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IMPROVEMENT OF THE SOLUTION SEARCH METHOD BASED ON THE CUCKOO ALGORITHM

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An improved method of finding solutions based on the cuckoo algorithm is proposed. The research object is the decision-making support systems. The research subject is the decision making process in management tasks using artificial intelligence methods. The hypothesis of the research is to increase the efficiency of decision making with a given assessment reliability. The proposed method is based on a combination of the cuckoo algorithm and evolving artificial neural networks. The method has the following differences:

– an additional processing of the source data takes place taking into account the uncertainty about the state of the control objects and the type of data noise about the state of the control object is additionally taken into account;

– the state model of the control object is adjusted taking into account the available computing resources of the system;

– added procedures to reduce the probability of detecting nests and reducing the length of the cuckoo's step;

– knowledge bases about management objects are additionally taught. The training procedure consists in learning the synaptic weights of the artificial neural network, the type and parameters of the membership function and the architecture of individual elements and the architecture of the artificial neural network as a whole. The effectiveness of the proposed method was evaluated and it was established that the proposed modification provides a better value of the objective function compared to the results obtained by other authors and ensures the fulfillment of all restrictions. The specified example showed an increase in the efficiency of data processing at the level of 21–28 % due to the use of additional improved procedures. It is advisable to use the proposed method in decision making support systems of automated control systems

Keywords: cuckoo algorithm, artificial neural networks, bio-inspired algorithms, heterogeneous control objects

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1. Introduction

Computational intelligence methods have acquired widespread for solving a set of complex tasks, both purely scientific and in the field of engineering, business, finance, medical and technical diagnostics, and other fields. These include intelligent data analysis (Data Mining), dynamic data analysis (Dynamic Data Mining), analysis of data streams (Data

Stream Mining), analysis of large data sets (Big Data Mining), Web-Mining, Text Mining [1, 2].

The increase in the volume of information circulating in various systems of information collection, processing and transmission leads to a significant use of computing resources of hardware. The armed forces of technically developed countries have integrated decision making architectures based on [3–5]:

– artificial intelligence and nanotechnologies;

– effective processing of large amounts of information;

– data compression technologies to increase the speed of their processing.

At the same time, the use of information systems with artificial intelligence elements will allow to increase the efficiency of planning, conducting operations (combat operations) and their comprehensive support, will affect the doctrine, organization and methods of application of groups of troops (forces).

At the same time, increasing the dynamism of operations (combats), increasing the number of various sensors and the need to integrate them into a single information space creates a number of problems:

– implemented algorithms for establishing correlations between events do not fully take into account the reliability of sources of intelligence information and the reliability of information in the dynamics of operations (combats);

– forms of information presentation complicate its transmission through communication channels;

– limited computing power of hardware;

– radio electronic suppression of short wave and ultrashort wave radio communication channels and cybernetic influence on information systems;

– transition to the principle of monitoring objects assessment «everything affects everything at once», which covers the aggregate network and computing resources of all types of armed forces.

Analysis and subsequent search for solutions requires analysis of data that are different in origin and measurement units. Data sources can be various sensors, receivers, sensors, etc. All this requires complex processing of various types of data coming from various sources of information extraction. The methods of artificial intelligence became the most widespread in solving these issues [1–6].

That is why it is necessary to develop algorithms (methods and techniques) that are capable of solving optimization problems from various sources of intelligence in a limited time and with a high degree of reliability.

2. Analysis of literary data and formulation of the problem

The work [7] presents cognitive modeling algorithm. The main advantages of cognitive tools are defined. The lack of consideration of the type of uncertainty about the analysis object state should be attributed to the shortcomings of this approach.

The work [8] reveals 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 taking into account the type of uncertainty about the state of the object of analysis and does not take into account the noise of the initial data.

The work [9] 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 paper.

The work [10] 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-making evaluation strategies, the lack of taking into account the type of uncertainty of the input data.

The work [11] presents a mechanism of transformation of information models of construction objects to their equivalent structural models. This mechanism is intended to automate the necessary conversion, modification and addition operations 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 [12] 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 [13] 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 [14] carries out an analysis of 30 algorithms for processing large data sets. Their advantages and disadvantages are shown. It was 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 [15] 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 [16] 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 [17] carries out a comparative analysis of existing decision making support technologies, 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 under 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 under conditions of risk and uncertainty, the use of the theory of fuzzy sets and neural networks is justified.

The work [18] develops 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 research 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 the non-compliance of the existing state of the system with the required one, which is 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 [19] 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 [20] indicated that the most popular evolutionary bio-inspired algorithms are the so-called «swarm» procedures (Particle Swarm Optimization – PSO). These algorithms have proven their effectiveness in solving a number of rather complex tasks and have already undergone a number of modifications, among which procedures based on harmonic search, fractional derivatives and adaptation of search parameters can be noted. At the same time, these procedures are not without some shortcomings that worsen the properties of the global extremum search process.

The work [21] analyzed the main bio-inspired algorithms, namely: ant algorithm, cuckoo algorithm, bat algorithm, etc. Their purposes are described, the main stages of their implementation, advantages and disadvantages are given. The algorithms given in the work are used for the analysis of various types of data, have increased efficiency and the possibility of self-learning. However, these algorithms have the following disadvantages: the noise and uncertainty of the initial data are not taken into account and deep learning algorithms of individuals (agents) are not used. As for the cuckoo algorithm, there is no nest detection probability reduction and cuckoo step length is not implemented.

An analysis of works [7–20] 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 data noise on the state of the control object, which creates corresponding errors while assessing its real state;

– the lack of deep learning mechanisms of knowledge bases;

– high computational complexity;

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

– the lack of search priority in a certain direction.

Therefore, the problem that needs to be solved is increasing the efficiency of solving optimization problems while ensuring the given reliability on the basis of the improved cuckoo algorithm. For this purpose, it is proposed to improve the method of finding solutions based on the cuckoo algorithm.

3. The aim and objectives of research

The aim of research is the development of the method of finding solutions based on the improved algorithm of the cuckoo of control objects. 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 in the interests of the combat management of the actions of troops (forces).

To achieve the aim, the following objectives were set:

– to analyze the canonical cuckoo algorithm for finding solutions regarding the state of the control object;

– to determine the algorithm for the implementation of the improved methodology;

– to evaluate the effectiveness of the grouping of troops (forces) developed during the analysis of the operational situation.

4. Research materials and methods

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 hierarchical nature of the object. The object of the research is decision making support systems. The subject of the research is the decision making process in management tasks using artificial intelligence methods.

Research hypothesisthere is an increase in the efficiency of decision making at given assessment reliability.

In the research, the optimization algorithm based on the behavior of the cuckoo (Cuckoo Search) was chosen as the basic algorithm for finding solutions. Cuckoos lay their eggs in the nests of other birds. In the CS algorithm, each egg in the nest is a solution, and the cuckoo's egg is a new solution. The aim of the cuckoo algorithm is to use new and potentially better (cuckoo) solutions to replace the less good solution in nests. In the simplest version of this algorithm, there is one egg in each nest.

The cuckoo algorithm is based on the following three rules: each cuckoo lays one egg at a time in a randomly chosen nest; the best nests with high-quality eggs (high fitness value) pass to the next generation; a cuckoo egg laid in a nest can be detected by the host with a certain probability and removed from the nest.

The proposed method was simulated in the MathSad 14 software environment (USA). As the task that was solved during the simulation was the assessment of the elements of the operational situation of the grouping of troops (forces).

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.

5. Outline of research on improving the method of finding solutions based on the cuckoo algorithm

5. 1. Analysis of the canonical cuckoo algorithm for finding solutions for an object

The cuckoo algorithm obtained in the work [21] was considered as the basic cuckoo algorithm.

In the general formulation, let's consider the deterministic continuous task of global conditional minimization:

$$\min_{X\in D\subseteq R^{|X|}} f(X)=f(X^*)=f^*, \quad (1)$$

where $f(X)$ is the scalar objective function (optimality criterion); $f(X^*)=f^*$ is the minimum value of the objective function; $X=(x_1, x_2, ..., x_{|X|})$ is the $|X|$-dimensional vector of changing parameters, which must be found;b D is the set of admissible values of this vector; $R^{|X|}$ is the $|X|$- dimensional arithmetic space.

The cuckoo algorithm is oriented to solve the problem of unconditional optimization, when $D=R^{|X|}$. Each egg in the nest is a solution and the cuckoo's egg represents a new solution. The aim is to use a new and potentially better solution (simulation of cuckoo behavior) to replace unacceptable solutions in nests. In the simplest form, there is one egg in each nest. The algorithm can be extended to a more complex case, when there are several eggs in each of the nests, representing some set of potential solutions.

The cuckoo algorithm is based on the following three rules:

1. Each cuckoo lays one egg at a time and places it in a randomly selected nest.

2. The best nests with high-quality eggs pass to the next generation.

3. The number of available nests is fixed and the cuckoo's egg can be detected by the host with probability $p_a\in(0,1)$. Detection affects some set of worst nests, the detected solutions are excluded from further computations, and instead of them, a corresponding number of new solutions are randomly generated.

The scheme of the canonical cuckoo algorithm looks like this:

1. An initialization of the population $S=s_i$, $i\in[1:|S|]$ with $|S|$ nests belonging to the host of the nest, thus, the initial values of the components of the vectors X_i, $i\in[1:|S|]$ are determined.

2. Perform random movements of the cuckoo in the search space using Lévy Flights [22] and find its new position X'.

3. A slot s_i, $i\in[1:|S|]$ is randomly selected and if $f(X')<f(X_i)$, then let's replace the egg in this nest with a cuckoo's egg, so $X'_i=X'$.

4. With probability p_a, let's remove several randomly selected nests from the population and build the same number of new nests according to the rules of Step 1.

5. If the condition for the end of the iteration is not met, proceed to Step 2.

While creating a new solution X', Lévy flights are performed according to the formula:

$$X'=X+A\otimes L_{|X|}(\lambda), \quad (2)$$

where $L_{|X|}(\lambda)$ is the $|X|$ – dimensional vector of independent real random numbers distributed according to Lévy's law:

$$\xi(x)=x^{-\lambda},\lambda\in(1;3), \quad (3)$$

where $\otimes$ is the symbol of the component product of vectors; $A=(a_1, a_2, ..., a_{|X|})$ is the step size vector; $a_j>0, j\in[1:|X|]$.

As a rule, all components of the last vector are considered the same and equal a, where the value a should be related to the scope of the search area.

Most of the population algorithms of global optimization use a migration operator of the form (2), but an even or normal distribution of the step size.

Lévy flights are one of the variants of random walks, when the Lévy distribution (3) is used to determine the random step length, which has a long, slowly falling «tail». Various researches show that many birds and insects in flight exhibit typical Levy flight characteristics. Human behavior, such as a hunter-gatherer, also shows features of Levy flights. One of the most effective algorithms for the numerical generation of pseudorandom numbers distributed according to Lévy's law is the Mantegna algorithm [23].

In the canonical cuckoo algorithm, during initialization, fixed values of parameters p_a and a are set, which do not change with the increase in the number of generations. However, if the value p_a is small and the value a is large, then the algorithm may converge slowly. On the contrary, if the value p_a is large and the value a is small, then the speed of convergence of the algorithm is usually high, but the possibility of localizing the global minimum of the objective function is low (the algorithm can get «stuck» in the local minimum).

5. 2. Algorithm for implementing the improved method of finding solutions based on the cuckoo algorithm

The method of finding solutions based on the improved cuckoo algorithm consists of the following sequence of actions:

1. Input of initial data. At this stage, the initial data about the control object to be analyzed are entered, the population $S=s_i$, $i\in[1:|S|]$ with $|S|$ nests belonging to the host of the nest is initialized, thus the initial values of the vector components X_i, $i\in[1:|S|]$ are determined.

2. Processing of initial data taking into account uncertainty (additional procedure).

At this stage, the type of uncertainty about the state of the control object is taken into account and the basic model of the state of the object is initialized [2, 17, 19, 22, 24–33]. At the same time, the degree of uncertainty can be: full awareness; partial uncertainty and total uncertainty. This implies a different possibility of detecting «good» and «bad» nests. If the solution in the nest is «good», then the probability of destruction of this nest should be low. On the contrary, the possibility of destroying nests with «bad» solutions should be increased. To implement the mentioned idea, at iteration n, the nests are sorted according to the growth of the corresponding values of the objective function (decreasing the quality of solutions) and we assign them numbers from 1 to $|S|$. Let's assign values $p_a(i)=p_a^{best}, p_a^{worst}$ that are free modification parameters to the probability of detecting a nest with the number i.

3. Taking into account the type of noisy data on the state of the control object (additional procedure).

At this stage, the type of noise of data on the state of the control object is taken into account. At the same time, the degree of obfuscation can be: complete; partial and full noise. The correction coefficients are given in the work [2].

4. Adjustment of the control object state model (additional procedure).

Adjusting the values of the free parameters p_a and a in the process of iteration according to the formulas:

$$p_a(t)=p_a^{\max}-\frac{t}{\tilde{t}}\left(p_a^{\max}-p_a^{\min}\right), \quad (4)$$

$$\alpha(t) = \alpha^{\max} \exp\left(c^t\right), \quad (5)$$

where t is the generation number, $p_a^{\min}$, $p_a^{\max}$, $a^{\min}$, $a^{\max}$ are the given constant values, $\hat{t}$ is the maximum permissible number of generations:

$$c = \frac{1}{\hat{t}} 1n\left(\frac{a^{\min}}{a^{\max}}\right). \quad (6)$$

The probability p_a of removing the worst nests from the population decreases with increasing generation number $p_a^{\max}$ to the size $p_a^{\min}$ and the step length α decreases exponentially from $a^{\max}$ to $a^{\min}$.

5. Reducing the probability of detecting nests and step length reduction (an optimized procedure of the canonical cuckoo algorithm):

$$\alpha = \alpha^{\min} + \left(\alpha^{\max} - \alpha^{\min}\right)\eta^t, \quad (7)$$

where $\eta \in (0,1)$ is the extinction coefficient, which will make it possible to explore the limits of the minimum and thereby increase the accuracy of its localization.

The essence of this procedure is that according to a formula similar to formula (7), the probability of detecting nests decreases with the growth of the generation number t:

$$p_a = p_a^{\min} + \left(p_a^{\max} - p_a^{\min}\right)\zeta^t, \zeta \in (0;1). \quad (8)$$

6. Correction of the route search step length (additional procedure):

$$\alpha = \beta_b \alpha, \beta_b \in (0;1); \quad (9)$$

otherwise, the step increases according to the formula:

$$\alpha = \beta_g \alpha, \beta_g > 1. \quad (10)$$

7. Learning knowledge bases.

With probability p_a, let's remove several randomly selected nests from the population and build the same number of new nests according to the rules of Step 1, taking into account the data in the knowledge bases and the training method. In this research, the learning method based on evolving artificial neural networks, developed in the research [2], is used for training knowledge bases.

The end of the algorithm.

5. 3. An example of the application of the proposed method while analyzing the state of an operational group of troops (forces)

The method of finding solutions based on the cuckoo algorithm is proposed. In order to assess the effectiveness of the developed method, its comparative evaluation was performed based on the results of research presented in works [3–6, 21, 34, 35].

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 earth sensing tools and unmanned aerial vehicles) To simplify the modeling, the same number of each tool was taken – 4 tools each;

– the number of informational signs by which the state of the monitoring object is determined – 12. These 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 are company, battalion, brigade. The results of the effectiveness of the assessment of the state of the operative grouping are given in the Table 1.

Table 1

Task solution results

No. iterations	Method of branches and boundaries	Genetic algorithm	Harmonious search	Improved cuckoo algorithm
N	T, s	T, s	T, s	T, s
5	1.125	1.125	1.125	1.114
10	0.625	0.625	0.625	0.600
15	48.97	58.20	58.28	57.71
20	106.72	44.29	43.75	46.95
30	–0.1790	–0.0018	–0.0002	–0.0001
40	–0.158	–0.070	–0.069	–0.049
50	97.76	–974.30	–3.72	–334.11
100	–133.28	–195.71	–196.24	–193.04
200	**7980.89**	**7207.49**	**7198.43**	**7036.48**

As it can be seen from the Table 1, the gain of the specified method of finding solutions is from 11 to 15 % according to the criterion of data processing efficiency.

The advantage of the specified method in comparison with the known ones lies in the reduction of computational complexity, which in turn increases the efficiency of decision making regarding the state of the operational situation of the grouping of troops (forces).

Table 2 presents the comparative results of the evaluation of the efficiency of training artificial evolving neural networks, which are used in the 7-th step of the cuckoo algorithm.

Table 2

Comparative results of the evaluation of the transaction learning capabilities of evolving artificial neural networks

System	Algorithm parameters	XB (Xi-Beni Index)	Time, sec
FCM (Fuzzy C-Means)	–	0.2104	3.15
EFCM	Dthr=0.30	0.1218	0.175
EFCM	Dthr=0.23	0.1262	0.21
The proposed system (batch mode)	delta=0.1	0.1	0.32
The proposed system (online mode)	delta=0.1	0.098	0.2

Before training, the features of the observations were normalized to the interval [0, 1].

The research showed that the specified training procedure provides an average of 10–18 % higher training efficiency of artificial neural networks and does not accumulate errors during training (Table 2).

The indicated results can be seen from the results in the last lines of the Table 2, as the difference of the Xi-Beni index.

At the same time, as already mentioned, in the course of the work, known methods accumulate errors, which is why the proposed method proposes the use of evolving artificial neural networks.

The results of the conducted evaluation coincide in some cases with the results of research [2–6, 21, 24, 34, 36–38].

According to the results of the comparative assessment (Tables 1, 2), it can be concluded that the total gain of the improved method is from 21 to 28 % according to the criterion of efficiency of decision making due to the use of additional and improved procedures:

– training of knowledge bases;

– reducing the probability of detecting nests and reducing the length of the step (optimized procedure of the canonical cuckoo algorithm);

– processing of initial data taking into account uncertainty (additional procedure);

– taking into account the type of noisy data on the state of the control object (additional procedure);

– adjustment of the state model of the control object (additional procedure);

– correction of the route search step length (additional procedure).

6. Discussion of the results regarding the improvement of the method of finding solutions based on the cuckoo algorithm

The advantages of the proposed method are due to the following:

– while searching for nests in which eggs can be laid, the type of uncertainty is taken into account (Step 2);

– the universality of solving the task of analyzing the state of management objects due to the hierarchical nature of their description (expressions (1)–(10));

– the possibility of rapid construction of models due to the simultaneous search for a solution by several individuals (Steps 1–7);

– the adequacy of the obtained results (expressions (1)–(10));

– the ability to avoid the local extremum problem (Steps 1–7);

– the possibility of in-depth learning of knowledge bases (Step 7).

The limitations of the research are the need to have an initial database on the state of control objects, the need to take into account the time delay for collection and proving information from intelligence sources. This should be transferred below – after the advantages.

The main advantages the proposed method are:

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

– unambiguousness of the received assessment of the management object state;

– universality of application due to adaptation of the system of indicators during 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 control objects;

– the possibility of finding a solution in several directions;

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

– an absence of falling into the local optimum trap.

The disadvantages of the proposed method include:

– lower accuracy of assessment on a single parameter of object condition assessment;

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

– lower assessment accuracy compared to other assessment methods.

The method will allow:

– to assess the condition of a heterogeneous object;

– to determine effective measures to improve management efficiency;

– to increase the speed of assessment of the object state;

– 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, 21].

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 analysis of the canonical cuckoo algorithm for finding solutions regarding the state of the control object was carried out.

During the analysis, the shortcomings of the canonical cuckoo algorithm were identified:

– the construction of the initial part of the search for a solution takes place without taking into account the type of uncertainty and noise of the initial data;

– the state model of the control object is static and does not take into account the available computing resources of the system;

– the procedures for the probability of detecting nests and the length of a cuckoo's step are described by a random law and require large computational costs;

– learning of individuals in the canonical cuckoo algorithm is not provided for.

2. An algorithm for the implementation of the method is proposed, which allows:

– to take into account the type of data uncertainty;

– to take into account the degree of uncertainty about the management object state;

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

– to take into account the priority of finding nests;

– to reduce the length of the route;

– to carry out accurate training of cuckoo individuals;

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

– to check the adequacy of the obtained results;

– to avoid the problem of local extremum.

3. An assessment of the effectiveness of the proposed method was carried out using the example of assessment and forecasting of the state of the operational situation of the grouping of forces. It is shown that the proposed modification provides a better value of the objective function compared to the results obtained by other authors and ensures the fulfillment of all restrictions.

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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