



Critical Infrastructures in the Digital World

**IWCI 2023 PROCEEDINGS & PROGRAMME OF
THE INTERNATIONAL WORKSHOP**

**March 16 – 21, 2023
Bolshoe Goloustnoe**

**CRITICAL INFRASTRUCTURES
IN DIGITAL WORLD - 2023
WORKSHOP
PROGRAMME**

March 16, 10:00

Thursday

**Departure from Irkutsk at 10:00
Arrival in the Bolshoe Goloustnoe**

March 16, 14:00

Thursday

Baikal Greeting

March 16, 20:00

OPENING CEREMONY

Welcome Party

March 21, 10:00

Tuesday

Departure of the participants to Irkutsk

SESSION 1

1. The main directions of scientific activity of the Institute of Computational Mathematics and Mathematical Geophysics of the SB RAS / **Marchenko Mikhail** (*ICMMG SB RAS, Novosibirsk*)
2. The main directions and results of digitalization of the Irkutsk National Research University / **Kopaygorodsky Aleksei** (*Irkutsk National Research Technical University, Irkutsk*)
Ontologies application for semantic search and classification of texts / **Kopaygorodsky Aleksei** (*Melentiev Energy Systems Institute SB RAS, Irkutsk National Research Technical University, Irkutsk*)
3. The main directions of scientific activity of the Melentiev Energy Systems Institute of SB RAS / **Massel Liudmila** (*Melentiev Energy System Institute SB RAS, Irkutsk*)
The purpose and IT-infrastructure architecture for building prototypes of intelligent control systems for the development and operation energy systems / **Massel Liudmila** (*Melentiev Energy System Institute SB RAS, Irkutsk*)
4. Cognitive and linear optimization models to study energy security threats / **Pyatkova Natalia, Massel Alexey** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
5. Semantic analysis of interrelationships within a system of models for evaluating the price elasticity of demand for electricity / **Vorozhtsova Tatiana, Galperova Elena** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
6. Development of information and computing system ICS WICS for assessing environmental pollution by energy facilities / **Kuzmin Vladimir** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
7. Reengineering the software complex "Analysis of the seismic process" / **Malinovtsev Ivan**¹, Massel Aleksei² (on-line)
¹*Irkutsk National Research Technical University, Irkutsk*
²*Melentiev Energy Systems Institute SB RAS, Irkutsk*

1. The terminology structure of the information system of state budget management / **Erzhenin Roman** (*LLC KRISTA-IRKUTSK, Irkutsk*)
2. The multidimensional time concept and areas of its application for the integration of critical systems / **Zinder Evgeny** (*National Association of Enterprise Architects, Russian Municipal Academy, Moscow*) (on-line)

March 18, 10:00

Saturday

SESSION 2

1. Experience in predicting occupational morbidity at the objects of critical infrastructure of the Irkutsk region / **Dyakovich Marina** (*Angarsk State Technical University, Angarsk, Russia*)
2. The technologies applied when developing the software "Forecasting of professional disease with the method of normalized intensive indicators (NII)" / **Manuylov Sergei** (*East-Siberian Institute of Medical and Ecological Research, Angarsk*)
3. The system of information support for plant production management processes / **Baimakov Aleksander, Zamaraev Aleksei, Ivanyo Yaroslav** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)
4. About three variants of linear programming problems applied to agricultural production / **Kovadlo Iliia, Ivanyo Yaroslav, Fedurina Nina** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)
5. Modeling of climatic and biological risks in agricultural production / **Kolokoltseva Irina, Ivanyo Yaroslav, Petrova Sofia** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)
6. Multi-stage models of mathematical programming and their applications in agriculture / **Sinitsyn Maksim, Ivanyo Yaroslav, Polkovskaya Marina** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)
7. Modeling of time series of characteristics associated with food production / **Tsyrenzhapova Valentina, Ivanyo Yaroslav, Barsukova Margarita** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)
8. "Smart lecture room": design, realization, use / **Asalkhanov Peter, Petrova Sofia, Ivanyo Yaroslav** (*Irkutsk State Agrarian University named after A.A. Ezhevsky*)

SESSION 3

1. The leading role of the Ygra Research Institute of Information Technologies in the digitalization of the Khanty-Mansiysk Region / **Melnikov Andrey** (*Yugorsky Research Institute of Information Technologies, Khanty-Mansiysk*)
2. Evaluation of the effectiveness of measures to create a comfortable urban environment based on neural network models / **Galagan Konstantin** (*Yugra State University, Khanty-Mansiysk*) (on-line)
3. Model of segmentation of forest logging in satellite images / **Abbazov Valeryan¹, Baluyev Vladimir¹, Melnikov Andrey^{1,2}, Rusanov Mikhail^{1,2}**
¹*Yugra Research Institute of Information Technologies, Khanty-Mansiysk*
²*Yugra State University, Khanty-Mansiysk* (on-line)
4. On the construction of the model of train movement along a railway section based on the queuing theory / Zharkov Maxim, **Lempert Anna** (*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*) (on-line)
5. On the application of multiphase queuing systems for solving engineering problems / Zharkov Maxim¹, **Vu Hoang²**
¹*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*
²*Irkutsk National Research Technical University, Irkutsk*
6. Routing problems for the area having dynamically changing properties / Lempert Anna¹, **Tran Viet²**
¹*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*
²*Irkutsk National Research Technical University, Irkutsk*
7. On the problem of covering three-dimensional bodies by spherical segments / Kazakov Alexander¹, **Nguyen Minh²**
¹*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*
²*Irkutsk National Research Technical University, Irkutsk*

SESSION 4

1. Integrating the research into resilience of energy and socio-ecological systems using artificial intelligence methods / Massel Liudmila, **Pesterev Dmitrii** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
2. Application of software “INTEC-A” for resilience assessment of energy systems / Massel Lyudmila, Massel Aleksei, **Mamedov Timur**, Gaskova Daria (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
3. Specification of concepts and relationships for the integration of the software INTEC-A and cognitive modeling / **Gaskova Daria**, Mamedov Timur, Massel Aleksei (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
4. Exploratory data analysis and machine learning methods for researching time series / **Tsybikov Aleksey**, Massel Aleksei (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
5. Development of a wind farm digital twin using the UNITY environment / Massel Aleksei, **Shchukin Nikita** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
6. Digital twin as a means of increasing cyber-physical resilience of smart energy system facilities / **Demidov Ivan**, Kolosok Irina, Korkina Elena (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
7. The accuracy estimation of forest fire risk prediction based on CBR (Case-Based Reasoning) approach / **Pestova Yulia** (*Matrosov Institute for System Dynamics and Control Theory RAS, Irkutsk*)
8. Development of practical approaches to the determination of reference intervals by indirect methods / **Kuz'menko Vladimir**¹, **Gornov Alexander**²
¹*ISMAPgE – Branch Campus of the FSBEI FPE RMACPE MOH Russia, Irkutsk*
²*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*

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1. Methodological approaches to assessing the level of digital transformation of the electric power industry in Belarus / **Zorina Tatiana** (*Energy Institute of the National Academy of Sciences of Belarus, Minsk, Belarus*) (on-line)
 2. Application of virtualization in construction of digital twins / **Massel Aleksei** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)

March 20, 10:00

Monday

SESSION 5

1. Risk assessment of the demand-response aggregator / Kolosok Irina, **Korkina Elena** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*) (on-line)
2. System for processing and visualizing the results of the data of solar panel stand monitoring / Ivanov Roman, **Maxakov Nikita** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
3. Computational technologies of optimization and applications / **Gornov Aleksander**, Anikin Anton, Zarodnyuk Tatiana, Sorokovikov Pavel, Tyatyushkin Aleksander (*Matrosov Institute for System Dynamics and Control Theory SB RAS, Irkutsk*)
4. Development of information and search system for the preparing the issues and working with the archive of the reviewed scientific journal / **Popova Maria** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*)
5. On training the of IT specialists at the Institute of Information Technologies and Data Analysis of IRNITU / **Bakhvalov Sergey, Bakhvalova Zinaida** (*Irkutsk National Research Technical University, Irkutsk*)
6. On the transformation of Ufa State Aviation Technical University into the Ufa University of Science and Technologies / **Tuktarova Polina** (*Ufa State Aviation Technical University*)

March 20, 12:30

Round Table

Monday

Categorical structures of system metaobjects / **Scripkin Sergey** (*Melentiev Energy Systems Institute SB RAS, Irkutsk*) (on-line)

March 20, 14:00

Monday

HOVERCRAFT (KHIVUS) TOUR TO PESCHANAYA BAY

March 20, 20:00

Monday

**FINAL DISCUSSION
CLOSING CEREMONY**

ONTOLOGIES APPLICATION IN SEMANTIC SEARCH AND CLASSIFICATION OF TEXTS

Kopaygorodsky Alex

Melentiev Energy Systems Institute SB RAS, Irkutsk

Introduction. The active development of information and telecommunication technologies has significantly affected the reduction in the time of the exit of new innovative developments to global market. First, we can observe such an effect because of accelerating the transfer of scientific knowledge and developing new production technologies based on them with the subsequent production of products. Scientific and technological forecasting and the organization of monitoring of innovative technological solutions in the energy requires the development of methods of semantic analysis of Big Data to develop assessments and leading recommendations, as well as the creation of new tools to support this activity. The National Technological Initiative (NTI) of Russia emphasizes the need to develop Big Data analysis and processing methods using intellectual information systems, and their use in the energy is correlated with the market of EnergyNet. In addition, recent years developed methods for determining new technological solutions based on intelligent semantic search technologies and Big Data [1, 2]. Tech Mining technique is used as a form of statistical contextual analysis of text documents based on scientific and technical resources to identify breakthrough technologies and developments, assess their innovative potential [3]. The author applies to the analysis and classification of text information NLP approach [4].

Semantics and conceptual basis. The semantic integration of data and knowledge is based on the use of the general conceptual basis and binding (comparison) of data based on it. To set this conceptual basis, the author offers to use the ontological space including a set of ontologies. The developed ontologies system contains the ontologies of the energy economy, energy sectors and individual energy technologies, and energy research. Statistical and linguistic analysis methods are used for implementation of semantic analysis. Statistical methods include an analysis of the frequency of words using (calculating a word count in text fragments, distribution of words frequency in sets of documents, etc.). Linguistic methods perform the identification of individual words, the analysis of their morphological characteristics, the release of the base (stemming), syntactic and semantic analysis of the text fragments. The task of classifying documents and calculating metrics is solved on the basis of the analysis of word-complexes. At the same time, formally different word-complexes (including different languages) can be described in virtually the same concepts. To solve this problem, the author proposed the use of linguistic ontology, including terms and definitions (abstract and basic concepts), as well as supporting synonymy (full or partial semantic proximity) in one or more different languages. The basic concepts in ontology can be identified by word-complexes, which in turn can be represented by stable phrases in Russian or English. Several basic concepts (for example, “petrol”, “gas”, “diesel fuel”) can be combined into one abstract concept (“fuel”). Figure 1 shows a fragment of linguistic ontology that defines the concept of “Wood Fuel”, “Coal”, “Biofuel” and “Fuel”. If necessary, we can introduce keywords and expressions in other languages, for this it is necessary to introduce additional nodes, the content of the word-complex, associated them with the basic concepts. This process can be automated through compilation of comparison with subsequent loading containing word-complexes in a new language and corresponding word-complexes in the already known, or word-complexes of the new

language and corresponding basic concepts. To simplify the process of including a new language and the translation of the corresponding concepts from the existing completed ontology, we can download a filtered subset according to the “English-language term” word-complexes and basic concepts.

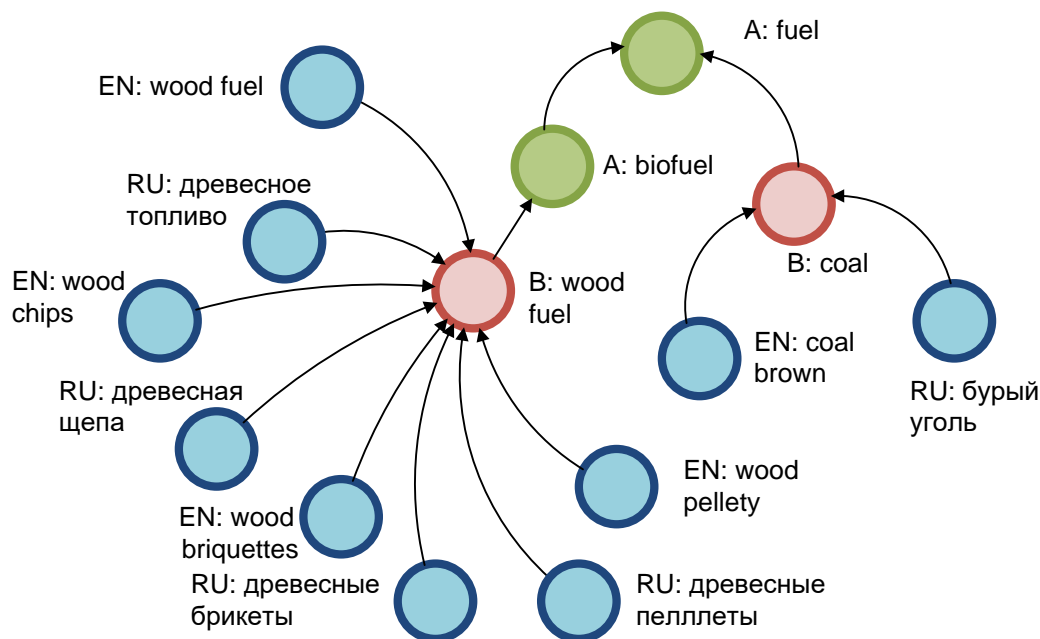


Fig. 1. A fragment of linguistic ontology that defines abstract concepts (A), basic concepts (B) and synonyms in several languages (EN, RU)

The technology of building linguistic ontology includes five main stages, the first two of which are mandatory:

1. Building the source list of terms and keywords of the subject area.
2. Binding of sets of word-complexes with the concepts of ontology.
3. Formation of a list containing words complexes characterizing keywords compared with the basic concepts of ontology.
4. Translation of word-complexes characterizing keywords and basic concepts to a new language.
5. The enrichment of ontology with new concepts (word-complexes from the new language) and connections with basic concepts.

Classification of texts. We can calculate vector representations for the concepts of ontology after determining the basic concepts and constructing the terminological dictionary of the subject area and after constructing ontology based on it. When processing arrays of text data at the first stage, filtration and separation from the frequently used words and other similar language elements are made that do not reflect the specifics of the selected subject area. After that, we can classify and semantic comparison depending on the language with the corresponding elements of ontologies. The use of the TF-IDF indicator for each incoming document allows to us evaluate the importance of a word or concept in the context of the document. The word-complex is proportional to the frequency of its use in the document and inversely proportional to the frequency of its use in all documents of the language corpora. When comparing documents from specialized language corpora and general text documents, it is possible to use intellectual methods for detecting and identifying new, previously disproportionate, special terms.

An intelligent information system is used to support the activities of researchers in energy sector forecasting [5]. Developers apply a service-oriented approach in implementing an intelligent information system, which allows independent development of individual system components and provides overall flexibility.

Conclusion. The implementation of semantic ontologies for texts classification and intelligent information will effectively solve scientific and practical problems associated both with the support of expert decisions on the strategic innovative development of the energy sector and in the field of scientific substantiation of strategic decisions on the digital transformation of the energy sector.

Acknowledgements. The author is grateful to the Russian Foundation for Basic Research (RFBR) for financial support. The reported study was funded by RFBR, project number 20-07-00994.

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THE PURPOSE AND IT- INFRASTRUCTURE ARCHITECTURE FOR BUILDING PROTOTYPES OF INTELLIGENT CONTROL SYSTEMS FOR THE DEVELOPMENT AND OPERATION OF ENERGY SYSTEMS

Massel Liudmila

Melentiev Energy System Institute SB RAS, Irkutsk

The development of intelligent control systems for the development and functioning energy systems is an urgent problem, the importance of which increases as the concept of integrated intelligent energy systems spreads. It is obvious that the solution of this problem is impossible without the use of scientific potential, which, in particular, is concentrated in the results of system research of energy, carried out at the Melentiev Energy Systems Institute (MESI) SB RAS and presented in the form of mathematical models and software systems. To realize this potential in a team headed by the author, it is proposed to use the concept of digital twins, the core of which can be mathematical and semantic models developed at the MESI SB RAS.

For their development and integration, it is proposed to create an IT-infrastructure for system research in the energy sector, which will integrate both existing models and an intelligent IT-environment to support semantic modeling, an instrumental IT-environment of basic software components for building digital twins, as well as a Data and Knowledge Warehouse and Ontological knowledge portal in the field of energy.

The architecture of the IT infrastructure that integrates these components has been developed¹. The definitions of computer and digital models and digital twins are considered based on GOST R 57700.37-2021, as well as digital images and smart digital twins. A scheme is proposed for the relationship between digital twins of energy facilities and smart digital twins of energy systems and the fuel and energy complex as a whole [1].

The ontological approach developed by the team to the construction of a digital twin and the proposed typical architecture of the digital twin of an energy facility, including the integration of machine learning methods, are considered. A typical architecture has been concretized to build digital twins of solar and wind power plants.

Two stages are proposed for the development of digital twins, and, accordingly, for the construction of an IT infrastructure: 1) creation of scientific prototypes with emulation of the necessary data; 2) development of operating prototypes using information flows of data from real energy facilities.

It seems that the results of the first stage can already be used to develop prototypes of intelligent control systems for the development and functioning of energy systems.

Acknowledgements. The work was carried out within the framework of the project according to the state task of the MESI SB RAS FNEU -2021-0007 № AAAA-A21-121012090007-7

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¹ With the participation of Massel A.G., Gaskova D.A.

COGNITIVE AND LINEAR OPTIMIZATION MODELS TO STUDY ENERGY SECURITY THREATS

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The main content of the tasks for studying the problem of energy security is to predict the conditions for the functioning and development of energy systems and the fuel and energy complex as a whole, taking into account possible critical and emergency situations (CS and ES), to assess the state in these conditions and identify "bottlenecks" in the systems of fuel and energy supply to consumers, in the choice of possible alternatives and specific measures to prevent emergency situations and emergencies in these systems or reduce their negative impact [1].

In modern conditions, it became necessary to improve the existing and develop new methodological, model and software tools for conducting such studies, since studies related to the concept of the risk of critical and emergency situations and their consequences begin to occupy a special place. Of particular importance is the task of analyzing possible threats and the formation on this basis of disturbance scenarios (critical and emergency situations) and the related problems of their modeling.

This work is an integral part of the energy security research conducted at the Energy Security Department of the MESI SB RAS [1]. Similar studies, developments and models for such studies are mainly focused on solving the problems of long-term planning of the energy industry work under normal operating conditions with a horizon of up to 15-20 years. Similar works carried out in other teams are a local or regional nature with the study of the certain problem aspects [2-5]. Comprehensive studies that allow assessing the possibilities of all energy industries interconnected work and determining the consequences for consumers of energy resources in the event of emergency situations in the operation of one industry or several industries at the same time have not been carried out before.

To study the energy security problems, a two-level technology is proposed that integrates the stages of qualitative analysis (using semantic modeling tools) and quantitative analysis (using linear economic and mathematical models and traditional software systems) (Fig. 1).

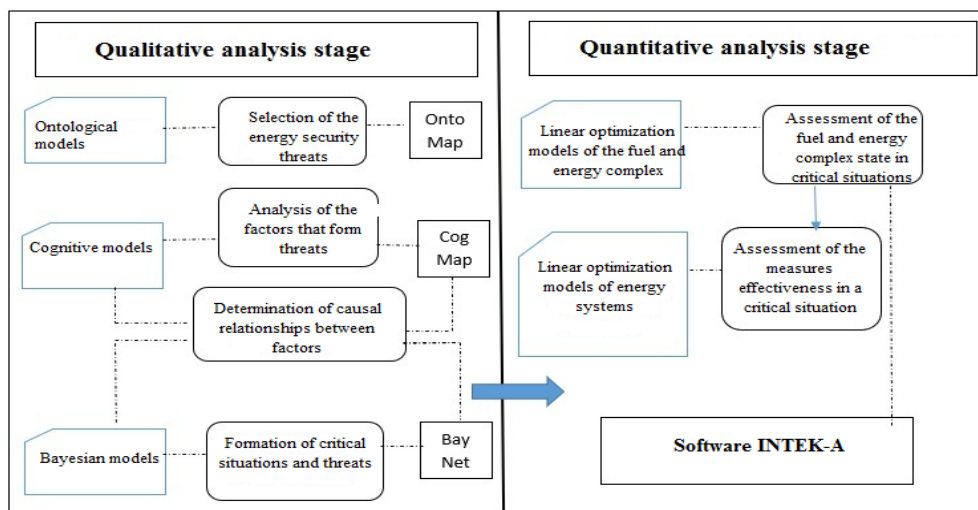


Fig 1. Tasks to be solved and modeling methods used in studies of assessing the impact of threats on the state of energy security

In modern conditions, the problem of studying threats to energy security and the factors that form these threats acquires the greatest importance. In this case, it is possible to justify the occurrence of certain critical or emergency situations.

Based on the analysis of the energy sector state and the conditions for its development, the main strategic threats to energy security were identified [1]:

- insufficient level of investment in the fuel and energy sector;
- insufficient growth of explored hydrocarbon reserves;
- reduced opportunities to increase gas production;
- high depreciation and low rates of equipment renewal in the fuel and energy sector.

The analysis of these threats and the formation of CS and ES on their basis takes place at the level of qualitative analysis. At this level, it is possible to use semantic modeling methods (Fig. 1), which can be considered as methods for analyzing and substantiating threats to energy security, the formation of CS and emergency situations, and as methods for situational analysis and management.

At the stage of qualitative analysis, using cognitive modeling methods, models of worsening/improving situations with investments and one of the important strategic threats "Reduced opportunities to increase gas production" were built (Fig. 2).

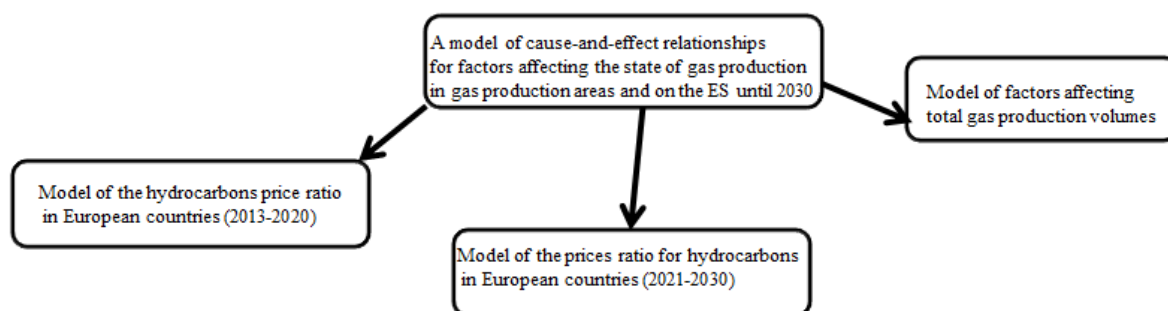


Fig. 2. The system of deterioration/improvement models for the strategic threat situation on the energy security "Reducing the opportunities to increase gas production"

Using the methods of semantic, namely cognitive, modeling for the analysis of energy security threats, it is possible to reasonably form various emergency situations and evaluate them at the stage of qualitative analysis.

At the stage of quantitative analysis, using a scenario approach, based on the knowledge of experts and of the studied threats cognitive models, critical situations are formed that arise among consumers of energy resources and in the energy industries.

Using linear optimization models of energy systems and fuel and energy complex [6], the tasks of the energy system state assessing in the conditions of threats realization to energy security in the form of critical situations are solved to determine:

- rational use of energy facilities production capacities;
- distribution of energy resources certain types by categories of consumers;
- rational use of interregional transport links capacity;
- the size of deficits in energy resources certain types for the considered categories of consumers across the country.

This paper proposes the use of mathematical and semantic modeling for conducting research on the analysis of threats to energy security. A two-stage scheme for conducting research and an

algorithm for experimental calculations are proposed. Examples of the cognitive threat models application with the construction of cause-and-effect relationships are given.

Acknowledgements. The work was carried out within the framework of the state assignment project FWEU-2021-0003, registration number: AAAA-A21-121012090014-5.

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SEMANTIC ANALYSIS OF INTERRELATIONSHIPS WITHIN A SYSTEM OF MODELS FOR EVALUATING THE PRICE ELASTICITY OF DEMAND FOR ELECTRICITY

Vorozhtsova Tatiana, Galperova Elena

Melentiev Energy System Institute SB RAS, Irkutsk

The relevance of the work is due to the importance of studying the mutual influence of price relationships and financial relationships of the economy and the energy sector [1]. One of the key items contained in the research agenda is to assess the impact of pricing policy in the energy sector on the demand for energy carriers and the feedback (re-adjustment) effect of changes in the demand for different types of fuel and energy resources on their cost and the future directions to be pursued by the energy sector.

Electricity is becoming the ultimate energy carrier, and available projections attest to a notable increase in its use in the years to come (Table 1). This fact contributes to the importance of research on the impact of the cost of electricity on its demand. As a rule, price elasticity of demand coefficients are used for this purpose, which indicate how demand for a particular energy carrier will change if its price changes by 1%.

Table 1. Dynamics of the share of electricity in the final consumption of energy resources in the world, according to the projections by the International Energy Agency (IEA) and the U.S. Energy Information Administration (EIA), %

Projection	2020	2030	2040	2050
IEA-2022	19,7	22,1	25,1	27,8
U.S. EIA-2019	18,0	20,0	21,6	22,7

Ref. [2] pointed out that there is no shortage of studies published abroad on how to assess the relationships between the demand for energy carriers and their prices, whereas the research on this topic in Russia is scarce.

The Laboratory of the Energy and Economy Interrelationships at the Melentiev ESI, SB RAS, has designed an array of models for a provisional assessment of the possible impact of the state pricing and tax policy on the development of the energy sector [1]. This is essentially a pool of individual models, each of which solves one or more specific problems. To address the issue of evaluating the price elasticity of demand for electricity, several models are chosen from the pool, with the solutions they generate complementing each other (Fig. 1). A successful study of this kind calls for a proper exchange of data between the models. As a rule, transferring data from one model to another requires their reconciliation and analysis by researchers who are experts in the field.

To visualize and analyze the inter-model information flows we proposed to use a semantic approach, including ontological modeling [3]. For this purpose, we designed ontologies describing the required inputs and outputs of each model used and the interrelationships between them, as based on their data exchange. The key basic concepts capturing such information interrelationships are represented by a meta-ontology in Figure 2.

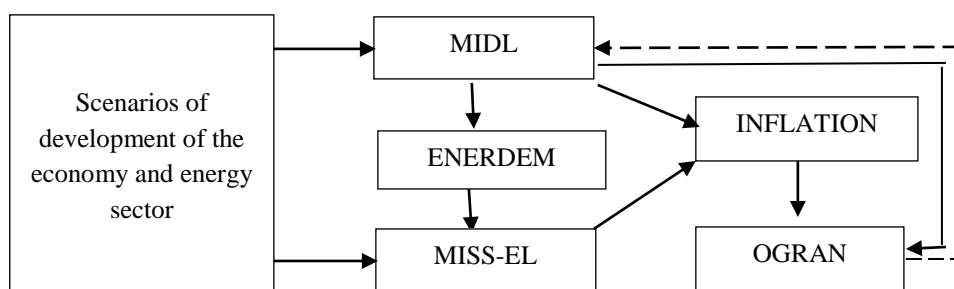


Fig.1. Composition of models and their interrelationships for evaluating the price elasticity of demand for electricity

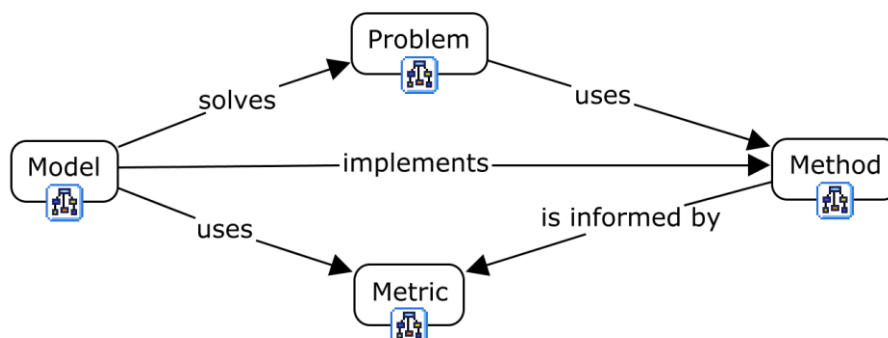


Fig. 2. Basic concepts of the meta-ontology

Due to the fact that this pool of models can be classed as legacy software systems yet remains relevant as a research tool, it may be necessary to re-engineer it in the future [4]. Ontological modeling of information exchange of data serves as one of the first steps in the analysis and taking inventory of the system in question in terms of its possible re-engineering.

Acknowledgements. The research is carried out as part of the State Assignment Project No. FWEU-2021-0007 (reg. No. AAAA-A21-121012090007-7) and the State Assignment Project No. FWEU-2021-0003 (reg. No. AAAA-A21-121012090014-5) of the Basic Research Program of the Russian Federation for 2021-2030.

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DEVELOPMENT OF INFORMATION AND COMPUTING SYSTEM ICS WICS FOR ASSESSING ENVIRONMENT POLLUTION BY ENERGY FACILITIES

Kuzmin Vladimir

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In the department of Artificial Intelligence in Energy Sector of ESI SB RAS the information and computing system (ICS) WICS is being developed. ICS WICS is designed to assess environmental pollution by energy facilities. It is based on author's methodic approach and technology for assessing environmental pollution by energy facilities and supporting decision-making to reduce their harmful effects [1].

In this report, development of ICS WICS will be discussed. An original algorithm for post-processing the results of calculating the dispersion of pollutants in the atmospheric air is considered. The necessity of development of such algorithm is explained by the lack of methods for calculating dispersion from objects that are at a considerable distance from each other in the existing normative methods. The IS EDC subsystem is presented, which is used for assessing the economic damage caused by emissions of energy facilities to the environment (the atmospheric air). The report also shows the results of the development of the visualization tools built into the ICS WICS:

- geovisualization of pollutant dispersion calculation results is improved;
- the ability to interpolate the results by the method of inverse weighted distances has been added to the subsystem for working with the results of the analysis of snow samples IS SMP.

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REENGINEERING THE SOFTWARE COMPLEX "ANALYSIS OF THE SEISMIC PROCESS"

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In the Institute of the Earth's Crust is working on a study of medium-term earthquake forecasting. To this end, the EQ software for computer analysis of the seismic process was developed in the 1990s. By now, this software implementation has moved into the category of outdated software.

The main tasks that this complex solves are based on providing analytical information about earthquakes, displaying geological information and comparing earthquake epicenters.

The report presents the results of the reengineering of this software. As part of the reengineering, a phased implementation of all functional requirements that were implemented in the previous version was proposed, as well as the possibility of expanding and adding new functions.

As part of the first stage, the C# language was defined for the implementation of the main code, a structure was developed and a database was implemented to store information about earthquake epicenters and existing geological faults. All information can be visualized on geographical maps. The function of selecting certain polygons for specifying the area of analysis is implemented.

THE TERMINOLOGY STRUCTURE OF THE INFORMATION SYSTEM OF STATE BUDGET MANAGEMENT

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Introduction. Financial management is a key activity that ensures the functioning of various public administration systems. Information about finances and financial activities is presented mainly in the form of laws, by-laws, regulations, instructions, regulations, procedures, i.e. in the form of a special normative language. A decisive role in an adequate understanding of such a description of the financial and budgetary institutional infrastructure belongs to various kinds of knowledge and experience gained in the subject area.

The use of information technology in public finance management has the longest history. It was in the calculation and calculation calculations for the first time in the field of public finance that computers began to be used and continue to be used everywhere.

In the context of the complication of both the information budgeting process itself and the program code associated with it, the scientific and practical task of developing a special design methodology capable of presenting a description of the subject area in the form of a language that would be simultaneously understandable to a person (specialist and non-specialist), and the car. The solution of this problem will allow at the same time to more effectively solve problems in the system of vocational education, as well as to create new information systems more efficiently and quickly and make the necessary changes.

As a basis for the development of this methodology, this publication proposes to use an ontological approach to system design, which makes it possible to single out a set of concepts and relationships between them at the conceptual level.

Complexity of the information system of state budget management. The large scale of the state budget management IS is determined by the number of management objects included in the budget system of the Russian Federation. As of January 1, 2022, the budget system of the Russian Federation included the federal budget, 85 budgets of the subjects of the Russian Federation, more than 23 thousand budgets of municipalities, incl. 1.8 thousand municipal districts, 1.7 thousand urban settlements and 19 thousand budgets of rural settlements.

The large scale of IS is associated with the unique territorial conditions of people's life (unequal distribution of people over a vast territory, with a large area of low population density). Thus, the complex of geographical-natural and historical-cultural conditions of people's life activity created administrative and organizational complexity, which, in turn, determined the complexity of personnel management.

The complexity factor of managing people over a wide area also affects the complexity of managing the development of IP. The complexity of managing the functioning of IS and the complexity of managing its development is also enhanced due to the high complexity of the system's functions, as well as due to the complexity of the regulatory "industry language".

Structure of sources of definitions of words. As an object of study, we define a system of concepts (concepts) of an interdisciplinary complex subject area (CDS) surrounding the functioning of a large-scale information system for managing the state budget.

The structure of the sources of the thesaurus of the SPD IS of state budget management was formed as follows:

- Regulatory legal acts (NLA):
 - o Codes - 1;
 - o Decrees - 2;
 - o Federal laws - 8;
 - o Government Decrees – 1;
 - o Other legal acts (rules, orders, procedures, etc.) - 6.
- Dictionaries:
 - o Dictionaries - 11;
 - o Glossaries - 2;
 - o Handbooks - 2;
 - o Encyclopedias - 4.
- Other sources:
 - o Statistical collections - 2;
 - o Standards (GOSTs) - 2;
 - o Techniques and methodologies - 4;
 - o Educational and scientific publications - 8;
 - o Electronic resources - 4.

In total, more than 1.2 thousand descriptions of almost 900 concepts have been included in the thesaurus so far.

The SPD classes are selected on the basis of the principle of highlighting the elements of reality, the list of which includes such groups of concepts as: subjects and objects of reality, various properties and attributes of these groups of concepts (see Fig. 1).

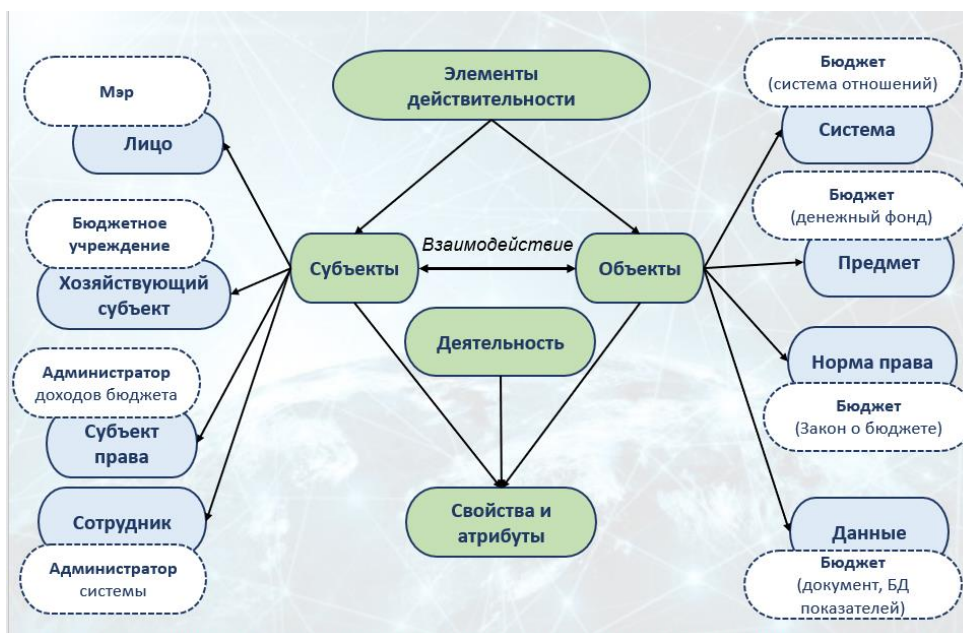


Fig.1. Relationships between the concepts of SPD

Formed on the basis of the groups of terms identified in the thesaurus, the ontology of the SPD concepts (see Fig. 2) includes such root groups as:

- Reality, including groups of terms related to the relationship of subjects and objects;

- Lexicons that indicate the non-semantic relationship of the SPD term to a particular (related) subject area;
- Model of the System, which forms an idea of the scope of the term in terms of its positioning on the information system.

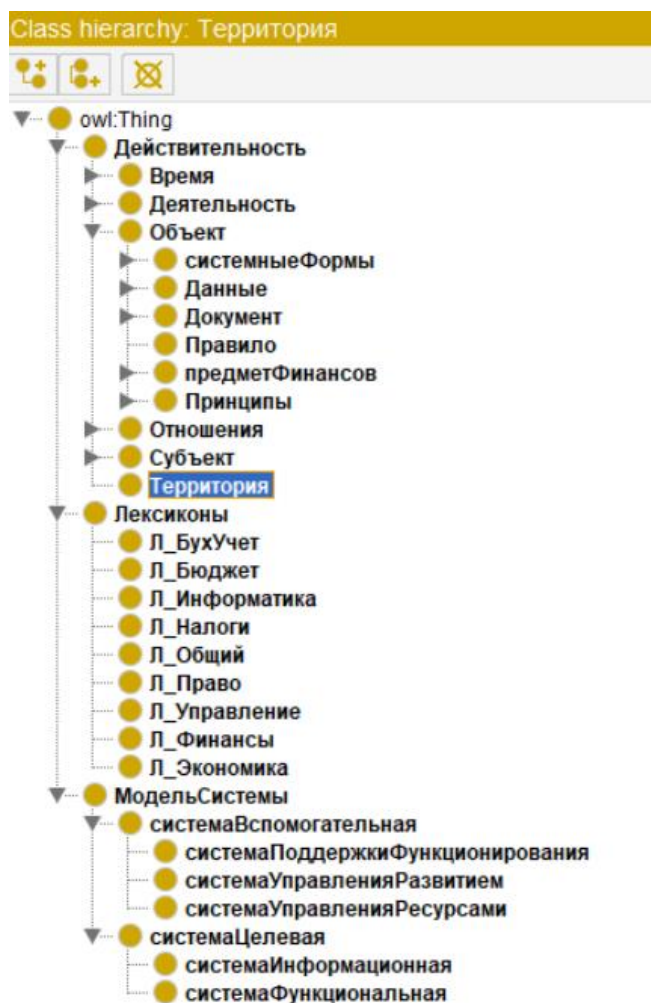


Fig.2. A working model of the ontology of the SPD IS of state budget management

Conclusion. Considered in this publication, some results of the analysis of the subject area made it possible to present structured knowledge about the use of information technologies in public budget management. This will allow at subsequent stages to analyze the criteria and models of the designed object, methods and design scenarios.

THE MULTIDIMENSIONAL TIME CONCEPT AND AREAS OF ITS APPLICATION FOR THE INTEGRATION OF CRITICAL SYSTEMS

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The importance of increasing the speed of changes in technologies, economy, and social structure is determined by a large increase in the number of changes and decisions made per unit of time. But time itself remains insufficiently studied and mastered both as a phenomenon and as a property of systems, enterprises and their associations. Often an enterprise strives to use one "single common" time (calendar, astronomical or otherwise), which is only one possible time model. However, one single time model is often poorly suited to all the features of the enterprise, up to generation of collisions both between interacting systems and between parallel processes of the enterprise and its ecosystem. Managing the joint functioning and dynamics of changes in a set of systems requires using more advanced time models and their integration. For this purpose, using multidimensional time, including its integration into the spatiotemporal field of an enterprise and its ecosystem, is suggested. This allows forming an integral and holistic foundation for the application of various methods of integrated management of systems and enterprises. In particular, these methods relate to a group of tasks "Threat prevention", as well as to "Concept of Operations" (CONOPs) as the broad area relevant for critical systems in the dynamics of their functioning.

EXPERIENCE IN PREDICTING OCCUPATIONAL MORBIDITY AT THE OBJECTS OF CRITICAL INFRASTRUCTURE OF THE IRKUTSK REGION

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According to [1], 16% of the world's population will reach the age of over 65, and the number of people aged 80 and over will triple by 2050. The demographic burden of the elderly, according to the forecast, will be 57.6 in Russia, and 50.0 in the Irkutsk region [2]. At present, the proportion of people over 60 years of age is about 20% (according to international criteria, the population is considered old if the figure is more than 12%) in the Irkutsk region [3]. So, the preservation of labor longevity of the economically active population is one of the priorities of the country's economic security. In this regard, the results of health assessment and analysis among people employed in various types of economic activity, including enterprises that can be classified as critical infrastructures, have not only scientific but also practical significance. They should form the basis for the development of targeted federal and regional programs to minimize the health risks.

Critical infrastructure objects that are necessary for the functioning of society and the country's economy are the Irkutsk aircraft plant, enterprises of the mining and petrochemical industries. Long-term hygienic and socio-psychological studies of the quality of the labor potential of these enterprises, the main "suppliers" of occupational diseases (OD) in Irkutsk region, showed the need for management decisions to reduce non-communicable diseases (NCDs) among workers. This is very important because NCDs, which cause 74% of deaths worldwide [4], and the associated risk factors pose a threat to the sustainable development of our region. The social significance of OD is great, as they affect people of working age and often cause permanent disability with the impossibility of full recovery of the worker's health, despite the termination of contact with the harmful factor. Trends in the dynamics of OD in the Irkutsk region have shown the need for its forecasting for the purpose of organizational, technical and medical and preventive correction. To accompany the medical technology of forecasting OD, together with Manuylov S.V., a software tool (ST) was developed that algorithmizes methods for calculating weight indices to assess the strength of the influence of OD predictor factors and normalize intensive indicators (NII) [5] to calculate the prognostic significance of factors. According to the identified predictor factors (industry, age of the victim, work experience in contact with a harmful factor, profession, main and concomitant harmful factors, type, form, severity of occupational disease, main and concomitant diagnoses), using ST, the degree of influence of each of the considered factors on OD; threshold values of the prognostic coefficient characterizing the probability of OD; prognostic matrix of a complex risk assessment of OD, possible ranges and risk groups are determined. With the help of ST, it was found that the greatest risk of OD is typical for the professions of an assembler-riveter and an excavator driver, in which contact with the combined effects of physical factors in a relatively short time (1-4 years) leads to the formation of OD at the most able-bodied age (20-39 years). The limitations of this NII model include the non-inclusion of clinical, functional, biochemical and socio-psychological indicators of workers among the predictor factors. Further research should be aimed at expanding the possibilities of using the NII- modeling tool, taking into account additional predictor factors.

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THE TECHNOLOGIES APPLIED WHEN DEVELOPING THE SOFTWARE «FORECASTING OF PROFESSIONAL DISEASE WITH THE METHOD OF NORMALIZED INTENSIVE INDICATORS (NII)»

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In the Irkutsk region there is a large number of the enterprises relating to primary branches of the industry: mechanical engineering, aviation industry, mining, metallurgy and others. Workers of the main productions of these enterprises often is affected by such harmful factors as physical impact (noise, vibration), contact with chemicals, a physical overstrain and other. It promotes increase in level of the professional disease (PD) in the region and, as a result, to reduction of number of able-bodied population and growth of costs of social assistance. There is a need for development of predictive model of forming of PD which will allow to estimate risk to ache for various categories of workers.

For creation of predictive models, it was necessary to automate a method of calculation of weight indexes for assessment of force of influence of different factors on forming PD and a method of the normalized intensive indicators (NII) [1] for calculation of the predictive importance of factors. The Software "Forecasting of professional disease with use of the NII method" allows to define risk of emergence of PD at workers under the influence of the considered factors and to select groups of the workers requiring priority holding preventive and medical and diagnostic actions.

When developing software used the different information technologies allowing to write quickly and qualitatively a program code, to organize interaction of different parts of software and to optimize development process.

For writing of software the high-level programming language of Python [2] was used. The Python programming language has such qualities as cross-platform, simplicity of syntax, availability on different operating systems: Windows, Linux, macOS. Python is free and public and has different free libraries, modules and packages which expand functionality of language.

For storage of data array the relational database management system (RDBMS) SQLite was used. This RDBMS has a number of advantages which defined its choice: free license; high speed of work with data; reliability; cross-platform; compatibility with the majority of programming languages, thanks to existence of special libraries; is the built-in file database.

In work of software the JSON technology for storage of configuration files of the program was used. JSON allows to store structured data, it is easy to write and read out the file with information, has simple syntax, the JSON files can be used with the modern languages of programming.

For more effective development of the program the control and management system for versions of a program code of Git was used. Git allows to save and restore different versions of the program thanks to what an opportunity easily appears to cancel the made changes, minimizing losses of the operable code if there is such need.

As the Python programming language is object-oriented, the object-oriented programming technique was applied to writing of the software code. The principle of modularity was applied to simplification of creation of the code and debugging of the program, that is the program code was

separated into separate modules, each of which carries out the task in the course of a program runtime. At the level of modules the design pattern of MVC (Model-View-Controller) allowing separating work of a display representation, the main logic of the application and logic of work with data [3] was applied.

Conclusion. Application of different technologies considerably simplifies development process and modifications of software, reduces costs of its creation, increases stability and overall performance of software.

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THE SYSTEM OF INFORMATION SUPPORT FOR PLANT PRODUCTION MANAGEMENT PROCESSES

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To solve the problems of managing the production of crop products, it is necessary to provide information support for various processes that ultimately determine the yield of agricultural crops. Other sectors of the agro-industrial complex, such as animal husbandry, processing and marketing of products, depend on this.

The modern development of agricultural production is associated with the use of digital technologies to manage a large number of operations to obtain planned products. Therefore, advanced agricultural organizations are striving to introduce digital technologies into production. Unfortunately, this process is slow and does not cover all technological operations as a whole, but only some of them.

This paper considers a project on the system of information support for the processes of managing the production of crop products based on the experience of the educational research and production sites of the Irkutsk State Agrarian University. Sensors provide data on the main types of field work in the spring, which include plowing, harrowing, fertilization, sowing and chemical protection of seedlings. In addition to information from the fields, satellite data is analysed to assess the condition of the soil for the purpose of spot fertilization. The same function of electronic maps is associated with the determination of seedling development for the use of protective equipment. The result of processing this information is the calculation of costs. At this stage of agricultural work, data from unmanned aerial vehicles can be used.

After spring work, data on crop care is monitored. Here attention is paid to the development of plants in different areas, operations are carried out to loosen the soil, destroy weeds, hilling, fertilize, control pests and plant diseases, and others. For the spot performance of these works, you can use satellite information or images of unmanned aerial vehicles. Costs are also estimated at this stage.

The harvesting stage is associated with methods of combine harvesters. The result of harvesting operations is to determine the gross harvest and product quality. To predict the timing of harvesting, you can use satellite information with the determination of the plant vegetation index. The economic outcome of harvesting is an estimate of costs, production costs, and predictive profits.

All stages of work are associated with external conditions for obtaining a crop. This implies the availability of an automated agrometeorological platform and satellite data on the impact of extreme events on plants. Such data, together with long-term observations, make it possible to predict the harvest using the method proposed by us and assess risks. The information obtained is ultimately used for subsequent planning of the economy using the developed optimization models. At the same time, the plans take into account possible risks.

ABOUT THREE VARIANTS OF LINEAR PROGRAMMING PROBLEMS APPLIED TO AGRICULTURAL PRODUCTION

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Precision farming systems, geographic information systems, systems for monitoring the state of fields are being intensively introduced into agricultural production. These funds allow to optimize the use of agricultural producers' resources.

The information obtained from various sources is applicable to the formation of big data for the purpose of managing production processes, which include operational decision-making, forecasting and planning.

Since the production of agricultural products is carried out on heterogeneous lands in terms of fertility, the information received from fields, agrometeorological sites, satellites, unmanned aerial vehicles, the Federal State Statistics Service, the hydrometeorological service, farm reports can be used to optimize plans with an objective function in the form of maximum profit.

The paper considers three linear programming models that take into account the heterogeneity of land resources. In these models, fields with a certain type of product are divided into heterogeneous areas.

The first model is linear, representing, in fact, a set of linear programming problems that describe heterogeneous fields.

The second model displays the dynamics of the variability of production and economic characteristics in the form of significant trends. It can be attributed to the parametric programming model. Unlike a linear programming problem, a problem with a time parameter can be used to plan production with some lead.

At the same time, agriculture is subject to various risks, therefore, as a third model, it is proposed to use the problem of mathematical programming with probabilistic estimates. Such a model contains coefficients for unknowns in the objective function and constraints that are associated with estimates of the impact on agricultural production of climatic, environmental, biological and technogenic events.

The developed models are implemented at simulation facilities using actual production, economic and climatic characteristics that reflect the conditions of activity of agricultural producers in the southern part of the Irkutsk region. Based on the simulation results, their capabilities for planning agricultural products are evaluated.

Unlike the models used to optimize the production of agricultural products, which do not take into account the heterogeneity of land, the proposed models better describe real situations. However, their application requires detailed information about the processes under consideration. Therefore, in order to solve problems of mathematical programming for farms or municipal districts, taking into account the heterogeneity of land resources in terms of fertility, data on the productive possibilities of field plots are needed.

MODELING OF CLIMATIC AND BIOLOGICAL RISKS IN AGRICULTURAL PRODUCTION

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A large number of literary sources are devoted to the description of various risks that must be taken into account when solving many problems in the spheres of the economy of the regions and the country. Agriculture with huge areas of land resources that are flooded, destroyed by wind and water erosion, polluted by industrial facilities, pest control means is most at risk. At the same time, climate change makes its own contribution to the sustainability of crop production.

Equally important are pandemics and epidemics that contribute to the death of farm animals, and also affect the health of workers serving this important area of human activity. Large crop losses are incurred by agricultural producers from pests and plant diseases, as well as locust invasions.

Evaluation of regularities in time series of hydrometeorological and biological events makes it possible to develop methods for predicting or evaluating events. In addition, the results obtained can be used to build mathematical models for planning the production of agricultural products, taking into account the risks of agricultural production.

In this work, models for probabilistic and deterministic assessment of the variability of climatic and biological events are generalized, and their impact on agricultural production is determined.

In some cases, it is difficult to isolate the significance of one or another factor in crop losses. This is due to insufficient data. At the same time, it is possible to assess the damage caused to agriculture as a result of the impact on the industry of many extreme events.

Factor analysis was used to identify the impact of extreme events of various origins on crop yields. Relationships between different types of low, high and medium bioproductivity and temperatures and precipitation were determined. This approach allows us to evaluate the features of the influence of certain meteorological factors for different groups of years, which characterize favorable, unfavorable and average or intermediate conditions.

Some works describe the influence of meteorological factors on the number and distribution of pests of agricultural crops and the conditions for locust invasion are determined. In other words, biological and climatic events are generally related. This fact complicates the task of assessing their individual impact on the loss of agricultural products. One of the reasons for this is the lack of data on biological events.

The constructed factor models can be used in parametric programming problems to simulate production in different natural and climatic conditions, taking into account the damage caused by biological events.

MULTI-STAGE MODELS OF MATHEMATICAL PROGRAMMING AND THEIR APPLICATIONS IN AGRICULTURE

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Modeling various aspects of agricultural production is of great importance for improving the efficiency of managing the activities of agricultural producers. When carrying out agricultural work to obtain products, a certain number of stages are sequentially performed. These stages include preparing the soil for sowing, sowing, caring for crops, harvesting and storing. In other words, the production of agricultural products is multi-stage. At the same time, due to the development of engineering and technology, the number of production operations can be reduced due to their parallel execution. In addition, long-term sustainable results of obtaining high yields depend on the correct crop rotation.

For this reason, to describe the production of agricultural products, it is necessary to use multi-stage models of mathematical programming. A number of articles and monographs present similar models for optimizing agricultural production. Here we can distinguish models that take into account crop rotations; models with price optimization when selling products; parametric programming models with annual adjustment of planned indicators; models using expert assessments.

In continuation of these works, a multi-stage model is proposed, which includes dynamic-stochastic characteristics and expert assessments. At the first stage, the task of planning agricultural production, taking into account the predecessors and the timeliness of technological operations, is solved. At the same time, crop yields are predicted using a multi-level trend. The results of the first stage of modeling are optimal plans related to predecessors, the timeliness of technological operations and possible risks. At the second stage, the solution is corrected on the basis of a comparative analysis with the development of the real situation. The number of steps or stages depends on the duration of planning for the short, medium or long term. To solve such problems, a parametric programming model with uncertain coefficients in the objective function and the left parts of the constraints is applied

When using the proposed model, it is especially necessary to highlight the assessment of possible risks in the production of agricultural products. The model allows taking into account various degrees of risks for the readiness of agricultural producers to implement measures to reduce losses.

An example of the implementation of the proposed multi-stage model is given. It should be emphasized that multi-stage modeling allows farms to quickly adapt their production to real conditions, since it involves taking into account not only the current situation, but also the development of activity of an agricultural commodity producer.

MODELING OF TIME SERIES OF CHARACTERISTICS ASSOCIATED WITH FOOD PRODUCTION

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When constructing mathematical models for optimizing the production of food products, data on production, economic, natural and climatic, ecological, food wild resources, commercial wild animals and other characteristics are required. Each of the characteristics included in a particular group has its own patterns of variability, the knowledge of which allows you to choose an adequate model of mathematical programming.

It is obvious that production processes and harvesting activities are characterized by a large number of uncertain coefficients with unknown objective functions and limitations. To remove the uncertainty of some of the characteristics of extremal problems, various authors propose trend, autoregressive, factorial, cyclic and mixed models that meet certain criteria of accuracy and adequacy. Since the management of food production should take into account the dynamics of various aspects of the activities of agricultural producers and harvesters of wild plants, the experience of statistical processing of a large number of time series of different characteristics shows that they can be divided into several groups according to dynamic and stochastic properties.

The first group includes characteristics whose time series are described by significant multilevel trends with significant coefficients of regression expressions. In other words, the entire time series and the sequences of lower and upper levels extracted from it are characterized by significant trends according to the statistical criteria for regression equations. These characteristics include crop yields, labor costs for the production of a unit of output, the number of farm animals, their productivity, and others.

The second group of characteristics of time series has a higher dispersion in relation to the first group. Here, the following case of a dynamic-stochastic description of a series in the form of multilevel trends can occur, at least one of the sequences (the entire series, sequences of lower and upper levels) does not have a significant trend. Such a group may include, in addition to crop yields and labor costs per unit of output, the harvesting of certain types of wild plants. They also include some biological characteristics.

And, finally, the third group of characteristics contains climatic and environmental characteristics. Their time series are random or have significant low autocorrelation coefficients. Typically, different types of liquid and solid precipitation are samples that obey the laws of probability distribution. Some series of air temperatures have significant autocorrelation relationships.

"SMART CLASSROOM": DESIGN, REALIZATION, USE

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The technologies of "smart systems" are constantly being improved. The Internet of things, artificial intelligence, cloud services and others are developing. The scope of their use is expanding. In particular, "smart classroom" projects are being developed and implemented. Their creation is becoming a priority in educational activities. The use of such classrooms improves the comfort of conducting classes, intensifies the development of the material by students, increases the security of software and hardware, and allows conducting classes in remote and mixed mode.

Since 2021, the Irkutsk State Agricultural University has begun implementing the project "Creating a smart classroom". The project highlights several interrelated modules: 1) multimedia (conducting online conferences and classes in full-time and remote format); 2) climate control; 3) accounting for student attendance; 4) video surveillance and security (protection against domestic accidents and intruders using a warning and alarm system); 5) lighting; 6) demonstration prototypes; 7) autonomous power supply; 8) individualization of the learning space of the student. At the same time, a feature of the "smart audience" is the creation of additional modules for monitoring the development of indoor plants, growing seedlings of different types of plants, automated watering, etc.

Most of the project modules were implemented for one of the auditoriums of the Agricultural University, which is used for both research and teaching purposes. When carrying out educational activities, the following modules were implemented: multimedia (multimedia board, video conferencing), security and video surveillance (equipment and software Aqara Home, voice assistant Yandex.Alisha), attendance recording in the form of a prototype (Arduino microcontroller with optical sensors, NFC reader were used and Odroid microcomputer), lighting, climate control, automated forklift prototype.

The project of the described audience is universal and open. Its further implementation and expansion of functions based on the listed modules is expected. The multimedia system needs to install speakers and sound receiving devices around the entire perimeter of the room. It is necessary to organize a convenient automated system for recording lectures and automatically sending them to the cloud. It is advisable to implement student attendance accounting by analyzing the video stream from the camera in the classroom. Individualization of the student's learning space is expected through the use of adaptive lighting for each workplace, the presence of special speakers for connecting personal devices to the electrical and Internet networks, equipping each workplace with a tablet computer or laptop. In addition, it is planned to implement a module for monitoring the development of plants.

The experience of designing and implementing the "smart classroom" project can be used for other university classrooms, adjusted for their intended purpose.

EVALUATION OF THE EFFECTIVENESS OF MEASURES TO CREATE A COMFORTABLE URBAN ENVIRONMENT BASED ON NEURAL NETWORK MODELS

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Annotation. At the moment, Russia is implementing the national project "Housing and Urban Environment". Within the framework of the Project, the government of the Russian Federation has determined an exhaustive list of measures aimed at improving the comfort of the urban environment. To assess their effectiveness, the Ministry of Construction of Russia has developed and approved a methodology for the formation of an index of the quality of the urban environment. The paper proposes an alternative method for evaluating activities aimed at improving the comfort of the urban environment, using neural network models of natural language.

Introduction. The index method for assessing the comfort of the urban environment, proposed by the Ministry of Construction of Russia, takes into account many quantitative and measurable indicators that characterize the level of living comfort in the corresponding city [1]. One of the indicators is the level of citizens' involvement in decision-making in the field of creating a comfortable urban environment (CCUE). One of the forms of interaction between citizens on CCUE issues is electronic voting for improvement projects on a specialized site of the Ministry of Construction of Russia [2]. Studies show [3] that this method of obtaining feedback from citizens is ineffective and needs to be improved.

Additional tools for obtaining feedback from citizens can be various kinds of sociological surveys and studies [4-7]. The disadvantages of this tool include: long time intervals from asking questions to obtaining results, a narrow range of issues covered and a limited audience. In [8], the author proposed a variant of receiving feedback through a mobile application. The authors of [9] use messages from the social network Twitter as a source of feedback.

In our study, we evaluate the effectiveness of activities aimed at the CCUE (Events), through the semantic similarity between the messages of citizens on the Internet (Messages) and the descriptions of the Events.

Data and experiment. In this work, we analyze more than 74 thousand text messages and descriptions affecting the problems and solutions to FCGS issues on the territory of the Khanty-Mansiysk Autonomous Okrug-Yugra. Texts of Messages and Events are represented by two sets of datasets. Datasets are grouped by municipalities, thematic categories and month. Brief characteristics of dataset sets are given in Table 1.

Table 1. Brief characteristics of dataset sets

Dataset set	Quantity datasets	Total messages in a set
Messages	6 224	73 897
Events	108	290

The study includes three main stages:

- Stage 1. Extraction of meaningful phrases and phrases (N-grams).
- Stage 2. Translation of the obtained N-grams into vector form, taking into account the context.
- Stage 3. Determining the semantic similarity of the obtained vectors of N-grams.

To extract the most significant key N-grams from messages, it is proposed to use the TF-IDF algorithm [10]. From each dataset, 100 most significant N-grams from N = 2 to N = 4 were extracted. The significance of each N-gram of the dataset was determined by the rank assigned to it (R_{ds}) according to the formula (1):

$$R_{ds} = TF_{n-gramm} \times IDF_{n-gramm}, (1)$$

where R_{ds} is the rank of an N-gram in the dataset, $TF_{n-gramm}$ is the frequency of an N-gram within a single message, $IDF_{n-gramm}$ is the inverse of the frequency with which an N-gram occurs in all messages in the dataset.

The total rank of each N-gram for the entire set is calculated by formula (2):

$$R_{sum} = \sum_{k=1}^m R_{ds_k}, (2)$$

where R_{sum} is the total rank of the N-gram, R_{ds} is the rank of the N-gram in the dataset.

The R_{sum} values for the TOP-20 extracted N-grams are given in Table. 2.

Table 2. R_{sum} values for all extracted N-grams

N value	Messages		Events	
	Max R_{sum}	Min R_{sum}	Max R_{sum}	Min R_{sum}
N=2	59,2314	0,0221	3,8184	0,0306
N=3	3,7017	0,0263	1,0693	0,0352
N=4	2,5768	0,0289	0,9183	0,4130

To obtain numerical vectors of the contextual representation of N-grams, a pre-trained neural network model Sentence-BERT (SBERT) is used [11]. SBERT is a modification of a pre-trained BERT network. A feature of the modification is the use of Siamese and triplet network structures to obtain semantically meaningful sentence vectors. This allows retraining the model on the task of determining semantically close texts. The model is further trained in such a way that sentences similar in meaning are encoded into vectors close in metrics, while maintaining semantic relationships between phrases. The dimension of the vector of each N-gram is 512.

To assess the semantic proximity of N-grams, the cosine distance between vectors is used, calculated by formula (3):

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^n A_i \times B_i}{\sqrt{\sum_{i=1}^n (A_i)^2} \times \sqrt{\sum_{i=1}^n (B_i)^2}}, (3)$$

where A and B are compared N-gram vectors, $\cos(\theta)$ is the cosine distance.

The result of comparing the TOP-20 N-gram vectors for N=2 is shown in fig. 1.

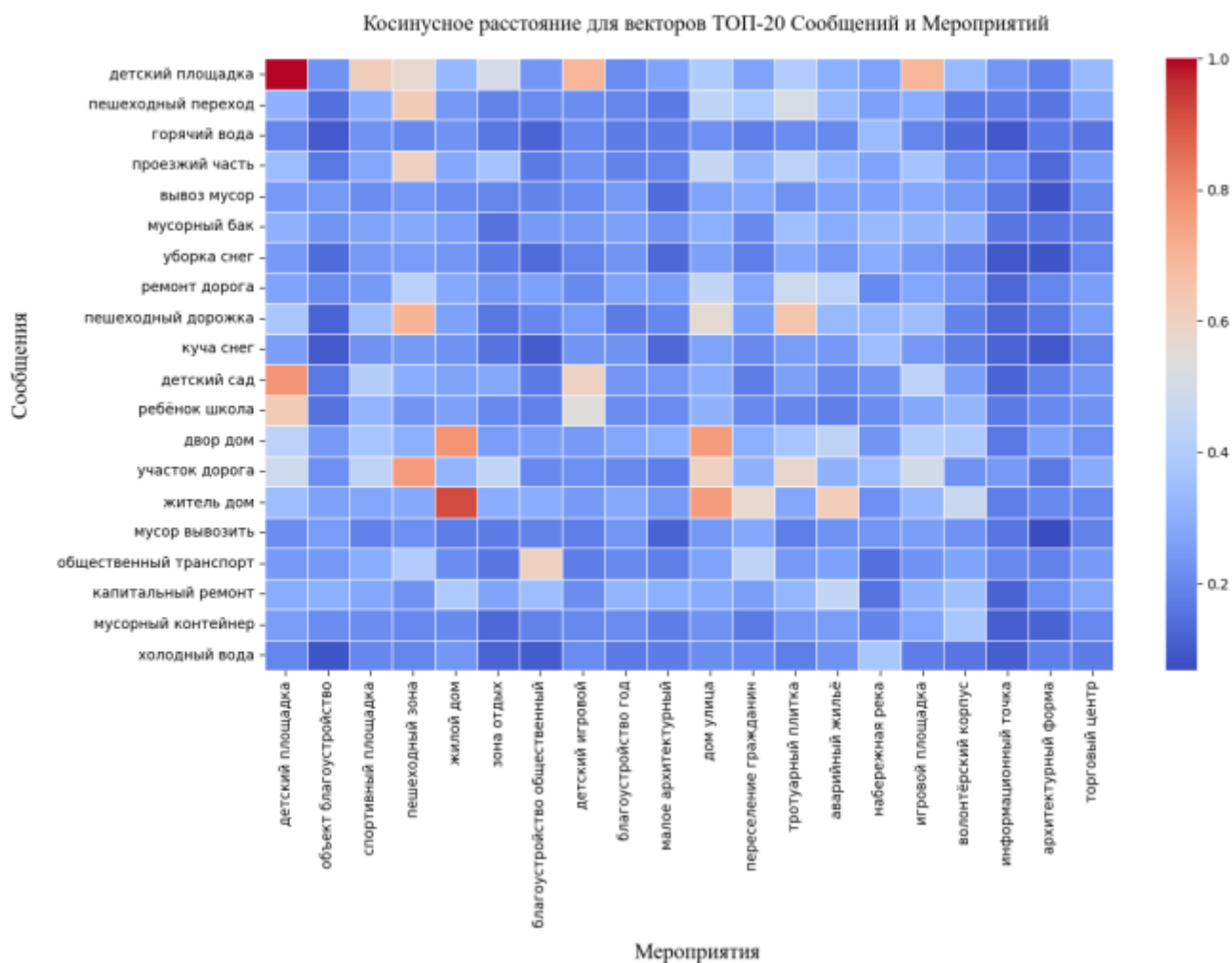


Fig. 1. Cosine distance heatmap for TOP-20 N-gram vectors

Conclusion. The result of the presented study was a set of N-grams extracted from text messages of citizens and the media, on the basis of which an assessment of the effectiveness of the Activities was given. The evaluation was based on a comparison of the semantic similarity between Message N-grams and Event N-grams. This assessment revealed a significant discrepancy between the expectations of citizens presented in the Messages and the Activities carried out by local authorities.

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MODEL OF SEGMENTATION OF FOREST LOGGING IN SATELLITE IMAGES

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The paper describes an approach to developing a machine learning model for the formation of logging polygons based on Sentinel-2 satellite images. The use of Sentinel-2 images is justified by the presence of 12 channels of different spectrum, which allows you to get more information from each image. Multispectral images require additional preprocessing, since the spectra have different resolutions. In order to use the spectra of images in the maximum available resolution, methods were implemented to increase the resolution to 10 meters per pixel using the DSen2 model (Deep Sentinel-2). The approach of segmentation of logging is based on the use of pairs of frames, before and after the appearance of logging. Iou, f-measure and recall metrics are used as model estimates. To assess the quality of the model, marked-up satellite image data was used for some areas of the Khanty–Mansiysk Autonomous Okrug - Yugra.

ON THE CONSTRUCTION OF THE MODEL OF TRAIN MOVEMENT ALONG A RAILWAY SECTION BASED ON THE QUEUING THEORY

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A railway section we mean a complex of railway stations on a relatively small territory that jointly performs operations for servicing and transit of trains [1]. It is characterized by the number of directions from which trains arrive, the number of stations, and trunk tracks (lines). The railway section has a nonlinear hierarchical structure with several train routes. At the same time, the duration of technical processes at stations and lines is affected by many random factors.

Queuing network (QN) is an effective tool for modeling such objects [2]. QN consists on a finite number of queuing systems (nodes) in which requests move from one node to another following a given route matrix. Based on this mathematical apparatus, we developed a methodology for modeling the operation of freight and marshaling railway stations [2]. Then we figured out that it was also applicable to modeling larger systems such as railway sections.

A mathematical model of train running through a railway section is based on an open QN. Each direction includes passenger, transit, and local freight trains. We use a separate Batch Markovian Arrival Processes (BMAP flow) to describe their arrival from each direction [2]. The operation of stations and lines is described by one or more nodes of the QN, in which group service of requests is allowed. To take into account different train routes, we use several types of requests, each of which has a separate route matrix.

To study the obtained queuing network, we develop its simulation model based on a discrete-event approach and Monte Carlo methods. The model is implemented as a software package and allows us to determine the performance indicators of QN, which includes up to 100 nodes, several BMAP flows, up to 10 types of requests and route matrices.

The report will present in more detail the methodology and the software package, as well as their application for the study of the northern section of the Ulaanbaatar railway, through which the shortest railway transport corridor from Central Russia to China passes. This railway is still not electrified and mostly has a single-track line, which limits the growth of transit. We will discuss the results of computational experiments and our recommendations for improving the operation of this object.

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ON THE APPLICATION OF MULTIPHASE QUEUING SYSTEMS FOR SOLVING ENGINEERING PROBLEMS

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A multiphase queuing system (QS) is a set of several sequentially located queuing system (QSs), in which the output request flow from one phase is incoming one for the next phase [1]. Each phase is characterized by the number of channels, the queue length, and the time for servicing requests. We use a temporary blocking of channels to prevent the loss of requests during its transition between phases if the queues are finite. It means that request remains in the channel after service and blocks its operation until the next phase is freed up enough space.

The multiphase QS is usually used to describe technical systems in which the service process includes processing one request on several sequentially located devices. Besides, it is a convenient mathematical model for describing the data transmission. Therefore, it is often applied in the study of telecommunication systems and computer networks. Properties of such systems are the random nature of data receipt and non-deterministic processing, regardless of their semantic meaning. These facts make it possible to use the developed mathematical apparatus in other areas related to the processing of incoming flows of requests of various natures.

Such systems include production and transport and logistics systems, in particular, warehouse, conveyors, ports, freight and sorting railway stations, transport hubs, and train stations [2]. They have a complex organizational structure that generates a multiphase service process. Moreover, the complexity of studying such systems increases due to the specifics of incoming flows. A transport unit is necessary to consider as a group of requests (passengers, goods, etc.) that are serviced separately from each other. It is also necessary to take into account changes in the operating mode of the system under the influence of various factors, including random: accidents, weather conditions, and daily and seasonal cycles.

In the report, we will present in more detail a description of multiphase QS with group acceptance of requests and functioning in a heterogeneous environment. We will also consider its application to solving engineering problems, in particular, to assess the capacity and improve the efficiency of the transport hub and marshaling yard.

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ROUTING PROBLEMS FOR THE AREA HAVING DYNAMICALLY CHANGING PROPERTIES

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Routing problems play an essential role in modern transport logistics. They become especially relevant in current conditions when the delivery cost has a steady upward trend and is often comparable to the cost of the product itself. The entire range of emerging problems can be divided into two classes: routing on a graph and infinite-dimensional routing. The first class includes the traveling salesperson problem, its numerous variants, and generalizations [1,2]. The second class deals with determining air or sea routes, as well as land routes with an infinite number of admissible trajectories [3,4]. These problems belong to the class of NP-hard problems.

We consider the vehicle routing problem in an environment with dynamically changing properties. The central feature of the study is that the optimality criterion is the minimum delivery time, but not the distance traveled. The optical-geometric approach developed by the authors, based on the analogy between the propagation of light in an optically inhomogeneous medium and the minimization of the integral functional, is used as a research tool. We use exact and approximate solutions of the eikonal equations to describe wave fronts.

Let us be given a metric space X , points $A(x_a, y_a)$ and $B(x_b, y_b)$, and $0 \leq f(t, x, y) \leq \beta$ be a piecewise continuous function of its arguments, which shows the instantaneous speed of movement at every point $(x, y) \in X$ at time t . The minimum moving time between two points $a, b \in X$ is determined as follows:

$$\rho(a, b) = \min_{\Gamma \in G(a, b)} \int_{\Gamma} \frac{d\Gamma}{f(t, x, y)},$$

where $G(a, b)$ is all continuous curves, which belong to X and connect the points a and b .

The key point here is the construction of the light wave front, which is determined from the solution of the eikonal equation [5], which is a non-linear non-homogeneous partial differential equation of the first order.

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ON THE PROBLEM OF COVERING THREE-DIMENSIONAL BODIES BY SPHERICAL SEGMENTS

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Due to the rapid pace of the development of information technology, three-dimensional covering problems became more relevant as they found application in this area. Such issues arise in monitoring system design for arranging surveillance devices or telemetry sensors in an optimal way [1]. In these systems, the range of the device may depend significantly on the properties of the environment where they are located. This property is especially pronounced in sonar-type devices when the signal transmission time allows us to estimate the distance [2,3]. Thus, the study of these problems needs to apply particular non-Euclidean metrics that take into account the state of the environment.

Let we are given a metric space X , a bounded domain $P \subset X$ with a continuous boundary ∂P , and n spheres $C_i(O_i)$ with centers $O_i = (x_i, y_i, z_i)$, and equal radii R . Let $0 \leq f(x, y, z) \leq \beta$ be a continuous function, which shows the instantaneous speed of movement at every point $(x, y, z) \in X$. If $f(x_i, y_i, z_i) = 0$, the point (x_i, y_i, z_i) is impassable. The minimum moving time between two points $a, b \in X$ is determined as follows:

$$\rho(a, b) = \min_{\Gamma \in G(a, b)} \int_{\Gamma} \frac{d\Gamma}{f(x, y, z)},$$

where $G(a, b)$ is all continuous curves, which belong to X and connect the points a and b . It is easy to see, that the shortest route between two points is a curve, that requires the least time to be spent.

In terms of the optimization theory, we have the following minimization problem:

$$R \rightarrow \min, \quad (1)$$

$$\forall p \in \partial P, \exists i \mid \rho(O_i, p) \leq R \quad (2)$$

$$O_i \in P, i = \overline{1, n} \quad (3)$$

Objective function (1) minimizes the radius of the covering. Constraint (2) guarantees the full covering of the surface ∂P , and (3) means that the center of each sphere is inside P .

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INTEGRATING THE RESEARCH INTO RESILIENCE OF ENERGY AND SOCIO-ECOLOGICAL SYSTEMS USING ARTIFICIAL INTELLIGENCE METHODS

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Studies of the sustainability of energy and ecological systems are considered in the sense of Resilience (in Russian, the word "elasticity", or "elastic resilience" is close in meaning). Resilience is the ability of a system to return to an equilibrium (stable) state after a temporary disturbance. The shorter the time to return to equilibrium and the lower the losses of the system, the more stable it is.

The presented study is devoted to the development of a new approach to the study of resilience, which is distinguished by the use of modern intelligent technologies. With their help, it is proposed to perform modeling of the relationship between energy and ecological systems, as well as to develop control actions. The purpose of control actions is to return systems to a resilience state after disturbances caused by natural and anthropogenic influences.

The criteria for resilience of energy and ecological systems, as well as the threat of violations of the resilience of energy and ecological systems are determined based on the analysis of threats to energy and ecological security in the Baikal region; a list of possible emergency situations (ES) in the energy sector, caused by identified threats, was formed; a list of control actions (preventive and operational measures) aimed at preventing or eliminating the consequences of emergencies has been developed. The substantiation of the choice of a machine learning model (LSTM-network) for carrying out computational experiments in studies of the resilience of energy systems has been performed [1].

The technology of knowledge management in studies of the resilience of energy and socio-ecological systems (ESES) is proposed, which includes: ontological modeling of threats and risks of resilience of ESES; cognitive modeling of threats, risks and resilience indicators of ESES; technique and algorithms for converting cognitive models into rule-based knowledge bases. A technique for studying the resilience of ESES using semantic and linear optimization models is also proposed [1].

The existing methods and tools have been adapted: 1) INTEC-A software for assessing the state of energy systems (design and prototype implementation of a cognitive modeling agent (CogMap) and its integration into INTEC-A software); 2) implementation of TCogMap - a tool for converting cognitive maps (CC) into production rules of an expert system in order to automate the analysis and interpretation of CC using the capabilities of expert system; 3) adaptation of the Information and Computing System (ICS WICS) for assessing the impact of energy facilities on environmental pollution; 4) the architecture of REESS (Resilience of Energy and Socio-Ecological System) is proposed - an instrumental system that integrates the tools and research methods described above. REESS is proposed to be developed to support research technologies for the resilience of ESES using the proposed methods and algorithms.

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APPLICATION OF THE SP "INTEC-A" FOR ASSESSING THE STABILITY OF ENERGY SYSTEMS

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In [1] it was proposed to assess the stability of energy systems on the basis of energy security studies, where the assessment of this or that situation includes many factors and is based on indicative analysis and a scale: "normal" (normal functioning), "pre-crisis" (critical situation), "crisis" (emergency situation) [2]. Taking into account this approach, a methodology for assessing sustainability was developed [1].

Current studies of assessing the stability of energy systems using situational management methods and PC "INTEC-A" includes a description of the state of the system using cognitive modeling and building cognitive models, and computational experiment of multivariate scenario of development of fuel and energy complex based on a model of optimization of balances of fuel and energy resources, that is, include qualitative and quantitative assessment of the stability of energy systems.

The paper presents a methodology for converting the concepts and weights of cognitive maps into parameters and scenarios of perturbations of the economic and mathematical model of the fuel and energy complex implemented in the SP "INTEC-A" and presentation of the results of model calculations in the form of cognitive maps. The methodology describes the integration of cognitive and mathematical modeling for the computational experiment.

Dangerous natural phenomenon, which can cause significant damage to power production in Siberian Federal District, is low water in Angara-Yenisei cascade of hydroelectric power plants. Electric power generation at these stations makes on average 88 thousand MWh per year or 46 % of total electric power generation in Siberian power system [3]. As a demonstration example is considered a threat of low water, the consequence of which is the reduction of electricity generation by HPPs by 0.976 billion kWh per year.

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SPECIFICATION OF CONCEPTS AND EDGES FOR INTEGRATION OF SOFTWARE PACKAGE “INTEC-A” AND COGNITIVE MODELING

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Software package (SP) “INTEC-A” is relevant in predictive studies of energy sector in view of requirements of energy security. Such research consists in forecasting the functioning and development of energy sector in generally under conditions of possible extreme situations in energy, assessing the state of energy sector and energy systems in this context, choosing possible alternatives for the development and functioning of energy sector and measures to prevent extreme situations or reduce their negative impact [1]. The research traditionally invokes economic and mathematical models of energy sector and describes multiple scenarios. SP “INTEC-A” implements one of these models. The TRV model is a model of fuel and energy resource of Russia by the subjects under conditions of possible disturbances [2]. It forwards to solve the classical optimization problem of linear programming.

The presented research to reduce the load on the expert during multivariate analysis intends to semantic modeling and cognitive modeling in particular at a qualitative level. The authors of the work [3] previously proposed the integration of cognitive and mathematical modeling, identified the main tasks of integration. One of the tasks is to develop a specification of concepts and edges of cognitive maps for the joint use of the SP “INTEC-A” and cognitive modeling. Cognitive maps display the results of computational experiments performed using SP “INTEC-A”. The report presents aspects of knowledge structuring for the construction of such cognitive models. Energy facility, indicators, threats and measures to ensure energy security regard as types of concepts with attributes. TRV model variables characterize the concepts of energy facilities whereas previously developed ontologies are the basis to construct threats and measures to ensure energy concepts. The method of indicative analysis provides formation of concepts of energy security indicators. The report presents aspects of edges set construction between types of concepts described above. The proposed cognitive maps have no weighting factors or functions on the edges. This gives reason to refer the cognitive maps obtained to quasi-dynamic sign maps.

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EXPLORATORY DATA ANALYSIS AND MACHINE LEARNING METHODS FOR RESEARCHING TIME SERIES

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One of the tasks of digital twins is to predict the behavior of an object in different situations. Machine learning and artificial neural networks are used to solve this prediction problem, but exploratory data analysis (EDA) is required to handle the data correctly. As an example, weather characteristics will be considered as a source of energy radon concentration and atmospheric pressure as precursors of an earthquake.

EDA is a preprocessing and analysis of basic data properties to find dependencies, distributions, and anomalies in the data, as well as to test hypotheses and build initial models. The analysis uses data visualization tools to simplify the perception and evaluation of the resulting information. Different purposes require different types of visual information. In the example presented, the main purpose is to find relationships between data, to find gaps and anomalies. For these purposes, lineplot and heatmap, and others will be used.

To analyze the dependencies between the data, learning with a teacher was used as a section of machine learning. The presented section is used to learn the dependencies between object and response pairs, where in the example the object is atmospheric pressure and the response is radon concentration. The main methods in the work were K-Neighbors Classifier, Linear Discriminant Analysis, Gaussian Naive Bayes, Support Vector Classification, but these methods gave low accuracy of about 5%.

To build a predictive model we use convolutional neural networks which are able to find correlation based on relations between data. Also recurrent neural networks that are able to continue the time series based on historical data. RNNs, unlike convolutional networks, are designed to process a sequence of values and are scalable to long sequences.

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DEVELOPMENT OF A WIND FARM DIGITAL TWIN USING THE UNITY ENVIRONMENT

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The last decades of computing technology development were accompanied by a significant increase in computing power of computers (more than dozens of times), which opened up opportunities for more detailed modeling of objects and their visualization. Currently, for these purposes it is possible to use environments for the development of 3D-applications, which help to significantly reduce the development time of the finished product.

3D application development environments now offer a wide range of tools for working with graphics. The benefit of using them is that the researcher gets a ready-to-use quality tool with a large number of features. In this regard, there is no need to write most of the basic program code, which is responsible for graphical visualization of primitives, sound accompaniment, interaction of objects in accordance with the program code, compliance with physical effects and laws. As a result, you can concentrate on the implementation of your objects and their interaction logic.

A significant advantage of using environments to develop 3D applications is the ease of visualization of the modeling process and its results. It is worth noting that the results of the simulation can be difficult to interpret to an untrained person, also it may be difficult to change simulation parameters. In terms of accessibility of model making and processing of simulation results, applications that provide full visualization of the simulated object and allow a person who has minimal knowledge in programming to create models that simulate various technical processes are more promising.

The report describes the approach to the development of a digital twin wind farm using the development environment for 3D applications (using the example of Unity). The mathematical model used to determine the parameters of wind farm operation is described, special attention is paid to the design of the architecture of the digital twin.

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DIGITAL TWIN AS A MEANS OF INCREASING CYBER-PHYSICAL RESILIENCE OF SMART ENERGY SYSTEM FACILITIES

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At present, one of the priority areas for the development of the energy sector is intellectualization. Intelligent (Smart) Energy Systems (SES) is a combination of a technological subsystem and an information and control subsystem, into a united system that monitors and automates the operation of all participants based on bilateral information exchange. But, besides obvious benefits, intellectualization makes energy facilities more vulnerable to cyberattacks (CA), which in turn can lead to significant damage. To reduce vulnerability to CA s, as a means of increasing the cyber-physical resilience (CPR) of SES facilities, digital twins (DT) of power facilities can be used.

DT is a virtual representation of an object or system that spans its entire life cycle, is updated based on real-time (RT) data, and uses modeling, machine learning to help make decisions. DT is a key element of such concepts as SES [1] and Energy 4.0 [2]. To date, it is known about a large number of successfully implemented projects for the introduction of a DT at SES facilities. In 2016, Siemens, together with Fingrid, introduced the digital model ELVIS (Electric Verkko Information System), which supports the management of energy assets and operations [3]. In 2021, a prototype of the Singapore Power Grid Digital Twin was launched [4]. Key benefits of the Grid DT include improved network configuration planning analysis and remote monitoring of asset condition, which saves manpower when conducting extensive physical inspections In 2016, the Russian company "National Bureau of Informatization", specializing in the development and integration of software, announced the successful implementation of 28 DT for the CHP plants of PJSC "T PLUS" [5]. With this project, an optimization of boiler units for three types of fuel was performed at some stations. Also based on the optimization results the calculation of planned values of technical and economic indicators was implemented.

DT allows one to increase the cybersecurity of physical object [6] and, in particular, its cyber-physical resilience. CPR is the ability of the system to contain local cyber-physical impacts, identify and delay the flow of corrupted data within the affected area, without further transmission and use of this data in managing the physical subsystem in order to avoid emergencies up to the development of major system accidents. An increase in CPR is possible due to the following functions of the DT – Intrusion detection; Anomaly detection; Diagnosis of violations and condition monitoring; Virtual Commissioning; Predictive analytics.

Intrusion detection. In [7] a CPS Twinning framework is presented, which can be used to detect extraneous intrusions by comparing model data and data obtained from a real object in real-time.

Anomaly detection. In [8] the authors conclude that the use of digital data makes it possible to identify potential anomalies caused by malicious cyber-physical intrusions using data from sensors and machine learning. Similarly, the architecture of the digital data center is presented [9], using the formal specification language, signal temporal logic (STL). This architecture of the DT allows anomalies to be detected in each process signal if any STL specification is violated.

Diagnosis of violations and condition monitoring. The service-oriented DT becomes a virtual representation of the CPS, providing ubiquitous access to knowledge through applications and services. This model can provide remote monitoring through various services such as fault diagnosis and state monitoring service, prognostics and scenario optimization service, manufacturing scenario execution service and the notification service. The same model allows for on-site monitoring with all of these remote services, as well as the "Augmented Assistance & Tutoring Service" [10]. A similar type of model was developed by STEP Tools Inc. [11] called "Digital twin machining application", which allows RT remote monitoring through web applications to access all data in the digital storage.

Virtual Commissioning. The six-layer architecture of the DT [12] consists of a practical layer capable of performing the role of virtual commissioning. The digital model can manage the sequence of process events without data flow between physical and digital objects. This is important when rapid prototyping and testing is needed. For example, detecting misconfiguration when testing in a virtual environment before integrating with a real environment, detecting manipulation by an attacker when a physical device is not consistent, performing system tests on a virtual model and simulations [7]. This approach can lead to increased safety.

Predictive analytics. The DT-based predictive maintenance software takes RT data and analyzes it against historical data about the failure modes of physical models, their criticality, their weak parts and scenarios in which the physical model can be infected [13]. The future state of the physical twin can be predicted before any failure occurs by predicting errors and problems in the hardware [12]. In [14], a new model performs data analytics (descriptive, diagnostic, predictive and prescriptive analytics) to identify error patterns and make decisions.

This work is aimed to determine the DT capabilities, which can improve the CPR of modern technical facilities. Next, it is necessary to analyze the most promising and suitable approaches for creating an energy facility DT. The main direction of further research is adaptation of these approaches to the features and conditions of the functioning of SES will allow developing a methodology for using a DT to increase the CPR of those facilities.

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THE ACCURACY ESTIMATION OF FOREST FIRE RISK PREDICTION BASED ON CBR APPROACH

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Natural and man-made fires remain a serious problem worldwide. They devastatingly impact the composition and structure of fauna and flora, air quality, soil, and water [1]. Effective monitoring and forecasting of their spread is the basis for planning and decision-making, including using remote sensing methods [2]. This task is particularly relevant for the Irkutsk region, as the forest cover on its territory has the highest percentage (78%) among the subjects of the Russian Federation, with fire-prone coniferous plantings (more than 90% of the total forested area) predominant [1].

The report considers the main stages of solving the task of predicting the risk of forest fires using the case-based reasoning (CBR) approach. They include pre-processing of data, formation of a precedent model, creation of a prototype of a precedent expert system, and analysis of the forecasting results. The main results of the study are: a precedent model of compact representation of information on weather conditions, vegetation type in terms of the risk of a forest fire; database of forest fires in the Irkutsk region from 2017 to 2020; and an assessment of the accuracy of the proposed method.

The accuracy assessment was performed on CBR results using datasets: on forest quarters with their characteristics of forest vegetation zones; weather information on the date of actual forest fires during the summer of 2020 and fire danger classes based on weather conditions; and historical data on forest fires in 2019. The result of the forecasting is an assessment of the probability of a fire on the territories of the forest quarters: from the unlikely to the most likely. Therefore, in all the quarters under consideration, a high risk of fire was expected as a result. The presence of precedent with similarity 0.8-1 determines the most likely risk of fire in the quarter. As a quantitative assessment of forecast accuracy, the ratio of the number of events with high risk (P) to the total number of events (N) is used. The accuracy of the approach considered was 87.4%. The approach was approved for individual forestry, specifically the Bodaibinsky and Kazachinsko-Lensky forests. The evaluation results showed that the use of the precedent approach can be considered as an initial stage for further deeper research using different methods (data intelligent analysis, neural networks) for a more accurate prediction.

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DEVELOPMENT OF PRACTICAL APPROACHES TO THE DETERMINATION OF REFERENCE INTERVALS BY INDIRECT METHODS

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Making an accurate diagnosis depends on the correct interpretation of the results of laboratory studies. This requires information about the reference interval (RI), the method of analysis, threshold values, data for calculating the critical difference in the values of indicators during repeated studies. The availability of this information facilitates the early detection of diseases, objective monitoring of changes in biological indicators during treatment, which has a positive effect on health and quality of life.

In accordance with the established requirements, the laboratory must determine biological RI, as well as revise them when analytical or preanalytical procedures change. The question of assessing the adequacy of certain RI is related to the magnitude of the analytical bias of the methodology, the characteristics of the examined contingent, as well as the tasks assigned to the laboratory by clinicians. For example, when examining representatives of different races, in sports medicine, residents of mountains or in geriatrics will have their own specific comparison groups. The simplest method of implementing RI in the transition to a new technology involves the transfer of previously established boundaries to a new population. However, this option does not take into account all the variety of differences between the laboratory performing specific studies and the sources that have established RI. An alternative option would be to develop RI for a specific laboratory, taking into account gender, age, biological cycles, physiological state and other characteristics of the subject.

Approaches to the definition of RY are divided into direct, recommended by the IFC (International Federation of Clinical Chemistry and Laboratory Medicine), and indirect (indirect). It should be noted that if the technology of RI transfer is quite simple and can be performed in a clinical laboratory, then the calculation of RI by a direct method with a set of laboratory results for a group of healthy individuals requires a lot of organizational and economic costs. The peculiarity of indirect methods for determining RI is that they are based on the analysis of the accumulated array of a large number of patient data; these methods are currently being intensively developed, and their application presupposes a good command of the mathematical apparatus.

The purpose of the study under discussion is to find an instrument acceptable for practicing physicians to calculate the RI of laboratory parameters based on the analysis of the patient data array (Big Data). The comparison of the previously proposed methods and the search for new approaches to solve the following tasks is carried out: sampling estimates, analysis of its homogeneity to exclude a bimodal distribution; assessment of the "normality" of the distribution; selection of methods for calculating the boundaries of RI; analysis of the acceptability of the calculated RI for natural emissions.

To fulfill the tasks set, a set of computational software tools is being implemented, based both on traditional approaches of mathematical modeling and on new methods related to the arsenal of artificial intelligence - neural models, Shepard's methodology, time series approximation and others.

APPLICATION OF VIRTUALIZATION IN CONSTRUCTION OF DIGITAL TWINS

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When developing digital twins, several goals are taken into account. Firstly, digital twins are aimed at working with real existing objects to manage processes and predict work. And secondly, the ideology of using digital doubles can help in the design of objects.

Just within the design of objects there is a question of simulation modeling, and here two elements become important: virtualization and visualization. The report will consider the main factors of virtualization in the development of digital twins on the example of the development of a DT of renewable energy sources.

Having a digital twins structure that includes mathematical models, a system for collecting and processing information, a system of control actions, it is possible to build a data center that can simulate the behavior of a real object using both real and emulated data.

The technology of initial analysis when designing the construction of real objects can be carried out using virtualized digital twins.

Thus, when designing renewable energy sources in different territorial areas, the necessary information is first collected (weather data, solar radiation intensity, possible number and type of consumers), then various layouts of devices (wind generators, solar panels, battery stations, diesel generators, consumers) are collected. The next stage is data emulation using machine learning methods (in particular, LSTM networks are used). After that, simulation modeling can be carried out and a decision can be made on the optimal composition of the digital twins.

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RISK ASSESSMENT OF THE DEMAND-RESPONSE AGGREGATOR

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The functioning of the DR-Aggregator [1] is proposed to be considered as a business-process [2,3]. This makes it possible to apply to it the requirement of Business Continuity (BC) [4] in conditions of adverse external influences. The goal of the business is a material result, and failures in the functioning of the business entail certain risks that lead to damage. Therefore, the BC is based on the availability of proactive (preventive) measures to protect the business and a mechanism for its recovery. The purpose of the DR-Aggregator as a business-process is to release free capacity from consumers and receive remuneration for the supply of released capacity to the wholesale market.

At the same time, the purpose of the DR-Aggregator as a demand management mechanism is to coordinate the interaction of consumers [1,2], who are energy facilities and can be represented as cyber-physical systems (CPS) [5]. In this case, it is necessary to take into account information and physical risks in adverse external conditions. Any system or object are not perfect and have some vulnerabilities, when detected, threats arise. If the threat is realized, then the risk turns into damage.

In [6], the relationship between the information security management system (ISMS) (respectively, and the IT-infrastructure management system) and the business security management system (BSMS) is considered. Both systems use risk analysis, but, as indicated in [6], in ISMS this analysis is fulfilled prophylactically, and in BSMS is carried out during emergency processes from the point of view of the business continuity process. [7] discusses what cyber risk is - the first step towards understanding the importance of cybersecurity by business, as the risk of financial losses. The area of cyber risks includes both the digitalization of business and the dependence of security areas on each other, for example, physical security on the Internet of Things. At this stage, it is already necessary to address the CPS problem and their security, especially when each participant of the DR-Aggregator is interpreted as the cyber-physical systems [8].

In [9] it is indicated that in the field of information security, reactive protection mechanisms (reaction to an accident) are very common, and they are recognized as quite effective. If we talk about the more complex and multiple interaction of digital technologies and CPS, it becomes obvious that reactive mechanisms are less effective and there is a need to support proactive (preventive) mechanism.

Thus, the following task is formulated: how to combine two qualities of a DR-Aggregator (business and cyber-physical nature) and develop common proactive and reactive measures to protect it in the face of adverse external influences. To do this, it is necessary to establish a causal relationship between the cyber-physical structure of the DR Aggregator, its vulnerabilities, threats of intrusion into the CPS through vulnerabilities (cyberattacks) and potential damages. It is known that the structure of an object, vulnerabilities and threats, as a rule, can be represented using an attack tree. The implemented attack and damage can be illustrated using the event tree. How to unite those trees? To trace the causal relationship of an emergency event and develop proactive and reactive protection measures, a bow-tie method exists [10]. Figure 1 shows such a "butterfly": in the center there is the main object, the left wing is the structure of the object and barrier (proactive protection measures), the right wing is the consequences of an adverse event (cyberattack), barrier

(proposed reactive protection measures) and a damage caused to the affected components. That damage must be determined.

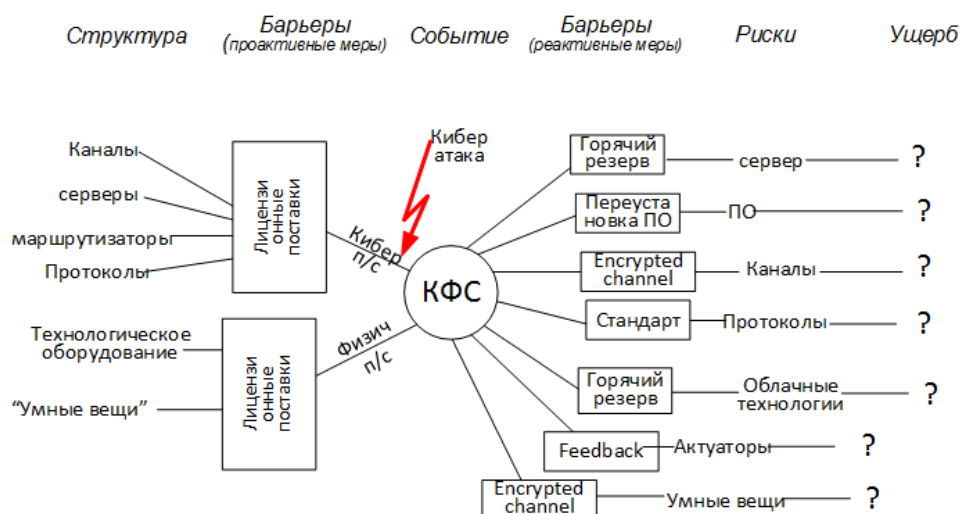


Fig. 1. Proactive and reactive measures to protect the CPS from cyberattacks

In the paper, as tools “before” and “after” an emergency event, it is proposed to use the “bow-tie” method and a mathematical apparatus of logical-probabilistic analysis.

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SYSTEM FOR PROCESSING AND VISUALIZING THE RESULTS OF THE DATA OF SOLAR PANEL STAND MONITORING

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To carry out monitoring the output indicators of solar panels, an experimental stand was installed at ISEM SB RAS. It is used to determine the optimal angle of inclination of panels, substantiate the feasibility of an automated sun-tracking system and verify regression models for determining solar radiation. For monitoring and offline data recording, there is proprietary equipment that has a high cost and limited functionality.

The authors have developed a counter – device for monitoring energy indicators in a DC circuit based on an Arduino microcontroller. To compare the options for installing solar panels, it is necessary to compare their capacities under the same conditions. To calculate the power, it is necessary to measure the current and voltage. The current readings are read by a shunt ammeter, and the voltages are read by a voltage divider. The developed Meter is assembled on a factory board with the possibility of modular connection of components. The data is automatically upload to the server by using a Raspberry Pi 3 single-board computer, which works as an intermediate communication center and receives data via Bluetooth protocol. The data is saved in a text file and transferred to the cloud storage on a local server.

The Meter collects data with an average value in 1 hour, transmits it to the server and duplicates it to a local SD card for backup in case of failures of wireless transmission of information. The received data is saved in *.csv format, which makes it easier to further view and process. In the theoretical calculation of solar radiation by climatic indicators using regression models with hourly resolution data, therefore, when verifying models, the resulting array of measurements does not need additional processing. The calculation of solar radiation depends on weather conditions such as cloud cover, temperature, humidity, etc. To get weather data, we used an open service rp5.ru. Rarely found on other services, but the necessary criteria for cloud cover are available on this service: the type of clouds (cumulus, layered, etc.), the height of the lowest clouds, the type of high and cirrus clouds.

To visualize the data obtained, a Web application based on the JavaScript language is being developed. A number of technologies are used in the development: React JS framework, ChartJS library, Redux Toolkit and others. At this stage, the data is connected from the local directory and converted into JSON objects for further processing. The received data is displayed both in the form of initial readings and in the form of power and solar radiation per square meter processed by the service (Fig. 1).

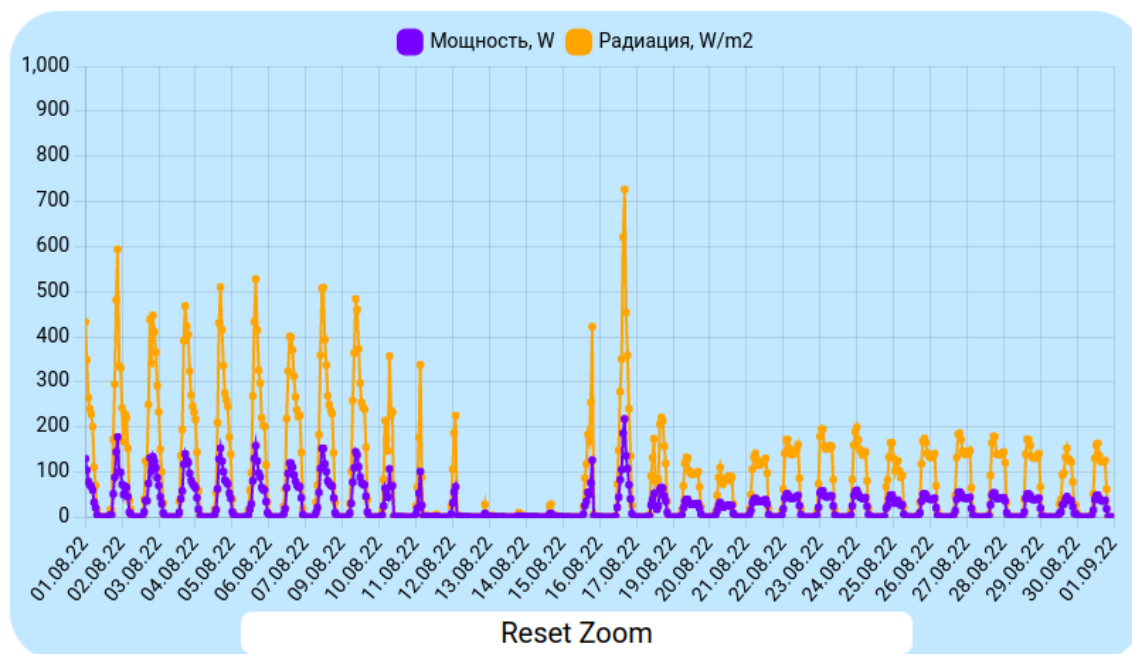


Fig. 1 Processed data on Web application

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COMPUTATIONAL OPTIMIZATION TECHNOLOGIES AND APPLICATIONS

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The report discusses the computational technologies proposed by the authors, focused on solving optimization problems of the various classes. The family of corresponding software systems is implemented with the project called OPTCON. The first tool implemented within the framework of the developed standards is the OPTCON-I, which is focused on finding the minimum of functionals in the optimal control problems; the computing server with remote access is implemented as part of the OPTCON-II; OPTCON-CL is focused on solving optimization problems for atomic-molecular clusters [2], including the problems of the large dimensions – huge-scale optimization problems (up to 10^8 variables) [3]. Software packages have been developed for solving problems of phase estimation – constructing approximations of the reachable sets of controlled dynamical systems and solving functional-differential equations of point-wise type.

The developed software allows us to study a lot of problems from various application areas. Among them are the optimization problems of the controlled dynamical systems: problem of investment programs of the Republic of Buryatia (economics), the optimization problem of the route of the mobile robot and the optimal control problem of the industrial manipulator (robotics), problems of the optimal design of the composite structures (materials science), the problem of the implementing quantum logic operations in nano-structures with quantum dots [4] (nanophysics), the problem of the seismic stability analysis buildings (seismology), as well as the finite-dimensional optimization problems from the fields of technical ecology, medicine, computational chemistry and others: the problems of analyzing the morbidity of the population of the large industrial centers and the territories of new development, the problem of the digital signal processing, the problems of optimization of the atomic-molecular clusters of Morse, Sutton-Chen, Keating and others.

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DEVELOPMENT OF INFORMATION - SEARCH SYSTEM FOR THE PREPARING THE ISSUE AND WORKING WITH THE ARCHIVE OF THE REVIEWED SCIENTIFIC JOURNAL

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The journal "Information and Mathematical Technologies in Science and Management" has been published at the ISEM SB RAS since 2016, in 2022. it was included in the list of scientific journals of the Higher Attestation Commission (HAC), in which the publication of the dissertation research results is recommended.

After including the journal in the HAC list the number of articles sent to the editorial office increased. The current methods of organizing work on issues have become inefficient, the workload on editorial staff has increased. In addition, authors do not have the ability to track the current status of their articles, only by writing a direct letter to the editors. To eliminate these problems, it was decided to develop our own information-search system (ISS) to organize the preparation of a peer-reviewed scientific publication.

The main function of this information-search system is to increase the efficiency of organizing work on the next issue, in particular, to simplify the control by the editors of the most stages through which the article passes and to automate reminders about dead-lines for reviewing and editing articles. The use of ISS minimizes errors caused by human factor. The plans also include the implementation of the ability for authors to track the stages of processing by the editors of the submitted articles, such as: submission to the editorial office, reviewing, checking by technical and chief editors, printing and uploading to electronic resources.

In addition to working on future issues, it is expected to facilitate work with a database containing information about all articles published in past issues of the journal: online search for articles by queries (by author's name, by article title, by keywords, by year of publication, by issue number, by the name of the organizations the authors work in. This ISS can also be useful for searching of reviewers who can be selected among the authors of past articles by keywords.

Thus, the development of the proposed system will be useful both in organizing the preparation of the next issues, and for working with the articles archive.

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CATEGORICAL STRUCTURES OF SYSTEM META OBJECTS

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In the complex of scientific and theoretical works of academician V.S. Stepin “Theoretical knowledge. Structure, historical evolution” presents the original concept of the structure and genesis of theoretical knowledge, developed by the author in the 1960s-90s within the framework of the Minsk Methodological School of the Belarusian University.

The content structure of the theory is determined by the system organization of abstract objects – theoretical constructs. Special subsystems are distinguished in them, which in their connections form theoretical models of the reality under study. Theoretical laws are formulated with respect to these models. Models form the core of the theory, theoretical schemes. In the developed theory, the author proposes to distinguish fundamental and particular theoretical schemes. With respect to the latter, laws of a lesser degree of generality are formulated, derived from the basic ones.

Theoretical schemes interact with the scientific picture of the world and empirical material and are displayed on them. The results of this mapping characterize the abstract objects of the theory in terms of the picture of the world. The connections of the mathematical apparatus with the theoretical scheme, displayed on the scientific picture of the world, create the possibility of semantic interpretation, and the connection of the theoretical scheme with experience - empirical interpretation.

Considering science in dynamics, Stepin shows that the strategy of theoretical search is changing in this process. These changes imply the transformation and restructuring of the foundations of science. The very restructuring of the foundations of science appears as a scientific revolution.

Stepin traces how the prerequisites for theoretical knowledge arise in traditional cultures. The transition in science led to the formation of scientific theoretical knowledge. Science, having arisen in the culture of technogenic civilization, according to Stepin, has its own distinctive features from other forms of human relations with the world.

Each branch of knowledge has relative autonomy and interacts with others. The foundations of science act as a special link that simultaneously belongs to the internal structure of science and infrastructure, defining the connection of science with culture. Stepin's works present a scientific picture of the world about nature and society, in which invariant characteristics of scientific character adopted in this historical epoch are given.

A promising direction for the development of the academician's ideas is the idea of creating multi-level meta-structures in various fields of scientific and practical activity.

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