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Intellectual Technologies in the Field of Fundamental Education of Navigators

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ABSTRACT: The problem of "reshaping" the fundamental education of navigators in the conditions of intensive development of modern computer mathematics, intelligent technologies and high-performance computing is considered. The main attention is paid to the formation of the information-educational environment that provides intellectual support for the trainee. Examples of the use of intelligent technologies that contribute to the organization of the learning process as a creative process of building knowledge are presented.

1 INTRODUCTION

In nature, there is an intrinsic hidden harmony inherent in it which is reflected in the procedures of intellectual support (IS) of learning process and onboard intellectual systems (IP) in the form of mathematical laws and logical structures. It is this harmony that makes it possible to explain many physical phenomena and to predict the vessel's behavior in emergency situations using combinations of observations, measurements, and mathematical analysis.

The development of scientific understanding of the problems of the evolutionary dynamics of a ship in emergency situations, that a university graduate of the navigational faculty has to study, requires a deep understanding of the modeling and functional analysis of the interpretation of the ship's dynamics in the behavior and control fields of modern catastrophe theory, computer mathematics and artificial intelligence (AI) [1] - [25]. The basis of this process is the idealization of the ship's dynamics in an emergency situation based on the integrated management of the learning process methods and models of which provide a mathematical description of dynamic processes within the framework of set-theoretic interpretation of complex systems (Figure 1).

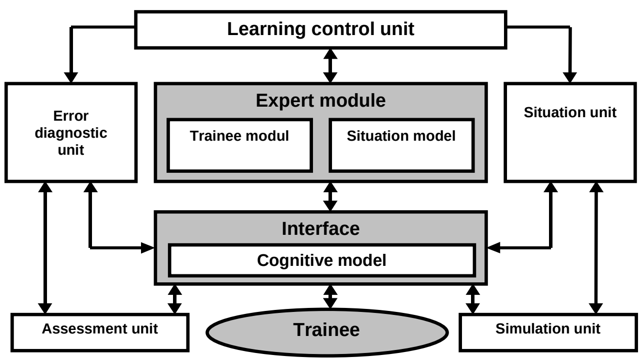

Figure 1. Intellectual support of navigators training process by means of emergency control methods

Homeostasis [11] is a functional state of the emergency control system in which the maintenance of dynamic constancy is maintained within the permissible limits of vital functions and parameters of the system during various changes in the external environment. The ability of the operator to provide the homeostasis with the quality of thinking in a formalized knowledge space determines the human potential at a specified time interval and the impact of human potential on the current state of the vessel as an object of control (OC) - the human factor.

The report discusses some of the most important aspects of the problem of improving the training of specialists using the IS system [12], [13], [15].

2 METHODS OF ARTIFICIAL INTELLIGENCE IN THE SYSTEM OF TRAINING NAVIGATORS

The developed concept of modeling the behavior of the vessel in the trainee's IS system determines the application of the theoretical principles of interpretation of evolutionary dynamics in complex systems. On the basis of conceptual decisions a continuous process of control over the development of an emergency situation is formalized - integration, abstraction and generalization- that determine the strategy of making management decisions.

The conceptual model of processing the flow of information based on a multi-model complex (MMC) of vessel's interaction interpretation in a complex dynamic environment is:

$$U(F) = \left\langle F\left(R^n, R^r\right): \left\{M(\tau) \times V(S) \times D(W)\right\} \to Y(R) \right\rangle, \qquad (1)$$

where U(F) – is the functional interaction space; $F(R^n,R^r)$ – function, that determines the spaces of behavior and control in the process of the situation development; $M(\tau)$ – set of models for interpreting the situation; V(S) – set of elements of the visualization system; D(W) – set containing procedures for generating solutions and generating control actions; Y(R) – set that forms the rules of a fuzzy formal system (FFS) of the learning process management; $\tau \in [t_0,t_k]$ – time interval for implementation.

Algorithmic relation feedback in the conceptual model (1) in the IS system is used to model the formation of control actions in the process of performing the proposed task. An important aspect of new ideas, concepts and theoretical principles of the learning model is universality. The implementation of the problem of universality consists in the use of a dynamic theory of catastrophes [10]. Within the framework of such an interpretation the construction of a ship's behavior model is carried out by studying the facts and phenomena of the interaction dynamics, transition to situations generalization and planning actions that provide modeling and software implementation of computational urgent computing technology (UC) [23]. The ideas of universality consist in the study of various interpretations of emergency situations, the scenarios of which, determine the actual processes of functioning in the IS system. Another aspect of universality is that the developed models open up the possibility of an effective combination of the achievements of intelligent technologies and high-performance information processing tools that indicate a close relationship between the methodology that exists between the theory of learning and methods for studying states and phase transitions in complex systems.

Formation of conceptual solutions during the operation of the IS system in the framework of engineering systematology knowledge envisages the inclusion of two interrelated phases of research of the task: generating alternative concepts and choosing the preferred alternative [10], [11].

The main direction of research in the IS system of the learning process is the construction and interpretation of MMC with direct and inverse mutual relations as well as various environmental factors. Such formalization provides the possibility of solving direct (forecast) and inverse (control) tasks based on various models, and greatly simplify the process of designing multiscale models from separate blocks: environmental models, behavioral models, interaction models.

Interpretation of the interaction dynamics is carried out within the configuration of the computing complex presented in the form of graph-interpretation [11]:

$$G(F_R) = \left(V(E,U), A(E,C)\right), \qquad (2)$$

formalizing events (V (E, U), describing actions in the IS system, and conditions A (E, C) - in the form of a logical description of the state of the vessel (Fig. 2).

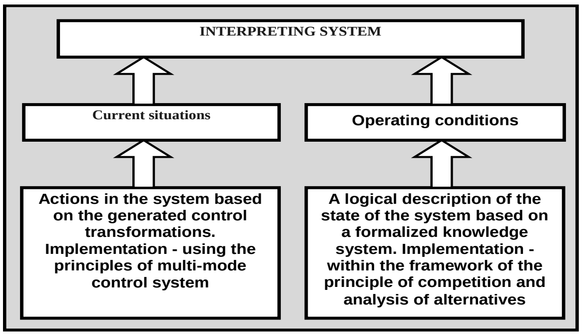

Figure 2. Evolutionary dynamics of IS interpreted system

As follows from this view, the control module of the software package of the IS system provides processing of the information flow associated with the states of the interaction system and its description conditions in a complex dynamic environment. The decision-making support (DMS) in the IS system is implemented within time interval $[t_0,t_k]$ which is matched by a sequence of discrete events.

$$S(t) \in S[t_0, t_k], \qquad (3)$$

formalized in the framework of the principle of competition [9], [15].

As a quantitative measure of the "human factor" the probability is taken that the decision maker (DM) transforms the emergency situation into a normal (regular) situation by searching for effective solutions for the operation of the IS system. An effective measure to reduce the "human factor" on the basis of modern IS technologies are intelligent learning systems (ILS) and simulators [15] with a virtual reality system. Figure 3 shows the sequence of operations in the operation of an intelligent simulator based on the onboard intelligent system of a new generation.

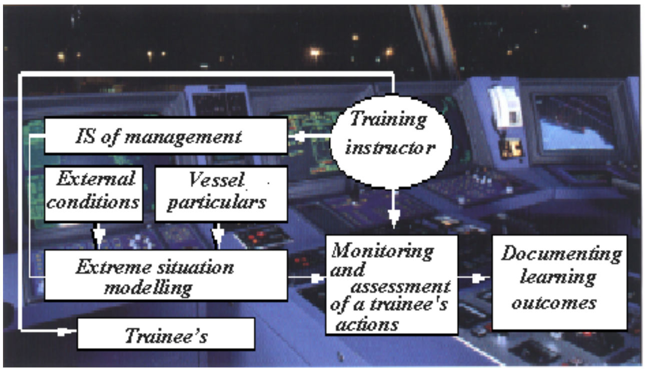

Figure 3. The flow of information during onboard IS operation as an intelligent simulator

These technologies illustrate the modern approach to the organization of IS methods reducing the role of the "human factor" in making management decisions, the support of which, is provided by the software package and the system of controlled remote experiment [2].

Thus, with the help of the considered intellectual technologies in the trainee's IS system, the operator's control activity is modeled to prevent and eliminate emergency situations through the interaction of natural and artificial intelligence in the DMS system [1], [2]. The control actions developed by the DMS system allow the interaction process to be carried out by managing various types of resources (material, energy, informational, psychological).

The development of theoretical principles for the interpretation of complex processes and phenomena in modern research and practical applications is characterized by the integration of intelligent technologies of the 21st century and high-performance computing. Such integration provides a solution to complex scientific and technical problems in the face of uncertainty and incompleteness of the initial information. The methodological aspects of developing the IS system [15] are implemented on the basis of conceptual solutions of the dynamic theory of catastrophes [10]. This theory opens up the possibilities of functional analysis and mathematical logic in analytic and geometric interpretation of the physical aspects of various applications in the spaces of behavior and control, defined by the processes of identification, approximation and prediction. Most applications are based on the integration of knowledge about the behavior of the studied phenomena on the basis of conceptual models, ontological principles and axiomatics of set theory. The core of the IS system that supports the creative process of forming a specialist is *a learning model* (Fig. 4).

a)

b)

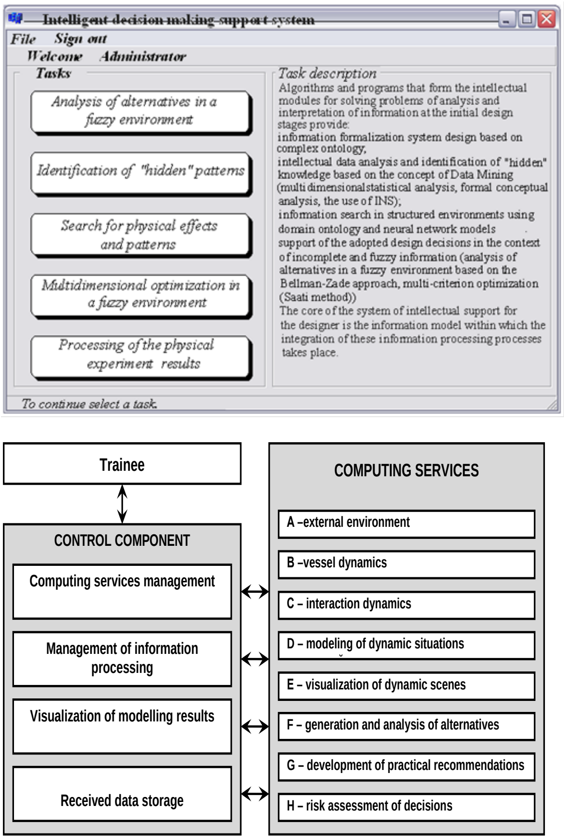

Figure 4. IS model: a - writing of intelligent modules; b - computing services

The training model is based on information processing methods using complex ontology, data mining and revealing "hidden" knowledge (Data Mining and Image Mining concepts [4]), alternatives analysis methods and decision generation using Soft Computing concepts [25], algorithms information retrieval in structured environments, realized with the help of domain ontology representation, neural network technologies, multi-agent, symbolic and cognitive modeling [9], [11]. The description of the modules of the trainee IS presented in Fig.4a provides a solution to the problems of modeling and interpreting solutions in various practical applications. The inclusion of new methods and algorithms for the interpretation of information in the form of additional modules of the IE creative learning process will expand the functionality of ILS and will not change its overall structure and concept of the use of intelligent technologies. The transformation of information in the IP modules is carried out within the framework of a service-oriented architecture [21].

As it can be seen from Figure 4, the tasks of information processing are the main content of the five main areas of the use of intelligent technologies and methods of modern computer mathematics, implemented by the IS system of the trainee. The end result of the operation of the IS system is to improve the quality and shorten the terms of servicing trainees with the help of software modules. As a result, the quality of the services provided by the system is improved, and the directions for the development of the generated solutions and the multidimensional analysis of the data obtained are defined using the concept of "optimal instructor" [6]. The complex solution of information processing tasks is a combination of hardware and software of the IS system for creating a dynamic and flexible information infrastructure that realizes the capabilities of ILS new generation.

3 FEATURES OF THE TRAINING MODEL IN THE FORMATION OF A SPECIALIST IN THE FIELD OF NAVIGATION

The features of the training model in the formation of a specialist in the field of navigation will be considered on the example of the functioning of the training model that provides the IS of the creative process. We focus on the practical implementation of conceptual solutions provided in the process of trainee's interaction with the program DMS system.

Multi-criteria optimization. The task of multi-criteria optimization is one of the difficult tasks when choosing management decisions. The origins of this task are connected with the famous task of L. Euler about the seven Koenigsberg bridges (Fig. 5).

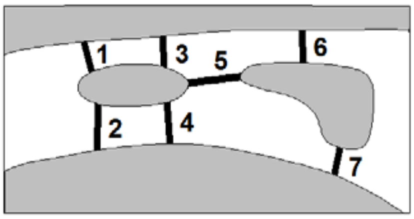

Figure 5. Fragment of the situation defining the L. Euler's task

The numbers in this figure indicate the numbers of bridges that need to be bypassed in the absence of repeated transitions. The solution to this problem is associated with enormous computational difficulties, which are defined as "combinatorial explosion". The trainee is offered a solution to this problem as applied to the selection of the optimal ship control strategy under specified external conditions based on the genetic algorithm (GA) [11], Bellman – Zadeh approach [3] and T. Saati's hierarchy analysis method [14] with the UC software package. Using the GA allows you to reduce the task to the search mapping

$$(X_1 - X_N) \rightarrow Opt(Str) \tag{4}$$

within the framework of the optimization structure:

$$J : X \rightarrow R,\ J = \varphi(X), \tag{5}$$

where ($X_1 - X_N$) are vector functions represented as a given structure; J - target functionality; f:Y→ R - criterial function; R is a real number characterizing the specific outcome of the alternative; j (X) is a function that implements the mapping X → Y.

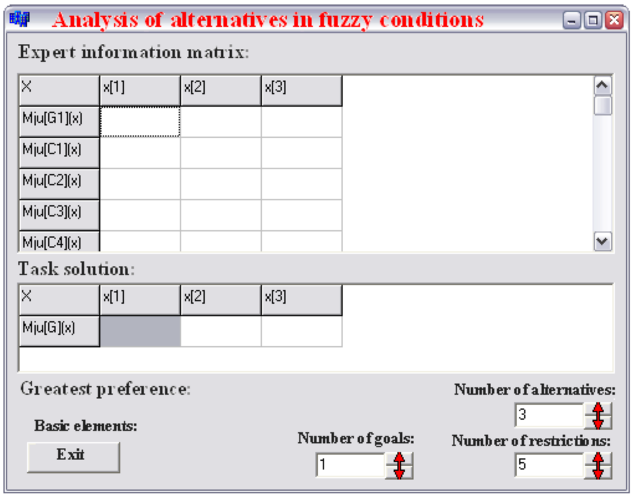

Figure 6. The sequence of actions for solving the problem of choosing solutions for three alternatives

This condition allows the trainee to solve practical problems of analyzing alternatives when choosing preferred solutions for a given formalization of a fuzzy interaction environment, which is especially important in controlling the dynamics of a vessel under conditions of intense icing and divergence of vessels. As an example of working with the software system, Figure 6 shows the sequence of actions for solving the problem of choosing solutions for three alternatives (the program allows up to 10 alternatives).

Multi-agent simulation of the process of divergence of vessels. The problem of ships diverging under conditions of intensive traffic flow (TF) is considered on the basis of multi-agent modeling (Fig. 7) which allows, in the process of learning, to build dynamically configurable interaction environments of intelligent agents (IA) depending on the characteristics of the TF structure.

As a model of the dynamics of the TF, the trainee is offered a choice of combinations of MASs depending on the characteristics of the interacting vessels, including those with an IA leader and with many agents operating in an integrated virtual environment [2].

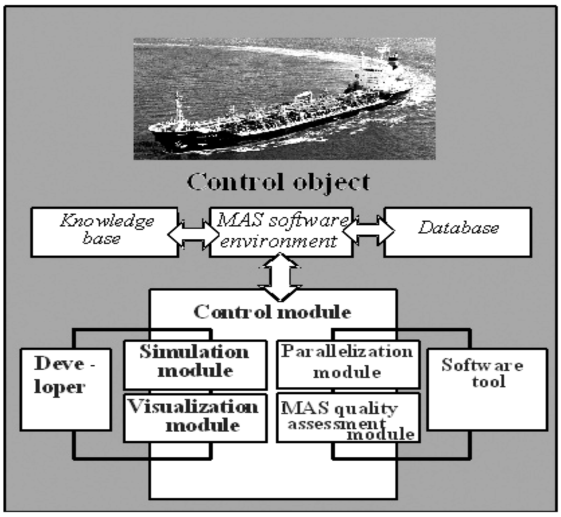

Figure 7. Modeling and visualization of traffic flow

This model of MAS allows you to combine certain aspects of the behavior of interaction objects and has the flexibility to account for various modifications of the TF. The input data for the simulation of the MAS is information on the models of the behavior of the TF with the interaction parameters and control objectives in space and time.

4 CONCLUSION

The implementation of the structural and functional configuration of the IS software package is carried out using fractal geometry and entropy analysis within the framework of the information processing paradigm in a multiprocessor computing environment [9], [11].

The problem of "embedded intelligence" in the synthesis of conceptual solutions and practical applications of research problems "Intelligent technologies of the twenty-first century" was discussed during 2009 - 2015. at International conferences and congresses, including the Forums for the Development of Modern Society (Section "Science and Education") in the USA (Washington, San Francisco) and the UK (Cambridge, Oxford, Edinburgh).

Expanding the function of "consciousness" and modeling behavior is the most important evolutionary task of the trainee. The great Plato said: "Thoughts rule the world. A thought devoid of striving and burning is barren".

Thus, the purpose of this study is to discuss the main directions of training of specialists in the field of navigation on the basis of modern approaches to controlling the dynamics of complex systems in the framework of the modern theory of catastrophes, intelligent technologies and high-performance computing. Conceptual solutions for the implementation of these problems are based on the fundamental results formulated on the basis of the concept of the minimum length of A.N. Kolmogorov's description [5] within the framework of the complexity theory [16], the principle of the bifurcation control by N.N. Moiseyev [8], the theory of incorrect) tasks of A.N. Tikhonov [17].

REFERENCES

1. Bondarev V.A., Volkogon V.A., Nechaev Yu.I. Conceptual basis for controlling marine disasters "Current issues of design, construction and operation of ships and constructions ", Sevastopol. 2016, pp.28 - 46.
2. Bondarev V.A., Nechaev Yu.I. Artificial Intelligence in Emergencies seafaring - St. Petersburg: Art Express, 2017. - 336 p.
3. Bellman R., Zade L. Decision Making in Vague Conditions. - M .: Mir, 1976. - 46 p.
4. Barsegyan AA, Kupriyanov M.S. Stepanenko V.V., Kholod I.I. Methods and models of data analysis: OLAP and Data Mining. - St. Petersburg. BHV-Petersburg, 2004. – 336 p.
5. Kolmogorov A.N. Information theory and theory of algorithms. - M .: Science, 1987. - 304 p.
6. Krasovsky, A.A., Naumov, A.I. Analytical theory of self-organizing control systems with a high level of artificial intelligence // Izv. RAS. Theory and control systems. 2001. No. 1, pp. 69–75.
7. Cook D., Bass G. Computer Mathematics. - M .: Science. 1990. – 272 p.
8. Moiseev N.N. Selected Works, M. Tairex Co., 2003. - 376 p.
9. Neurocomputers in intellectual technologies of the XXI century. - M .: Radio engineering, 2011. – 352 p.
10. Nechaev Yu.I. Catastrophe theory: a modern approach to decision making. - St. Petersburg: Art-Express, 2011. - 392 p.. Petersburg: Art Express, 2015. - 325 p.
12. RF patent №2310237 dated 10.11.2007. Intellectual learning system / Nechaev Yu.I. and etc.
13. RF Patent No. 2356100 dated May 20, 2009. Method of rating testing in higher education institution / Nechaev Yu.I. and etc.
14. Saaty T. Decision Making with Dependencies and Feedback. - I .: LKI, 2008. - 369 p.
15. Systems of artificial intelligence in intellectual technologies of the XXI century. - St. Petersburg: Art Express, 2011. - 376 p.
16. Solodovnikov V.V., Tumarkin V.I. The theory of complexity and design of control systems. - M .: Science, 1990. - 341 p.
17. Tikhonov A.N., Arsenin V.Ya. Methods for solving incorrect problems. M .: Nauka, 1986.– 285p.
18. Haken G. Information and self-organization. Macroscopic approach to complex systems. -M .: Kom Kniga, 2005.– 419 p.
19. Figueira G., Almada-Lobo B. Hybrid simulation – optimization methods: A taxonomy and discussion // Simulation Modeling Practice and Theory. - 2014. - V. 46. - P. 118–134.
20. Foster I., Zhao Y., Raicu I., Lu S. Cloud Computing and Grid Computing 360-Degree Compared// eprint arXiv: 0901.0131, 2008 [Electronic resource]: http://arxiv.org/ftp/arxiv/papers/0901/0901.0131.pdf
21. Lublinsky B. Defining SOA as an architectural style. 9 January 2007. [Electronic resource]: http://www.ibm.com/ developerworks/architecture/library/ar–soastyle/
22. Szalay A. Extreme data-intensive scientific computing // Computing in Science & Engineering. 2011. - V. 13. - №. 6. - p. 34-41.
23. Urgent Computing Workshop 2007. Argonne National Lab, University of Chicago, April 25-26, 2007.
24. Wille R. Restructuring lattice theory / ordered sets / editor I.Rival. - Dordrecht-Boston, 1982.R. 314 - 339.
25. Zadeh L. Fuzzy logic, neural networks and soft computing // Software on ASM-1994. Vol.37. №3, pp.77–84.