is necessary to select the type of ventilation (displacement, direct-flow, dilution), the type of air diffusers (wall or ceiling) and their number. Also, when designing ventilation, it is necessary to calculate the required volume of ventilated air flow in order to lay the appropriate technological niches for ventilation pipes. At the same time, the engineer should not be guided by the Russian air exchange rate, which is at least 30 m³ / h [8]. To substantiate this statement, it is necessary to make an appropriate calculation.



Fig.2 Ventilation Study Information. 1- room with 30 employees, 2- room with 20 employees, 3- critical CO2 concentration

The required volume of ventilated air flow is easy to find out based on the permissible concentration of carbon dioxide:

$$V_B = V_d / (k_{max} - k_B) \quad (1)$$

- V_B - "ventilation speed", the volume of air supplied to the room (and removed from it) per unit of time, m^3 / h ;
- V_d - "respiration rate", the volume of oxygen replaced by carbon dioxide per unit of time. Respiration rate (unequal volume of consumed oxygen and exhaled carbon dioxide) is not taken into account, m^3 / h ;
- k – concentration, ppm;
- $k(t)$ - CO2 concentration versus time, ppm;
- k_B - concentration of CO2 in the supplied air, ppm;
- k_{max} - maximum allowable concentration of CO2 in the room, ppm;

For one person with $V_d = 20 l / h (= 0.02 m^3 / h)$, $k_{max} = 1000 ppm (= 0.001)$ and clean air outside the window with $V_B = 400 ppm (= 0.0004)$ we get:

$$V_B = 0,02 / (0,001 - 0,0004) = 33 m^3 / h$$

This is the minimum amount of ventilation per person. It does not depend on the area and volume of the room, only on the "breathing rate" and on the concentration of carbon dioxide inside and outside the room. In reality, the concentration in the outside air can be even higher, and inside the building there can be other sources of CO2 emission. From this calculation, it can be concluded that air exchange of $30 m^3 / h$, which is normalized by Russian standards, does not ensure the maintenance of carbon dioxide concentration at a level that does not affect human well-being. The standard of $72 m^3 / h$, which is provided by European documents, allows you to feel comfortable in the room. From this it can be concluded that the approach to the regulation of the concentration of carbon dioxide in the air should be revised and the actual state of ventilation should be assessed to ensure the required air quality for each individual building.

In some cases, a complete reconstruction of the ventilation system of a building in order to improve its efficiency is impractical or even impossible, but at the same time it is necessary to qualitatively improve the existing solution with the use of minimal equipment costs. As one of

the ways of such improvement, you can use the dynamic change of ventilation operating modes, which is described in the American standard ANSI / ASHRAE Standard 62.1-2004 [9]. The volume of supplied air is regulated by means of DCV (Demand-Controlled Ventilation, DCV) by determining the actual situation, which is determined by the number of people currently in the room. Accordingly, in order to assess the atmosphere inside the premises and the subsequent reaction of the ventilation system, it is necessary to continuously monitor the state of not only the concentration of carbon dioxide, but also the other parameters of the microclimate, which were described in the introduction to this article. At the moment, there is a significant reduction in the cost of inverter fan speed control systems through the use of an increasingly available electronic component base. This may be an objective prerequisite for the use of this technology in domestic practice. DCV technology is discussed in the article [10].

In order to continuously monitor the concentration of carbon dioxide in a room (for example, to implement DCV technology), there are specialized electronic sensors based on the chemical or physical properties of the measured gas. The most interesting and promising are metal oxide, electrochemical and optical carbon dioxide sensors [11].

Metal oxide sensors are built on the property of certain semiconductor metal oxides to change their electrical characteristics in the presence of certain gases. When polycrystalline films made of such materials are exposed to gaseous impurities, their potential decreases and, accordingly, conductivity increases. When they are heated (a special inert resistive layer is used as a heating element, which is heated to a temperature of about 320 ° C), the tin dioxide layer is cleaned of gases adsorbed at low temperatures. As a rule, the graph of the voltage drop across the sensor depending on the gas concentration in logarithmic coordinates has the form of a straight line for the working range of impurity concentrations (from a few ppm to several thousand ppm). Such sensors do not have exceptional selectivity, as they react to a wide range of gases, which is why they are not suitable for industrial applications. The only way to determine the concentration of a specific substance is to compare the reference values of the rate of change in the conductivity of the sensor with the measured ones, since this rate will be different for different gases. Typically, metal oxide sensors are made on the basis of tin dioxide (SnO_2), the technology for their production is well developed, as a result of which they are quite simple and reliable devices that can be easily matched with electronic devices.

Electrochemical sensors are based on an electrochemical method for determining the concentration of pollutants. Such sensors can be built on the basis of two principles: voltage measurement (potentiometric) and conductance or resistance measurement (conductometric). The design of any of the electrochemical sensors contains at least two special electrodes, between which there is an electrolyte. The analyzed gas through a dust filter enters into a chemical reaction with the electrolyte in the area of the working electrode, which is made of any noble metal and provides a catalytic effect. As a result, charged particles appear in the solution and enter the measuring circuit. The concentration of the test gas, in this case, will be directly proportional to the voltage drop across the resistor connected in series to the measuring circuit. The main advantages of such sensors are versatility, high reliability, low power consumption and small weight and size parameters. But it should be borne in mind that the sensor resource is consumed regardless of whether it is used or not, therefore, their storage / use period rarely exceeds 36 months.

Optical sensors are based on the physical property of electromagnetic waves to change some of their parameters, such as polarization, intensity, etc. in the test gas environment. Such a sensor usually consists of three parts: a radiation source, a waveguide, and a photodetector that converts a light signal into an electrical one. Optical detectors have a fast response, ease of operation and a minimum number of false alarms, but due to their rather complex design, the price for them is several times higher than for other sensors. Compared to electrochemical

sensors, the lifespan of an optical sensor is much longer. This is mainly due to the fact that such sensors do not burn out or wear out when exposed to gases.

But what can be done in cases where, for some reason, it is not possible to ensure adequate air quality using ventilation systems? P. Ole Fanger wrote about such methods for reducing the content of harmful gases in indoor air in his work [12]. He noted that various methods of air purification are being actively developed, which make it possible to improve air quality (the purification efficiency can be up to 80%) and, as a consequence, partial replacement of ventilation. In his work, the author separately identified two methods of air purification: photocatalytic oxidation and adsorption.

Photocatalytic oxidation has now proved to be excellent as a means of air purification from volatile organic compounds, but specifically for reducing the content of carbon dioxide, it is useless, since this type of filtration requires the release of water in the form of steam and carbon dioxide. Adsorption, on the other hand, allows you to achieve high results when solving the problem of air filtration from carbon dioxide. Adsorption filters are traditionally produced on the basis of activated carbon, but sometimes more modern materials are used. Due to their simple design and internal content, such filters are absolutely safe, easy to maintain, cheap and provide a high degree of purification of the supply air. The only drawback of such filters is their short service life, since one conventional unit of mass of the filtering composition can absorb a limited amount of carbon dioxide. However, such filters can successfully remove excess carbon dioxide when ventilation is not possible.

CONCLUSION

Currently, there is a sufficient number of proven technical means and methods that solve the problem of monitoring environmental parameters. The most affordable and effective method is the forced ventilation system, which, with proper determination of the required air exchange and air distribution parameters, can provide optimal microclimate parameters for comfortable human work. It should be noted that in the calculations of such systems, one should not rely on the minimum values that are specified in Russian standards, since they do not allow achieving the required indoor air quality. In other words, the regulatory framework for the design of ventilated systems needs to be adjusted. Also, if there is no possibility to build a ventilation system, it is possible to reduce the concentration of carbon dioxide by using adsorption filters.

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COGNITIVE MODEL FOR FORECASTING UNIVERSITY POSITIONS IN INTERNATIONAL RATINGS

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Abstract — The relevance of the problem being solved is due to the need to develop scientifically grounded proposals to achieve the required values of the basic indicators of the university's activity in accordance with the international institutional rating QS to the required values necessary for the university to enter the TOP-500 universities by 2025. To solve this problem, an approach is proposed to the study of weakly structured systems, the class of which includes universities and their activities, based on scenario forecasting methods by building a fuzzy cognitive model to determine the necessary increments of target values. The proposed approach allows, under the given constraints, to find the most acceptable scenario for planning the increment of baseline indicators to target values.

Keywords: cognitive model; scenario forecasting; basic indicators; institutional rating.

INTRODUCTION

The purpose of developing a cognitive model of scenario forecasting is to substantiate the list of necessary measures to ensure the increments of the values of the target indicators of the university's activity in accordance with the international institutional rating QS up to the required values necessary for the university to enter the TOP-500 universities by 2025. To achieve the stated goal of the study, the application of methods for solving poorly structured tasks was substantiated based on the development of a scenario forecasting (planning) model using fuzzy cognitive maps, which made it possible to determine the probable trends in the development of events by alternative options and the possible consequences of decisions made to choose the most preferred alternative. The proposed approach allows, under the given constraints, to find the most acceptable scenario for planning the increment of the values of basic indicators and functional (university rating) to target values due to impulse influences on latent factors that ensure guaranteed achievement of the goal. The analysis of the sources [1-7] showed the expediency of using the class of fuzzy cognitive models.

METHODOLOGY FOR SOLVING THE PROBLEM

The method of scenario forecasting based on cognitive maps makes it possible to determine the probable trends in the development of events by alternative options and the possible consequences of decisions made to choose the most preferable alternative [3]. As you know, a scenario is a certain relative, conditional assessment of the possible development of the

object or situation under study, since it is always built within the framework of assumptions about future development conditions, which are often fundamentally unpredictable. A feature of scenario forecasting is that it allows you to simultaneously consider several options for the development of a situation, analyze opportunities and risks. To solve this problem, an approach to scenario forecasting based on a fuzzy cognitive map is proposed, which includes the following stages [3]: - scenario generation and risk assessment, - scenario adjustment at discrete time intervals (in our case, annually), considering the achieved values of the place in the QS rating of the functional and indicators. At the end of the next time interval, a new scenario is built to achieve the next set goal (adjusted considering current calculations). At the first stage of the study, the identification and interpretation of the latent factors affecting the baseline indicators was carried out, and their significance was assessed using the methods of factor analysis, which is a class of multivariate statistical analysis procedures aimed at identifying the latent variables (factors) responsible for the presence of linear statistical relationships. (correlations) between the observed variables [8-12]. At the second stage of the study, to identify the factors affecting the basic performance indicators of the university, to identify the most significant factors for the subsequent implementation of an approach to solving the problem based on cognitive modeling methods, their SWOT analysis was carried out [13-14].

The result of the SWOT analysis was the identification and grouping of a set of factors that affect the performance of the university. Since the number of factors influencing the activities of the university is a significant value, it became necessary to highlight the most significant factors, considering the correlation relationships, including the factors of the second level that affect the factors of the first level. At the third stage of the study, to identify the most significant factors, one of the most common methods of factor analysis was used - the principal component method, which allows one to reduce (reduce) many related correlated variables, since a large number of variables significantly complicates the analysis and interpretation of information [12]. Calculations based on the method of principal components were carried out in the environment of the analytical platform Deductor 5.3 using the "Factor analysis" module. The use of the apparatus of factor analysis made it possible to solve two main problems: reducing the dimension of the number of used variables due to their explanation by a smaller number of factors and grouping, as well as structuring the data obtained. The novelty of the proposed approach is determined by: - solving the problem of structuring knowledge using the object-structural approach when constructing the problem field of the situation, which provides a more effective grouping of latent factors and building an adequate architecture of the cognitive map; - identifying the most significant latent factors affecting the baseline indicators, as well as assessing the degree of this influence based on the methods of factor analysis; - the implementation of a cognitive model based on a fuzzy cognitive map, which provides adaptation to the uncertainty of the initial data and the conditions of the problem being solved, which, in turn, made it possible to form an adequate cognitive model and increase the reliability and accuracy of modeling results.

SCENARIO PREDICTIONS OF UNIVERSITY PERFORMANCE INDICATORS BASED ON A COGNITIVE MODEL

In contrast to classical cognitive maps, fuzzy cognitive maps (FCM) are represented as a fuzzy directed graph with feedback, the nodes of which are fuzzy sets. NCC combines the properties of fuzzy systems and neural networks [16-19]. As a result of the selection of the most significant factors affecting the baseline indicators, a cognitive map was built that reflects their relationships, as well as the weight of these relationships. The weights of the relationships are determined based on the use of correlation analysis and expert methods. The directed graph (digraph) of the NCC is specified using a set of sets [14]

$$HKK = \langle C, F, W \rangle, \dots \dots \dots (1)$$

where $C = \{C_i\}$ - the set of graph vertices, called concepts, which are the factors that are most significant from the point of view of studying the system under consideration;

$F = \{F_k\}$ - set of directed graph arcs - connections between concepts;

$W = \{W_{ij}\}$ - set of weights of arcs (links). The connections between concepts can be positive, “enhancing” the influence of the C_i concept on the C_j concept ($W_{ij} > 0$), or negative, “weakening” the influence of the C_i concept on the C_j concept ($W_{ij} < 0$).

Each concept is characterized by a term-set of a linguistic variable

$$T_i = \{T_1^i, T_2^i, \dots, T_{mj}^i\} \dots\dots\dots (2)$$

where m_j is the number of typical states of the i -th concept. To describe each term T_k^i , a term is constructed - a set with a membership function $\mu_{T_i}(x)$. Connections between typical states of each pair of concepts are specified by fuzzy variables described by the corresponding fuzzy sets. The values of the weights (bond strengths) W_{ij} are set using a fuzzy linguistic scale, which is an ordered set of linguistic values (terms) of bond strength estimates, for example, of the form: LINK_POWER = {Does not affect; Weak; Average; Strong; Very strong}. Each of these values is associated with a certain numerical range belonging to the segment $[0, 1]$ for positive links (Table 1), or the segment $[-1, 0]$ for negative links.

The strength of the connection between the concept C_i and the concept C_j is chosen by the expert by one of the linguistic values presented in the table, as well as by some "point" estimate of the strength of the connection - a number within this range (if there are several experts, then the weight W_{ij} is averaged). In the general case, a weighted digraph with arbitrary values of the weights $W_{ij} \in [-1, 1]$ is described by the dynamics of its state change in time. The state of the digraph (NCC) is determined by the set of states of its concepts C_i , ($i = 1, 2, \dots, n$), each of which is described by the state variable $X_i(t)$, taking values in the interval $[0, 1]$. Based on setting the values of the initial data using formula (3), setting the weights of the mutual influences of factors using expert estimates and the results of correlation-regression analysis, describing the behavior of the digraph using equations of state (4), (5) and indicating the values of the initial increments of factors, analysis of the dynamics of changes in factors and their influence on the development of the system of indicators. Considering the preliminary results of the computational experiment, during the scenario modeling, the required intensity of influence on the control factors in percentage terms was calculated for a given increment of the target factor. The problem was solved under the conditions of the given restrictions on the resources allocated to ensure the increment of latent factors.

INTERPRETATION OF THE NUMERICAL EXPERIMENT RESULTS

Considering the achievable values of latent factors in the interval 2020-2021, the scenario of their increment is selected, shown in Fig. 1. The greatest intensity of impact will be required for latent factors: Number of publications in the Scopus database, WoS, Joint research projects, Demand for areas of training, stimulating factors, the least for latent factors: Changes in the structure of teaching staff employment, Areas for educational activities, the share of teaching staff planning to build an international scientific career.

The results of calculating the predicted values of growth indicators of basic indicators and functional in 2020, considering the chosen scenario, are presented in Fig. 2. The obtained results of scenario forecasting show that the largest increase should be obtained by the PP indicator (reputation with the employer) - 54%, and the smallest - by RS/T (the ratio of the number of students to the number of teachers) - 16%. An increase in the values of basic indicators should lead to an increase in the value of the functional by 23%, that is, to achieve its planned value. Thus, the goal of the study has been achieved.

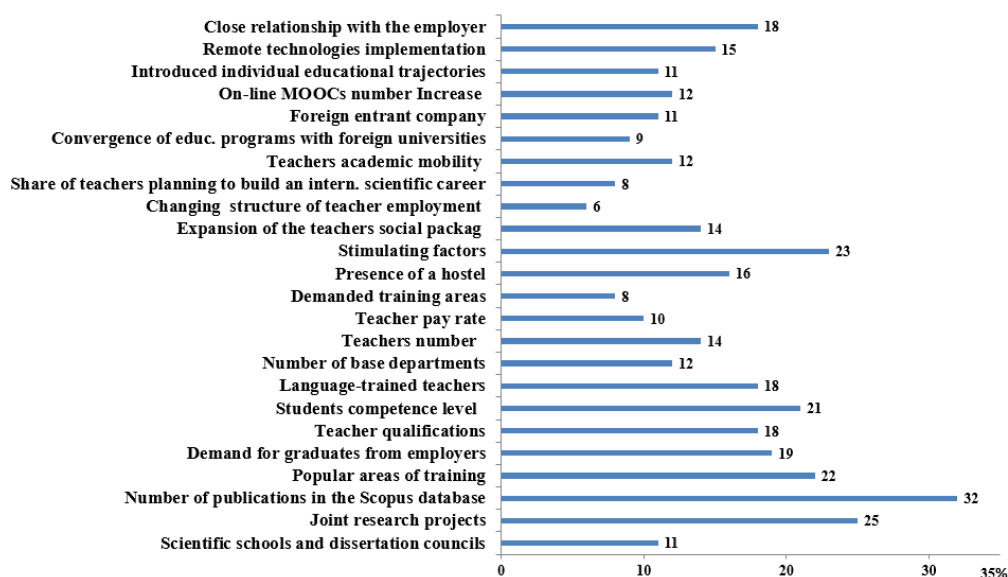


Fig. 1 Calculated values of the intensities of control actions on latent factors in the form of increments in%, necessary to achieve the target increase basic indicators and functionality in 2021

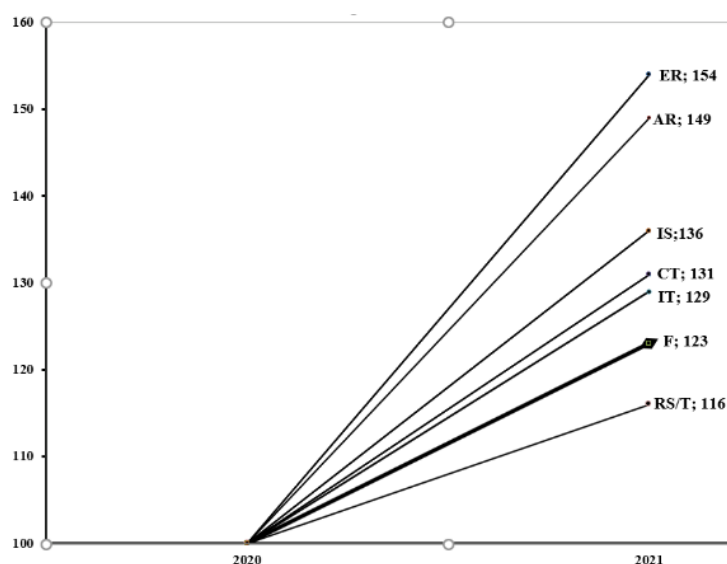


Fig. 2 Predicted values of growth indicators of basic indicators and functional in 2021 compared to 2020 (2020 -100%)

Scenario analysis of the development of the situation made it possible to choose the most preferable scenario, which, under the conditions of the given restrictions, ensures the achievement of the required planned value of the target indicator with minimal resource consumption for the increment of latent factors.

The required intensity of influence on the control factors as a percentage for a given increment of the target factor were calculated during scenario modeling.

The calculations made the following conclusions: To guarantee the achievement of the value of the functional $F = 26.89$ by 2025, corresponding to the 435 (451) place in the QS rating, it is necessary to stepwise increase the values of indicators, taking into account the factors influencing them, identified on the basis of factor analysis methods, in the interval 2020 -2025.

CONCLUSION

During the research, an iterative learning cognitive model of scenario forecasting of activities to achieve the required values of the target performance indicators of the university in the QS international institutional ranking was developed. Based on the developed model, the calculation of the most preferable from the point of view of cost minimization of the scenario variant of the set of required intensities of influence on the control variables (latent factors) for a given planned increment of the value of the target factor was carried out. The novelty of the proposed approach is determined using factor analysis methods to determine the relationships between latent factors that ensure the identification of the most significant latent factors, as well as the implementation of a cognitive model based on a fuzzy cognitive map that provides adaptation to the uncertainty of the initial data and the conditions of the problem being solved. The proposed approach allows training the developed model by adjusting the structure of the cognitive map and its parameters based on the results of updating the initial data for its construction. As a direction for further research, it is advisable to solve the problem of identifying latent factors of the third level, which will increase the reliability and accuracy of the cognitive model.

ACKNOWLEDGMENTS

This work was supported by RFBR (grants No. 19-07-01137, 20-07-00926).

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RETAIL SEGMENT OF THE RUSSIAN PHARMACEUTICAL MARKET DEVELOPMENT TRENDS

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Abstract — The article considered the main patterns of development of the retail sales segment of the pharmaceutical market in Russia, which have developed in the last decade and which are characterized by changes in the population's demand for medical products in the context of a decrease in its income, an increase in the concentration of pharmacy chains, ambiguous results of its activities associated with a growth in the value of product sales and the overall business unprofitableness according to the reported indicators. It is noted that an improvement in the supply of the Russian population in such conditions can be achieved through the implementation of reasonable measures of state regulation of the activities of the main participants in the country's pharmaceutical market.

Keywords — pharmaceutical market, demand, supply, concentration, revenue, profit, morbidity, population income.

INTRODUCTION

At present, taking into account the current epidemiological situation, the general state and development trends of the pharmaceutical industry could be characterized as positive, on a par with online retail. However, in this sector for several years experts have noted a number of deep fundamental contradictions, which, despite the revival of the market in the short term caused by the COVID-19 pandemic, can lead to serious crisis consequences.

The pharmaceutical market is traditionally divided into 2 main segments: commercial (retail) and public (hospital). Currently, both of these components of the market are experiencing the impact of external and internal effects from the changing demand and supply of pharmaceutical products, which can seriously change its entire conjuncture.

Predicting these changes based on identifying patterns in the formation and development of various elements of the Russian pharmaceutical market is a necessary stage in the development of a general policy to improve medical care for the country's population. This article presents the

results of the development patterns analysis of one of the significant elements of the Russian Federation's pharmaceutical market – pharmacy retail chains, the state of which directly affects the quality of drug supply to the population.

PROBLEM STATEMENT

The main factors influencing the development trends of the Russian pharmaceutical market and its particular elements, in our opinion, include the state of the economy, the standard of living of the population and changes in the structure of consumer demand.

The official Rosstat data on the annual levels of Russia's GDP in \$US for 2009-2019, adjusted for purchasing power parity and inflation, indicate that after significant growth, since 2013 in the country there was a significant decrease in this indicator from 2626.43 billion \$US in 2013 to billion \$US 1,874.55 in 2016. Then, by 2018, this indicator rose to the level of billion \$US 2092.95, and in 2019 again declined to the level of billion \$US 2059.09 (see Fig. 1) [1, 2].

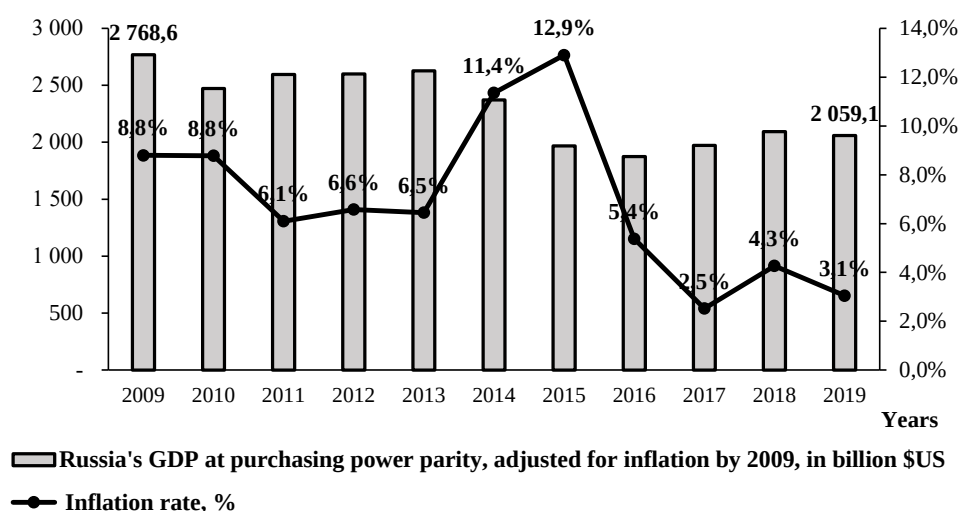


Fig. 1 – Dynamics of the inflation rate (%) and GDP of Russia adjusted to 2009 for purchasing power parity and inflation, in billion \$US

At the same time, it is expected that in 2020 the value of this indicator in Russia will continue to decline, which will inevitably lead to a decrease in demand and purchasing power, the dynamics of which in the reviewing period generally corresponded to the regularity of the country's GDP development [3].

According to Rosstat data, in the Russian Federation real disposable income per capita also declined in the period from 2014 to 2017. The most significant decrease was noted in 2016 – by 4.5% compared to 2015. Then in 2018-2019 it increased slightly, but in 2020 decreased again. In particular, according to the data for the 3rd quarter of 2020, the decrease in the level of per capita income of the population in Russia was 5.3% compared to 2019 [4].

These changes in the value of monetary income were accompanied by rather significant changes in the structure of consumer demand, associated with an increase in the share of costs for food and medicine. In particular, the population expenses on the medical category of goods from all consumer spending in 2013-2019 did not change significantly. Wherein, since 2016 they have been at a constant level of 2.2%. However, in the 2nd quarter of 2020 compared to the same period in 2019, these expenses increased to 2.9% (fig. 2).

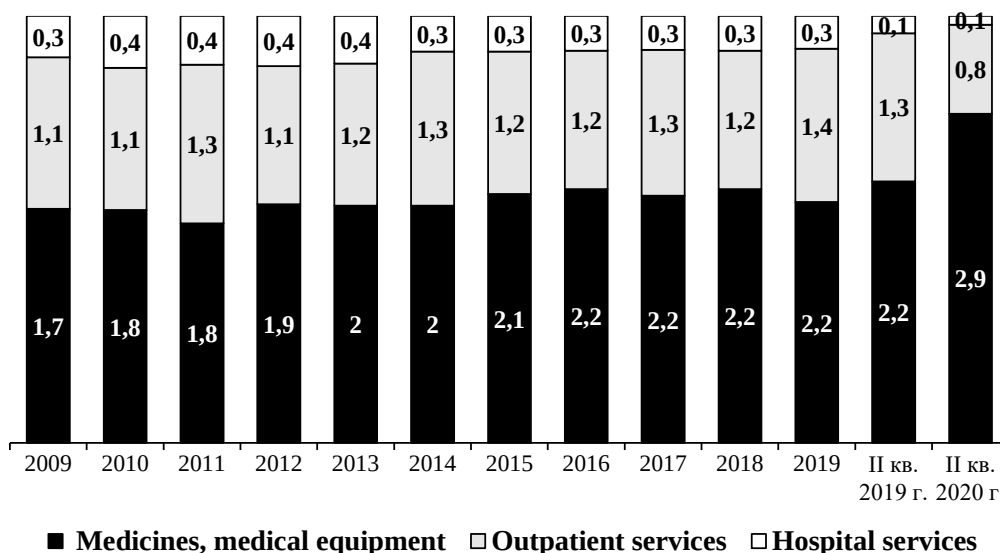


Fig. 2 – The structure of expenditures of the population of the Russian Federation on the consumption of goods / services in the healthcare sector for the period 2009-2019 and for the 2nd quarter of 2020 in the general structure of consumer spending

The noted change in the structure of drug consumption is especially significant, considering the general downward trend in the incidence rate of the population of the Russian Federation for the period 2009-2019, which in 2019 amounted to 780.2 cases against 797.50 cases per 1000 population in 2009. [5].

In general, the increase in the share of medical goods in the structure of consumer spending of the population indicates people's more attentive attitude (not only in Russia, but throughout the world) to their health, the result of which, according to experts, was the spontaneously changed nature of consumer behavior, which is most likely will remain in the short and medium term and will also have an impact on the pharmaceutical market over a longer time horizon. This fact in Russia can also be explained by the increase in prices for medicines due to the devaluation of the ruble (the Russian pharmaceutical market is significantly dependent on the supply of foreign finished medical products and pharmaceutical substances, i.e. the market is highly import-oriented), owing to which cheap medicines are gradually withdrawing from the product matrix of pharmacies, and then of the manufacturers, since it becomes economically unreasonable for manufacturers to produce drugs in a cheap price category due to the state regulation of prices for them. In particular, "vital and essential drugs" (VED), which occupy about 50% of the Russian market for medicines, are under strict price control by the state. Among the drugs in this group, there are quite a few cheap medical products in the price range of up to 500 rubles per package.

By the beginning of 2020, more than 64 thousand pharmacy outlets were represented on the retail pharmaceutical market in Russia, but the market itself is quite concentrated, since the country's TOP 20 chains captures 45.3% of the market (according to the analytical agency AlphaRM) [6], among which the most significant chain brands are Rigla, Implozia, Erkafarm Group, Group 36.6, Planeta Zdoroviya (Planet of Health), NEO-PHARM, VITA, Aprel' (April), Farmland and others. It is important to note that the share of TOP 20 players in this market has grown significantly in recent years: in 2016 it was 34.96%, in 2017 – 38.2%, in 2018 – 43%.

As of the end of 2019, the market leader was the Rigla pharmacy chain, with a 5.8% share. The second place was taken by the Implozia pharmacy chain – 4.7%, the third by Erkafarm Group – 4.3%, etc. Gubernskie apteki and Rodnik & LekOptTorg round out the list of TOP 20 pharmacy chains with market shares of 0.7% and 0.6%, respectively. There is a very significant

difference between the 1st and the 2nd places in terms of their market share – 1.1%, the rest of the participants not so significantly differ in their figures.

At the same time, we can say that in Russia there is a fairly high density of pharmacies per capita: with the population as of January 1, 2020, 146 748 590 people (according to Rosstat), it is about 4.4 pharmacy outlets per 10 000 population. This indicator is one of the highest in the world community. In support of this statement, we present below similar data for the United States, China and Germany.

- USA – about 88 thousand pharmacies [7], as of January 1, 2020 the population was about 329 064 917 people [8]. Thereby the density of pharmacies is approximately 2.67 pharmacies per 10 000 population.

- China – about 388 thousand pharmacies [9] with a population of 1 439 323 726 people at the beginning of 2020 [10]. Thus, there are 2.7 pharmacies per 10 000 population in China.

- Germany – about 20 thousand pharmacy sales points [11], the population at the beginning of 2020 [12] was 83 517 045 people. The density of pharmacy outlets formed at the level of 2.4 pharmacies per 10,000 population.

In general, despite the noted oversaturation of the Russian pharmaceutical market, a decrease in real disposable income and a relatively stable share of spending on drug consumption by the population, the turnover of pharmacy chains continues to grow. The sales volumes of the TOP 20 pharmacy chains in the Russian Federation for at least 5 years have been fixed at a level higher than the same indicator for the pharmaceutical market (commercial segment) as a whole, even taking into account the inflation rate, although the growth rate of this indicator is decreasing in the markets under consideration (fig. 3). The market capacity data, on the basis of which the dynamics indicators were calculated, were taken from the reports for 2016-2019 of the DSM analytical agency [13].

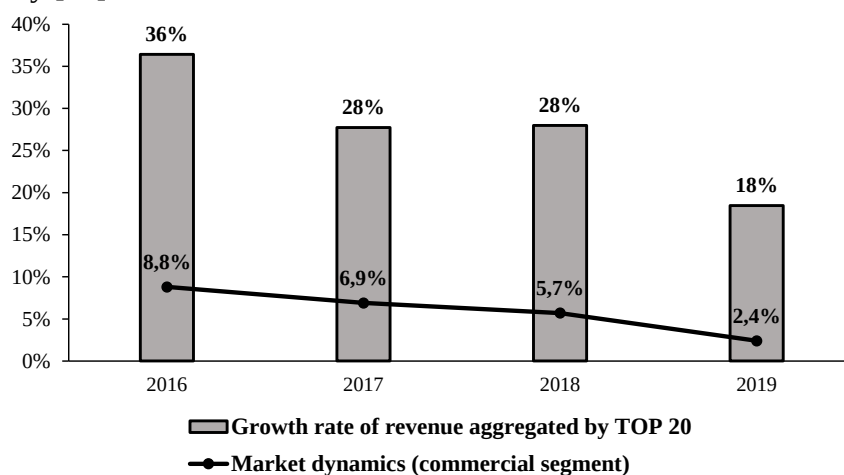


Fig. 3 – Revenue growth rates of TOP 20 chains in comparison with the pharmaceutical commercial market growth rate for the period 2016-2019

At first glance, this situation may indicate an incomplete saturation of the pharmaceutical market, the gap in which is gradually being filled by its participants. However, given the density of the number of pharmacies per capita and the downward trend in its income, the reasons for this development of the pharmaceutical market are presumably different. These reasons include the fact that large pharmacy chains are growing through mergers and acquisitions (M&A) processes, by capturing the market and reducing the share of small players and single pharmacies.

In support of this, it is mentioned the data on the annual revenue growth rates of the Erkafarm pharmacy chain, which on average for the period 2015-2019 amounted to 111%. However, in 2017 this indicator increased by 268% compared to 2016 due to the joining of Raduga pharmacies to this chain.

At the same time, it is important to mention that with a steady increasing trend in the revenue of pharmacy leaders, their profitability since 2016 is in the negative zone or at an extremely low level (see Table 1).

Since 2016, the current leaders of the sector have shown an increase in their unprofitability, which, however, in 2019 has significantly decreased (in more than 6 times in comparison to the previous year). To a certain extent, this happened due to the implementation of an improved marketing system of contractual relations, which is based on sales incentive bonuses paid by manufacturers to their customers (distributors or pharmacy chains) for the sale of certain volumes of medicines of a certain brand or manufacturer. This indirectly led to the emergence at the industry-wide level of a phenomenon that market participants called “spillover” [14], implying the artificial fulfillment of plans by pharmacy chains selling a number of drugs in order to receive a bonus. In part, it was the reason for the decrease in their unprofitability.

TABLE 1. – Dynamics of aggregated indicators of revenue and net profit for TOP 20 pharmacy chains in Russia (as of the end of 2019) in million rubles.

Year	Indicator value	
	Revenue	Net result
2015	195757,33	1201,58
2016	267037,39	-6120,19
2017	341062,04	-9694,44
2018	436453,16	-18749,93
2019	517057,20	-2932,97
Total	1757367,12	-36295,95

This new mechanism for operating in the market entailed a number of regulatory changes and initiatives, which in an already “unhealthy” market could have a key negative impact on the business of market participants and lead to massive crisis phenomena in the sector. These legislative projects include the labeling of drugs, one of the goals of which is to try to track the product being put on the market in order to reach the end consumer instead of re-launching the products into turnover by selling them on the secondary market. It can also be assumed that the abolition of the simplified tax system, which for many chains can lead to a deterioration of their economic condition and a decrease in competitiveness, can lead to a reduction in pharmacy chains and to an increase in monopolization of the pharmaceutical market in general.

CONCLUSION

All in all, based on the results of the research of the patterns of the pharmaceutical market retail segment development in the Russian Federation, the following conclusions can be drawn.

The trends in the development of the commercial segment of the pharmaceuticals market in Russia in the last decade are characterized by certain contradictions. On the one hand, this market has seen, albeit insignificant, an increase in the cost of products sold, even in the context of declining incomes of the population. Due to the COVID-19 pandemic, a slight rise in the growth rate of this indicator can be expected over several years, which, however, may be associated with an increase in the prices of medicines (including products of the foreign manufacturers due to the devaluation of the ruble), and with the inexpediency of producing cheap drugs in the country which are subject to price regulation by the state.

On the other hand, with the growth of sales volumes, pharmacy chains incur certain losses, with the observed increase in the concentration of these sales organizations. Suffice it to note that the share of the TOP 20 leading pharmacy chains in 2020 approached 50% in the pharmaceutical market and is expected to rise due to the increase in the number of mergers and acquisitions, the collapse of small chain companies and individual pharmacies.

In such a situation, certain possibilities for improving the supply of medicines to the population of Russia may be related to an increase in the effectiveness of measures of state regulation of the main players activities. Nevertheless, the observed consequences of the introduction of some of these regulatory measures on the Russian pharmaceutical market, and, in particular, those related to the modernization of the contractual relations system and the labeling of drugs, did not bring the expected results. In this regard, the development of effective measures of state regulation of the pharmaceutical market in Russia should be based on a more detailed analysis of the patterns of its development, taking into account both – the trends in the formation of demand and supply for drugs, and the consequences of the influence of the proposed measures on the performance of the main participants in this market.

ACKNOWLEDGMEN

This work was supported by RFBR (grant №20-010-00307)

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Materials of
the International Scientific - Practical Conference
INFORMATION INNOVATIVE TECHNOLOGIES

Edited by S.U. Uvaysov;
Executive editor I.A. Ivanov

Printed in author's redaction

Signed to print 14.05.2021
Format 60x84/8. Paper «Pioneer»
Conventional quires 32,99 Print run 500 copies Order № 43

Prepared for publication
Association of graduates and employees of AFEA named after prof. Zhukovsky,
Moscow, the 4th st. March 8, 6A.
Nasledie-vvia.ru

Printed in the printing house of HSE
Moscow, Kochnovsky fare, 3
hse.ru