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Heuristic Modeling of NBIT Capabilities: Cognitive Aspects

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The complexity of modeling the functioning of dynamic systems of various nature (sensors, detectors, intelligent materials and other sources of information) is due to their nonlinearity, uncertainty and ambiguity. Therefore, it became necessary to develop a new heuristic modeling method based on a fractal triangle and a natural honeycomb structure. The nature of the restructuring of the structure of fractal cyclic signals of various nature (sensors, detectors, intelligent materials and other sources of information) contains hidden information about the individual features of their functioning in unforeseen conditions. The purpose of the work is to develop natural methods for heuristic modeling on a transdisciplinary basis. The complexity of modeling the action of environmental or activity stress factors leads to safety problems and the complexity of managing the functioning of complex dynamic systems. Stress factors increase the uncertainty of spatio-temporal relationships, the analog signature analysis of which makes it possible to estimate the relative change in their configurations and powers of microstates. Therefore, the dynamic structure of a fractal signal can be analyzed in real time using complementary probabilistic and deterministic methods. Hybrid processing of time series and parametric representation of the difference in their patterns and signatures in the transdisciplinary cognitive space have a great innovative potential for solving security problems (functional, informational, energy) and usability individualization. In particular, the visualization of hidden spatial and temporal features of signals demonstrates the advantages and validity of cognitive visualization of the functioning of various information sources and their transmission media.

Keywords: Technology convergence, Biomimicry, Fractal triangle, Signature analysis, Cognitive aspects.

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1. INTRODUCTION

Digitalization and automation of complex dynamic systems (energy, transport, etc.) have increased the number of information sources (sensors, detectors, spectrometers, signals, etc.), as well as the complexity of time series (responses) that are of a fractal nature. The integration of computing resources with physical processes has led to the creation of cyber-physical systems that adapt to external conditions (INDUSTRY 4.0). However, in abnormal conditions, new problems arose, which are due to the individuality of cognitive aspects [1-3]. Therefore, INDUSTRY 5.0 cannot ensure the effective interaction of elements of complex dynamic systems (CDS), including a team of people. In abnormal conditions, the viability of CDS is determined by the human factor (HF). The key issues are:

- manifestation of the individuality of the functioning of information sources (sensors, transducers, etc.);
- the complexity of the form of sensor signals (detectors, spectrometers, etc.) and their multidimensionality;
- a variety of ways to display information that limit the possibilities of cognitive graphics;
- a variety of processing methods and means of cognitive graphics;
- systematic errors due to heterogeneity of information sources and transmission media.

They determine the cognitive aspects of the interaction of a person with a machine (computers, information systems, robots, equipment), which leads to an increase in the number of manifestations of the human factor phenomenon in transport. HF engineering did not allow solving new problems on the basis of an interdisciplinary approach. Its further development showed that the solution of cognitive problems requires complementary research methods [2].

Three methods are key:

- geometrization of signal dynamics in the space of dynamic events based on extreme principles of mechanics. It made it possible to reconstruct the dynamic structure of the information flow (signal, etc.), the nature of the restructuring of the hidden structure of which allows the necessary "cognitive effect" to arise;
- visualization of the functioning cycle of a dynamic system, the restructuring of the hidden structure of which reflects the transitional states of information sources when exposed to stress factors of the environment and activity. Visualization made it possible to identify the transition states of a dynamic system by the dynamic, energy and informational features of the functioning of the elements of the dynamic system, which generate heterogeneity of information sources and information transmission media;
- induced relationships, the increasing complexity of the structure of which limits the development of the unique capabilities of artificial intelligence. The method made it possible to link the asymmetry of positive and negative feedbacks with structure-forming and structure-destroying factors [3].

General difficulties and problems of science and technology are associated with induced cognitive distortions, the hidden individuality of which limits the development of artificial intelligence [9]. In real conditions, the metaphysical approach [2, 3], based on the transdisciplinary approach [5], proved to be effective. The development of the metaphysical approach made it possible to identify the causes of problems in the development of NBIT and usability.

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The purpose of the work is to develop natural methods of heuristic modeling on a transdisciplinary basis.

2. INCREASING COMPLEXITY OF DIGITAL SIMULATION

Cognitive aspects of complexity. New problematic fields (phenomena, effects) require their understanding not only within the boundaries of their own space. The complexity of modeling the functioning of dynamic systems of various nature (sensors, detectors, intelligent materials and other sources of information) is due to their non-linearity, uncertainty and ambiguity. They, as shown in the works [1, 2], are connected with Gödel's theorem [6], which is in the foundations of metamathematics. In the neurosciences (neural networks, neuroergonomics, etc.) [7], as well as in the life sciences (information biology, engineering psychology, etc.), it has been established that:

- non-linear effects in complex dynamic systems (CDS) are described by appropriate physical and biological models;
- the future of the CDS determines the behavior of the nonlinear system in the present;
- instability of the CDS element with a small external influence can determine its further evolution.

Therefore, each functional state of the CDS element has information and energy components, the interaction of which determines its evolution. As a result, the non-linearity, uncertainty and ambiguity of the functioning of CDS elements increase the number of manifestations of the HF phenomenon in man-made, environmental and other disasters. At the beginning of the 21st century, UNESCO decisions on education recommended a transition from interdisciplinarity to trans disciplinarity. Such programs have been implemented at universities in the USA and China.

Cognitive distortions. Causal relationships with different types of complexity are considered in our works [1, 3]. They show that cognitive distortions are the result of individual perception of complexity, instability and non-linearity. Changing the dynamic structure of the hidden relationships of the information flow determines the functionality of the information source. Therefore, cognitive distortions create many problems that are caused by an increase in the induced complexity of conjugated relationships [1, 3]. The key issues are:

- selection of relevant sources of information;
- effective selection of stress-resistant sensors and other sources of information;
- monitoring the functional state of the information source online.

The complexity of interdisciplinary problems. Desynchronization of information flows leads to an increase in the complexity of their analysis and the uncertainty of results. Therefore, the solution of these problems in the multidisciplinary cognitive space has not been achieved. The distortion of the structure of information flows of various nature in transmission lines, as well as in systems for processing, displaying and analyzing information, is associated with the Le Chatelier principle [9]. Spatial inhomogeneities induce temporal inhomogeneities that distort information flows. The increasing complexity of interdisciplinary problems and technologies limits the possibilities for their study.

Cognitive dualism. The use of neurosciences (neuroergonomics, neuropsychology, etc.) made it possible to establish that cognitive problems depend on the psychophysiological state of a person. Therefore, the study of activities in the digital world limits many problems. The key problems for cognitive perception are:

- presentation and analysis of little formalized information;
- studying the features of thinking and identifying cognitive distortions;
- diversity and scale of information sources.

They give rise to contradictions between the style of thinking and the methods of processing, displaying and analyzing information. All problems are connected with the complexity of discrete thinking, which is based on intuition. Therefore, when implementing individual scenarios of adaptation to external influences, a person intuitively uses the flexible logic of antonyms. Obviously, cognitive dualism is associated with an intuitive search for a spatio-temporal balance between extremes. The duality of the perception of nature, the individuality of thinking and the functional asymmetry of the cerebral hemispheres determine the features of cognitive activity [10].

Induced cognitive distortions. The degree of information distortion under external and internal influences depends on the psychophysiological state of a person, which psychologists determine using conflicting color tests. This is due to the unreasonable choice of 4 primary colors (blue, red, yellow and green). Whereas the circle of natural colors according to Goethe includes primary colors (blue, red and yellow) in the form of a triangle, and colors of the first order in the form of an inverted triangle (violet, orange and green). Note that Goethe developed the theory of the circle for 40 years and considered it his greatest achievement [11].

As can be seen from Fig. 1, a combination of harmonious colors located side by side strengthens them, and a combination of less harmonious colors leads to disharmony. Emotional intelligence and intuition are associated with successful experience in solving real problems.

3. PROBLEMS OF THE DEVELOPMENT OF NANO-, BIO- AND INFORMATION TECHNOLOGIES

Technology safety. The study of the nanoworld at the end of the 20th century contributed to the development of bio- and information technologies (NBIT) [12]. The difficulties of their control are related to the digitalization of education and science, which have increased the manifestation of the phenomenon of the HF in man-made and environmental disasters. Therefore, despite significant developments in aviation ergonomics, engineering psychology and HF engineering, it was not possible to overcome safety problems in aviation systems [13]. With the development of digital ecosystems and INDUSTRY 4.0 and 5.0, as well as the rapid development of unmanned aerial systems, new challenges (risks, problems, manifestations) have emerged.

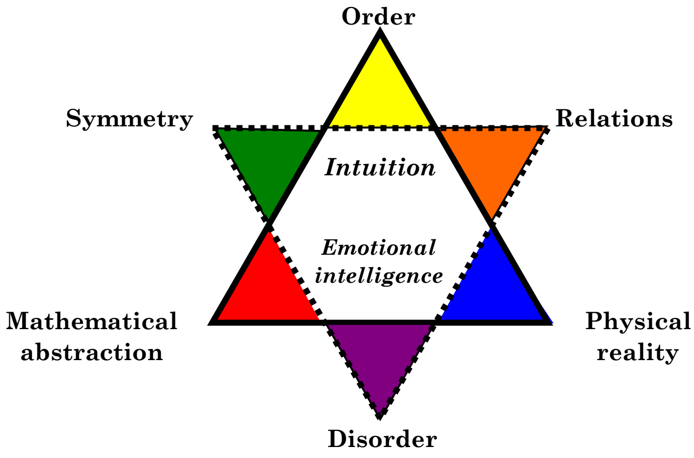

Fig. 1 – Aesthetic perception of natural colors contributes to the development of intuition

Difficulties in their control have increased the manifestation of the HF phenomenon in technologies, and its cause is human activity, whose resistance to stress cannot yet be predicted. The human being is the key element of the CDS. Therefore, it is not yet possible to control the safety of new technologies. On the one hand, the unique possibilities of genetic engineering are widely used. On the other hand, the lack of effective methods of control and forecasting creates new problems, the causes of which cannot be identified within the framework of existing approaches.

Distortion of information during the exchange. Systematic errors induced by environment and activity stress factors cause spatial and temporal distortions of the information flow. They are associated with local inhomogeneities of information sources of various nature (sensors, detectors, etc.), as well as with local inhomogeneities of transmission channels [3]. All this significantly affects the network topology (physical, logical and informational). However, within the framework of a transdisciplinary approach, they can be universal sources of information, from which, using the measured time series (scalar signal), one can reconstruct a topological 3D model [1].

Heuristic value of honeycomb structure. In cybernetic and psychological literature, heuristic methods are aimed at searching for the unknown. At the same time, logical thinking is only an instrument of proof, but not an invention, and therefore does not create anything new (A. Poincaré) [14]. In our opinion, heuristic activity includes both logic and intuition, which is based on individual successful experience and biomimicry [15]. Logic and intuition are the two components of heuristic activity, which is aimed at discovery, invention and know-how. Therefore, digital modeling is based on modern metaphysics [16], and a triad of complementary principles is important in heuristic modeling [17]. From these principles follows the innovative potential of the fractal triangle and natural honeycomb structure, the connection of which with the natural harmony of colors in nature "turns on" emotional intelligence.

Fractal triangle. Fractality and nonlinearity are fundamental properties of the surrounding world. Therefore, the physical fractals created by nature, in quantity and variety, significantly exceed mathematical fractals created by man [18]. Most physical fractals turn out to be multifractals, and therefore their multifractal analysis is relevant. Dynamic multifractals arise naturally in the study of nonlinear dynamical systems. On the other hand, in nature there is a set of honeycomb structures in which there are two conjugate triangles. In addition, a number of triangles (Pascal's triangle, Sierpinski's triangle, Penrose's triangle, fractal antenna, etc.) have a hidden connection with each other. Obviously, therefore, the use of a fractal triangle in heuristic modeling made it possible to analyze the similarity of different heuristic models in form and their difference in physical content, which makes them complementary (Fig. 2).

The relationship of models. Thus, a static model (a.) can be represented as a graph, a Sierpinski triangle, or a Koch Snowflake fractal [19, 20]. In the dynamic model (b.), the induced uncertainty is displayed, which is due to the asymmetry of feedbacks. At the same time, the asymmetry of feedbacks generates distortions (noise, fluctuations, jumps), which increase the uncertainty of the dynamic structure of the information flow. In the statistical model (c.), the difference in the areas of conjugate triangles reflects the asymmetry in the powers of subsets of microstates. At the same time, the induced variability (uncertainty) of capacities in each technology is the same. Therefore, the induced uncertainty in models (b.) and (c.) has the form of conjugated triangles, the difference in the areas of which reflects the information imbalance. This makes models (b.) and (c.) mutually pollinating, which allows you to analyze dynamic and statistical patterns online. This testifies to the high information content of dynamic and statistical variability, which made it possible to establish the dominant role of local heterogeneities in ensuring the synergy of technologies.

Aesthetic perception of the digital world. Natural colors contribute to the development of intuition and emotional intelligence (Fig. 1). Therefore, a cognitive analysis of heuristic models of NBIT (Fig. 2) revealed systemic problems that limit the possibilities of convergence of nano-, bio- and information technologies. It follows from them that:

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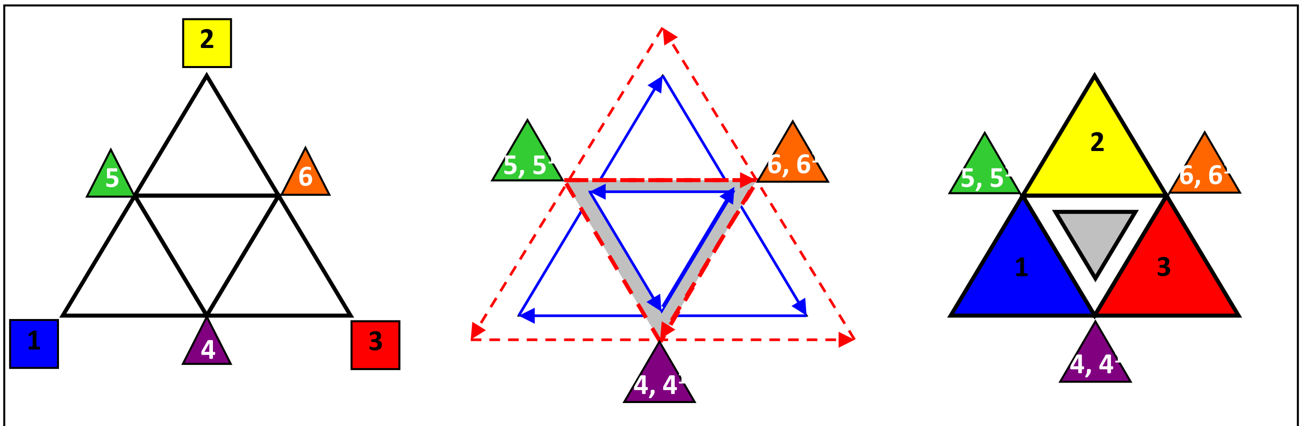

a) Static model – graph b) Dynamic model c) Statistical model

Fig. 2 – Heuristic models of NBIT relationships (in the figure:Nanotechnologies, 2 – Biotechnologies, 3 – Information technologies, 4, 5 and 6 – induced states (connections, conjugated states and subsets, respectively)

- cognitive dissonance is caused by a local disruption of the dynamic and energy balance in information flows of various nature, which limits the possibilities of cognitive computing and its development;
- only the balance of all information and energy resources, as well as the symmetry of feedback in each of the technologies will reduce uncertainty and predict the safety of technologies.

Note that the use of the Goethe color wheel has a cognitive value for heuristic modeling of NBIT, control of a cyber-physical system, as well as for usability aesthetics.

4. CONCLUSIONS

The problems of digital modeling are associated with the individual characteristics of the cognitive perception of information flows of various nature. The heuristic modeling is based on a fractal triangle and a natural honeycomb structure. It allowed to:

- realize the complementarity of key research methods;
- reveal the induced interconnections of technologies;
- establish that the problems of information exchange are based on local violations of symmetry, balance and order.

The use of hybrid processing of analog and digital signals and parametric representation of the difference between their patterns and signatures in the cognitive space of dynamic events made it possible to establish that:

- synergy of technologies is possible with a balance of information and energy exchange not only in each technology, but also in all technologies;
- multifractal structure of electrophysiological signals contains information about hidden cognitive distortions (systematic errors) [20];
- spatio-temporal structure of dynamic processes of different nature in the space of dynamic events is similar to [18].

All this indicates that the heuristic value of the space of dynamic events has a transdisciplinary basis. Therefore, the visualization of the hidden spatio-temporal features of signals of various nature in the cognitive space demonstrates the advantages and validity of studying the functioning of various sources of information in it. In particular, the multifractal structure of signals (time series) of various nature is important for the meta-analysis of new problems of the human factor.

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Евристичне моделювання можливостей НБІТ: когнітивні аспекти

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Складність моделювання функціонування динамічних систем різної природи (сенсори, детектори, інтелектуальні матеріали та інші джерела інформації) обумовлена їх нелінійністю, невизначеністю і неоднозначністю. Тому виникла необхідність розвитку нового методу евристичного моделювання, в основі якого фрактальний трикутник та природна стільникова структура. Характер перебудови структури фрактальних циклічних сигналів різної природи (сенсори, детектори, інтелектуальні матеріали та інші джерела інформації) містить приховану інформацію про індивідуальні особливості їх функціонування в непередбачених умовах. Мета роботи – розвиток природних методів евристичного моделювання на трансдисциплінарній основі. Складність моделювання впливу факторів стресу навколишнього середовища або діяльності призводить до проблем безпеки та складності управління функціонуванням складних динамічних систем. Фактори стресу збільшують невизначеність просторово-часових взаємозв'язків, аналоговий сигнатурний аналіз яких дозволяє оцінити відносну зміну їх конфігурацій і потужностей мікростанів. Тому динамічна структура фрактального сигналу може бути проаналізована в реальному часі з використанням взаємодоповнюючих імовірнісних та детермінованих методів. Гібридна обробка сигналів і параметричне представлення відмінності їх патернів і сигнатур у трансдисциплінарному когнітивному просторі має великий інноваційний потенціал для вирішення проблем безпеки (функціональної, інформаційної, енергетичної) та індивідуалізації юзабіліті. Зокрема, візуалізація прихованих просторово-часових особливостей сигналів демонструє переваги та обґрунтованість когнітивної візуалізації функціонування різних джерел інформації та середовищ їх передачі.

Ключові слова: Конвергенція технологій, Біомімікрія, Фрактальний трикутник, Сигнатурний аналіз, Когнітивні аспекти.