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IMPROVEMENT OF THE OPTIMIZATION METHOD BASED ON THE CAT PACK ALGORITHM

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The problem that is being 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 research is the decision-making support systems. The subject of the research is the decision-making process in management tasks using an improved cat flock algorithm. The research hypothesis is the possibility of increasing the efficiency of decision-making with a given assessment reliability. In the course of the research, an improved method of parametric optimization based on the improved algorithm of the cat flock was proposed. In the course of the research, the general provisions of the theory of artificial intelligence were used to solve the problem of analyzing the state of objects and subsequent parametric management in intelligent decision-making support systems.

The essence of the method improvement lies in the use of the following procedures, which improve basic procedures of the cat flock algorithm, namely, search and chase:

– training of individuals of a cat flock with the help of evolving artificial neural networks;

– taking into account the type of uncertainty of the initial data while constructing the metric of the path of the cat flock, which reduces the time of searching for the optimal solution;

– searching for a solution in several directions using individuals from the cat flock, which reduces the time of searching for the optimal solution;

– initial display of individuals from the cat flock not randomly;

– additional consideration of the chase parameter, which limits the chase area, which allows to take into account the priority of the search;

– the ability to determine the need to involve additional network hardware resources.

An example of the use of the proposed method is presented on the example of assessing the state of the operational situation of a group of troops (forces). The specified example showed a 17–23 % increase in the efficiency of data processing due to the use of additional improved procedures

Keywords: management object, cat pack algorithm, uncertainty of data, efficiency of assessment, reliability of decisions

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1. Introduction

Computational intelligence methods are used to solve a variety of complex tasks, both purely scientific and in the field of engineering, business, finance, medical and technical diagnostics, and other fields. This is related to information processing, including intelligent data analysis (Data Mining), dynamic data analysis (Dynamic Data Mining), data stream analysis (Data Stream Mining), etc. The following decision-making methods are used to solve the problems of information processing, data flow analysis and intelligent data analysis [1–6]:

– artificial neural networks;
– unclear logic;
– genetic algorithms;
– unclear cognitive models, etc.

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 [7–15]:

– 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 elements of artificial intelligence will make it possible 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 SW and USW 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.

That is why it is necessary to improve 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.

Taking into account the above, an urgent scientific task is to improve the optimization method based on the cat flock algorithm, 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. Analysis of literary data and formulation of the problem

The cognitive modeling algorithm is presented in the work [9]. The main advantages of cognitive tools are defined. The lack of consideration of the type of uncertainty about the state of the analysis object and the impossibility of conducting a search in several directions should be attributed to the shortcomings of this approach.

The work [10] revealed 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 state of the analysis object and does not take into account the noise of the initial data.

The work [11] carried 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 [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] shows the 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 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 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 [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 processing 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 technologies, namely: the method of analyzing hierarchies, neural networks, fuzzy set theory, genetic algorithms, ant colony algorithm, 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 [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 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 [21] presents a cognitive approach to simulation modeling of complex systems. The advantages of the specified approach, which allows describing 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 which procedures based on harmonic search, fractional derivatives, adaptation of search parameters and, finally, «crazy cats» can be noted. At the same time, these procedures have some shortcomings that worsen the properties of the global extremum search process.

An analysis of works [9–22] 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 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.

For this purpose, it is proposed to improve the method of parametric optimization based on the improved algorithm of the cat flock.

3. The aim and objectives of the research

The aim of research is the improvement method of parametric optimization based on the improved algorithm of the cat flock. This will allow to increase the efficiency of optimization 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 goal, the following tasks were set:

– to improve the search procedure for the parametric optimization method;

– to improve the procedure of chasing the parametric optimization method;

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

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 the cat flock algorithm. *The hypothesis of the research* is to increase the efficiency of decision-making with a given assessment reliability.

In the course of the conducted research, the general provisions of the theory of artificial intelligence were used to solve the problem of analyzing the state of objects in intelligent decision-making support systems. Thus, the theory of artificial intelligence is the basis of the mentioned research. The research uses the cat flock algorithm and the apparatus of evolving artificial neural networks. The simulation was carried out using MathCad 2014 software (USA) and an Intel Core i3 PC (USA). The basic algorithm of the cat flock was used as the basis of the research and its improvement was carried out in terms of search and pursuit.

5. Improvement of the parametric optimization method based on the improved algorithm of the cat flock

5. 1. Improved search procedure for the parametric optimization method

To find the global extremum of the scalar function $f(x)$ of the vector argument $x=(x_1, x_2, ..., x_n)^T \in R^n$, the authors [22] suggested using the model of the behavior of cat swarms (cat swarm – CS), while it is assumed that each cat cat_p flock consisting of Q individuals ($p=1, 2,...,Q$) can be in one of two states: Seeking Mode (SM) and Tracing Mode (TM). The general visualization of the parametric optimization method based on the improved cat pack algorithm is shown in Fig. 1.

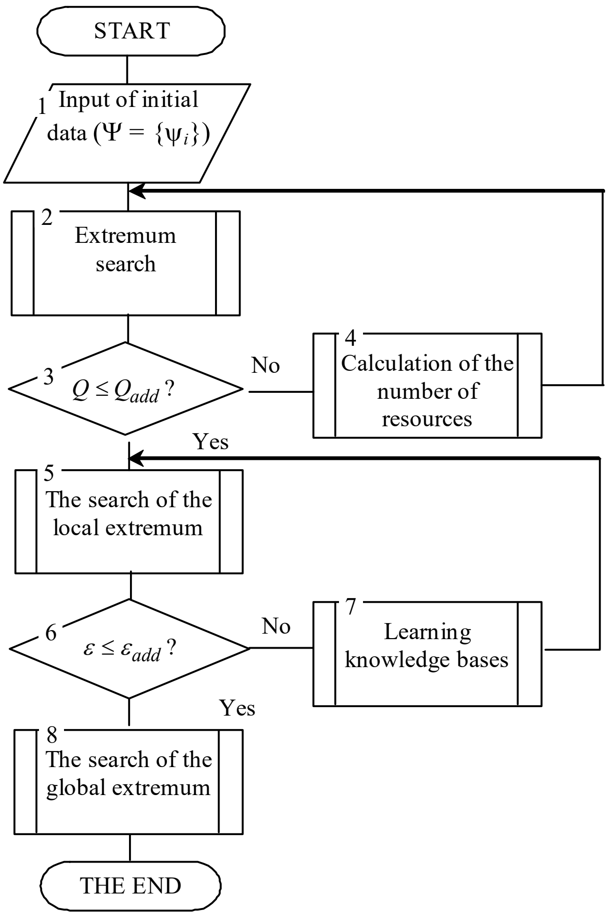

Fig. 1. Algorithm for the implementation of the parametric optimization method based on the improved algorithm of the cat flock

At the same time, the search mode is associated with slow movements with a small amplitude near the starting position (space scanning in the current position). The chase mode is determined by fast jumps with a large amplitude and allows to remove the cat_p from the local extremum, if it got there. The combination of local scanning and sudden changes in the current state allows to find the global extremum with a higher probability compared to traditional methods of multiextrema optimization.

The process of finding an extremum using a cat flock can be implemented in the form of the following sequence of steps (step 2 in Fig. 1):

Step 2.1: Create a pack of cats as a set of n-dimensional vectors $x_p^{(0)}$, distributed over a set of admissible values of the arguments R_x^n taking into account the degree χ of awareness of the state of the object (full uncertainty – exposure randomly, partial uncertainty – exposure taking into account the coefficient of correction of the position of cats χ=0.01÷0.99), so $x_p^{(0)} \in R_x^n \subset R^n$; estimate the value of the optimized function (fitness function) $f(x_p(0))$ at all Q points, while it is assumed that the goal of optimization is to find the global minimum of $f(x)$.

Step 2.2: Enter the state parameter SPC (self position consideration), which takes two values 1 or 0. Randomly divide the pack of cats into two groups: cats in search (SPC=1) and cats in pursuit (SPC=0).

Step 2.3: If SPC=1, start the corresponding group of cats to search. In this case, it is suggested to limit the search limit to priority directions. The search priority is proposed to be determined by two search limits in the two-dimensional search vector taking into account χ (namely, the upper and lower search limits). Put the remaining cats with SPC=0 into chase mode.

Step 2.4: Evaluate the value of the fitness function and store the new states x (1) corresponding to the smallest value of $f(x_p(1))$.

Step 2.5: Go back to step 2.1 with the updated flock $x_p(1)$, p=1,2,...,Q and mark the region that is unexplored.

Step 3 and 4. Based on the information about the unexplored area, determine the need to involve additional network hardware resources.

The search mode is determined by three main factors: the volume of the search memory (seeking memory pool – SMP), which determines the number of copies of each cat cat_p, the step of change in each space coordinate R_x^n (seeking range of the selected dimension – SRD) and changing coordinates (counts of dimension to change – CDC). Actually, the local extremum search mode can be implemented in the form of the following sequence of steps (step 5):

Step 5.1: If SPC=1, create C (C=SMP) copies of cat_p.

Step 5.2: According to accepted CDC, change the state of cat_p.

Step 5.3: Estimate the value of the optimized fitness function for each changed state of cat_p.

Step 5.4: enter the probability of choosing each changing state and exclude the cat with the maximum value of P_p from further consideration. The cat with the value P_p=0 is the "best" copy of cat_p, since it corresponds to the smallest value of the function being optimized $f_{\min}(x_p(\tau))$:

$$P_p = \frac{f(x_p(\tau)) - f_{\min}(x_p(\tau))}{f_{\max}(x_p(\tau)) - f_{\min}(x_p(\tau))}, \quad \tau = 1,2,\ldots,T. \tag{1}$$

At this stage, while choosing P_p, additional training of each cat from the flock takes place using the method of learning an evolving artificial neural network that [2] (steps 6, 7).

5. 2. Improved procedure of chasing the method of parametric optimization

The pursuit mode corresponds to the global search process, which allows to "skip" the local extrema of the optimized function, and can be implemented in the form of a sequence of steps (step 8):

Step 8.1: if SPC=0, for a group of cats in pursuit, calculate for each cat_p the speed of movement along each coordinate using the recursive expression:

$$\upsilon_{pi}(\tau+1) = \upsilon_{pi}(\tau) + \chi(\tau)\eta_{TM}\left(x_{best,i}(\tau) - x_{pi}(\tau)\right), \tag{2}$$

where $\upsilon_{pi}(\tau)$ – the speed of movement of the p-th cat along the i-th coordinate at the τ-th iteration of the chase, $0<\chi(\tau)<1$ – the chase parameter, which is limited by the priority of the chase and takes the value from step CS 3, η_{TM} – constant pursuit step, $x_{best,i}(\tau)$ – the best solution of the optimization problem obtained at the τ-th iteration.

Step 8.2: enter the maximum possible values of speeds $\upsilon_{\min}$ and $\upsilon_{\max}$ for each cat, check the condition and if it is violated, make $\upsilon_{pi}(\tau+1)$ equal to the corresponding value of υ_{min} or υ_{max}:

$$\upsilon_{\min} < \upsilon_{pi}(\tau+1) < \upsilon_{\max}. \quad (3)$$

Step 8.3: Change the position of each cat in the chase according to the ratio

$$x_{pi}(\tau+1) = x_{pi}(\tau) + \upsilon_{pi}(\tau). \quad (4)$$

Step 8.4: Check if it belongs $x_p(\tau+1)\ R^n_{xi}$.
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 proposed method was simulated 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.

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, as well as with a range of responsibility in accordance with current regulations.

Initial data for optimization of decision-making regarding the state of the operational grouping of troops (forces) using the proposed method:

– the number of sources of information about the operational grouping of troops (forces) is 3 (radio monitoring tools, remote sensing of the earth 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 operational grouping of troops (forces) and parametric management is determined is 200. Such parameters include: affiliation, type of organizational and staff formation, priority, minimum width along the front, maximum width along the front. The number of personnel, the minimum depth along the flank, the maximum depth along the flank, the total number of personnel, the number of WME samples, the number of types of WME samples and the number of communication devices) are also taken into account;

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

To determine the effectiveness of the proposed method, researches were conducted in comparison with other swarm methods, namely the ant algorithm (AA), the particle swarm optimization (PSO) method, and the classic cat swarm algorithm. The results of the experiments are given in Table 1 to solve the task of analyzing the operational situation.

In addition, the method operates with a smaller number of parameters and, accordingly, does not require high computational costs.

The main advantage of the method based on the behavior of the cat flock is that while using it, the probability of hitting the local optimum and the global optimum is sharply reduced and time is reduced due to parallelization. At each iteration, it is equal to the search time in the most promising block.

Table 1

Comparative analysis of bio-inspired algorithms

Number of intermediate solution points	The particle swarm method	Ant algorithm	The classic method of cat packs	The proposed method
N	T, sec	T, sec	T, sec	T, sec
5	0.282	0.276	0.232	0.19
10	0.723	0.4	0.423	0.34
15	6,641	0.999	1.1	0.88
20	10.7	2.5	2.7	2.16
30	21.3	4.5	4.7	3.76
40	42	7.9	7.4	5.92
50	56	10.1	9.2	7.36
100	120	17.6	19.6	15.68
200	727	74.2	80.2	64.2
Complexity	$O\left(\frac{(N-1)!}{4}\right)=O(N!)$	$O(N^2+N)=O(N^2)$	$O(n^2)$	$O(n^2\times0,8)$

According to the results of the analysis of the data given in the Table 1 shows that the proposed method has an acceptable computational complexity.

In the range (from 50 to 100), the proposed method becomes more efficient in terms of algorithm operation time compared to other algorithms (faster than the particle swarm method by 82–90.6 % and the ant method by 27–29.1 and the classic cat swarm algorithm by 20 %. The proposed method allows to obtain adequate solutions with a complex hierarchical structure of the monitoring object. The effectiveness of the proposed method is on average from 15 to 23 % for different hierarchies of the construction of the monitoring object, in the role of which is the operational grouping of troops (forces), as can be seen from the analysis of the results of the Table 1.

FCM and a system based on the evolving fuzzy clustering method (Evolving Fuzzy Clustering Method, EFCM) with different values of the threshold parameter were used to compare the quality of clustering (which is used as a training procedure).

The Xi-Beni index was used as a criterion for assessing the quality of clustering.

Table 2 presents the comparative results of clustering.

Table 2

Comparative clustering results

System	The number of clusters	Parameters of the algorithm	XB (Xi-Beni index)	Clustering time, t
FCM (Fuzzy C-Means)	15	–	0.1903	2.69
EFCM	9	Dthr=0.24	0.1136	0.14
EFCM	12	Dthr=0.19	0.1548	0.19
The proposed system (batch mode)	12	delta=0.1	0.0978	0.37
The proposed system (online mode)	12	delta=0.1	0.1127	0.25

To conduct the next experiment, a sample of data describing the characteristics of the operational grouping of troops (forces) was used (Table 3). Each observation was described by seven parameters:

– the number of personnel;

– the total number of personnel;

– the number of organizational staff structures;

– the number of samples of weapons and military equipment;

– the number of communication devices;

– the number of types of weapons and military equipment and the type of communication devices.

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

Table 3

Comparative results of clusterization

System	The number of clusters	Parameters of the algorithm	XB (Xi-Beni index)	Time, sec
FCM (Fuzzy C-Means)	3	Dthr=0.6	0.2963	0.81
EFCM	4	Dthr=0.6	0.2330	0.54
The proposed system (batch mode)	3	delta=0.4	0.2078	0.45
The proposed system (online mode)	3	delta=0.4	0.2200	0.30

The parameters of the analyzed systems and the number of detected clusters, are also given in the Table 3. The Xi-Beni (XB) index was used to assess the quality of the systems. It is worth noting that the proposed system showed a better PC (partition coefficient) result in comparison with EFCM and a better result in terms of operation time compared to FCM. Both the proposed systems and FCM identified three fuzzy clusters.

The research of the proposed training procedure showed that the mentioned training procedure provides an average of 10–18 % higher efficiency of training artificial neural networks and does not accumulate errors during training (Tables 2, 3). The specified results can be seen from the results in the last lines of Table 2 and Table 3, and the difference of the Xi-Beni index.

6. Discussion of the results of improving the optimization method based on the cat flock algorithm

The obtained results on increasing the efficiency of optimization are explained by the use of an improved algorithm of the cat flock. Unlike classical empirical expressions and the classical herding algorithm, the algorithm of the herding cat is not used in a classical way. The classical algorithm is improved with the help of evolving artificial neural networks and additional directed search and chase procedures.

The main advantages of the proposed optimization method based on the cat flock 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 to use expressions to select a vector of indicators;

– unambiguousness of the obtained decision (1)–(4);

– 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 training procedures for individuals of the cat flock (steps 6, 7);

– taking into account the type of uncertainty of the initial data while constructing the metric of the path of the cat flock (step 2. 1);

– high reliability of the obtained solutions while searching for a solution in several directions using individuals from the cat flock (step 2. 1);

– additional consideration of the chase parameter, which limits the chase area, which allows to take into account the priority of the search (expression 2);

– the ability to determine the need to involve additional network hardware resources (steps 3 and 4).

Disadvantages of the proposed method include:

– lower accuracy of assessment and parametric management for a single parameter;

– 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.

This method will allow:

– to assess the state of the object and its parametric management;

– to determine effective measures to improve management efficiency;

– to increase the speed of assessing the object state and decision-making management regarding the management of its parameters;

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

– to calculate the need to involve additional computing resources of the system.

The proposed method allows to solve the task of increasing the efficiency of the process of optimizing its parameters due to the synthesized algorithm of the cat flock.

This method is advisable to use in decision-making support systems to optimize decision-making as a software product. It is proposed to be used in the interests of combat management of the actions of troops (forces).

The limitations of the research are:

– the need to know the completeness of information about the state of the control object for determining the correction coefficients;

– the need to know the number of computing resources of the decision-making support systems.

This research is a further development of researches aimed at the development of methodological principles for increasing the efficiency of information and analytical support, which were published earlier [2, 4–6, 23–37].

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. The search procedure for the parametric optimization method has been improved. The essence of the improvement consists in the initial display of cats taking into account the degree of awareness of the object state. Search priority is determined by two search boundaries

in a two-dimensional search vector, taking into account the awareness factor. Also, in this procedure, additional training of each cat from the flock takes place using the method of learning an evolving artificial neural network.

2. The procedure for chasing the parametric optimization method has been improved. The essence of the improvement lies in determining the priority of the pursuit.

The specified procedures are basic for the method of parametric optimization based on the cat flock algorithm, on the basis of which the algorithm for the implementation of the specified method was formed.

An algorithm for implementing the method is defined, which allows:

– to take into account the type of data uncertainty;

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

– to determine the necessary computing resources of the system for operational assessment of the object's condition;

– to take into account the priority of searching by individuals from the cat flock;

– to conduct an initial display of individuals of the cat flock;

– to carry out accurate training of the individuals of the cat flock using the expressions developed in the work [2].

3. Conducted example of using the proposed method on the example of assessing the state of the operational situation of an army (force) grouping. The specified example showed a 17–23 % increase in the efficiency of data processing due to the use of additional improved procedures. The obtained data made it possible to conclude that the time complexity of the algorithm does not exceed the polynomial complexity.

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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Availability of data

The manuscript has associated data in the data repository.

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