Technique for Development of Information-Analytical Processes in Cyber-Physical Systems Based on Neural-Fuzzy Petri Nets

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Abstract

The article is devoted to the technique for development information-analytical processes in cyber-physical systems based on the proposed variation of neuro-fuzzy Petri nets, which includes generalized stages of formalization, modeling, analysis and modification of information-analytical processes. The proposed technique allows to diagnose and determine the reachability of various events of information-analytical processes, their cyclicality, as well as to eliminate the bottlenecks of processes. This, in turn, allows to identify and avoid complicating processes, creating unnecessary processes, reduce the number of false messages about the inadmissibility of their execution, and as a result, prevent possible errors in the development of information-analytical processes. The proposed technique can also be used to monitor the status of information-analytical processes in cyber-physical systems and control them.

Keywords 1

Ontology, Cyber-physical systems, Information-analytical processes, Neuro-fuzzy Petri nets

1. Introduction

Currently, for various cyber-physical systems operating in conditions of uncertainty, as well as in conditions of close interaction of the main technological and information-analytical processes, there is an acute problem of increasing the efficiency of developing information-analytical processes, which include the processes of collection, processing, generalization, evaluation and predicting the state of systems, developing sound management decisions and assessing their feasibility.

The ontological approach [9] is the basis for the implementation of modern scientific and technological solutions when adapting information-analytical processes (and the main processes in cyber-physical systems as a whole).

Various approaches are used in development of information-analytical processes in cyber-physical systems. Within the traditional approach, even at the design stage, the requirements for the main and information-analytical processes of the system are rather strictly set [5]. Information-analytical processes are "embedded" in the main processes of cyber-physical systems in the form of program code.

The advantages of this approach include the high efficiency of process design. However, maintaining these processes up to date requires significant financial costs. This is due to the high complexity of implementation of the necessary changes related to the influence of the external environment, or changes in internal systems, as well as increased risks of committing such changes during the operation of the system. Thus, a decision is often made to refuse improvements and move to a new version of the system. Significant shortcomings also include the "semantic gap" between experts, architects and developers of information-analytical processes. In addition, as a rule, seamless "migration" between versions is not possible (Figure 1).

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A constant change in external factors and requirements for the implementation of the main processes, a steady increase in the volume of heterogeneous information from heterogeneous sources, provides increased requirements for the quality and speed of adaptation, especially information-analytical processes.

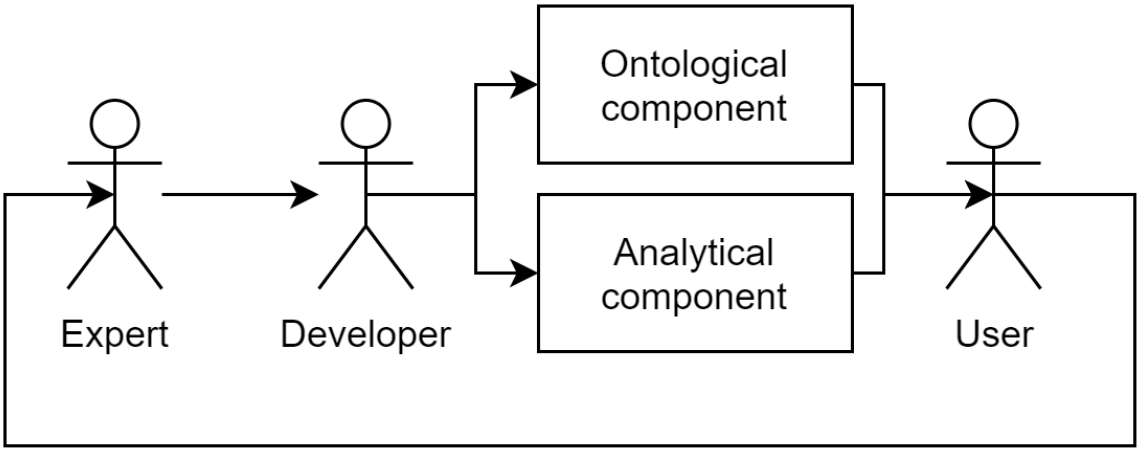

Figure 1: The traditional approach to the development of information and analytical processes

A promising approach to the development of information-analytical processes in these conditions is their creation without the involvement of developers. Developers create a software-instrumental environment based on the ontological approach (tools of such an environment can directly operate with informational entities of information-analytical processes), and experts, using the capabilities of the software-instrumental environment, implement the basic algorithmic constructs and develop information-analytical processes themselves [7].

The main advantage of this approach is the eliminating of the “semantic gap” be-tween experts, architects and developers of information-analytical processes. At the same time, the involvement of developers is only necessary in situations where the development of new or adjustment of existing environmental tools is required. Experts for the development of information-analytical processes should have only basic skills in development of program code.

Despite the fact that the financial and time costs for the implementation of the software and instrumental environment are significantly higher than for the implementation of information and analytical processes “embedded” in system’s program code, however, the life cycle of the software and instrumental environment can be several times higher, and the costs of developing new and modifying existing information-analytical processes are lower, and, as a rule, “migration” between their versions is feasible.

The article implements an approach consisting in the coordinated use of ontological and analytical components that form the software and instrumental environment for developing information-analytical processes in a cyber-physical system.

Petri nets [8], [10], [11], which have good graphic and expressive capabilities, have proven themselves to formalize, model, and design information-analytical processes oriented to a discrete-event nature. from a mathematical point of view.

For formalizing and designing information-analytical processes in cyber-physical systems, a variation of neuro-fuzzy Petri nets is proposed in the work, which adequately reflects the structure and dynamics of changes in the state of these systems, the nodes and transition rules of which are formed on the basis of the neuro-fuzzy basis of operations, as well as providing adaptive structural and parametric tuning when changing system and external factors based on machine learning algorithms.

2. Approach to the development of information-analytical processes in cyber-physical systems

To eliminate the “semantic gap” between analysts and developer, when developing information-analytical processes in cyber-physical systems, it is proposed to implement an approach consisting in the coordinated use of ontological and analytical components that unite in a software-instrumental environment for the development of information-analytical processes (Figure 2).

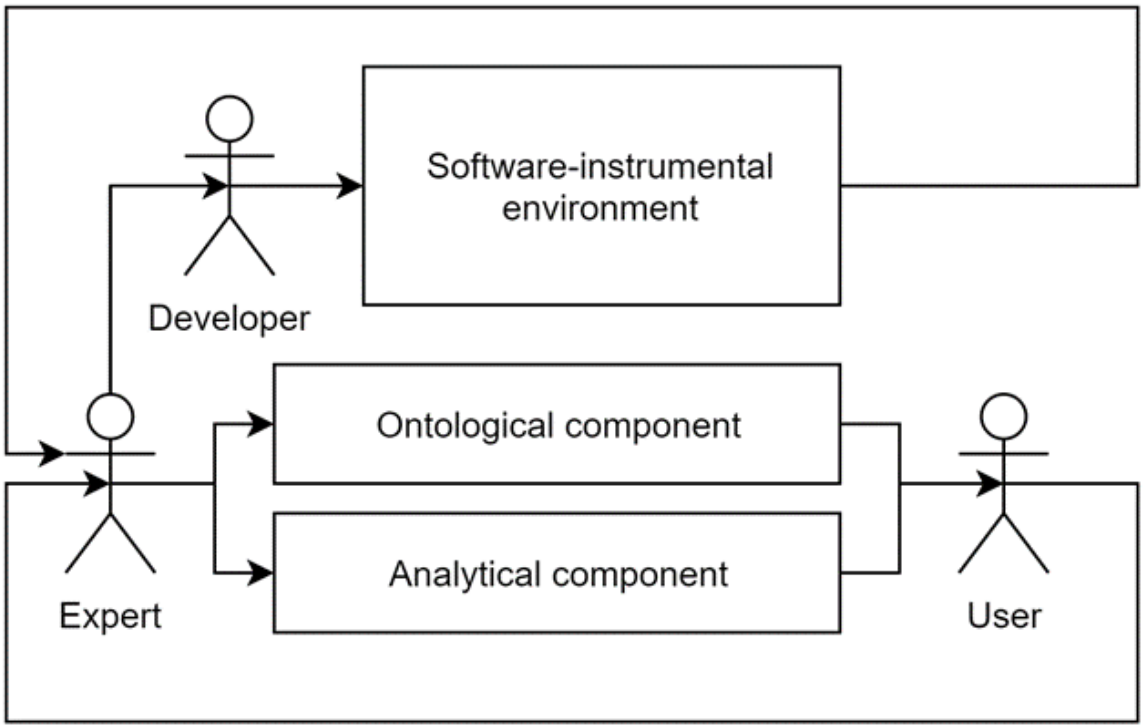

Figure 2: Illustration of the proposed approach to the development of information-analytical processes in the cyber-physical system

The ontological component should include tools for creating a quasi-hierarchical data structure of arbitrary nesting with the necessary additional relationships between hierarchy levels. Using this approach, an expert using the functionality of the soft-ware and instrumental environment, without involving programmers, is able to form the data structure himself and configure the necessary connections.

As a basis for organizing data storage, it is proposed to use an object-oriented approach, within which the subsystem "Class Tree" is formed.

The class, in accordance with the object-oriented approach, is a description of objects through their common attributes. Each attribute of a class has a name that is unique within this class, and is also characterized by the type of data that will be used to store the attribute value. In addition to attributes, the required number of methods that implement the actions and events characteristic of this class can be associated with a class to provide support for the system's response to information changes.

The analytical component should include tools for the development and modification of information-analytical processes, as well as tools that control both the data entering the system and the data produced by the system during its operation.

In cyber-physical systems, for their full functioning, there is not enough opportunity for input and output of information. A feature of systems oriented to use by engineering and technical personnel is the need to provide the user with analytical data obtained as a result of the functioning of information and analytical processes.

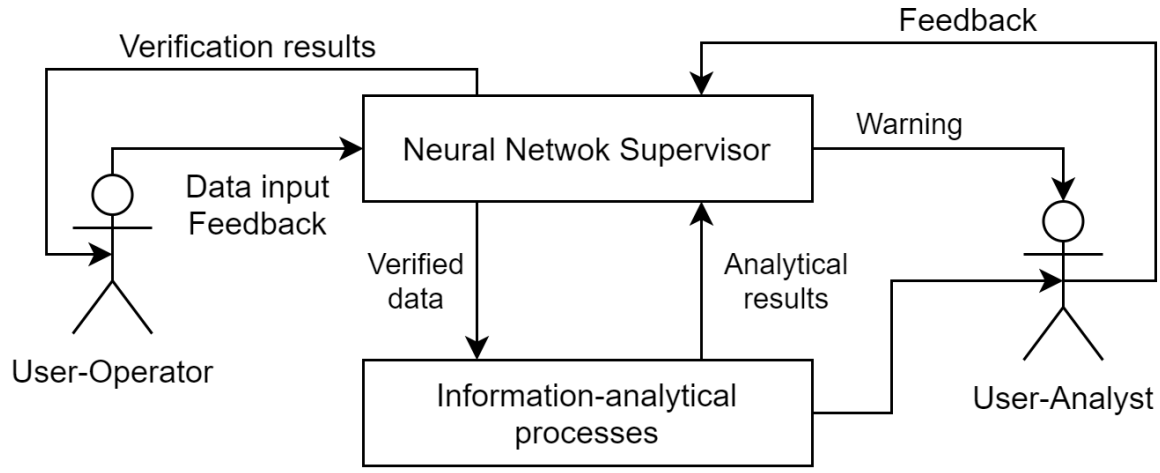

Figure 3: Analytical component

One of the possible solutions to the quality problem of source and analytical data in cyber-physical systems is the use of a neural network supervisor module that is able to verify data in real time. If there is a possibility of incorrect data entry or the appearance of incorrect analytical data, the supervisor reports this to the user involved in the information-analytical process. For additional training, the "Neural Network Supervisor" monitors the response of users to messages sent to them about possible errors. Also, training can take place under the supervision of a trained system user. Using the "Neural Network Supervisor" allows to improve the quality of the input data and strengthen control over the results of analytical processes.

3. The technique of developing information-analytical processes based on neuro-fuzzy Petri nets

Then several experts develop information-analytical processes for a cyber-physical system, difficulties arise in unifying the intrasystem specification of these processes. Experts solving the same problem can be guided by a different logic, use a different sequence of steps, etc.

As a result, when one expert needs to modify the process developed by another expert, he needs to spend time studying the code and discovering all the details of the process to be sure that the modification does not violate the logic of processes work.

To speed up the development of a new information-analytical process or reduce the time required to familiarize yourself with the process, it is necessary to convert the program code that implements the information-analytical process into a readable scheme. Using a schematic interface, you can significantly accelerate the development or modification of the structure of the information-analytical process.

As an example of the implementation of such a tool, we can consider the automatic construction of a flowchart of the process. The advantages of this approach include fast implementation, the ability to modify the information-analytical process directly on the diagram. The disadvantages include too cumbersome presentation of any large information-analytical process.

As an effective approach to solving this problem, a method for modeling and de-signing information-analytical processes in cyber-physical systems based on fuzzy Petri nets is proposed.

The proposed method includes generalized stages of designing, modeling, analysis and modification of information-analytical processes, which are iteratively repeated until the results meet the established criteria.

Figure 4 shows a fragment of the information-analytical process, designed on the basis of the neuro-fuzzy Petri network, built on the basis of the fuzzy neurons Kwan and Kei [1].

As a result of using the proposed method, diagnostics are carried out, the attainability of various events of the information-analytical processes, their cyclicality is determined, and the "bottlenecks" of the processes are eliminated. This, in turn, al-lows expert to identify and avoid complicating processes,

creating unnecessary processes, reduce the number of false messages about the inadmissibility of their execution, and as a result, prevent possible errors in the design of information-analytical processes.

The proposed method can also be used to monitor the status and control information-analytical processes in cyber-physical systems.

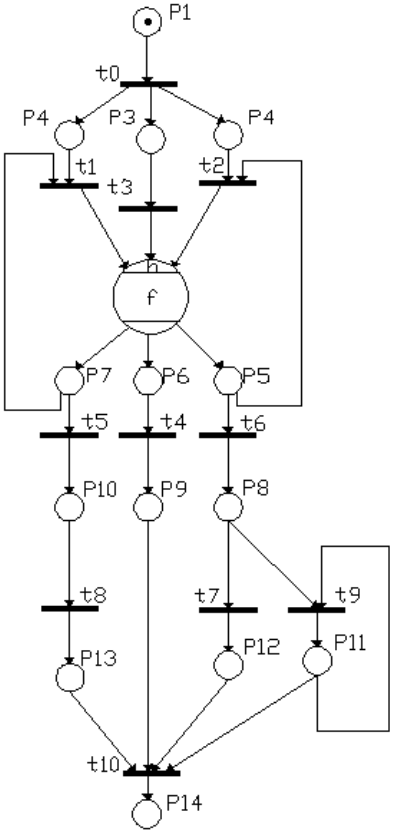

Figure 4: A fragment of an information-analytical process based on a neuro-fuzzy Petri net

4. Example of the technique implementation

Based on many years of experience and analysis of existing systems designed to ensure the industrial safety of the enterprise, the specialists of ZAO GIAP-DISTcenter set the following tasks:

- the expert himself must be able to set and adjust the logic for calculating analytical parameters;
- the values of the analytical parameters must be updated within 3 hours;
- the development of the logic of information-analytical processes should be visualized using diagrams and assistants. This is necessary to reduce entry.

Ontological and analytical components unite in the software-instrumental environment for the development of information-analytical processes.

The results of information-analytical processes can be processed both on-demand and in the background, using the subsystem “Background process queue”.

The GIAP-DIST CENTER industrial information system for collecting and processing data is a client-server application that can be accessed both from desktop computers and mobile devices, both from a local computer network and via the Internet, which significantly increases the flexibility of working with it and also increases the efficiency of access to the necessary data. [4]

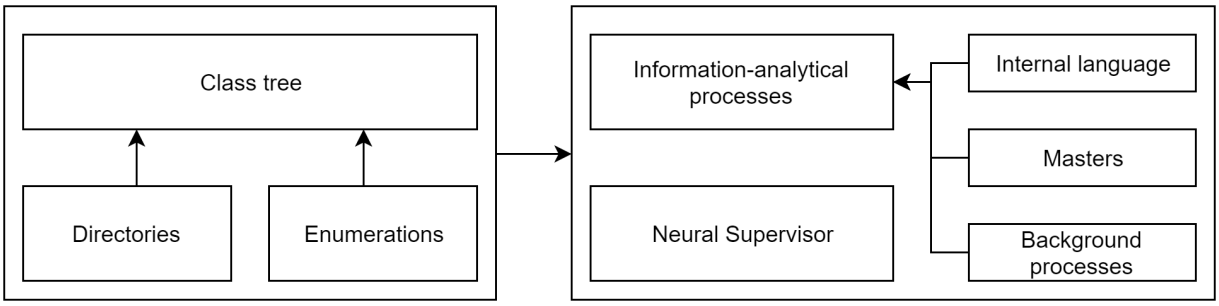

Figure 5: The components of the software-instrumental environment

A system has been developed that is capable of:

- store and process information;
- create and promptly implement changes in information-analytical processes and evaluate the result of these changes.

The subsystem "Class Tree" is responsible for the development and modification of the data structure. [8]

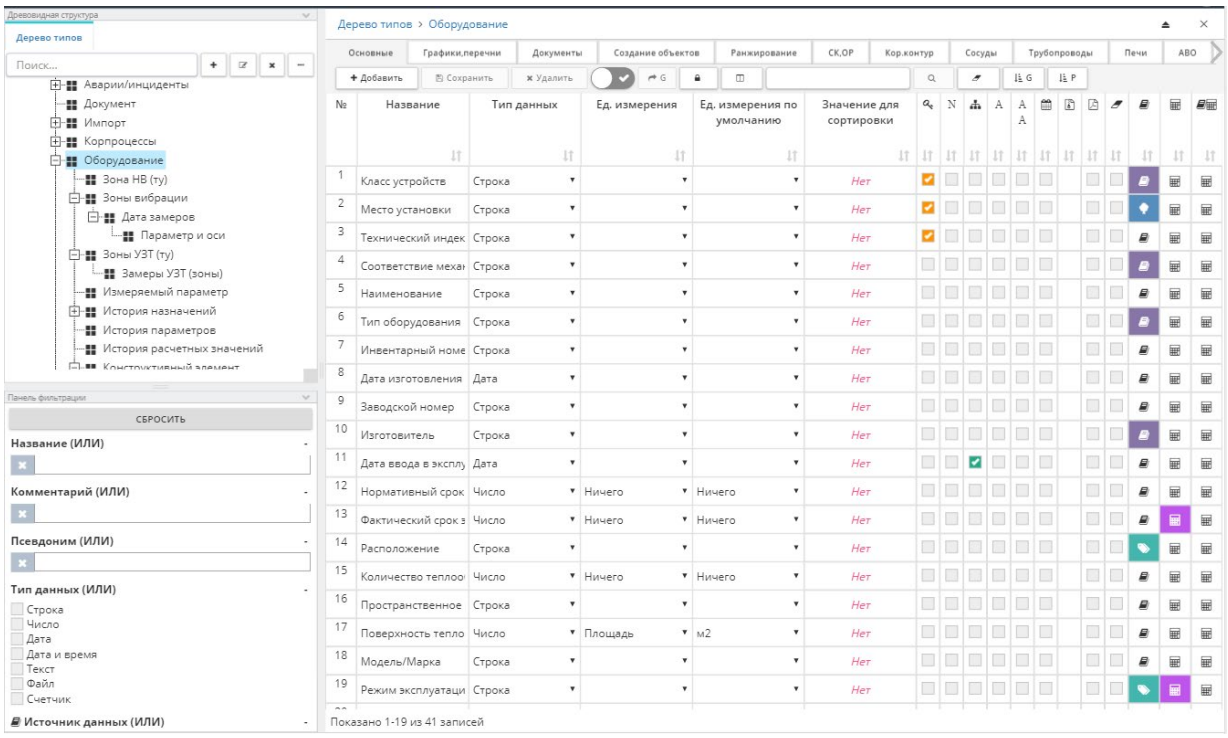

Figure 6: Class tree

An internal language for the description of information-analytical processes has been developed. This language is integrated with the ontological component of the system and the informational entities of the system are available for accessing directly from the language structures. The basic principles of linear programming and more than a hundred functions are implemented: mathematical functions; logical functions; date functions statistical functions; functions for working with strings; functions for working with documents Excel, Word; functions for working with informational entities of the system. The processing of the following data types has been implemented: date, with the ability to set the time; string, number, boolean, object, array, two-dimensional array. It is possible to create custom functions. [2]

An expert can set the logic of the information-analytical process using the internal programming language that implements step-by-step creation of an algorithm using the “wizards”. The expert has the opportunity to debug the process, as well as creating a block diagram according to the calculation code.

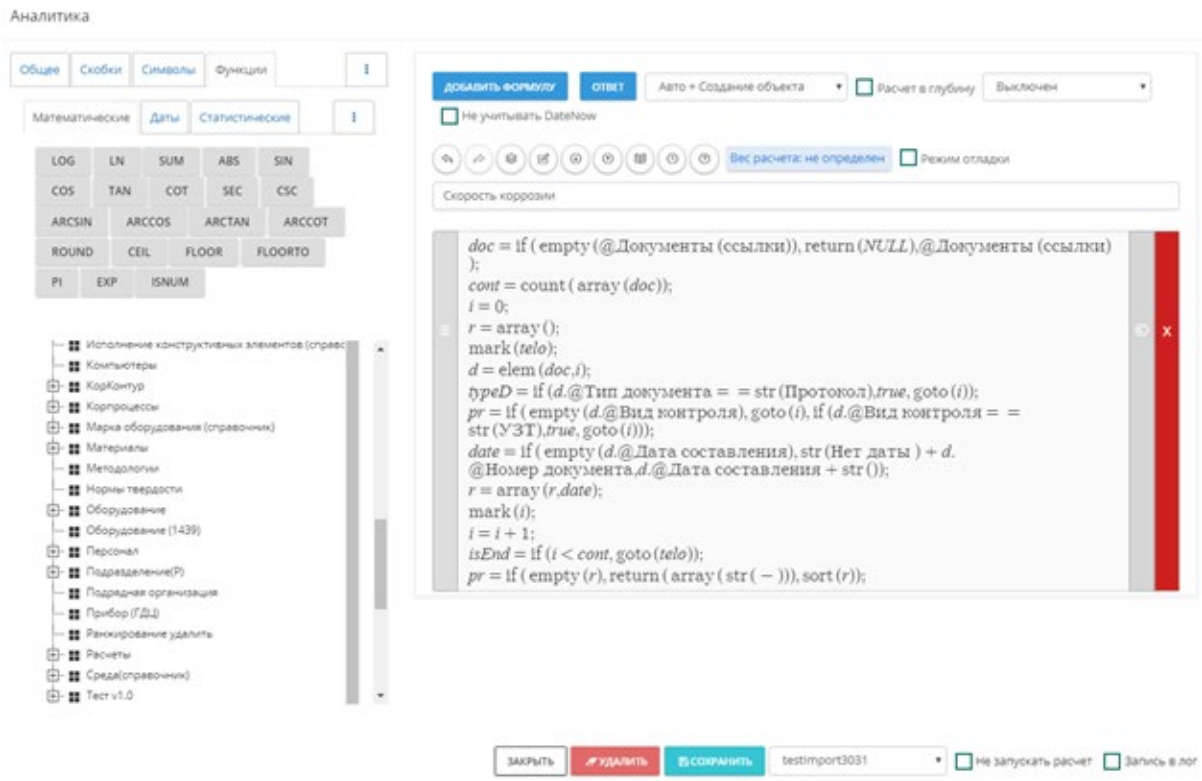

Figure 7: Internal language

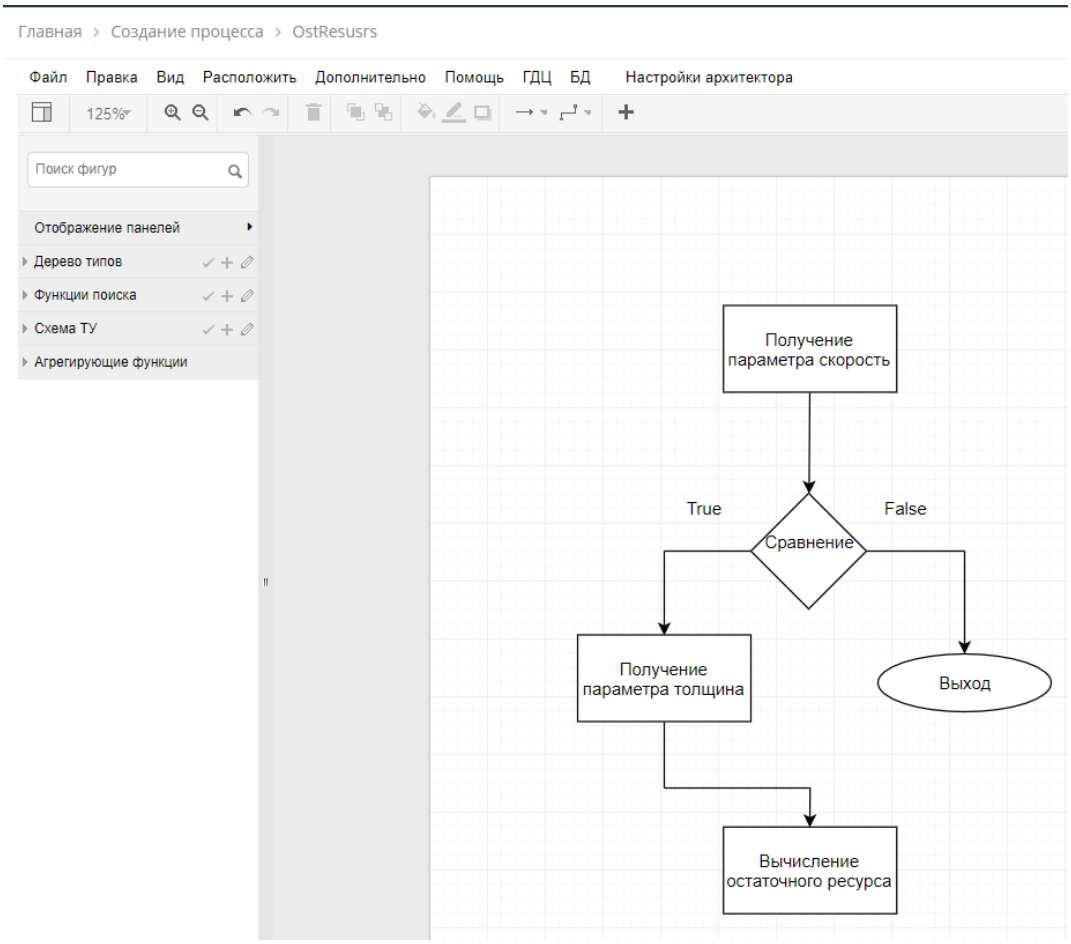

Figure 8: Information-analytical process development

The tool has been developed with the help of which an expert can create the structure of an information-analytical process. The tool is a block diagram editor; each block diagram is added using a wizard.

The proposed system also allows to monitor data changes in the cyber-physical system and initiate information-analytical processes; monitoring of system indicators required for analysis; determine the logical-temporal characteristics of the analysis procedure; Assess the complexity of the analysis and redistribute the priority of the processes.

Due to the use of the proposed method when processing a large amount of data, the efficiency of information and analytical processes has increased by an average of 20%. The load on hardware was reduced by an average of 7%.

5. Conclusion

The approach for development of information-analytical processes in cyber-physical systems, which unites the ontological and analytical components in form of the soft-ware and instrumental environment to eliminate the "semantic gap" between experts, architects and developers, is proposed.

For the formalization and development of information-analytical processes in cyber-physical systems, a variation of neuro-fuzzy Petri nets is proposed that adequately reflects the structure and dynamics of changes in the state of these systems, the nodes and transition rules of which are formed on the basis of the neuro-fuzzy basis of operations, as well as providing adaptive structural -parametric adjustment when changing system and external factors based on machine learning algorithms.

A technique is proposed for developing information-analytical processes in cyber-physical systems based on the proposed variety of neuro-fuzzy Petri nets, which includes generalized stages of formalization, modeling, analysis and modification of information-analytical processes, which are iteratively repeated until the results are meet established criteria.

The proposed technique allows to diagnose, determine the reachability of various events of information-analytical processes, their cyclicality, as well as to eliminate the bottlenecks of processes. This, in turn, allows to identify and avoid complicating processes, creating unnecessary processes, reduce the number of false messages about the inadmissibility of their execution, and as a result, prevent possible errors in the development of information-analytical processes. The proposed method can also be used to monitor the status and control information-analytical processes in cyber-physical systems.

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