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DEVELOPMENT OF A METHOD FOR ANALYZING AND FORECASTING THE STATE OF MULTIDIMENSIONAL OBJECTS USING A METAHEURISTIC ALGORITHM

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The object of the study is multidimensional objects. The problem solved in the study is to increase the efficiency of assessing the state of multidimensional objects, regardless of the number of dimensions of object state assessment. The subject of the study is the process of assessing the state of multidimensional objects using an advanced butterfly optimization algorithm (BOA), an advanced genetic algorithm and evolving artificial neural networks.

The originality of the study is as follows:

– the initial setting of butterfly agents (BA) on the plane of multidimensional objects is carried out taking into account the type of uncertainty using appropriate correction factors for the degree of awareness of nectar source locations (in our case, priority search directions);

– adjusting the initial BA velocity allows determining search priority;

– the fitness of BA nectar collection sites is determined, which reduces the time for assessing the state of multidimensional objects;

– the possibility of global restart of the algorithm, which allows the algorithm to go beyond the current optimum and improve the exploration ability, which reduces the time for assessing the state of multidimensional objects;

– the possibility of clarification at the stage of collecting nectar clusters due to ranking nectar sources by the level of stimulus intensity;

– improved ability to select the best BA in comparison with traditional selection using an advanced genetic algorithm.

The proposed method should be used to solve the problems of assessing the state of multidimensional objects under uncertainty and risks characterized by a high degree of complexity. The method showed a 14–16 % increase in the efficiency of assessing the state of multidimensional objects

Keywords: multidimensional objects, advanced genetic algorithm, artificial neural networks, swarm algorithms

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1. Introduction

Evaluation of multidimensional objects is a complex process of determining a set of possible states for a wide range of problems, including management decision-making [1–3].

Assessments of multidimensional objects are discontinuous, undifferentiated and multimodal. Considering the above, classical gradient deterministic algorithms [4–6] are inappropriate for solving this type of problem.

The most common approaches to assessing the state of multidimensional objects are swarm intelligence algorithms (swarm algorithms). The most well-known swarm algorithms are the particle swarm optimization algorithm, artificial bee colony algorithm, firefly algorithm, ant colony optimization algorithm, wolf optimization algorithm and sparrow search algorithm [6–8].

However, most of the basic bio-inspired algorithms mentioned above are unable to maintain a balance between exploration and exploitation, resulting in poor performance for real-world complex optimization problems.

This encourages the implementation of various strategies to improve the convergence rate and accuracy of basic bio-inspired algorithms.

Therefore, research on the development of new approaches assessing the state of multidimensional objects is relevant.

2. Literature review and problem statement

The works [9–11] define the main advantages and disadvantages of cognitive algorithms. The disadvantages of these approaches include the lack of consideration of the type of uncertainty, the inability to conduct a search in different directions by several agents.

The work [12] presents an approach focused on the search for hidden information in large data sets. The method is based on analytical baselines, variable reduction, sparse feature detection and rule formation. The disadvantages of this method include the inability to take into account various decision-making strategies, the lack of consideration of the type of uncertainty of the initial data.

The works [13, 14] present an approach to transforming information models of objects to their equivalent structural models. This mechanism is designed to automate the necessary conversion, modification, and addition operations during such information exchange. The shortcomings of the mentioned approach include the inability to assess the adequacy and reliability of the information transformation process, as well as to make appropriate correction of the obtained models.

The work [15] proposed a method of fuzzy hierarchical evaluation, which allows assessing the quality of library services. The disadvantages of the specified method include the inability to assess the adequacy and reliability of the assessment and, accordingly, determine the assessment error.

The work [16] analyzed the 30 most common big data algorithms. It was found that the analysis of large amounts of data should be carried out in layers, take place in real time and have the opportunity for self-learning, searching for a solution in different directions and take into account data noise.

The works [17, 18] present approaches to the evaluation of various data for decision support systems, based on clustering the basic set of input data, after which the system is trained based on the analysis. However, given the static architecture of artificial neural networks, an accumulation of errors occurs.

The work [19] carried out a comparative analysis of existing decision support technologies, namely: analytic hierarchy process, neural networks, fuzzy set theory, genetic algorithms and neuro-fuzzy modeling. The advantages and disadvantages of these approaches are indicated. For the problems of assessing the state of hierarchical systems under risk and uncertainty, using artificial neural networks and gradient algorithms is justified.

The work [20] developed approaches to the structural and objective analysis of the development of weakly structured systems. In this case, the problem is defined as the inconsistency between the existing state of the weakly structured system and the required one. At the same time, the disadvantages of the proposed approaches include the problem of local optimum, the lack of consideration of system computing resources and the inability to conduct a multidirectional search.

An analysis of the works [9–20] showed that the common shortcomings of the above studies are:

– the lack of possibility of hierarchical processing of various data;

– the lack of possibility of additional involvement of necessary computing resources of the system;

– the lack of consideration of the type of uncertainty and noise of data on information circulating in the system;

– the lack of deep learning mechanisms for knowledge bases;

– the lack of priority of the search in a certain direction.

3. The aim and objectives of the study

The aim of the study is to develop a method for analyzing and forecasting the state of multidimensional objects. This will increase the efficiency of assessing and forecasting the state of multidimensional objects with a given reliability and developing subsequent management decisions. This will help develop software for intelligent decision support systems.

To achieve the aim, the following objectives were set:

– to determine procedures of implementing the method for analyzing and forecasting the state of multidimensional objects using a metaheuristic algorithm;

– to give an example of assessing and forecasting the state of multidimensional objects when analyzing the operational situation of a group of troops (forces).

4. Materials and methods

The object of the study is multidimensional objects. The problem solved in the study is to increase the efficiency of assessing the state of multidimensional objects, regardless of the number of dimensions of object state assessment. The subject of the study is the process of assessing the state of multidimensional objects using an advanced butterfly optimization algorithm (BOA), an advanced genetic algorithm and evolving artificial neural networks.

The hypothesis of the study is the possibility of increasing the efficiency of assessing the state of multidimensional objects while ensuring the given assessment reliability at the level of 0.9.

Simulation of the proposed method approach was carried out in the MathCad 14 software environment (USA). The problem solved during the assessment was to assess the elements of the operational situation of a group of troops (forces). The hardware of the research process is AMD Ryzen 5 (USA).

As an object of assessment and forecasting of the future state, an operational group of troops (forces) was considered. An operational group of troops (forces) formed on the basis of an operational command with a standard composition of forces and means according to the wartime staff and with a range of responsibilities under current regulations. Using this example is related to the high dynamics of operations (combat operations), a large number of various units in groups of troops (forces), a variety of forms and methods of organizing operational structure and nature of actions.

Parameters of the method approach:

– number of iterations – 100;

– number of individuals in the flock – 50;

– range of the feature space – [–1,000, 1,000].

The research is based on BA for assessing and forecasting the state of multidimensional objects and an advanced genetic algorithm for BA selection. For BA training, evolving artificial neural networks are used. The butterfly optimizer was chosen due to the possibility of using different search strategies depending on the available computing resources of the system. Evolving artificial neural networks allow learning not only the parameters but also the architecture of artificial neural networks.

5. Development of a method for analyzing and forecasting the state of multidimensional objects using a metaheuristic algorithm

5. 1. Procedures of implementing the method for analyzing and forecasting the state of multidimensional objects using a metaheuristic algorithm

BOA is based on the foraging behavior of a flock of butterflies. As a rule, butterflies can determine the source of fragrance accurately and distinguish between different fragrances. Butterflies move from their place to other places with more nectar. Butterflies produce fragrance as they move to share their current location and personal information with other butterflies.

The inspiration and behavior of butterflies can be formulated in this study as an optimization method, where butterflies represent search agents, and the fragrances produced characterize the optimization values.

In BOA, butterfly agents (BA) can generate a fragrance/fitness value with some power to distinguish it from other fragrances. This behavior can assist other BA in updating their position in the search space. Once the BA that finds the best nectar in the search space produces a fragrance, all neighboring BA move to the best location for the BA. Such an update of the mechanism is called a global search in BOA. On the other hand, BA will move randomly in the search space if the fragrances of other BA are detected, known as local search.

The method for analyzing and forecasting the state of multidimensional objects consists of the following sequence of steps:

Step 1. Entering initial data. At this stage, the main algorithm parameters are determined, such as:

– type of problem being solved;

– number of BA in the population;

– number of variables characterizing the problem of analyzing and forecasting multidimensional objects to be solved;

– available computing resources of the system for analyzing and forecasting multidimensional objects;

– complexity of multidimensional objects to be evaluated;

– parameters of an advanced genetic algorithm (selection parameters, mutations), number of individuals to be selected;

– type of uncertainty about the state of multidimensional objects (complete uncertainty, partial uncertainty and complete awareness);

– volume and type of the training sample for artificial neural networks;

– volume and type of the test sample for artificial neural networks;

– architecture of an artificial neural network, etc.

Step 2. Creating a flock of BA. The primary (initial) BA population X_i (i=1, 2, ..., n) is initialized. All BA form a population (flock) defined by the matrix X. The initial BA population (flock) is generated in the study taking into account uncertainty about the state of multidimensional objects based on the constraints of the problem under consideration (analysis and/or forecasting):

$$X=\begin{bmatrix} X_1 \\ . \\ . \\ . \\ X_i \\ . \\ . \\ . \\ X_N \end{bmatrix}_{N\times m} = \begin{bmatrix} x_{1,1}\times\iota_{1,1} & \cdots & x_{1,d}\times\iota_{1,d} & \cdots & x_{1,m}\times\iota_{1,m} \\ \vdots & & \vdots & & \vdots \\ x_{i,1}\times\iota_{i,1} & \cdots & x_{i,d}\times\iota_{i,d} & \cdots & x_{i,m}\times\iota_{i,m} \\ \vdots & & \vdots & & \vdots \\ x_{N,1}\times\iota_{N,1} & \cdots & x_{N,d}\times\iota_{N,d} & \cdots & x_{N,m}\times\iota_{N,m} \end{bmatrix}_{N\times m}, \quad (1)$$

where X is the matrix describing the BA population on the problem solving plane, X_i is the i-th BA, which is a solution candidate, $x_{i,d}$ is the d-th dimension of the multidimensional object in the solution search space, N is the number of BA in the population (flock), m is the number of solution variables describing the state of a multidimensional object.

Step 3. Assigning a serial number to each AM in the flock, i, $i\in[0, S]$. This step allows determining the parameters of finding a solution for each BA in the population.

Step 4. Setting the initial velocity of each BA.

The initial velocity for an individual BA v_0 is described by the following mathematical expression:

$$v_i=(v_1,v_2,...v_s),\ v_i=v_0. \quad (2)$$

The population update of each BA is determined in the study to find the balance between the two major exploration and exploitation procedures. These procedures define the global and local search process. The process of updating the BA population is based on simulating two strategies of the exploration phase and the exploitation phase.

Step 5. Selecting BA for solving problems.

The fitness of each BA for solving problems is determined in each iteration using the advanced genetic algorithm proposed in [20] and comparing the obtained values with standardized functions. The fitness of the BA in the search flock (row in matrix X) is measured and compared with the fitness of the rest of BA (other rows of matrix X).

Step 6. Preliminary assessment of the BA search area. In this procedure, the search area in natural language is determined precisely by the halo of BA existence, where butterflies live.

Step 7. Classification of nectar sources for BA.

The location of the best cluster of nectar sources for BA is (FS_{ht}), which is nearby and requires the least energy to find and collect it. The most distant clusters of nectar sources are denoted as FS_{at}.

Other individual nectar sources are denoted as FS_{nt}:

$$FS_{ht}=FS(\text{sorte\_index}(0,7)), \quad (3)$$

$$FS_{at}(1:3)=FS(\text{sorte\_index}(1:4)), \quad (4)$$

$$FS_{nt}(1: NP\text{-}4)=FS(\text{sorte\_index}(2: NP)). \quad (5)$$

Step 8. Determining the fragrance intensity of nectar sources.

The fragrance intensity for BA is mathematically modeled as follows:

$$pf_i = cI^a, \quad (6)$$

where pf_i is the power of fragrance from the i-th BA, I is the stimulus intensity, c is the sensory modality, and a is an indicator for the degree of dependence on the modality.

Step 9. Determining the amount of available computing resources of the system.

At this stage, the amount of computing resources available for calculations is determined. Under the provisions outlined in Step 4, the concept of updating the BA position is chosen.

Step 10. Exploration of nectar sources (global search).

The location of each BA is represented as a vector of certain problem values. This BA location can be updated by trying to find a better location using the following formula:

$$x_i^{t+1} = x_i^t + F_i^{t+1}, \quad (7)$$

where x_i^t is the current position of BA i in iteration t, x_i^{t+1} is the following position of the i-th BA and F_i^{t+1} is the fragrance used by x_i to update its position during iterations.

In the global search, the i-th BA moves to the strongest BA g^*, which can be represented as:

$$F_i^{t+1} = \left(r^2 \times g^* - x_i^t\right) \times pf_i, \quad (8)$$

where r is a random number in the range [0, 1].

Step 11. Verification of hitting the global optimum. At this stage, the condition for the algorithm to hit the global optimum by the specified criterion for assessing the state of a multidimensional object is checked.

Step 12. Global restart procedure.

The restart procedure can effectively increase the algorithm's ability to go beyond the current optimum and improve the exploration ability of the algorithm. If the optimal population of the algorithm remains unchanged after T iterations, the population is likely to fall into a local optimum. Thus, the candidate solution will be initialized randomly to accelerate the exit from the global optimum.

Step 13. Nectar extraction phase (exploitation).

In the local search, the movement of BA updates can be formulated as follows:

$$F_i^{t+1} = \left(r^2 \times x_j^t - x_k^t\right) \times pf_i, \quad (9)$$

where x_j^t and x_k^t are the positions of the j-th and k-th BA in the search area. A new parameter, called switching probability p, is used in BOA to switch the algorithm behavior between local and global search to obtain the best balance between exploration and exploitation.

Step 13. Checking the stop criterion. The algorithm terminates when the maximum number of iterations is completed. Otherwise, the behavior of generating new locations and checking conditions is repeated.

Step 14. Training of BA knowledge bases.

In the study, the training method based on evolving artificial neural networks developed in [2] is used to train the knowledge bases of each BA. The method is used to change the movement nature of each BA, for more accurate analysis results in the future.

The end of the algorithm.

5. 2. Example of assessing and forecasting the state of multidimensional objects when analyzing the operational situation of a group of troops (forces)

This section analyzes the behavior of BA in exploration and exploitation due to its significant impact on the solution of analysis and forecasting problems. The success of metaheuristics lies in their ability to achieve the best balance between exploration and exploitation. These two terms conflict in their search behavior. At the exploration stage, the algorithm has a high ability to explore and move through unexplored areas of the search space, while at the exploitation stage, the algorithm processes focus on deep search in known areas of the search space.

To determine the effectiveness of the proposed method for analyzing and forecasting the state of multidimensional objects using a metaheuristic algorithm, a simulation was carried out. To solve the problem of determining the composition of the operational group of troops (forces) and elements of its operational structure in order to determine the expediency of regrouping troops (forces).

The effectiveness of the method is compared with metaheuristic algorithms, using a set of CEC2017 test functions given in Table 1. The efficiency assessment criterion is the speed of decision-making (ms) with a given assessment reliability (0.9).

Table 1

Comparison of the proposed method with other metaheuristic algorithms for a defined set of test functions

Type of test functions	Metrics	Particle swarm optimization algorithm	Ant colony optimization algorithm	Black widow optimization algorithm	Bee colony algorithm	Canonical butterfly optimization algorithm	Proposed method
1	2	3	4	5	6	7	8
CEC 2017-F1	Average	3.61E+09	7.21E+07	3.54E+09	7.98E+09	5.38E+09	2.36E+05
	Standard	3.15E+09	1.21E+08	1.70E+09	5.03E+09	3.18E+09	8.39E+04
CEC 2017-F2	Average	8.46E+31	4.75E+29	3.91E+31	3.21E+34	7.36E+34	1.97E+33
	Standard	4.49E+32	2.54E+30	1.53E+32	1.75E+35	3.95E+35	1.08E+34

Continuation of the Table 1

1	2	3	4	5	6	7	8
CEC 20I7-F3	Average	1.57E+05	1.11E+05	5.58E+04	6.82E+04	6.87E+04	2.12E+04
	Standard	5.23E+04	3.72E+04	1.02E+04	2.04E+04	1.46E+04	1.05E+04
CEC 2017-F4	Average	8.33E+02	6.40E+02	1.02E+03	1.22E+03	9.81E+02	6.99E+02
	Standard	1.86E+02	5.06E+01	2.56E+02	7.74E+02	4.35E+02	2.34E+02
CEC 2017-F5	Average	7.35E+02	7.07E+02	7.19E+02	6.72E+02	6.36E+02	6.37E+02
	Standard	2.49E+01	3.09E+01	3.47E+01	3.66E+01	4.20E+01	2.09E+01
CEC 2017-F6	Average	6.57E+02	6.56E+02	6.38E+02	6.32E+02	6.23E+02	6.08E+02
	Standard	1.1 IE+01	8.62E+00	1.03E+01	1.01E+01	8.22E+00	6.15E+(X)
CEC 2017-F7	Average	1.26E+03	1.14E+03	1.31E+03	9.83E+02	9.26E+02	8.78E+02
	Standard	7.14E+01	7.87E+01	1.30E+02	5.10E+01	5.80E+01	3.01E+01
CEC 2017-F8	Average	9.65E+02	9.63E+02	1.00E+03	9.48E+02	9.18E+02	9.00E+02
	Standard	1.82E+01	2.78E+01	3.37E+01	2.80E+01	2.67E+01	1.97E+01
CEC 2017-F9	Average	8.82E+03	6.16E+03	6.71E+03	5.40E+03	4.06E+03	3.18E+03
	Standard	1.80E+03	9.63E+02	1.33E+03	1.53E+03	1.54E+03	7.41E+02
CEC 2017-F10	Average	7.54E+03	5.19E+03	8.27E+03	4.64E+03	4.74E+03	3.52E+03
	Standard	4.70E+02	7.04E+02	3.05E+02	1.15E+03	1.59E+03	6.20E+02
CEC 2017-F11	Average	3.48E+03	2.53E+03	2.20E+03	8.37E+03	1.19E+04	131E+03
	Standard	1.35E+03	1.10E+03	9.02E+02	4.34E+03	6.41E+03	1.88E+02
CEC 2017-F12	Average	1.80E+09	7.55E+07	1.62E+09	5.92E+08	5.87E+07	6.77E+07
	Standard	9.48E+08	3.90E+07	9.40E+08	1.96E+09	8.65E+07	5.88E+07
CEC 2017-F13	Average	7.05E+07	2.18E+04	1.15E+08	4.58E+04	8.45E+04	7.63E+04
	Standard	1.39E+08	2.43E+04	1.36E+08	4.80E+04	6.59E+04	7.05E+04
CEC 2017-F14	Average	3.06E+06	3.07E+05	1.10E+06	4.25E+05	5.37E+05	3.55E+05
	Standard	4.63E+06	3.06E+05	1.07E+06	5.26E+05	5.94E+05	3.42E+05
CEC 2017-F15	Average	8.43E+03	2.81E+05	1.05E+06	2.96E+04	4.87E+04	5.04E+04
	Standard	3.08E+03	1.57E+05	1.10E+06	2.27E+04	4.26E+04	5.56E+04
CEC 2017-F16	Average	3.60E+03	3.56E+03	4.12E+03	3.02E+03	3.05E+03	3.19E+03
	Standard	4.40E+02	1.90E+02	8.26E+02	4.96E+02	4.26E+02	4.50E+02
CEC 2017-F17	Average	2.82E+03	2.58E+03	2.90E+03	2.79E+03	2.34E+03	2.67E+03
	Standard	2.71E+02	1.65E+02	3.62E+02	3.04E+02	1.97E+02	3.08E+02
CEC 2017-F18	Average	4.28E+06	4.65E+06	3.70E+07	1.61E+06	1.84E+06	1.83E+06
	Standard	3.92E+06	2.52E+06	4.64E+07	1.44E+06	1.40E+06	1.56E+06
CEC 2017-F19	Average	9.03E+05	3.77E+03	2.12E+07	3.31E+05	1.30E+05	4.71E+05
	Standard	1.08E+06	2.05E+03	1.84E+07	9.21E+05	2.12E+05	5.42E+05
CEC 2017-F20	Average	3.26E+03	2.99E+03	2.94E+03	3.00E+03	2.85E+03	2.79E+03
	Standard	2.52E+02	1.10E+02	2.03E+02	2.47E+02	2.11E+02	1.86E+02
CEC 2017-F21	Average	2.20E+03	2.20E+03	2.20E+03	2.20E+03	2.20E+03	2.20E+03
	Standard	1.60E+00	3.25E-06	2.98E-02	1.49E-01	5.43E-03	1.26E-03

As can be seen from Table 1, a 14–16 % increase in the efficiency of assessing the state of hierarchical systems is achieved by using additional procedures.

The method converges to the true value for most unimodal functions with the highest convergence rate and accuracy, while the convergence results of the black widow optimization algorithm are far from satisfactory.

6. Discussion of the results of developing a method for analyzing and forecasting the state of multidimensional objects

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

– the initial setting of BA on the plane of multidimensional objects is carried out taking into account the type of uncertainty (Step 2). This is done using appropriate correction factors for the degree of awareness of nectar source locations (in our case, priority search directions), compared to [9, 14, 20];

– adjusting the initial BA velocity (Step 4) allows determining search priority, compared to [9–15];

– the fitness of BA nectar collection sites is determined, which reduces the time for assessing the state of multidimensional objects (Step 6), compared to [14, 16, 17];

– the possibility of global restart of the algorithm, which allows the algorithm to go beyond the current optimum and improve the exploration ability (Step 11). This is achieved by reducing the time needed for assessing the state of multidimensional objects, compared to [9–15];

– universality of solving the problem of assessing the state of hierarchical BA systems due to the hierarchical nature of their description (Steps 1–14, Table 1), compared to [9, 12–18];

– the possibility of simultaneous search for a solution in different directions (Steps 1–14, Table 1);

– adequacy of the results obtained (Steps 1–14), compared to [9–20];

– the possibility of clarification at the stage of collecting nectar clusters (Step 12) due to ranking nectar sources by the level of stimulus intensity, compared to [9, 12–18];

– improved ability to select the best BA in comparison with traditional selection by using an advanced genetic algorithm (Step 5), compared to [9–15];

– the ability to avoid the local extremum problem (Steps 1–14);

– the possibility of deep learning of BA knowledge bases (Step 14), compared to [9–20].

The disadvantages of the proposed method include:

– lower accuracy of unidirectional solution search due to gradient search;

– loss of credibility of the obtained solutions when searching for a solution in several directions simultaneously;

– lower assessment accuracy compared to other assessment approaches.

This method will allow you:

– to assess the state of multidimensional objects;

– to determine effective measures to improve the efficiency of assessing the state of multidimensional objects while maintaining the given reliability;

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

The limitations of the study are the need for an initial database on the state of multidimensional objects, the need to take into account the delay time for collecting and communicating information from intelligence sources.

The proposed method should be used to solve the problems of assessing the state of multidimensional objects under uncertainty and risks characterized by a high degree of complexity.

This study is a further development of research aimed at developing method principles for increasing the efficiency of processing various data, published earlier [2, 4–6, 20].

Areas of further research should be aimed at reducing computing costs while processing various data in special-purpose systems.

7. Conclusions

1. Procedures for analyzing and forecasting the state of multidimensional objects using a metaheuristic algorithm are defined, which allows you:

– to take into account available information on the state of multidimensional objects that determines awareness of their state;

– to implement various strategies of searching for nectar sources for BA;

– to determine the BA nectar extraction strategy taking into account the available computing resources of the system and assessment priority;

– to change the search area of individual BA;

– to change the velocity of BA movement in the specified search direction;

– to carry out the initial BA setting considering the type of uncertainty;

– to conduct a local and global search taking into account the degree of uncertainty;

– 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, as well as the architecture of individual elements and the architecture of the artificial neural network as a whole;

– to classify nectar clusters according to assessment priority;

– to adjust the BA nectar collection route due to ranking nectar clusters according to the stimulus level;

– to avoid the problem of local extremum.

2. An example of using the proposed method when solving the problem of determining the composition of an operational group of troops (forces) and elements of its operational structure is provided. The specified example showed a 14–16 % increase in the efficiency of assessing the state of multidimensional objects by using additional advanced procedures.

Conflict of interest

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

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Data availability

The manuscript has associated data in the data repository.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies while creating the presented work.

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