UDC 004.81
DOI: 10.15587/1729-4061.2025.326468

DEVELOPMENT OF A METHODOLOGICAL APPROACH FOR ASSESSING THE CONDITION OF COMPLEX ORGANIZATIONAL AND TECHNICAL SYSTEMS

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In this study, the object of research is organizational and technical systems. The primary issue addressed is the enhancement of operational efficiency in assessing the state of such systems under constraints related to data reliability, regardless of the volume of incoming data acquired from information sources. The subject of the research is the process of evaluating the condition of organizational and technical systems. The study presents the development of a methodological approach for assessing the condition of complex organizational and technical systems. The originality of the proposed approach lies in the implementation of advanced auxiliary procedures that enable the following:

– deployment of a search population of hippopotamus agents across the search plane, accounting for uncertainty in the information acquired through technical means about the organizational and technical system, by employing appropriate corrective coefficients. This enables a reduction in the time required for initial configuration of the subsystem responsible for processing heterogeneous data from extraction sources;

– additional consideration of the velocity of each agent within the hippopotamus swarm, allowing the prioritization of search tasks by each individual agent within the corresponding search space (across elements and components of the organizational and technical system);

– verification of the algorithm's convergence to local and global optima;

– replacement of ineffective search agents by refreshing the population of hippopotamus agents;

– implementation of deep learning mechanisms for the knowledge bases of the hippopotamus agent swarm;

– estimation of the required computational resources in cases where the available computational capacity is insufficient for performing the necessary calculations.

An illustrative example demonstrated a 13–16 % increase in decision-making efficiency due to the integration of additional procedures, while ensuring a decision reliability level of 0.9

Keywords: hierarchical structures, metaheuristic algorithms, evolving artificial neural networks, destabilizing factors

Received 14.01.2025
Received in revised form 17.03.2025
Accepted 01.04.2025
Published 30.04.2025

How to Cite: *Mohammed, B. A., Stanovska, I., Kashkevich, S., Lebedynskyi, A., Vakulenko, Y., Protas, N., Klyuchak, O., Lastivka, O., Semeniuk, A., Kivshar, O. (2025). Development of a methodological approach for assessing the condition of complex organizational and technical systems. Eastern-European Journal of Enterprise Technologies, 2 (3 (134)), 47–53. https://doi.org/10.15587/1729-4061.2025.326468*

1. Introduction

The issue of evaluating the state of complex hierarchical systems for decision support systems (DSS) is of critical relevance in modern information and automated systems of various functional purposes. Recent armed conflicts involving the use of advanced information and network-centric technologies have demonstrated that only a small fraction (5–10 %) of the data describing the state of a complex system is processed and taken into account during its evaluation [1–3]. The remaining data are either not processed at all or only partially considered, which is unacceptable for a comprehensive assessment of organizational and technical systems.

The low efficiency in processing heterogeneous data arises from the following reasons [2, 3]:

– the dominant role of the human factor in processing heterogeneous data that describe the state, position, and components of organizational and technical systems;

– a large number of heterogeneous information sources integrated into information and automated systems that supply data regarding the organizational and technical system;

– the processing of heterogeneous data is characterized by varying degrees of uncertainty and noise, resulting in significant time delays and the need for extensive computational resources;

– the presence of a substantial volume of destabilizing data, which affects the dynamic and ever-expanding responsiveness of heterogeneous data processing;

– the presence of both structured and unstructured data within information and automated systems, all of which require processing.

Considering the heterogeneity of information sources, the multitude of destabilizing factors, and the varying dimensionality of descriptive indicators, along with the necessity to process large volumes of diverse data, it is imperative to explore new approaches for data processing [4]. One such promising approach is the application of metaheuristic algorithms [5–8]. For instance, reference [5] presents a methodology for processing heterogeneous data, while [6] introduces a comprehensive method for heterogeneous data processing. These studies are grounded in the use of metaheuristic algorithms in their classical form, without accounting for contemporary functional features of decision support systems. In [7], an approach is presented for creating databases for mobile robotic platforms, also based on artificial intelligence methods, particularly metaheuristic algorithms. Reference [8] outlines a method for evaluating hierarchical objects using classical metaheuristics to solve novel mathematical computation problems.

While canonical metaheuristic algorithms indeed enhance the responsiveness of heterogeneous data processing, further improvements in efficiency cannot be achieved through the canonical forms alone. This necessity drives the implementation of new conceptual principles aimed at increasing the convergence speed and accuracy of fundamental metaheuristic algorithms when applied to heterogeneous data. One promising direction is the enhancement of these algorithms by introducing new procedures within their canonical structure.

2. Literature review and problem statement

In [9], an algorithm for cognitive modeling is presented, highlighting the advantages of cognitive tools. However, a significant drawback is the lack of consideration for the type of uncertainty regarding the analyzed object's state.

In [10], the essence of cognitive modeling and scenario planning is discussed. The authors propose a system of complementary principles for building and implementing scenarios, outline various approaches for scenario construction, and describe a modeling procedure based on fuzzy cognitive maps. Nonetheless, this approach does not accommodate the type of uncertainty or the noise present in the initial data.

Reference [11] analyzes key approaches to cognitive modeling. Cognitive analysis enables exploration of issues involving fuzzy factors and interrelations, consideration of environmental changes, and leveraging objectively emerging trends. However, it does not address the description of complex and dynamic processes.

In [12], a method for analyzing large data arrays is introduced, aimed at discovering hidden information within such datasets. The method includes generating analytical baselines, variable reduction, sparse feature detection, and rule induction. Its drawbacks include the inability to accommodate different decision evaluation strategies and the lack of consideration for input data uncertainty.

Reference [13] presents a mechanism for transforming informational models of construction objects into their equivalent structural models, intended to automate operations related to conversion, modification, and augmentation during information exchange. However, it lacks mechanisms for assessing the adequacy and reliability of the transformation process and for correcting the resulting models.

In [14], the development of an analytical web platform for analyzing the geographical and temporal distribution of incidents is described. The platform includes several dashboards with statistically significant regional data. Nonetheless, it cannot evaluate the adequacy and reliability of information transformation and is characterized by high computational complexity and non-unidirectional solution search.

In [15], a fuzzy hierarchical method for evaluating library service quality is developed. It enables assessment across multiple input parameters, but it does not provide mechanisms to verify the adequacy and reliability of evaluations or determine the margin of error.

Reference [16] analyzes 30 algorithms for processing large data sets, outlining their strengths and weaknesses. It concludes that big data analysis should be layered, conducted in real-time, and include self-learning capabilities. Limitations include high computational complexity and lack of mechanisms for verifying the adequacy of evaluations.

In [17], an approach to evaluating input data for decision support systems is proposed, involving clustering, analysis, and training based on initial datasets. However, this method suffers from error accumulation over time due to the absence of adequacy assessment for decision-making.

In [18], a method is described for processing data from multiple sources. While it allows for multisource data handling, it yields low evaluation accuracy and lacks mechanisms for verifying result reliability.

Reference [19] compares various decision support technologies – including the analytic hierarchy process (AHP), neural networks, fuzzy set theory, genetic algorithms, and neuro-fuzzy modeling. Each method's advantages, disadvantages, and application areas are discussed. AHP performs well with complete initial information but involves high subjectivity due to the need for expert comparisons and evaluation criteria selection. For forecasting tasks under uncertainty and risk, the use of fuzzy set theory and neural networks is justified.

In [20], a combined strategy of various metaheuristic algorithms is discussed. The drawback of this approach lies in the insufficient responsiveness when processing heterogeneous data with multiple algorithms simultaneously.

The analysis of studies [9–20] reveals the following common shortcomings:

– lack of mechanisms for forming a hierarchical system of indicators for evaluating the heterogeneous data processing in organizational and technical systems;

– failure to consider computational resources in systems managing heterogeneous data processing;

– absence of correction mechanisms for the indicator system managing heterogeneous data processing;

– lack of deep learning mechanisms for knowledge bases to correct assessment errors;

– high computational complexity;

– no consideration for available computational (hardware) resources in DSS;

– absence of prioritization in search directions.

In light of these issues, the research should focus on developing a methodological approach for assessing the state of complex organizational and technical systems.

3. The aim and objectives of the study

The aim of this study is to develop a methodological approach for assessing the condition of complex organizational and technical systems. This will enable an increase in the responsiveness of system state assessment by improving the efficiency of heterogeneous data processing with a predetermined level of reliability and by supporting subsequent managerial decision-making. The results of this study will facilitate the development (or enhancement) of software tools for supporting such decision-making processes.

To achieve this aim, the following objectives were set:

– to define the algorithm for implementing the proposed method;

– to provide an example of the method's application for processing heterogeneous data within organizational and technical systems.

4. Materials and methods

The object of this study is organizational and technical systems. The central problem addressed involves enhancing the timeliness of assessing the state of organizational and technical systems under constraints on data reliability, regardless of the volume of data received from information sources. The subject of the study is the process of evaluating the condition of organizational and technical systems through the application of the following components:

– an improved hippopotamus algorithm – aimed at increasing the responsiveness of state evaluation for organizational and technical systems by utilizing a herd protection strategy against predators. This algorithm enables the rapid acquisition of accurate solutions within small search areas, making it a promising candidate for further refinement;

– evolving artificial neural networks – employed for deep learning of the knowledge bases associated with hippopotamus agents, allowing the learning process to adapt both network parameters and architecture. Their use enables deep learning through structural adaptation of the artificial neural networks, thereby facilitating comprehensive correction of the training process when the system encounters suboptimal conditions.

The research hypothesis posits that it is possible to improve the responsiveness of decision-making while maintaining a predefined level of processing reliability by utilizing an enhanced hippopotamus swarm algorithm.

The modeling of the proposed methodological approach was conducted using the Microsoft Visual Studio 2022 software environment (USA), during which an operational grouping of military forces was determined. The research computations were carried out on hardware based on an AMD Ryzen 5 processor.

Parameters of the improved algorithm:

– number of iterations: 25;

– number of agents in the swarm: 25;

– feature space range: [–100, 100].

5. Development of a methodological approach for assessing the state of complex organizational and technical systems

5. 1 Sequence of the methodological approach for assessing the state of complex organizational and technical systems

The methodological approach for assessing the state of complex organizational and technical systems consists of the following sequence of actions:

Step 1. Input of initial data.

At this stage, the available input data regarding the data collection subsystem and destructive influences on the information-gathering assets are entered. This includes:

– the number of technical information-gathering tools (radio and radar reconnaissance tools based on ground and air platforms, and visual reconnaissance means of various types);

– the number and types of enemy electronic countermeasure systems;

– technical specifications of the information-gathering tools;

– technical specifications of the electronic countermeasure systems;

– topological interconnections between the data collection tools;

– topological interconnections between the electronic countermeasure tools;

– the type of data circulating within the system;

– computational resources of the subsystem responsible for evaluating the state of the organizational and technical system;

– a set of conditions and factors describing the operational environment, among others.

Step 2. Initialization and formation of the general population of hippopotamus agents.

This algorithm is inspired by the behavior of hippopotamuses in the wild. A hippopotamus population typically includes adult females, their offspring, adult males, and a dominant male. The females protect the young and their habitat by forming a protective circle around the dominant male. When the offspring reach maturity, they are driven away by the dominant male to compete elsewhere.

Mathematically, the initialized population is represented within the upper and lower bounds of a lake or pond:

$$P_i^m : p_{i,j}^m = P_{i,j} + \left(y_1\left(D_{dom} - I_1 p_{i,j}\right)\right)\gamma, \tag{1}$$

$$i = 1, 2, \ldots, \left[\frac{N}{2}\right], j = 1, 2, \ldots, m,$$

where P^m – position of male agents; D_{dom} – position of the dominant agent; i – solution variant, j – decision variable;

$y_1=[0, 1]$, $I_1=[1, 2]$, N – population size, γ – uncertainty level regarding enemy ECM systems.

Expressions (2) and (3) represent possible positions of the calves and their mothers within the population, based on a random variable h and threshold T:

$$h(s)=\begin{cases}\{I_2\vec{r}_1+(\sim Q_1),\\ 2\vec{r}_2-1,\\ \vec{r}_3,\\ I_1\vec{r}_4+(\sim Q_2),\\ \vec{r}_5,\end{cases} \quad (2)$$

where – $\vec{r}_1, \vec{r}_2, \vec{r}_3, \vec{r}_4, \vec{r}_5=[0,1]$, I_1, $I_2=[1, 2]$, Q_1, Q_2 – tuning coefficients (0 or 1);

$$T=\exp\left(-\frac{t}{T}\right), \quad (3)$$

$$P_i^{fem}: p_{i,j}=\begin{cases}p_{i,j}+h_1\left(D_{dh}-I_2Mgi\right)\text{ if } T>0.7,\\ E,\text{other},\end{cases} \quad (4)$$

where h – number of females (hippo), Mgi – mean distance between randomly chosen agents (hippo), T – distance between a calf and its mother.

Step 3. Assignment of initial identifiers to each hippopotamus agent.

Each agent is assigned a unique index α, $\alpha\in[0, S]$. This facilitates individualized parameter management in the search space.

Step 4. Initialization of agent velocity.

The initial velocity v_0 for each hippopotamus agent is defined as:

$$v_i=(v_1, v_2, \ldots, v_S),\ v_i=v_0. \quad (5)$$

Step 5. Preliminary evaluation of the search area.

Here, the search area is interpreted as the habitat of the hippopotamus agents.

Step 6. Classification of food sources.

The best food source (FS_{ht}) is defined as the one closest to the agent and requiring the least energy to obtain. The most energy-intensive yet desirable sources are labeled FS_{at}.

While non-priority survival food sources are labeled FS_{nt}.:

$$FS_{ht}=FS(\text{sorte\_index}(1)), \quad (6)$$

$$FS_{at}(1:4)=\text{FS}(\text{sorte\_index}(1:4)), \quad (7)$$

$$FS_{nt}(1:NP\text{-}4)=\text{FS}(\text{sorte\_index}(4: NP)). \quad (8)$$

Step 7. Predator avoidance strategy.

In this procedure, hippopotamus agents enhance the safety of the population by clustering into large groups, deterring predators through their considerable size and collective presence within the solution search space.

The protective strategy employed by hippopotamus agents when grouping is mathematically described as:

$$\Pr_j=Lb_j+\vec{r}_b\left(Ub_j-Lb_j\right),\ j=1,2,\ldots,m. \quad (9)$$

$$\vec{D}=\left|\Pr_j-P_{i,j}\right|,$$

where $\vec{D}$ – the distance from the i-th agent to the predator, $\vec{r}_b$ – a random parameter that varies in the range 0 to 1:

$$P_i^R: P_{i,j}^R=\begin{cases}\overline{RL}\oplus\text{Predator}_j+\\ +\dfrac{\hbar}{\left(A-d\cos(2\pi g)\right)}\left(\dfrac{1}{\overline{D}}\right)F_{\text{Predator}_j}<F_i,\\ \overline{RL}\oplus\text{Predator}_j+\\ +\dfrac{\hbar}{\left(A-d\cos(2\pi g)\right)}\left(\dfrac{1}{2\overline{D}+r_9}\right)F_{\text{Predator}_j}\geq F_i,\end{cases} \quad (10)$$

$$i=\left[\frac{N}{2}\right]+1,\left[\frac{N}{2}\right]+2,\ldots,N,\ j=1,2,\ldots,m,$$

where $F_{\text{Pr}j}$ – a function modeling the defensive behavior of hippopotamus agents against predators, $\hbar\in[2, 4]$, $c=[1, 1.8]$, $d=[2, 4]$, $g=[-1, 1]$, r_9 – a random vector 0 to 1, $\overline{RL}$ – a Lévy-distributed random vector defined as:

$$Levy(v)=0.05\frac{w\sigma_w}{|v|^{1/v_1}}, \quad (11)$$

w, v – random numbers from 0 to 1, $v_1=1.6$:

$$\sigma_w=\left[\frac{\Gamma(1+v_1)\sin\left(\dfrac{\pi v_1}{2}\right)}{\Gamma\left(\dfrac{(1+v_1)}{2}\right)v_1*2\dfrac{(v_1-1)}{2}}\right]^{\frac{1}{v_1}}, \quad (12)$$

where Γ – the gamma function.

Step 8. Checking for local minima:

$$P_i=\begin{cases}P_i^{Rb}\ if\ F_i^{Rb}<F_i,\\ P_i,\ F_i^{Rb}\geq F_i.\end{cases} \quad (13)$$

If a member of the herd is attacked, another hippopotamus takes its place in the defensive formation. Once the attack is repelled, the displaced member returns to its original position:

$$Lb_j^{loc}=\frac{Lb_j}{t},$$

$$Ub_j^{loc}=\frac{Ub_j}{t}, t=1,2,\ldots,T_{\max}, \quad (14)$$

where Lb_j^{loc} – j-th upper position, Ub_j^{loc} – local j-th lower position, t – current iteration, T – maximum number of iterations;

$$P_{i,j}^{Eb}=p_{i,j}+r_{10}\left(Lb_j^{loc}+S\left(Ub_j^{loc}-Lb_j^{loc}\right)\right), \quad (15)$$

$$i=1,2,\ldots,N,\ j=1,2,\ldots,m,$$

$P_{i,j}^{Eb}$ – defines a safe position for a hippopotamus within the habitat, with $r_{10}=[0, 1]$.

Step 9. Checking for global extrema:

$$P_i=\begin{cases}P_i^{Eb}\text{ if } F_i^{Eb}<F_i,\\ P_i\quad F_i^{Eb}\geq F_i,\end{cases} \quad (16)$$

P_i – denotes the position of the i-th hippopotamus agent in the solution space.

Step 10. Stopping criterion for the agents of the algorithm.

Execution of the hippopotamus algorithm procedures terminates when the maximum number of iterations is reached. Otherwise, the algorithm continues with the generation of new positions and conditions.

Step 11. Knowledge base training of the swarm agents of the combined algorithm.

To minimize error in the algorithm's performance, an enhanced training method based on artificial neural networks [2] is employed.

Step 12. Estimating the required computational resources of the decision support system.

This step involves evaluating both engaged and available computational resources. The required resources for stable algorithm performance are then calculated using a set of expressions proposed in [20].

5. 2. Example of applying the proposed methodological approach to the assessment of an organizational and technical system

The methodological approach was simulated to assess the state of an organizational and technical system (specifically, an operational military force group) under the initial conditions specified in Section 4.

The effectiveness of the proposed methodological approach was evaluated using a set of benchmark functions, as shown in Table 1. As shown in Table 1, the increase in decision-making responsiveness reaches a level of 13–16 % due to the implementation of additional procedures and the achievement of a decision reliability level of 0.9. The proposed methodological approach ensures the stable performance of the algorithm when applied to the main benchmark functions of both unimodal and multimodal types.

Table 1

Evaluation of the effectiveness of the proposed methodological approach based on information processing efficiency criteria

Function name	Metric	Canonical Hippopotamus Algorithm [19]	Ant Colony Algorithm [19]	Black Widow Algorithm [20]	Grey Wolf Optimizer [20]	Cheetah Optimization Algorithm [19]	Proposed Methodological Approach
U22-1	Mean value	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Standard deviation	5.21E-274	1.8338E-07	1.02E-45	7.45E-46	4.35E-45	1.6067E-07
B22-2	Mean value	403	400.265772	401.7973158	480.261772	481.3986579	389.5315439
	Standard deviation	4.9248E-08	1.051427534	1.411892282	1.01427535	1.126419212	1.338343398
B22-3	Mean value	5.13E-171	1.47E-148	1.011E-45	5.13E-150	2.74E-149	2.12E-26
	Standard deviation	0.021617	0.164980	0.104506	0.0524630	0.13801151	0.10116424
B22-4	Mean value	823.5653	811.3281	813.8789	814.30001	826.266848	811.769366
	Standard deviation	9.127175	7.364210	10.30806	7.1866250	9.13610732	8.05991317
B22-5	Mean value	890.7438	899.9504	892.9726	899.80078	900.545204	855.201631
	Standard deviation	0.771226306	1.324558753	1.155779755	0.803385622	0.635781924	1.28982565
B22-6	Mean value	1819.524	1864.869	1856.294	1547.1849	1888.92695	1780.878175
	Standard deviation	126.2561	90.22185	68.00003	31.769803	140.693674	124.321087
H22-7	Mean value	2021.479	2021.758	2017.556	2012.2386	2028.17797	2010.12860
	Standard deviation	5.106897	7.027195	4.813487	6.4464892	8.00396844	5.99773319
H22-8	Mean value	2222.108	2201.537	2203.070	2113.1402	2230.88847	2216.19053
	Standard deviation	4.559655	2.753408	3.895282	3.8856694	5.45165400	4.33135398
H22-9	Mean value	2410.930	2542.930	2926.358	2398.2160	2523.64462	2415.21601
	Standard deviation	64.93880	64.93880	84.77894	47.385851	73.5899769	55.3158517
C22-10	Mean value	2584.615	2564.833	2575.256	2491.2101	2305.30419	2510.30198
	Standard deviation	47.20132	48.71807	55.10340	55.365867	43.5739519	44.1038255
C22-11	Mean value	2687.981	2655.587	2633.855	2210.6213	2300.16841	2600.33278
	Standard deviation	115.3652	108.1475	136.3336	115.50987	113.791384	100.300867
C22-12	Mean value	2866.067	2458.742	2554.959	2261.4146	2859.40778	2799.71816
	Standard deviation	8.364347	13.88960	4.539104	15.961337	15.0054516	11.3411178

6. Discussion of the results of the methodological approach for assessing the state of organizational and technical systems

The advantages of the proposed methodological approach are due to the following:

– the initial deployment of the hippopotamus agent search population in the search space is conducted with consideration of uncertainty in the information obtained by technical means about the organizational and technical system (see expression 1), through the use of appropriate correction coefficients, as compared to the approaches in [9]. This reduces the time required for initial configuration of the subsystem for heterogeneous data processing from various sources;

– the velocity of each hippopotamus agent in the swarm is additionally considered (see expression 5), enabling the prioritization of search operations by each agent within the corresponding search plane (by elements and components of the organizational and technical system), in contrast to the methods used in [12];

– the algorithm incorporates verification of convergence to local and global optima (Steps 8 and 9), enabling real-time control over its operation, which distinguishes it from the work in [11];

– the suitability of the decisions made by the hippopotamus agents when evaluating the state of organizational and technical systems is assessed with regard to a set of external factors, thereby reducing the time required to arrive at a solution (Step 5), as compared to the methodology in [14];

– the versatility of the agents' food-search strategies allows for classification of the set of conditions and factors influencing the state assessment process of organizational and technical systems (Step 6), compared to [16]. This makes it possible to identify the most appropriate solution options based on a defined optimization criterion;

– the approach enables exploration of solution spaces defined by non-standard functions, by leveraging the predator avoidance strategy (Step 7), as opposed to the methods in [15];

– replacement of unfit agents in the search population is supported through the updating of the hippopotamus agent swarm (Step 7), which is an improvement over [13];

– the method allows for the simultaneous search for solutions regarding the state of organizational and technical systems across multiple directions (Steps 1–12, Table 1);

– the approach includes the capability for deep learning of the knowledge bases of the hippopotamus agent swarm (Step 10), offering an advantage over [17];

– the system can estimate the required computational resources in cases where current resources are insufficient (Step 12), which improves upon limitations in [15].

The disadvantages of the proposed methodological approach include:

– loss of informativeness in the state assessment of organizational and technical systems due to the construction of the membership function;

– lower accuracy in evaluating the system's state when considering individual assessment parameters;

– reduced reliability of the obtained decisions regarding the state of the system when conducting multi-directional searches simultaneously;

– lower evaluation accuracy compared to other approaches used for assessing the state of organizational and technical systems.

This methodological approach enables:

– identification of effective measures for improving the responsiveness of state assessments in organizational and technical systems;

– increased processing speed for heterogeneous data collected from sources monitoring the state of such systems while maintaining a defined decision reliability level;

– reduction in the use of computational resources in decision support systems.

Limitations of this study include the requirement for data on destructive means (e.g., electronic countermeasures), and the necessity to account for time delays in both data processing and delivery to the end user.

The proposed methodological approach is particularly recommended for solving assessment tasks in organizational and technical systems characterized by a high degree of complexity.

7. Conclusions

1. A sequence of implementation steps for the methodological approach has been defined, which enables the following:

– deployment of a search population of hippopotamus agents in the search space, accounting for uncertainty in information acquired via technical means about the organizational and technical system, through the use of correction coefficients. This reduces the time required for the initial configuration of the subsystem responsible for processing heterogeneous data from various sources;

– consideration of the individual velocity of each hippopotamus agent, which enables prioritization of search actions by each agent within the relevant search plane (by system elements and components);

– verification of the algorithm's convergence to local and global optima;

– evaluation of the suitability of decisions made by hippopotamus agents in assessing the state of organizational and technical systems, with regard to external influencing factors, thereby reducing decision search time;

– development of universal strategies for identifying food sources by the agents, which allows for classification of the set of conditions and factors affecting the system state assessment process, compared to related works. This facilitates the identification of optimal solution variants according to the defined optimization criterion;

– ability to explore solution spaces of functions described by atypical characteristics, due to the implementation of a predator-avoidance strategy;

– replacement of ineffective agents via population updates within the hippopotamus swarm;

– simultaneous execution of searches for the state of an organizational and technical system in multiple directions;

– calculation of the required computational resources in cases where current computing capacities are insufficient for task execution.

2. An example of applying the proposed methodological approach has been demonstrated through the assessment of the state of an operational military force grouping. The example shows an increase in decision-making responsiveness by 13–16 % due to the use of additional procedures, and ensured decision reliability at a level of 0.9.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship-related, or any other factors that could have influenced the research and its results as presented in this article.

Financing

This research was conducted without any financial support.

Data availability

The manuscript has associated data available in a data repository.

Use of artificial intelligence

The authors confirm that no artificial intelligence technologies were used in the preparation of this manuscript.

References

1. Bashkyrov, O. M., Kostyna, O. M., Shyshatskyi, A. V. (2015). Rozvytok intehrovanykh system zviazku ta peredachi danykh dlia potreb Zbroinykh Syl. Ozbroiennia ta viyskova tekhnika, 1, 35–39. Available at: http://nbuv.gov.ua/UJRN/ovt_2015_1_7
2. Dudnyk, V., Sinenko, Y., Matsyk, M., Demchenko, Y., Zhyvotovskyi, R., Repilo, I. et al. (2020). Development of a method for training artificial neural networks for intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 3 (2 (105)), 37–47. https://doi.org/10.15587/1729-4061.2020.203301
3. Sova, O., Shyshatskyi, A., Salnikova, O., Zhuk, O., Trotsko, O., Hrokholskyi, Y. (2021). Development of a method for assessment and forecasting of the radio electronic environment. EUREKA: Physics and Engineering, 4, 30–40. https://doi.org/10.21303/2461-4262.2021.001940
4. Pievtsov, H., Turinskyi, O., Zhyvotovskyi, R., Sova, O., Zvieriev, O., Lanetskii, B., Shyshatskyi, A. (2020). Development of an advanced method of finding solutions for neuro-fuzzy expert systems of analysis of the radioelectronic situation. EUREKA: Physics and Engineering, 4, 78–89. https://doi.org/10.21303/2461-4262.2020.001353
5. Zuiev, P., Zhyvotovskyi, R., Zvieriev, O., Hatsenko, S., Kuprii, V., Nakonechnyi, O. et al. (2020). Development of complex methodology of processing heterogeneous data in intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 4 (9 (106)), 14–23. https://doi.org/10.15587/1729-4061.2020.208554
6. Shyshatskyi, A. (2020). Complex Methods of Processing Different Data in Intellectual Systems for Decision Support System. International Journal of Advanced Trends in Computer Science and Engineering, 9 (4), 5583–5590. https://doi.org/10.30534/ijatcse/2020/206942020
7. Yeromina, N., Kurban, V., Mykus, S., Peredrii, O., Voloshchenko, O., Kosenko, V. et al. (2021). The Creation of the Database for Mobile Robots Navigation under the Conditions of Flexible Change of Flight Assignment. International Journal of Emerging Technology and Advanced Engineering, 11 (5), 37–44. https://doi.org/10.46338/ijetae0521_05
8. Shyshatskyi, A., Stasiuk, T., Odarushchenko, E., Berezanska, K., Demianenko, H. (2023). Method of assessing the state of hierarchical objects based on bio-inspired algorithms. Advanced Information Systems, 7 (3), 44–48. https://doi.org/10.20998/2522-9052.2023.3.06
9. Ko, Y.-C., Fujita, H. (2019). An evidential analytics for buried information in big data samples: Case study of semiconductor manufacturing. Information Sciences, 486, 190–203. https://doi.org/10.1016/j.ins.2019.01.079
10. Ramaji, I. J., Memari, A. M. (2018). Interpretation of structural analytical models from the coordination view in building information models. Automation in Construction, 90, 117–133. https://doi.org/10.1016/j.autcon.2018.02.025
11. Pérez-González, C. J., Colebrook, M., Roda-García, J. L., Rosa-Remedios, C. B. (2019). Developing a data analytics platform to support decision making in emergency and security management. Expert Systems with Applications, 120, 167–184. https://doi.org/10.1016/j.eswa.2018.11.023
12. Chen, H. (2018). Evaluation of Personalized Service Level for Library Information Management Based on Fuzzy Analytic Hierarchy Process. Procedia Computer Science, 131, 952–958. https://doi.org/10.1016/j.procs.2018.04.233
13. Chan, H. K., Sun, X., Chung, S.-H. (2019). When should fuzzy analytic hierarchy process be used instead of analytic hierarchy process? Decision Support Systems, 125, 113114. https://doi.org/10.1016/j.dss.2019.113114
14. Osman, A. M. S. (2019). A novel big data analytics framework for smart cities. Future Generation Computer Systems, 91, 620–633. https://doi.org/10.1016/j.future.2018.06.046
15. Gödri, I., Kardos, C., Pfeiffer, A., Váncza, J. (2019). Data analytics-based decision support workflow for high-mix low-volume production systems. CIRP Annals, 68 (1), 471–474. https://doi.org/10.1016/j.cirp.2019.04.001
16. Harding, J. L. (2013). Data quality in the integration and analysis of data from multiple sources: some research challenges. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-2/W1, 59–63. https://doi.org/10.5194/isprsarchives-xl-2-w1-59-2013
17. Kosko, B. (1986). Fuzzy cognitive maps. International Journal of Man-Machine Studies, 24 (1), 65–75. https://doi.org/10.1016/s0020-7373(86)80040-2
18. Koval, M., Sova, O., Shyshatskyi, A., Artabaiev, Y., Garashchuk, N., Yivzhenko, Y. et al. (2022). Improving the method for increasing the efficiency of decision-making based on bio-inspired algorithms. Eastern-European Journal of Enterprise Technologies, 6 (4 (120)), 6–13. https://doi.org/10.15587/1729-4061.2022.268621
19. Kashkevich, S. (Ed.) (2025). Decision support systems: mathematical support. Kharkiv: TECHNOLOGY CENTER PC, 202. https://doi.org/10.15587/978-617-8360-13-9
20. Shyshatskyi, A. (Ed.) (2024). Information and control systems: modelling and optimizations. Kharkiv: TECHNOLOGY CENTER PC, 180. https://doi.org/10.15587/978-617-8360-04-7