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Article

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THE DEVELOPMENT OF A METHOD FOR VISUALIZING THE STATES OF THE NATIONAL SECURITY SYSTEM

The scientific task, which is solved in the research, is the cognitive display of the state of the national security system with a complex hierarchical structure. As a rule, images are created individually taking into account a specific application field and interpreted by an expert (a group of experts) based on accumulated knowledge. Cognitive mapping is designed to support decision making by an expert (group of experts), monitoring and managing in real time. The object of research is the system of ensuring national security. The subject of the research is the functioning of the national security system. The research developed a method of visualization of the states of the national security system. An overview of the methods of visual graphic presentation of information about the state of multidimensional objects and systems was carried out.

The novelties of the proposed method are:

- *creation of a visual, multi-level and interconnected description of the national security system;*
- *increasing the efficiency of decision making while assessing the state of the national security system;*
- *solving the problem of falling into global and local extremes while assessing the state of the national security system;*
- *combination of graphic and numerical display of controlled state parameters of the national security system;*
- *avoiding the problem of loops while visualizing the state of the national security system in real time.*

The specified method should be implemented in specialized software, which is used to analyze the state of the national security system and make management decisions.

Keywords: *graphical and numerical display, national security, cognitive modeling, operational efficiency of decision making, hierarchical systems.*

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1. Introduction

Nowadays, there are no single principles for building cognitive images capable of carrying information in a concise and at the same time accessible to the user, sufficient for making an adequate management decision [1–3].

As a rule, images are created individually, taking into account a specific field of application and interpreted by an expert (a group of experts) on the basis of accumulated knowledge. Multidimensional data with the help of electronic computing tools can be correlated to a cognitive graphic image in the form of integral functional profiles reflecting the features of the state of the object in the sphere of national security interests [3–5].

The existing mathematical methods of analysis and visualization of multidimensional data are poorly applicable to real-time dynamic systems and do not have sufficient universality, which prevents their widespread implementation.

The aim of the research is the development of a method of displaying the states of the national security system, which has the following features [4–7]:

- the functioning of the national security system takes place in real time;
- the architecture of the national security system is hierarchical;
- different scales and ranges of changes of controlled parameters are used;
- there are gaps in data flows and work failures [2].

To visualize the current state in the system of the specified type, a cognitive graphic image is required that meets the following requirements [3, 4]:

- the presence of a mathematical apparatus for transforming the space of signs into the space of images;

– expressiveness of images, which accelerates the experts' understanding of the current situation;
– unambiguous and accurate display of the situation class «normal», «anomaly», «critical», «no info» («lack of information»);
– the ability to display the state of the national security system as a whole and the states of its individual subsystems at all levels of the hierarchy;
– the ability to display parameters with an indication of the level of deviation from the average value in the permissible operating range;
– the presence of a single formalism for describing relationships important for decision making in a symbolic space of large dimensions.

2. Materials and Methods

The object of the research is national security system.

The subject of the research is functioning of the national security system.

The research problem is to increase the efficiency and reliability of decision making regarding the state of the national security system. Modeling was carried out using MathCad 14 (USA). Aser Aspire based on the AMD Ryzen 5 processor was used as hardware. Fuzzy cognitive visual representation was chosen as the basic mathematical apparatus in the proposed research.

3. Results and Discussion

3.1. The development of a method of cognitive mapping of the state of the national security system

3.1.1. An analysis of methods of presenting information about the state of complex systems. Taking into account the methods of building cognitive images, it follows that multi-level ways of presenting the situation are most effective for monitoring the national security system. The number of levels in practical applications does not exceed three, since their increase complicates perception and reduces the efficiency of state analysis [1, 4, 6, 8–19]. The results of the review of the methods of presenting the state of complex hierarchical objects are summarized in Table 1.

An analysis of Table 1 shows that the formulated requirements are best satisfied by the cognitive presentation of information using a fractal. Nevertheless, it has several disadvantages that reduce its ergonomic qualities, namely: a large number of small details, a small allowable multiplicity of nesting and a lack of numerical information on the cognitive image slide.

3.1.2. The development of a method of cognitive mapping of the state of the national security system. As a basis for the transformation of the space of parameters into the space of graphic images, let's take the method of integral contour representation:

– ordinary epicycloid:

$$\begin{cases} x=(R+d)\cos\varphi-d\cos(m+1)\varphi, \\ y=(R+d)\sin\varphi-d\sin(m+1)\varphi; \end{cases} \quad (1)$$

– ordinary hypocycloids:

$$\begin{cases} x=(R-d)\cos\varphi+d\cos(m-1)\varphi, \\ y=(R-d)\sin\varphi-d\sin(m-1)\varphi, \end{cases} \quad (2)$$

where R is the radius of a fixed circle; r is the radius of the rolling circle; $d=r$ is the distance of point M from the center C of the derived circle; φ is a parameter describing the angle of inclination of the segment between the centers of the circles to the OX axis; m is an integer, $m=R/r$.

While turning near the center $0(x_0,y_0)$, per angle, multiple $2\pi r/R$, the epicycloid (hypocycloid) combines with itself. Both the epicycloid and the hypocycloid consist of m congruent branches. Let j be the number of branch and $j=1,\ldots,m$, then from expressions (1) and (2) let's obtain the parametric equations for the j-th congruent branch of the epicycloid:

$$\begin{cases} x=x_0+(R+d)\cos\psi-d\cos(m+1)\psi, \\ y=y_0+(R+d)\sin\psi-d\sin(m+1)\psi; \end{cases} \quad (3)$$

– hypocycloids:

$$\begin{cases} x=x_0+(R-d)\cos\psi+d\cos(m-1)\psi, \\ y=y_0+(R-d)\sin\psi-d\sin(m-1)\psi, \end{cases} \quad (4)$$

where x_0 and y_0 are the coordinates of the center of the fixed circle, $\psi\in[j\alpha,(j+1)\alpha]$, $\alpha=2\pi/m$.

Table 1

The review of methods of representing the state of complex hierarchical objects

No.	Name	An appointment	Types of systems		Deviation level	Versatility	Source
			Dynamic	Complex hierarchies			
1	*n*-simplex	Pattern recognition	–	+	+	+	[1]
2	Aim	Pattern recognition	–	+	+	–	[1]
3	Star	Graphical representation of multidimensional data	+	–	–	+	[12]
4	Botanical tree	Visualization of complex hierarchies	–	+	–	–	[11]
5	Novoselov fractal	Diagnostics and visualization for a complex technical object	+	+	–	+	[8]
6	An image for operators of nuclear power plants	Reflection of anomalies and the current situation during the operation of a complex object	+	+	+	–	[9]
7	Color coding based on the evaluation function	An assessment of compliance with the state of the object at a certain point in time	+	–	+	–	[6]
8	Image separator drum	Decision making support by operators of nuclear power plants	+	–	+	–	[19]
9	Choquet integral	Selection of restrictions on the parameters of the fuzzy aggregation operator of interrelated criteria	–	–	+	–	[18]
10	Fuzzy cognitive maps	Decision making support of the analyst	–	–	+	–	[4]

From equations (3) and (4), let's obtain a generalized formula for the branches of the epicycloid and hypocycloid:

$$\begin{cases} x = x_0 + (R+\xi d)\cos\psi - \xi d\cos(m+1\xi)\psi, \\ y = y_0 + (R+\xi d)\sin\psi - d\sin(m+1\xi)\psi, \end{cases} \quad (5)$$

where $\xi = 1$ for the epicycloid and $\xi = -1$ for a hypocycloid.

Let the national security system be characterized by a set of parameters $Z = \{z_1, z_2, ..., z_j, ..., z_m\}$. It is proposed to use formula (5) as the basis of the integral contour representation to solve the problem of detecting the output of parameter values z_j outside the permissible range of values $[z_{j_{\min}}, z_{j_{\max}}]$. Let's take d equal to the value of the parameter z_j, but normalized to the interval $[-\delta, \delta]$. For normalization, let's use the formula:

$$\bar{z}_j = \delta\left(2\left(\frac{z_j - z_{j_{\min}}}{z_{j_{\max}} - z_{j_{\min}}}\right) - 1\right), \quad (6)$$

where $\delta = R/2\Phi^2$, Φ is the ratio of the golden section.

Then, if the parameter z_j is equal to the average value in the permissible range, then $d = \bar{z}_j = 0$ and curve (5) is the part of a circle. If $\bar{z}_j < 0$, then curve (5) is a congruent branch of the hypocycloid. If $\bar{z}_j > 0$, then curve (5) is a congruent branch of the epicycloid.

Let's substitute in formula (5) ξd on $\bar{z}_j$, and d on $|\bar{z}_j|$, then the type of curve (5) will be determined by the deviation of the controlled parameter from the average value in the permissible range:

$$\begin{cases} x = x_0 + (R+\bar{z}_j)\cos\psi - \bar{z}_j\cos(m+\eta)\psi, \\ y = y_0 + (R+\bar{z}_j)\sin\psi - |\bar{z}_j|\sin(m+\eta)\psi, \end{cases} \quad (7)$$

where

$$\eta = \begin{cases} 1, \text{ if } & \bar{z}_j > 0, \\ -1, \text{ if } & \bar{z}_j < 0, \\ 0, \text{ if } & \bar{z}_j = 0. \end{cases}$$

In cases, if $z_j = q_1 z_{j_{\min}}$, $q_1 > 1$ or when $z_j = q_2 z_{j_{\max}}$, $q_2 > 1$, $\{q_1, q_2\} \in R$, then d, corresponding $|\bar{z}_j|$, will be greater than r and curve (7) will be a branch of an elongated epicycloid or hypocycloid and form «loops». To exclude «loops», let's replace the branches of the epicycloid with an elliptic arc, if $\bar{z}_j > r$ and the branch of the hypocycloid – to the branch of the hyperbola, if $\bar{z}_j < -r$.

Let's adjust formula (7) according to the introduced clarifications:

$$\begin{cases} x = x_0 + (R+\bar{z}_j)\cos\psi - \bar{z}_j\cos(m+\eta)\psi, \\ y = y_0 + (R+\bar{z}_j)\sin\psi - |\bar{z}_j|\sin(m+\eta)\psi, \end{cases}$$
$$\text{if } -r \le \bar{z}_j \le r;$$
$$\begin{cases} x = x_0^e + a^e\cos\beta\cos\tau - b^e\sin\beta\sin\tau, \\ y = y_0^e + a^e\cos\beta\sin\tau + b^e\sin\beta\cos\tau, \end{cases}$$
$$\text{if } \bar{z}_j > r;$$
$$\begin{cases} x = x_0 + a^h\cosh\theta\cos\tau - b^h\sinh\theta\sin\tau, \\ y = y_0 + a^h\cosh\theta\sin\tau + b^h\sinh\theta\cos\tau, \end{cases}$$
$$\text{if } \bar{z}_j < -r, \quad (8)$$

where $\tau = j\alpha + \alpha/2$ is an angle of rotation of the ellipse or hyperbola around the point $O(x_0, y_0)$,

$$x_0^e = x_0 + R\cos\frac{\alpha}{2}\cos\tau, \; y_0^e = y_0 + R\cos\frac{\alpha}{2}\cos\tau,$$

$$a^e = 2\bar{z}_j + R - R\cos\frac{\alpha}{2}$$

is the semimajor axis of the ellipse, $b^e = R\sin\alpha/2$ is the semi-minor axis of the ellipse, $a^h = R + 2\bar{z}_j$ is the real semi-axis of the hyperbola,

$$b^h = \frac{a^h R\sin\frac{\alpha}{2}}{\sqrt{\left(R\cos\frac{\alpha}{2}\right)^2 - \left(a^h\right)^2}}$$

is the imaginary semiaxis of the hyperbola, $\theta \in [-2\pi, 2\pi]$, $\beta \in [-\pi/2, \pi/2]$.

3.2. The results of the analysis and discussion of the results. The proposed method differs from the existing ones:

– it creates a visual, multi-level and interconnected description of the national security system;

– it increases the efficiency of decision making while assessing the state of the national security system;

– it solves the problem of falling into global and local extremes while assessing the state of the national security system;

– it combines graphic and numerical display of controlled state parameters of the national security system;

– it allows to visualize the state of the national security system in real time;

– it allows to avoid the problem of loops while visualizing the state of the national security system in real time;

– the accuracy of visualization of the state of the national security system does not depend on the number of individual components that make up the system.

The advantages of the research include:

– the possibility of performing calculations with source data that are different in nature and units of measurement;

– the possibility of avoiding the formation of loops while visualizing the state of the national security system;

– creating a visual, numerical, multi-level and interconnected description of the national security system.

The shortcomings of the mentioned research should include the availability of appropriate computing power and time for calculations.

It is advisable to implement the specified method in specialized software used for condition analysis of the system of ensuring national security and management decision making.

The direction of further research should be considered the further improvement of the specified method to take into account a greater number of factors during the analysis of the system state of ensuring national security and management decision making.

4. Conclusions

1. The research developed a method of visualization of the states of the national security system.

2. The novelty of the proposed method consists in:

– the creation of a visual, multi-level and interconnected description of the national security system;

– increasing the efficiency of decision making while assessing the state of the national security system;

– solving the problem of falling into global and local extremes while assessing the state of the national security system;

– a combination of graphic and numerical display of controlled state parameters of the national security system;
– avoiding the problem of loops while visualizing the state of the national security system in real time.

3. It is advisable to implement the specified method in specialized software used for condition analysis of the system of ensuring national security and management decision making.

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 no associated data.

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