The Diagnostics Methods for Modern Communication Tools in the Armed Forces of Ukraine Based on Neural Network Approach

Oleg Klymovych[1[0000-0003-3863-4984]1], Volodymyr Hrabchak[2[0000-0003-3569-0681]], Oleksandr Lavrut[3[0000-0002-4909-6723]], Tetiana Lavrut[4[0000-0002-1552-9930]], Vasyl Lytvyn[5[0000-0002-9676-0180]], and Victoria Vysotska[6[0000-0001-6417-3689]]

[1-4] Hetman Petro Sahaidachnyi National Army Academy, Lviv, Ukraine
[5-6] Lviv Polytechnic National University, Lviv, Ukraine
Vasyl.V.Lytvyn@lpnu.ua

Abstract. Timely diagnostics of the technical state and technical support of complex multifaceted systems that provide comprehensive automation of control processes requires the development of new, high-precision and reliable troubleshooting methods. Using one of these methods may include a neural network apparatus.

Keywords: Communication Tools, Diagnostics Method, Armed Forces, Neural Network.

1 Introduction

The level of preparedness of the Armed Forces of Ukraine (AFU) to perform assignment directly depends on the availability of state-of-the-art weapons and military equipment, but neither weapons nor any equipment will be able to ensure effective performance of combat missions without quality command and weapons. Modern control and communication systems must not only have high combat readiness, bandwidth, stability, mobility, accessibility, controllability, but also ensure trouble-free operation of the system and guarantee the quality of information exchange.

In recent years, the AFU have been expanding and improving the system of communication and the automatic control of forces. With the introduction of the widespread use of modern digital radio stations of the Harris, Aselsan and Elbit companies, the performance and functionality has increased, while the element base of electronic equipment has become more complicated [1-2]. The complexity of the equipment reduces the reliability of modern radio electronic equipment, which increases the likelihood of failure and complicates its search. The main contradiction of modern technology is that the more complex the instrument, the less reliable it is, the more accurate the measuring (diagnostic) tool, the more expensive it is. Thus, it is necessary to find the optimal ratio of parameters for measurement during diagnostics and accuracy class of measuring equipment.

The requirement of reliable operation of electronic equipment in the system of complex automation of control processes with the use of complex multifaceted systems, communication and automation tools (CAT) is especially acute. Therefore, the development of new, high precision and reliable faultfinding methods is becoming increasingly urgent. Considering the complexity of modern CAT, there is a need to automate the process of diagnostics for troubleshooting of equipment. One such method may be the development and use of a neural network apparatus [3-5].

2 Problem Formulation

In connection with the use in the Armed Forces of modern CATs, the improvement of their diagnostics should carried out based on the use of scientifically grounded criteria, modern diagnostic tools and the necessary specialized software. During the Joint Forces Operation (JFO), the search for expedient ways of creating and improving a scientifically grounded, economically feasible system of diagnostics of the CAT is continued, aimed at ensuring that the accumulated knowledge, scientific achievements work primarily to ensure national security and defense of Ukraine.

The purpose of the article is to increase the efficiency of the diagnosis of CAT by using a basic method of the neural network tool to assess the reliability and ensure the guaranteed quality of operation of the means of this class.

3 Related Work

A variety of research methods can used in the diagnostic system, which include theories of graphs, decision support systems, fuzzy sets, neural networks, multi-criteria optimization methods, expert methods [3-11].

According to the graph theory, it is possible to solve many problems in the field of economics, technology and many other areas of human activity. An abstract oriented graph is the basis for planning the actions of a human operator, changing the order of the sequence of his actions, performing various operations. The setting of network planning tasks begins with the identification of the nodal moments (events) of the operation, which determine the beginning and end of its main stages, after which the measures (work) are defined that lead to the implementation of each event and are accompanied by the cost of time and resources. Then the events and the corresponding stages of work are presented in the form of some logical sequence, namely a project graph that reflects all the ways to achieve the goal of the operation. In the general case, the network graph (Fig. 1) is a graph which nodes a_x is events and oriented arcs A_{xy} is the stages of work, $x \le y$. Thus in the graph any arc reflects only one stage of work, and in a case of a situation when two stages of work have the same output and input nodes (events) an additional fake stage of work is added, not related to the time and other resources.

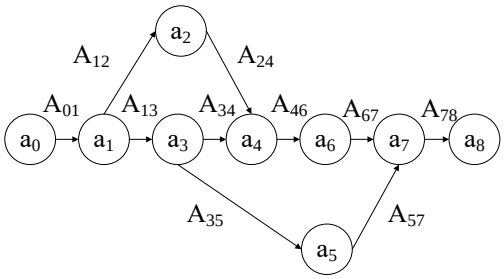

Fig. 1. Project graph

One possible sequence of events and workflows from the original event to the final event is the path of the project graph, and the path that has the maximum execution time of each of the work stages and the total execution time of the entire operation is a critical path. Decision Support Systems (DSS) are special interactive information systems that use hardware, software, data, model databases and manager work to support all stages of decision making in the analytical modeling process. In other words, DSS is a set of software tools that includes a set of different decision support algorithms, a model base, a database, ancillaries, and a management program (Fig. 2). The leading program provides the decision-making process based on the specificity of the problem [12-18]. DSS is used to support various decision-making activities specifically for:

- Facilitating interaction between data, data analysis and processing procedures and decision-making models, on the one hand, and the decision-maker, as a user of these systems, on the other;
- Providing supporting information, especially for performing non-structured or semi-structured tasks, for which it is difficult to determine in advance the data and procedures of the relevant decisions.

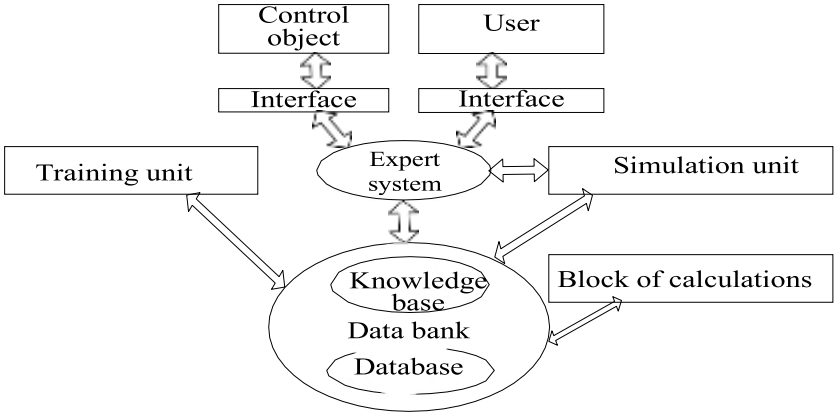

Fig. 2. Structural diagram of the interactive information system

Decision-making in problem-oriented information systems and systems of control is carried out in the conditions of a priori uncertainty due to inaccuracy or incompleteness of input data, stochastic nature of external influences, and lack of adequate mathematical model of functioning, fuzzy purpose and human factor [4, 19-28]. Uncertainty in the system increases the risk of inefficient decision making, which can result in negative economic, technical and social consequences. The uncertainties in decision-making systems are the outcome of the variety of artificial intelligence methods. Methods based on the rules of fuzzy logic are used for effective decision-making in case of uncertain conditions of system operation. Such methods are based on fuzzy sets and use linguistic quantities and utterances to describe decision-making strategies [3, 7, 9, 10, 29-38].

4 The Diagnostics Methods

The method of expert evaluation gives an objective description of the qualitative and quantitative aspects of the object of forecasting based on processing and analysis of a set of individual opinions of experts.

The quality of the experts' review, its reliability and validity are crucially dependent on the developed methodology and processing of individual expert values, which includes the following steps:

- Selection of experts and assessment of their competence;
- Preparation of questionnaires for expert interviews;
- Obtaining expert opinions;
- Assessing the consistency of expert opinions;
- Evaluation of the reliability of the results.

The advantage of expert methods is their relative simplicity for predicting almost any situation, including in the context of incomplete information. An important feature of these methods is the ability to predict the qualitative characteristics of the process for the diagnosis of CAT. The disadvantages of expert methods include the subjectivity of the opinions of experts and the limitations of their judgment.

Multi-criteria optimization or programming is the process of simultaneously optimizing two or more conflicting target functions in each given areas. A multi-criteria problem is often understood not as a verbal description of the problem itself, but rather by its model, namely: a multi-criteria task is a mathematical model of making the optimal decision by several criteria. These criteria may reflect evaluations of the various qualities of the object or process of diagnosis of a protected area that is being decided.

Formal instrument for processing expert information is a mathematical apparatus of fuzzy sets, which allows you to formulate decision rules for the diagnosis of CAT. It is possible to formalize the relevant information using the linguistic variables "A", "B", "C", "D". The linguistic variables "A", "B", "C" are the input variables, the linguistic variable "D" is the output variable. Affiliation functions are built for each linguistic variable, a fuzzy knowledge base is formed based on production rules, which is necessitated by the need to account for the real time scale and convenience of presenting information on procedures and conditions of their execution. Therefore, the solution of

the problem of determining the order of diagnostics of system nodes is based on the use of the instrument of fuzzy sets theory [3, 7]. In the future, the result of the evaluation of the diagnostic system of the CAT can used with the application of the theory of neural networks. The essence of a neural network (NN) is to approximate the functions of many variables through linear operations. A set of values is given to the network input and a corresponding set of output values is set in parallel (Fig. 3) [3, 4].

Neural networks and fuzzy logic are universal approximations of complex (nonlinear) functional dependencies in many intellectual cybernetics problems.

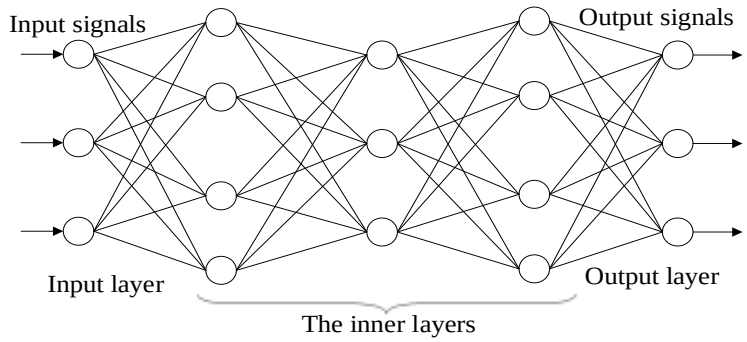

Fig. 3. Structure of the neural network

The main feature of neural networks is their ability to learn, which is implemented using specially designed algorithms. No prior information about the structure of the requested functional dependency is required for training the neural network. A training sample in the form of experimental input-output pairs is. The advantage of fuzzy logic is the ability to use expert knowledge of the structure of an object in the form of linguistic expressions: if "inputs", then "output". However, the apparatus of fuzzy logic does not contain learning mechanisms, so the results of fuzzy inference depend heavily on the kind of membership functions that formalize fuzzy terms. The result of combining fuzzy logic with neural networks is a neural-fuzzy network has two major intellectual properties: linguistics, that is, the use of natural language knowledge, and the ability to learn in real time [3]. The use of different methods of evaluation of the diagnostic system determines the choice of the basic method. The analysis of the literature showed that the use of neural networks for the diagnosis of communications (for example, during routine of technical maintenance (TM), repair, as well as in a state of continuous operation) is today a poorly understood and relevant direction that will allow to solve this problem. There are several types of TM, each of which involves performing the appropriate list of works. For virtually all types of TM work is carried out to check the performance of the built-in control system or measurement of basic electrical parameters using many measuring equipment, which has significant dimensions and high cost. It takes even longer to find repair failures, measurement tools, deployment of specialized ports, and the involvement of highly qualified personnel.

It is possible to speed up and simplify the diagnosis process by using the neural network apparatus, which have several important advantages:

- High performance of complex logic operations;
- The possibility of solving difficult formalized problems that share data of logically incompatible nature (incomplete, incorrect);
- Sustainability of work that is compatible with the expansion, transformation and improvement of knowledge;
- The reliability that is provided by the many paths to logical inference and the ability to recover lost data;
- Ability to build self-learning and self-configuring systems;
- It is well combined with the traditional "computing" information processing algorithms, which allows building complex control systems with maximum reliability, adaptability and minimum resources used.

To solve the problems logically, it is sufficient to use one of the following functions, which determine the value of V excitation of a neuron, depending on the magnitude of V_i and excitation of related neurons, weight ω_i of these connections and threshold h [4]:

1. $V := \xi(\sum_i V_i\omega_i - h)$,

$$\left(\xi(x) = \begin{cases} x, & if \quad x \geq 0 \\ 0, & otherwise \end{cases}\right);$$

2. $V := \xi(\sum_i V_i\omega_i - h)$,

$$V := if\ V > A \quad then\ A \quad else \quad V;$$

3. $V := \sum_i V_i\omega_i$,

$$V := if\ V > h \quad then\ V \quad else \quad 0;$$

4. $V := \sum_i V_i\omega_i$,

$$V := if\ V \geq h \wedge V < 1 \quad then\ V - h \quad else \quad if\ V \geq 1 then \quad 1 - h\ else \quad 0;$$

5. $V := \frac{1}{n}\sum_i V_i\omega_i$,

$$V := if\ V \geq h \quad then\ V \quad else \quad 0;$$

where n is the amount of neuron's active inputs.

Taking into account the advantages of the NN instruments, the task of diagnostics in TM of different types of CAT can reduced to the process of pattern recognition, where the image is the state of CAT as a whole or its individual components. In this case, the decision on the status of the CAT is made using the NN apparatus and it is possible to carry out both a quantitative assessment of the parameters and to predict its state for a certain period.

Depending on the formulation of the problem, the input signals can be the basic parameters (transmitter power, receiver sensitivity, etc.) and auxiliary (frequencies,

currents, and voltages at different control points of individual blocks) depending on the problem statement. The output layer of the neural network characterizes the different states of the system. In the course of training NN, the values of individual parameters and the state of a particular CAT are generally memorized (image creation). The use of this image in subsequent TM is the criterion for evaluation of "serviceable - faulty".

5 Experiment, Result and Discussion

As an example, a neural network (Fig. 4) is built to diagnose communication equipment (an example of constructing a network for a task). The method of support vector networks or tracing is used during the construction. As inputs (standards) working effects are used: those that get on the device during its intended use, and those that are its main output parameters (you can also use specially generated test effects). At the output layer, the expected response to the defined input standard is formed.

Take, for example, the neural network shown in Fig. 4. Suppose that all the same neurons perform a single transfer function, and that the scales and thresholds realize equal and general capabilities. We introduce the transfer function of an arbitrary *j*-th neuron with the number of inputs *m* [4, 5]:

$$V := \xi(\sum_{j=1}^{m} V_j \omega_{ij} - h_i), \qquad \xi(x) = \begin{cases} 0 & if \quad x \leq 0 \\ x & if \quad x > 0 \end{cases},$$

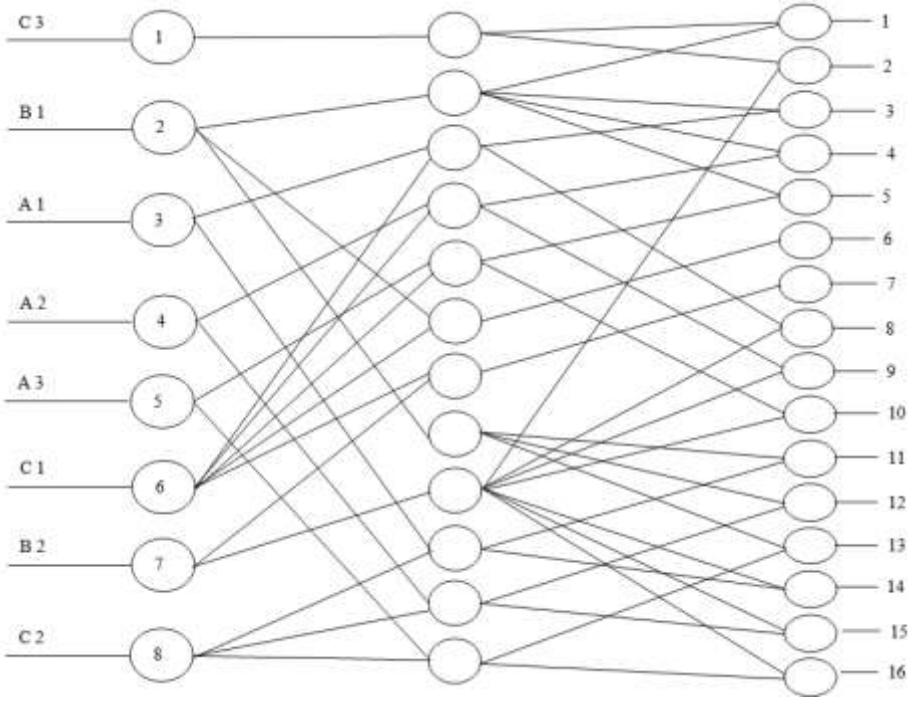

Fig. 4. A neural network built to diagnose military communications equipment

Table 1. The results of the calculation of the processing decisions

Stand-ard	Output date															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A1,B1,C1	0.28	0	1.4	0.76	0.76	0.92	0.28	0.92	0.28	0.28	0.76	0.28	0.28	0	0	0
A2,B1,C1	0.28	0	0.76	1.4	0.76	0.92	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0	0	0
A3,B1,C1	0.28	0	0.76	0.76	1.4	0.92	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0	0	0
B1,C1	0.28	0	0.76	0.76	0.76	0.92	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0	0	0
B1,C3	0.76	0.28	0.28	0.28	0.28	0	0	0	0	0	0.28	0.28	0.28	0	0	0
B2,C3	0.28	0.76	0	0	0	0	0.28	0.28	0.28	0.28	0	0	0	0.28	0.28	0.28
A1,B2,C1	0	0.28	0.92	0.28	0.28	0.28	0.92	1.4	0.76	0.76	0	0	0	0.76	0.28	0.28
A2,B2,C1	0	0.28	0.28	0.92	0.28	0.28	0.92	0.76	1.4	0.76	0	0.28	0	0.28	0.76	0.28
A3,B2,C1	0	0.28	0.28	0.28	0.92	0.28	0.92	0.76	0.76	1.4	0	0	0.28	0.28	0.28	0.76
B2,C1	0	0.28	0.28	0.28	0.28	0.28	0.92	0.76	0.76	0.76	0	0	0	0.28	0.28	0.28
A1,B1,C2	0.28	0	0.76	0.28	0.28	0.28	0	0.28	0	0	1.4	0.76	0.76	0.28	0.28	0.28
A2,B1,C2	0.28	0	0.28	0.76	0.28	0.28	0	0	0.28	0	0.76	1.4	0.76	0.28	0.92	0.28
A3,B1,C2	0.28	0	0.28	0.28	0.76	0.28	0	0	0	0.28	0.76	0.76	1.4	0.28	0.28	0.28
A1,B2,C2	0	0.28	0.28	0	0	0	0.28	0.76	0.28	0.28	0.92	0.28	0.28	1.4	0.76	0.76
A2,B2,C2	0	0.28	0	028	0	0	0.28	0.28	0.76	0.28	0.28	0.92	0.28	0.76	1.4	0.76
A3,B2,C2	0	0.28	0	0	0.28	0	0.28	0.28	0.28	0.76	0.28	0.28	0.92	0.76	0.76	1.4

where V_j is the amount of excitation (of another neuron) that arrives at the j-th input; ω_{ij} is weight of connections; h_i – thresholds.

For example, let us define that $\omega_{ij} = 0{,}8$; $h_i = 0{,}2$ and submit the situation to the input (standart) {A1, B1, C2} is "distortion of the signal of the 1st path within the normal range". According to the inputs of neurons 2, 3, 8, they receive single impulses. The energy data of impulses of the output neurons is calculated then considering the weighted connections between the neurons. Because of the calculation, we obtain that the maximum excitation value (1, 4) reached the output neuron 11 (Exit 11).

Based on the calculations for the construction of the network, we compose a Table 1, which reflects the correct operation of the network when making different decisions. Analyzing the terms of the table, which correspond to reliable situations, it can seen that the maximum excitation is determined correctly enough. This allows us to assert that the neural network, designed directly for the task, is built correctly.

In [4, 5] it was shown the necessity of creating a measuring and diagnostic complex, which may consist of a personal computer, a neural network (its software implementation) and a switching device.

For realization of this complex, it is necessary to use the device of neural networks in carrying out diagnostics of other CATs with the use of a single package of applications. Thus, one workplace will provide diagnostics during TM and troubleshooting.

6 Conclusion

The analysis showed that the Armed Forces of Ukraine are undergoing a gradual re-equipment of units for CATs, which allows providing a variety of information and telecommunication services. Timely diagnostics of the technical state and technical support of complex multifaceted systems that provide comprehensive automation of control processes requires the development of new, high-precision and reliable troubleshooting methods. Using one of these methods may include a neural network apparatus.

Technically, the process of diagnostics of various CATs can implemented by a single measuring and diagnostic complex based on a personal computer (PC). With a switching device that connects the outputs of the equipment to the PC input, the status recognition process takes seconds. The results of the construction of a neural network for solving the problem of diagnostics of modern CAT are given, which will allow reducing the time for conducting TM and the number of measuring instruments involved.

In the future, it is necessary to create a single package of applications for diagnostics of different types of communication devices based on neural networks, as well as a switching device by which the outputs of the equipment should connected with the input of the PC of the operator's workplace.

References

1. Lavrut, O.O., Klymovych, O.K., Lavrut, T.V., Zdorenko, Y.M.: Novitni tekhnolohiyi ta zasoby zv″yazku u Zbroynykh Sylakh Ukrayiny: shlyakh transformatsiyi ta perspektyvy rozvytku [The latest technologies and means of communication in the Armed Forces of Ukraine: the path of transformation and prospects for development]. In: Nauka i tekhnika Povitryanykh Syl Zbroynykh Syl Ukrayiny, 1(34), 91-101 (2019).
2. Lavrut, O.O., Klymovych, O.K., Tarasjuk, M.L., Antonjuk, O.L.: Stan ta perspektyvy suchasnykh tekhnologhij ta zasobiv radiozv'jazku v Zbrojnykh Sylakh Ukrajiny [The state and prospects of using and modern technologies and means of radio communication in the Armed Forces of Ukraine]. In: Systems of Arms and Military Equipment, 1(49), 42-49. (2017).
3. Bublyk, M.I., Rybytska, O. M.: The model of fuzzy expert system for establishing the pollution impact on the mortality rate in Ukraine. In: Computer sciences and information technologies (CSIT), 1, 253–256. (2017)
4. Lytvyn, V., Peleshchak, I., Vysotska, V., Peleshchak, R.: Satellite spectral information recognition based on the synthesis of modified dynamic neural networks and holographic data processing techniques. In: Proceedings of the International Conference on Computer Sciences and Information Technologies, CSIT, 330-334. (2018)
5. Lavrut, A.A., Skydan, A.A., Lavrut, T.V.: Perspektyvy razvytyya tekhnycheskoy dyahnostyky sovremennykh sredstv svyazy v vooruzhennykh Sylakh Ukrayny [Prospects for the development of technical diagnostics of modern communications in the Armed Forces of Ukraine]. In: Zbirnyk naukovykh pran′ Kharkivs′koho universytetu Povitryanykh Syl, 3(15), 72-75 (2007).
6. Lokazyuk, V.M., Lyashkevich, V.Y.: Informatsiyna systema poshuku diahnostychnoyi infor-matsiyi mikroprotsesornykh prystroyiv. In: Radioelektronni i komp″yuterni systemy, 6(18), 103-109 (2006).

7. Lytvyn, V., Vysotska, V., Demchuk, A., Demkiv, I., Ukhanska, O., Hladun, V., Kovalchuk, R., Petruchenko, O., Dzyubyk, L., Sokulska, N.: Design of the architecture of an intelligent system for distributing commercial content in the internet space based on SEO-technologies, neural networks, and Machine Learning. In: Eastern-European Journal of Enterprise Technologies, 2(2-98), 15-34. (2019)
8. Lytvynenko, V., Wojcik, W., Fefelov, A., Lurie, I., Savina, N., Voronenko, M. et al.: Hybrid Methods of GMDH-Neural Networks Synthesis and Training for Solving Problems of Time Series Forecasting. In: Lecture Notes in Computational Intelligence and Decision Making, 1020, 513-531. (2020)
9. Tarasov, V.O., Herasymov, B.M., Levin, I.O., Korniychuk, V.O.: Intelektual′ni systemy pidtrymky pryynyattya rishen′: teoriya, syntez, efektyvnist′. Kyyiv, Mizhnarodna akademiya komp″yuternykh nauk i system (2007)
10. Lytvynenko, V., Savina, N., Krejci, J., Voronenko, M., Yakobchuk, M., Kryvoruchko, O.: Bayesian Networks' Development Based on Noisy-MAX Nodes for Modeling Investment Processes in Transport. In: CEUR Workshop Proceedings, Vol-2386, 1-10. (2019)
11. Pomorova, O.V., Olar, O.Y.: Metod predstavlennya znan′ u bahatokomponentnykh intelektual′nykh systemakh diahnostuvannya mikroprotsesornykh prystroyiv. In: Radioelektron-ni i komp″yuterni systemy, 6 (18), 110-114 (2006).
12. Bublyk, M., Rybytska, O., Karpiak, A., Matseliukh, Y.: Structuring the fuzzy knowledge base of the IT industry impact factors. In: Computer sciences and information technologies (CSIT). (2018)
13. Gozhyj, A., Kalinina, I., Gozhyj, V.: Fuzzy cognitive analysis and modeling of water quality. In: International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), 289-294. (2017)
14. Babichev, S., Lytvynenko, V., Gozhyj, A., at.: A fuzzy model for gene expression profiles reducing based on the complex use of statistical criteria and Shannon entropy. In: Advances in Intelligent Systems and Computing, 754, Springer, 545-554. (2018)
15. Sachenko, S., Lendyuk, T., Rippa, S., Sapojnyk, G.: Fuzzy Rules for Tests Complexity Changing for Individual Learning Path Construction. Svitlana Sachenko. In: International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 945-948. (2015)
16. Sachenko, S., Chereshnyuk, O., Panasyuk, V., Banasik, A., Golyash, I.: Fuzzy-multiple Approach in Choosing the Optimal Term for Implementing the Innovative Project. In: International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 533-537. (2017)
17. Kravets, P.: The control agent with fuzzy logic. In: Perspective Technologies and Methods in MEMS Design, MEMSTECH, 40-41. (2010)
18. Kravets, P.: The game method for orthonormal systems construction. In: The Experience of Designing and Application of CAD Systems in Microelectronics, CADSM, 296-298. (2007)
19. Kravets, P., Kyrkalo, R.: Fuzzy logic controller for embedded systems. In: International Conference on Perspective Technologies and Methods in MEMS Design, 58-59. (2009)
20. Paliy, I., Turchenko, V., Koval, V., Sachenko, A., Markowsky, G.: Approach to recognition of license plate numbers using neural networks. In:International Conference on Neural Networks – Conference Proceedings, 2965-2970. (2004)
21. Babichev, S.: An Evaluation of the Information Technology of Gene Expression Profiles Processing Stability for Different Levels of Noise Components. In: Data, 3 (4), 48. (2018)

22. Babichev, S., Durnyak, B., Pikh, I., Senkivskyy, V.: An Evaluation of the Objective Clustering Inductive Technology Effectiveness Implemented Using Density-Based and Agglomerative Hierarchical Clustering Algorithms. In: Advances in Intelligent Systems and Computing, 1020, 532-553. (2020)
23. Boreiko, O. Y., Teslyuk, V. M., Zelinskyy, A., Berezsky, O.: Development of models and means of the server part of the system for passenger traffic registration of public transport in the "smart" city. In: Eastern-European Journal of Enterprise Technologies, 1(2-85), 40-47. (2017)
24. Kazarian, A., Teslyuk, V., Tsmots, I., Tykhan, M.: Implementation of the Face Recognition Module for the “Smart” Home Using Remote Server. In: Advances in Intelligent Systems and Computing III, AISC 871, Springer, 17–27. (2019)
25. Matseliukh, Y., Vysotska, V., Bublyk, M.: Intelligent System of Visual Simulation of Passenger Flows. In: CEUR workshop proceedings, Vol-2604, 906-920. (2020).
26. Batiuk, T., Vysotska, V., Lytvyn, V.: Intelligent System for Socialization by Personal Interests on the Basis of SEO-Technologies and Methods of Machine Learning. In: CEUR workshop proceedings, Vol-2604, 1237-1250. (2020).
27. Berko, A.Y., Aliekseyeva, K.A.: Quality evaluation of information resources in web-projects. In: Actual Problems of Economics 136(10), 226-234. (2012)
28. Chyrun, L., Chyrun, L., Kis, Y., Rybak, L.: Automated Information System for Connection to the Access Point with Encryption WPA2 Enterprise. In: Lecture Notes in Computational Intelligence and Decision Making, 1020, 389-404. (2020)
29. Kis, Y., Chyrun, L., Tsymbaliak, T., Chyrun, L.: Development of System for Managers Relationship Management with Customers. In: Lecture Notes in Computational Intelligence and Decision Making, 1020, 405-421. (2020)
30. Chyrun, L., Kowalska-Styczen, A., Burov, Y., Berko, A., Vasevych, A., Pelekh, I., Ryshkovets, Y.: Heterogeneous Data with Agreed Content Aggregation System Development. In: CEUR Workshop Proceedings, Vol-2386, 35-54. (2019)
31. Chyrun, L., Burov, Y., Rusyn, B., Pohreliuk, L., Oleshek, O., Gozhyj, A., Bobyk, I.: Web Resource Changes Monitoring System Development. In: CEUR Workshop Proceedings, Vol-2386, 255-273. (2019)
32. Gozhyj, A., Chyrun, L., Kowalska-Styczen, A., Lozynska, O.: Uniform Method of Operative Content Management in Web Systems. In: CEUR Workshop Proceedings, Vol-2136, 62-77. (2018)
33. Chyrun, L., Gozhyj, A., Yevseyeva, I., Dosyn, D., Tyhonov, V., Zakharchuk, M.: Web Content Monitoring System Development. In: CEUR Workshop Proceedings, Vol-2362, 126-142. (2019)
34. Veres, O., Rusyn, B., Sachenko, A., Rishnyak, I.: Choosing the Method of Finding Similar Images in the Reverse Search System. CEUR Workshop Proceedings, 2136, 99-107. (2018)
35. Basyuk, T., Vasyliuk, A., Lytvyn, V.: Mathematical Model of Semantic Search and Search Optimization. In: CEUR Workshop Proceedings, Vol-2362, 96-105. (2019)
36. Lytvynenko, V., Lurie, I., Krejci, J., Voronenko, M., Savina, N., Taif., M. A.: Two Step Density-Based Object-Inductive Clustering Algorithm. In: CEUR Workshop Proceedings, Vol-2386, 117-135. (2019)
37. Berko, A., Alieksieiev, V., Lytvyn, V.: Knowledge-based Big Data Cleanup Method. In: CEUR Workshop Proceedings, Vol-2386, 96-106. (2019)
38. Leoshchenko, S., Oliinyk, A., Skrupsky, S., Subbotin, S., Zaiko, T.: Parallel Method of Neural Network Synthesis Based on a Modified Genetic Algorithm Application. In: CEUR Workshop Proceedings, Vol-2386, 11-23. (2019)