The object of research is the decision making support systems. The subject of the research is the decision making process in management tasks using an advanced jumping frog algorithm (JFA), an advanced genetic algorithm and evolving artificial neural networks. A method of finding solutions with the use of improved JFA is proposed. The research is based on the JFA to find a solution regarding the object state. Evolving artificial neural networks are used to train frog agents (FA). The method has the following sequence of actions:

– an input of initial data;

– processing of initial data taking into account the degree of uncertainty;

– calculation of the value of the criterion of optimality of each permutation from the initial FA population;

– global search of FA;

– an improvement of the FA position in the search space;

– a regulation of the speed of vehicle movement;

– an improvement of the working conditions of JFA;

– the FA rearrangement;

– an unification of all memplexes into one group;

– the verification of the fulfillment of the conditions of JFA operation;

– the search for the best FA;

– training of the FA knowledge bases.

The originality of the proposed method consists in the arrangement of the FA taking into account the uncertainty of the initial data, the improved procedures of global and local edge taking into account the degree of data noise about the analysis object state, the adjustment of the degree of data noise during the FA movement, the adjustment of the speed of the FA movement.

Also, the peculiarity of the proposed method is the use of an improved procedure for FA training. The use of the method makes it possible to increase the efficiency of data processing at the level of 14–18 % due to the use of additional improved procedures. The proposed method should be used to solve the problems of evaluating complex and dynamic processes in the interests of solving national security problems

Keywords: decision making efficiency, decision making support systems, jumping frog algorithm

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THE DEVELOPMENT OF SOLUTION SEARCH METHOD USING IMPROVED JUMPING FROG ALGORITHM

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1. Introduction

Metaheuristic algorithms are widely used for optimization in various tasks, in particular for the purpose of selecting informative subsets of features while building a machine learning model [1–5]. Removing redundant features helps to avoid overtraining the model and reduce its complexity. While using metaheuristics as a feature selection tool, a necessary condition is the algorithm's ability to search in binary space [3–7]. However, while some metaheuristics, such as the genetic algorithm, were originally designed to work with binary input vectors, others were designed to work in a continuous search domain. It is obvious that the genetic algorithm alone is not capable of being a universal tool for any data as it contradicts the free breakfast theorem [8].

The most famous representative of heuristic methods is the swarm intelligence, which describes the collective behavior of a decentralized, self-organizing system [5, 6].

There are a large number of swarm algorithms, for example: particle swarm method, ant algorithm, cuckoo, bat, fish, bee algorithm, colonization algorithms, etc. [7–13].

The use of swarm algorithms to find solutions regarding the state of the analysis objects allows:

– to analyze the stability of the state of heterogeneous objects in the process of combat use (exploitation);

– to analyze the direct, aggregated and mediated interaction of systemic and external factors;

– to assess the reach of target situations of facility management;

– to scenario analyze for various destructive effects;

– to forecast the changes in the state of heterogeneous objects under the influence of destabilizing factors during the combat use (exploitation);

– to model and analyze the dynamics of changes in the state of interdependent parameters of heterogeneous objects.

At the same time, the use of the above mentioned swarm algorithms in the canonical form does not allow to obtain an operational assessment of the object state with a given reliability. The above mentioned determines the search for new (improvement of existing) approaches to the assessment and forecasting of the objects state by combining already known swarm algorithms with their further improvement.

Taking into account the above, an urgent scientific task is the development of a method of finding solutions using an improved algorithm of jumping frogs, which would allow to increase the efficiency of the decisions made regarding the management of the parameters of the control object with a given reliability.

2. Literature review and problem statement

The work [9] presents a cognitive modeling algorithm. The main advantages of cognitive tools are defined. The lack of consideration of the uncertainty type about the analysis object state should be attributed to the shortcomings of this approach.

The work [10] disclosed the essence of cognitive modeling and scenario planning. A system of complementary principles of building and implementing scenarios is proposed, different approaches to building scenarios are highlighted, the procedure for modeling scenarios based on fuzzy cognitive maps is described. The approach proposed by the authors does not allow to take into account the type of uncertainty about the analysis object state and does not take into account the noise of the initial data.

The work [11] carries out an analysis of the main approaches to cognitive modeling. Cognitive analysis allows: to investigate problems with unclear factors and relationships; to take into account changes in the external environment and use objectively formed trends in the development of the situation in one's interests. At the same time, the issue of describing complex and dynamic processes remains unexplored in this work.

The work [12] presents a method of analyzing large data sets. The specified method is focused on finding hidden information in large data sets. The method includes the operations of generating analytical baselines, reducing variables, detecting sparse features and specifying rules. The disadvantages of this method include the impossibility of taking into account different decision evaluation strategies, the lack of taking into account the type of uncertainty of the input data.

The work [13] presents a mechanism of transformation of information models of construction objects to their equivalent structural models. This mechanism is intended to automate the necessary operations of conversion, modification and addition during such information exchange. The shortcomings of the mentioned approach include the impossibility of assessing the adequacy and reliability of the information transformation process, and the appropriate correction of the obtained models.

The work [14] developed an analytical web-platform for the research of geographical and temporal distribution of incidents. Web-platform, contains several information panels with statistically significant results by territory. The disadvantages of the specified analytical platform include the impossibility of assessing the adequacy and reliability of the information transformation process, and high computational complexity. Also, one of the shortcomings of the mentioned research should be attributed to the fact that the search for a solution is not unidirectional.

The work [15] developed a method of fuzzy hierarchical assessment of library service quality. The specified method allows to evaluate the quality of libraries based on a set of input parameters. The disadvantages of the specified method include the impossibility of assessing the adequacy and reliability of the assessment and, accordingly, determining the assessment error.

The work [16] carried out an analysis of 30 algorithms for processing large data sets. Their advantages and disadvantages are shown. It has been established that the analysis of large data sets should be carried out in layers, take place in real time and have the opportunity for self-learning. Among the disadvantages of these methods should be attributed their high computational complexity and the impossibility of checking the adequacy of the obtained estimates.

The work [17] presents an approach for evaluating input data for decision making support systems. The essence of the proposed approach consists in the clustering of the basic set of input data, their analysis, after which the system is trained based on the analysis. The disadvantages of this approach are the gradual accumulation of assessment and training errors due to the lack of an opportunity to assess the adequacy of the decisions made.

The work [18] presents an approach to data processing from various sources of information. This approach allows to process data from various sources. The disadvantages of this approach include the low accuracy of the obtained estimate and the impossibility of verifying the reliability of the obtained estimate.

The work [19] carried out a comparative analysis of existing decision making support systems, namely: the method of analyzing hierarchies, neural networks, the theory of fuzzy sets, genetic algorithms and neuro-fuzzy modeling. The advantages and disadvantages of these approaches are indicated. The spheres of their application are defined. It is shown that the method of analyzing hierarchies works well in the condition of complete initial information, but due to the need for experts to compare alternatives and choose evaluation criteria, it has a high share of subjectivity. For forecasting problems in the conditions of risk and uncertainty, the use of the theory of fuzzy sets and neural networks is justified.

The work [20] developed a method of structural and objective analysis of the development of weakly structured systems. An approach to the research of conflict situations caused by contradictions in the interests of subjects that affect the development of the studied system and methods of solving poorly structured problems based on the formation of scenarios for the development of the situation. At the same time, the problem is defined as a discrepancy between the existing state of the system and the required one set by the management entity. At the same time, the disadvantages of the proposed method include the problem of the local optimum and the inability to conduct a parallel search.

The work [21] presents a cognitive approach to simulation modeling of complex systems. The advantages of the specified approach, which allows to describe the hierarchical components of the system, are shown. The shortcomings of the proposed approach include the lack of consideration of the computing resources of the system.

The work [22] indicated that the most popular evolutionary bio-inspired algorithms are the so-called «swarm» procedures (Particle Swarm Optimization – PSO). Among them, there are optimization algorithms based on cat swarms (Cat Swarm Optimization – CSO), which are very promising both from the point of view of speed and ease of implementation. These algorithms have proven their effectiveness in solving a number of rather complex tasks and have already undergone a number of modifications. Among the modifications, procedures based on harmonic search, fractional derivatives, adaptation of search parameters and, finally, «crazy cats» can be noted.

In this work [23], the jumping frog algorithm (JFA) is researched, which is successfully used to optimize the parameters of the classifier.

At the same time, the researches [22, 23] are not without some shortcomings that worsen the properties of the global extremum search process.

The basic FA algorithm consists of the following sequence of actions:

1. Setting the initial parameters.
2. Generation of the frog population.
3. Evaluation of the suitability of each frog.
4. Population sorting.
5. Division of the population.
6. Local search.
7. Unification of different groups.
8. Checking the maximum number of iterations.

At the same time, the basic JFA requires a long search for solutions and significant computing costs, which does not allow it to be used in real time.

An analysis of works [9–23] showed that the common shortcomings of the above mentioned researches are:

– the lack of possibility of forming a hierarchical system of indicators;

– the lack of consideration of computing resources of the system;

– the lack of mechanisms for adjusting the system of indicators during the assessment;

– a failure to take into account the type of uncertainty and noise of data on the analysis object state, which creates corresponding errors while assessing its real state;

– the lack of deep learning mechanisms of knowledge bases;

– a high computational complexity;

– the lack of consideration of computing (hardware) resources available in the system;

– the lack of search priority in a certain direction.

The problem that needs to be solved in the research is to increase the efficiency of solving the tasks of analysis and multidimensional forecasting of the object state, while ensuring the given reliability.

For this purpose, it is proposed to develop a method for finding solutions using an improved algorithm of jumping frogs.

3. The aim and objectives of the research

The aim of the research is the development of a method for finding solutions using an improved algorithm of jumping frogs. This will allow to increase the efficiency of assessment and multidimensional forecasting with a given reliability and the development of subsequent management decisions. This will make it possible to develop software for intelligent decision making support systems.

To achieve the aim, the following objectives were set:

– to determine the algorithm for implementing the method;

– to give an example of the application of the method in the analysis of the operational situation of a group of troops (forces).

4. Research materials and methods

The problem, which is solved in the research, is to increase the efficiency of decision making in management tasks while ensuring the given reliability regardless of the object hierarchy. The object of research is the decision making support system. The subject of the research is the decision making process in management tasks using an improved jumping frog algorithm, an improved genetic algorithm and evolving artificial neural networks.

Research hypothesis is an opportunity to increase the efficiency of decision making due to the use of an improved algorithm of jumping frogs with a given assessment reliability.

A simulation of the work of the proposed method was carried out in the MathSad 14 software environment (USA). As a problem, which was solved during the simulation, there were assessment elements of the operational situation of a group of troops (forces). The hardware of the research process is AMD Ryzen 5.

The operational grouping of troops (forces) was considered as an object of assessment and management. An operational grouping of troops (forces) formed on the basis of an operational command with a typical composition of forces and devices according to the wartime staff and with a range of responsibility in accordance with current regulations.

The research is based on algorithm of jumping frogs – for finding a solution regarding the object state. Evolving artificial neural networks are used to train jumping frogs.

5. The development of a method for finding solutions using an improved algorithm of jumping frogs

5. 1. An algorithm for implementing the method of finding solutions using the improved algorithm of jumping frogs

The method of finding solutions using the improved algorithm of jumping frogs consists of the following sequence of actions.

Step 1. Input of initial data. At this stage, the initial data available on the object to be analyzed are entered. The existing model of the analysis object is also initialized. The initiation of the initial population of frog agents (FA) is represented as a set of points in the space of permutations S_n with the Kendall metric of the form $S=(s_1, s_2,..., s_n)$. Each element of the vector corresponds to the features of the observation table, n is the number of features. The value of the vector element $s_i=0$ shows that the i-th feature does not participate in the classification, $s_i=1$ means that the first feature is used by the classifier. In this action, a modification of algebraic operations is proposed, which allows the algorithm to operate on binary input vectors, since all arithmetic operators are replaced by logical ones. According to this idea, the operations of multiplication, addition, and subtraction are replaced by conjunction, disjunction, and strict disjunction, respectively:

$$S^* = r \wedge \left(S_b \oplus S_w\right) \vee S_w, \tag{1}$$

where r is the arbitrary binary vector.

Step 2. Processing of raw data taking into account the degree of uncertainty.

At this stage, the type of uncertainty about the object to be analyzed is taken into account and the basic state model of the object to be analyzed is initialized [2, 19, 21]. At the same time, the degree of uncertainty can be: full awareness; partial uncertainty and total uncertainty. This is done with the help of correction coefficients.

Step 3. Calculation of the value of the criterion of optimality of each permutation from the initial population of FA. This procedure is carried out using an improved genetic algorithm developed by the authors in the work [22].

Step 4. Ordering of the decision in order of decreasing value of the criterion of optimality.

Step 5. Global FA search.

The procedure consists in sorting the input vectors by the value of the fitness function and dividing the population of FA into subgroups. Within each subgroup, a local search is carried out independently, in which the worst vectors are updated.

In the fitness function, it is important to take into account both the quality of the construction of the classification model and the share of selected features in order to reduce their number:

$$Fit(S) = \alpha \times Error(S) + (1-\alpha) \times \frac{n^*}{n}, \tag{2}$$

where $Error(S)$ is the classification error on the vector S, n^* is the number of elements in the vector S equal to one, α is the priority coefficient of one part of the function over another.

The vectors are updated according to the following principle. Z_b and Z_w are selected as vectors with the best and worst values of the fitness function in the group. Then, the intermediate vector Z^* is calculated:

$$Z^* = r \times c \times \left(Z_b - Z_w\right) + Z_w, \tag{3}$$

where r is a uniformly distributed random number from 0 to 1, c is the vector update coefficient. If the value of the fitness function of the vector Z^* exceeds the fitness function of the vector Z_w, Z^* replaces Z_w. Otherwise, the Z^* vector is recomputed, but the global best vector Z_0 is used instead of Z_b. If even in this case it is not possible to improve the vector Z_w, it is overwritten with a randomly generated deviation.

The algorithm accepts the following parameters as input: the number of subgroups G, the number of vectors in this group F, the update factor of input vectors c, the number of iterations for global and local search T_{gl} and T_k, respectively.

Separation of FA solutions into memplex blocks in such a way that the first FA in the sorted list goes to the first memplex, the second FA is entered into the second memplex, etc. This continues until all FA are distributed into the specified number of memplexes.

Step 6. Regulation of the vehicle movement speed.

In each memplex with the number $k \in \{1, 2,..., K\}$, find the best s_{k1} and the worst s_{k2} solution. To perform this action, it is necessary to have some continuous vector that characterizes the features. Most often, such a vector is a velocity vector. There is no such vector in the canonical JP algorithm, so it is suggested to calculate the speed of the worst vector S_w as follows:

$$V = \left(S_0 - S_w\right) \times r_1 + \left(S_b - S_w\right) \times r_2, \tag{4}$$

where r_1 and r_2 are vectors filled with random real values in the range from 0 to 1. Then, the received value must be matched with a binary equivalent.

Step 6. 1. At the first step, the transformation function, taking as input the value of the velocity of the element of the vector S_w, calculates a number that belongs to the range [0;1].

Step 6. 2. Direct update of elements according to the transformation rule.

Several families of transformation functions are distinguished. The two most commonly used families are S- and V-shaped charts. As an S-shaped transformation function, the basic version of the sigmoid was used:

$$F_1(v_i) = 1 / \left(1 + e^{-v_i}\right), \tag{5}$$

where v_i is the speed value of the i-th element.

V-like functions have a wide variety of variations, so two functions were chosen for the research. The first is calculated using the hyperbolic tangent:

$$F_2(v_i) = \left|\tanh(v_i)\right|, \tag{6}$$

the second is given by the following expression:

$$F_3(v_i) = \left|v_i / \sqrt{1+v_i^2}\right|. \tag{7}$$

Transformational rules differ in the principle of updating elements. In the first rule R_1, the element is given a strictly binary value:

$$\text{if } rand < F(v_i), \text{ then } s_i=1, \text{ otherwise } s_i=0, \tag{8}$$

where $F(v_j)$ is one of the three transformation functions, $rand$ is a uniformly distributed random number, $rand \in [0,1]$. The second rule R_2 either replaces the element with its opposite or does not change it:

$$\text{if } rand < F(v_i), \text{ then } s_i = s_i \oplus 1. \tag{9}$$

Step 7. Improvement of the FA position in the search space. An improvement of the position of the worst FA by moving it in the direction of the best FA, taking into account the degree of noise of the original data [3]. This happens using the crossover operator $s=Cross\ (s_{k1}, s_{k2})$.

Step 8. An improvement of working conditions of JFA.

If the previous operation does not improve the solution, try to improve the position of the worst FA by moving it in the direction of the globally best FA $s=Cross\ (s_{k1}, s_{11})$.

Step 9. FA rearrangement.

If the last operation does not lead to an improvement in the position of the FA, then instead of the FA, randomly create a new FA in the search area – a permutation.

Step 10. Unification of all memplexes into one group.

The function compares two binary vectors element by element; if the value of the element at the same position coincides, then the given value will be written to this position in the resulting vector. Otherwise, a random number is generated from the interval from 0 to 1 [24–35]. If it is less than or equal to 0.5, then the corresponding position of the new vector is written by the element from the worse vector. Otherwise, an element from a better vector will be displayed at this location.

Thus, the merge function can be given as follows:

$$merge\left(S_w, S_b\right) = \begin{cases} s_i^* = s_{wi} = s_{bi}, \text{ if } s_{wi} = s_{bi}, \\ s_i^* = s_{wi}, \text{ if } s_{wi} \neq s_{bi} \text{ and } rand \leq 0.5, \\ s_i^* = s_{bi}, \text{ if } s_{wi} \neq s_{bi} \text{ and } rand > 0.5, \end{cases} \quad (10)$$

where *rand* is a random uniformly distributed number, $rand \in [0,1]$.

Step 11. If the conditions for completing the algorithm are not met, then proceed to step 3.

Step 12. Search for the best FA.

The last globally best FA corresponds to a suboptimal solution to the problem.

Step 13. Training of the knowledge bases of FA.

In this research, the learning method based on evolving artificial neural networks, developed in the research [2], is used to learn the knowledge bases of each FA.

The end of the algorithm.

5. 2. An example of the application of the proposed method in the analysis of the operational grouping of troops (forces)

The proposed method of finding solutions with the use of improved JFA.

The simulation of the solution search processing method was carried out in accordance with steps 1–13. Simulation of the work of the proposed method was carried out in the MathSad 14 software environment (USA). The assessment of elements of the operational situation of the group of troops (forces) was the task to be solved during the simulation.

An initial data for assessing the state of the operational situation using the improved method:

– the number of sources of information about the state of the monitoring object is 3 (radio monitoring tools, remote sensing of the earth and unmanned aerial vehicles). To simplify the modeling, the same amount of each tool was taken – 4 tools each;

– the number of informational signs by which the state of the monitoring object is determined is 12. Such parameters include: ownership, type of organizational and staff formation, priority, minimum width along the front, maximum width along the front. The number of personnel, minimum depth along the flank, maximum depth along the flank, the number of samples of weapons and military equipment (WME), the number of types of WME samples and the number of communication devices), the type of operational construction are also taken into account;

– the variants of organizational and personnel formations – company, battalion, brigade.

Two-time cross-validation was used in the simulation. The algorithm was run 30 times on each sample. The task that was solved when the algorithm was launched was to determine the organizational and staff structure of the operational group of troops (forces). The classification was carried out according to a set of relevant features that determine the affiliation and type of organizational staff structure to one or another class. The final result is the determination of the number of objects and their corresponding classification. The resulting classification quality scores were averaged over the number of runs and two samples of each signature. The following indicators were recorded: overall accuracy, false rejection rate (FRR), false acceptance rate (FAR), and the number of features remaining in the set.

The structure of the classifier was generated by the algorithm taking into account the extreme values of the classes. Triangular functions of accessories were chosen as terms. The JFA parameters are as follows: the number of groups is 4, each of them has 10 vectors; local iterations are 5, global iterations are 50. The coefficient in the fitness function was equal to 0.5. In the table 1 presents a list of binarization methods used in JFA and their designations.

Table 2 contains the received classification indicators on test samples. The best results by indicator are marked in bold.

The average ranks obtained while comparing the results of all users using the Friedman criterion are presented in the Table 3.

The best overall accuracy results were demonstrated by V-shaped transformation functions with the R_2 rule (11). At the same time, function F_2(8) showed the best result in combination with the merging operation and function F_3(9) – individually. The first-order error was the smallest while using F_2 with the R_2 rule both in the absence and presence of the merge operation. The smallest second-order error was obtained using F_1(7) and the R_1 rule (10) in combination with the merge operation. The best feature reduction ability was demonstrated by the F_3 function with the R_1 rule and the merge operation.

Table 1

Numbering of JFA binarization

The method		The method	
MAO	Modified algebraic operations (3)	F3R2	The transformation function F_3(9)+rule R_2(11)
merge	Merge operation (4)	F1R1m	The transformation function F_1(7)+rule R_1(10)+merger operation
MAOm	Modified algebraic operations+merger operation (5)	F2R1m	The transformation function F_2(8)+rule R_1(10)+merger operation
F1R1	The transformation function F_1(7)+rule R_1(10)	F3R1m	The transformation function F_3(9)+rule R_1(10)+merger operation
F2R1	The transformation function F_2(8)+rule R_1(10)	F1R2m	The transformation function F_1(7)+rule R_2(11)+merger operation
F3R1	The transformation function F_3(9)+rule R_1(10)	F2R2m	The transformation function F_2(8)+rule R_2(11)+merger operation
F1R2	The transformation function F_1(7)+rule R_2(11)	F3R2m	The transformation function F_3(9)+rule R_2(11)+merger operation
F2R2	The transformation function F_2(8)+rule R_2(11)		

Table 2

The results of building a fuzzy classifier on subsets of features selected by JFA

The method	Precision	FRR	FAR	Characteristics
MAO	83.9±7.5	25.1±14.0	7.1±8.1	43.9±4.3
merge	86.7±6.9	20.2±13.0	6.3±7.6	34.2±3.6
MAOm	85.5±7.7	21.1±14.3	7.9±9.2	20.5±4.1
F1R1	85.2±7.4	23.0±13.3	6.5±8.0	40.4±4.1
F2R1	85.6±7.3	21.9±13.5	7.0±8.2	28.0±4.2
F3R1	86.1±7.2	20.7±13.7	7.0±8.3	24.6±4.3
F1R2	83.8±7.6	25.4±14.2	7.1±8.2	43.5±4.1
F2R2	87.0±7.2	19.3±13.3	6.8±8.1	30.0±4.0
F3R2	87.1±7.0	19.4±13.1	6.4±7.7	31.1±4.0
F1R1m	85.3±7.3	23.2±13.5	6.2±7.8	39.1±3.9
F2R1m	85.9±7.5	20.1±13.9	8.0±9.3	19.7±5.1
F3R1m	85.6±7.7	20.1±14.1	8.6±9.6	17.6±4.6
F1R2m	84.2±7.4	24.2±13.6	7.5±8.6	44.8±4.1
F2R2m	87.1±7.0	19.0±12.9	6.9±8.1	29.4±4.0
F3R2m	86.7±6.9	20.0±13.0	6.7±7.9	30.1±3.9

Table 3

Average ranks according to the Friedman's criterion

The method	Precision	FRR	FAR	Characteristics
MAO	4.8	11.3	7.8	13.9
merge	10.9	6.2	6.1	10.0
MAOm	5.9	8.9	10.5	2.8
F1R1	8.1	9.2	6.4	11.9
F2R1	7.1	9.0	8.4	5.3
F3R1	8.0	8.0	8.1	4.0
F1R2	4.7	12.1	7.5	13.5
F2R2	11.0	4.6	7.3	7.4
F3R2	11.6	5.1	5.7	8.9
F1R1m	8.4	9.7	5.3	11.1
F2R1m	6.9	7.4	11.0	2.2
F3R1m	6.1	7.6	12.0	1.0
F1R2m	5.5	10.2	8.9	14.6
F2R2m	11.1	4.6	8.0	6.0
F3R2m	10.1	6.2	7.1	7.5

The results of the comparative evaluation according to the criterion of efficiency of the evaluation are shown in the Table 4.

Table 4

The results of problem solving

No. iteration	Method of branches and boundaries [17]	Genetic algo-rithm [12]	Canonical JFA [23]	Improved JFA
N	T, s	T, s	T, s	T, s
5	1.125	1.125	1.125	1.05
10	0.625	0.625	0.625	0.450
15	48.97	58.20	58.28	55.71
20	106.72	44.29	43.75	41.33
30	–0.1790	–0.0018	–0.0002	–0.00008
40	–0.158	–0.070	–0.069	–0.08
50	97.76	–974.30	–3.72	–331.18
100	–133.28	–195.71	–196.24	–198.12
200	7980.89	7207.49	7198.43	7022.85

As can be seen from the table 4, the gain of the specified method of searching for solutions is from 14 to 18 % according to the criterion of speed of data processing.

6. The discussion of the results of the development of the method of finding solutions using the improved algorithm of jumping frogs

The main advantages of the proposed method are:

– it has a flexible hierarchical structure of indicators, which allows reducing the task of multi-criteria evaluation of alternatives to one criterion or using a vector of indicators for selection;

– a smaller error in assessing the state of the object due to the improved transformation procedure;

– an unambiguousness of the obtained assessment of the analysis object state;

– an universality of application due to adaptation of the system of indicators during the work;

– it does not accumulate learning error due to the use of the learning procedure;

– the possibility of comprehensive learning of the architecture and parameters of artificial neural networks;

– taking into account the type of uncertainty of the initial data while building models of a heterogeneous analysis object;

– the possibility of finding a solution in several directions;

– a high reliability of the obtained solutions while searching for a solution in several directions;

– an absence of falling into the local optimum trap.

The limitations of the research are the need to have an initial database on the analysis object state, the need to take into account the time delay for collection and proving information from intelligence sources. The advantages of the proposed method are due to the following:

– the type of uncertainty is taken into account while setting up an FA (Step 2);

– during the movement of the FA, the degree of noise of the data on the state of the object is taken into account;

– the universality of solving the task of analyzing the state of FA objects due to the hierarchical nature of their description (Steps 1–13);

– the possibility of quick search for solutions due to the simultaneous search for a solution by several individuals (Steps 1–13);

– the adequacy of the obtained results (Steps 1–13);

– the ability to avoid the local extremum problem (Steps 1–13);

– taking into account the degree of noise of the data on the state of the object during the movement of the FA (Step 7);

– using improved binarization procedures (Step 1, expression (1));

– by calculating the speed of the FA (Step 6, expressions (4), (5));

– the possibility of in-depth learning of the knowledge bases of FA (Step 13).

The disadvantages of the proposed method include:

– the loss of informativeness while assessing the analysis object state due to the construction of the membership function;

– a lower accuracy of assessment on a single parameter of assessment of the analysis object state;

– the loss of credibility of the obtained solutions while searching for a solution in several directions at the same time;

– a lower assessment accuracy compared to other assessment methods.

This method will allow:

– to assess the state of the heterogeneous analysis object;

– to determine effective measures to improve management efficiency;

– to increase the speed of assessment of the state of a heterogeneous analysis object;

– to reduce the use of computing resources of decision making support systems.

The proposed approach should be used to solve problems of evaluating complex and dynamic processes characterized by a high degree of complexity.

This research is a further development of researches aimed at developing method principles for increasing the efficiency of processing various types of data, which were published earlier [2, 4–6, 23].

The directions of further research should be aimed at reducing computing costs while processing various types of data in special purpose systems.

7. Conclusions

1. An algorithm for the implementation of the method has been determined, thanks to additional and improved procedures, which allows:

– to take into account the type of uncertainty and noisy data;

– to take into account the available computing resources of the state analysis system of the analysis object;

– to take into account the priority of the traffic of FA;

– to carry out the initial exhibition of individuals of FA, taking into account the type of uncertainty;

– to carry out accurate training of FA individuals;

– to determine the best individuals of FA using a genetic algorithm;

– to conduct a local and global search taking into account the degree of noise of the data on the analysis object state;

– to conduct training of knowledge bases, which is carried out by training the synaptic weights of the artificial neural network, the type and parameters of the membership function, the architecture of individual elements and the architecture of the artificial neural network as a whole;

– to be used as a universal tool for solving the task of analyzing the state of analysis objects due to the hierarchical description of analysis objects;

– to check the adequacy of the obtained results;

– to calculate the speed of the FA;

– to avoid the problem of local extremum.

2. An example of the use of the proposed method was conducted using the example of assessing and forecasting the state of the operational situation of a group of troops (forces).

The specified example showed a 14–18 % increase in the efficiency of data processing due to the use of additional improved procedures.

The mentioned procedures: addition of correction coefficients regarding the uncertainty and noise of data, selection of FA, calculation of the speed of FA movement and FA training.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, including financial, personal, authorship, or any other, that could affect the research and its results presented in this article.

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The availability of data

The manuscript has associated data in the data repository.

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