Axiomatic basis and methods for interpreting conflict situations in an urgent computing environment

Yu.I.Nechaev[1], V.P.Osipov[2], V.I.Baluta[2,3]
nyui33@mail.ru | Osipov@keldysh.ru | Vbaluta@yandex.ru
[1]Saint Petersburg state Maritime technical University
[2]Keldysh Institute of applied mathematics, Russian Academy of Sciences
[3]Plekhanov Russian University of Economics

The article deals with the issues of developing an axiomatic basis and interpreting conflict situations in conditions of high uncertainty based on the dynamic theory of catastrophes. Control over conflict situations is provided using applied modeling at the expense of the supercomputer center through system integration of technologies and tools for processing large amounts of current information. Functional components of the center for applied simulation implement dynamic visualization and development of management decisions. The key factor in ensuring the safety of critical facilities in a complex conflict situation is the speed of assessment of the situation and the development of adequate management decisions for the implementation of the response. Adequate management is based on experience, as a rule, obtained experimentally in the course of physical modeling of impacts (exercises, trainings, experiments, etc.), and accumulated in the form of a knowledge base of the information and analytical decision support system of the center for applied simulation.

***Key words**: basis, axiomatics, axiomatic basis, interpretation, interpretation methods, conflict situations, urgent calculations.*

1. Introduction

The purpose of experimental studies conducted in the development of functional elements of the center for applied simulation (CAS) is to study the features of conflict interaction in the system of complex security of critical objects based on Urgent computing System (UCS). At the same time, a typical situation is when due to high uncertainty, the characteristics of the control object (CO) of interest are not available for direct observation and measurement, and obtaining data from a physical experiment can be quite difficult and expensive. In this case, by analyzing and generalizing materials describing conflicts of various origins, some indirect information about the object of conflict interaction under study is obtained. Such information is determined by the nature of the phenomenon being studied, the peculiarities of the process of origin, formation and development of various forms of antagonistic conflicts. The identification and formalization of conflict behavior entities of interacting parties makes it possible to develop a software and tool set for high-performance computing based on a CAS.

Diagnostics of the object of interaction is provided by system integration of methods of planning and conducting computational experiments in order to further solve problems related to the formation of scientific ideas and the development of effective management decisions in conflict situations. The theoretical basis for the study of conflict situations and certain methodological principles for the study of complex systems in high-performance environments urgent computing are formulated in [1-26]. A characteristic feature of the interpretation problems that arise in this case is that in the course of research, it is necessary to conclude about the properties of the CO in a conflict situation based on their indirect manifestations, established as a result of a series of computational experiments.

Thus, the CAS formulates and solves complex interdisciplinary problems associated with the creation of an integrated computer modeling system based on a multiprocessor computer complex, combining information and computational resources of expert and research activities to form scientific representations for solving applied problems in the field of conflictology. The development of effective management decisions is implemented on the basis of the formalization of antagonistic conflicts within the framework of problem-oriented methods that allow us to determine the causes of conflict situations as a result of experimental studies and practical observations. Problems of this type are commonly called *inverse problems* [2]. Causal inverse problems of the emergence and development of conflict situations are individual and are used in the construction of mathematical models of interaction based on the dynamic theory of catastrophes [3].

2. Space behavior and management in the interpretation of conflict situations in CAS models

The procedure for solving problems involving the reversal of causal relationships is often associated with overcoming complex mathematical difficulties. The success of the solution is determined not only by the quality and quantity of information obtained from the experiment, but also by the way it is processed. That is why the developed conceptual solutions based on the dynamic theory of catastrophes provide for the use of procedures for geometric and analytical interpretation of the CO behavior using specially developed mathematical models, including modified Mathieu and Duffing differential equations [3]. At the same time, the solution of the inverse problem in complex conflict situations is preceded by a study of the properties of the direct problem based on a conceptual analysis [4-8]. It is assumed that the source data has large dimensions (a set factors and states of CO), does not always follow the normal distribution, and is incomplete, inaccurate, and noisy. Usually the data is extremely difficult to establish as a result of specially organized physical modeling and the only way to obtain them is a computational experiment. The given characteristic of the initial data allows us to formulate the following basic requirements for the mathematical model

---

of interaction when performing urgent calculations in a CAS:

- *meaningful interpretability* using the concept of Soft Computing and Data Mining based on the geometric and analytical components of the dynamic disaster model;
- *efficient computability* based on parallel information processing algorithms in a multiprocessor supercomputer computing environment.

These two requirements determine the construction of an interaction model when developing algorithms for conflict control and testing knowledge models that define UCS procedures under various interaction conditions.

For fig.1 presents a conceptual framework of supercomputer technologies that implements information transformation procedures for interpreting the behavior of objects in conflict situations based on the dynamic theory of catastrophes.

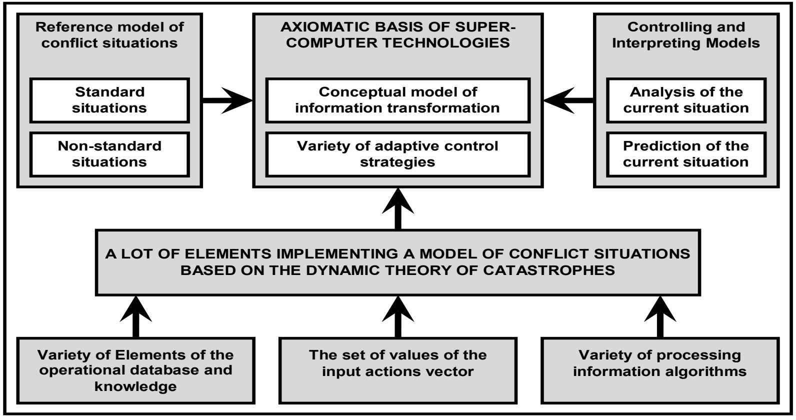


Fig. 1. Axiomatic basis of supercomputer technologies for interpreting dynamic situations based on UCSUCS

The model of conflict situation interpretation in this figure is presented in the form of an interaction area, in which information transformations are performed and its geometric representations are constructed, which allow us to understand the processes of learning and development and identify the "subtle effects" of the studied phenomenon. The cognitive process provides "compression" of the code of the processed signal and maximum possible abstraction of the description contained in the signal to achieve a higher degree of predictability [4].

The concept of dynamic catastrophe theory defines the study of CO behavior within the framework of spatio-temporal interpretation. The formal model for converting information based on UCS procedures looks like:

$$\left\{R_1^n(t)\times R_1^r(t)\to R_1(t),\dots,R_m^n(t)\times R_m^r(t)\to R_m(t)\right\}, \quad (1)$$

where $\{R_1^n(t),\dots,R_m^n(t)\}$ and $\{R_1^r(t),\dots,R_m^r(t)\}$ - spaces of behavior and control that determine the result of the transformation of information about the conflict on the basis of which the reconstruction of the original formal models of interaction; j = 1,...,m - the sequence of events that define the evolution of the system.

The model is used as an operator for nonlinear transformation of information about the evolution of the CO:

$$f_j(\bullet): R_j^n(t)\times R_j^r(t)\to R_j(t), \quad (2)$$

where $R_j^n(t)$, $R_j^r(t)$, $R_j(t)$ are spaces of internal and external variables controlled by the function $f_j(\bullet)$, which can be considered as a smooth function taking into account the accepted assumptions.

To display the results of the functioning of the CPM using the function $f_j(\bullet)$, quasi-stationarity sections are considered in the process of evolution of the interaction system. The physical interpretation of the features of CO behavior in these areas is carried out within the framework of synergetic control theory [9]. When discussing this problem in the framework of dynamic catastrophe theory, the unified fundamental apparatus for the study of nonlinear systems is preserved. In complex situations, especially in non-stationary interaction, in addition to the usual behavior and control spaces, the corresponding functions that characterize the variety of conflict situations under study are considered.

Thus, the CAS in the interpretation of conflict situations is considered as a developing *active dynamic system* functioning in a complex dynamic environment. Management of CAS is to establish the procedures, *minimizing* an objective function that ensure *the maximum effectiveness of* management in the current situation. Active elements are defined as *CAS* objects whose functions are aimed at modeling and visualizing the dynamics of interaction between elements of a conflict environment within the framework of the UCS concept. When generating alternatives and developing control actions, a collective strategy is selected, taking into account the strategy of the active elements of the multi-agent system (MAS). The hypothesis *of independent behavior* of active elements (intelligent agents-IA) is considered within the framework of the paradigm of information processing in a multiprocessor computing environment [3]. The synthesis *of an* optimal control function for active elements of distributed intelligence MAS ensures maximum efficiency of information processing procedures in UCS mode. Multiple *actions to implement* IA in the Multiagent Modeling System (MMS) is defined by a set of decision support procedures (DPS). *Planning actions* in assessing the state of the CO and predicting its development in the MMS consists in choosing effective planning procedures based on the criteria of optimality [4].

We formalize the problem of evaluating the effectiveness of the developed management decisions in the CAS models. Let $x\in R^n$ be the vector of parameters defining the generated solutions, and $w \in R^m$ be the vector of the state of the conflict interaction environment in which the controlled CO functions. If $[x, w] \in A$, then the technical solution with the parameter vector x ensures the effective functioning of the CO in an environment characterized by the vector w. If $[x,w] \in B$ then the generated solution leads to inefficient operation of the system. These conditions define the problem of choosing a solution:

$$x^*(X,W) > 0, \forall (X, W) \in A ;$$
$$x^*(X,W) < 0, \forall (X, W) \in B , x^* \in X^* , \qquad (3)$$

where x* is the selected class of dividing functions.

When conditions (3) are implemented, the CAS models establish a range of possible values for controlled CO parameters, which is limited by various factors, including the specifics of functioning and the level of development of intelligent technologies. Each specific implementation of a technical solution corresponds to certain values of parameters that meet the conditions [10]:

$$X_{1\min} \le X_i \le X_{n\max}, i = 1, \dots, n. \qquad (4)$$

Thus, in the n-dimensional parameter space for each implementation, a parameter vector can be represented

$$X = (x_1, \dots, x_n)^T, \qquad (5)$$

which belongs to the parameter space defined by inequalities (4).

The parameter vector (5) uniquely defines the characteristics of the CO, the set of which is denoted by $(\mathrm{Ch})_j$, j=1,…,m. The number of characteristics is determined by the CO functionality and features of the conflict situation.

We will match each set of CO characteristics with a vector

$$H = ((\mathrm{Ch})_1, \dots, (\mathrm{Ch})_m)^T \qquad (6)$$

m-dimensional space of interaction.

In this case, technically, the CO can be considered as a certain system that has ninputs for parameters x_i and moutputs for interaction characteristics $(\mathrm{Ch})_j$. For each vector X of the parameter space (5), such a system matches the vector of the technical characteristics space defined by the relation (6).

The considered CO model allows us to construct a geometric interpretation of various variants of problems, their analysis and optimal design of operations in the CAS system.

3. The axiomatic basis of the system complexity elements of the CAS

The main aspects of the system analysis of structural components S of the CAS reflect the measure of complexity θ(S) of the system: hierarchy, connectivity and dynamic behavior, expressed in the following axioms [11].

Axiom 1..*Hierarchy* defines the occurrence of subsystem S_0 in the system S as an inequality

$$\theta(S_0) \le \theta(S), \qquad (7)$$

in other words, a subsystem cannot be more complex than the system as a whole.

Axiom 2. *Connectivity* characterizes *parallel* connection

$S = S_1 \oplus \dots \oplus S_k$ subsystems S_i

$$\theta(S) = \max \theta(S_i), i = 1, \dots, k. \qquad (8)$$

or *serial* connection $S = S_1 \otimes \dots \otimes S_k$ subsystems S_i

$$\theta(S) \le \theta(S_1) + \dots + \theta(S_k). \qquad (9)$$

Axiom 3. If the *dynamic behavior*in volves a feedback connection (Σ^{-1}) from system S_2 to system S_1, then

$$\theta(S_1 \oplus S_2) \le \theta(S_1) + \theta(S_2) + \dots + \theta(S_2(\Sigma^{-1})S_1). \qquad (10)$$

Obviously, axiom 3 is a special case of axiom 2 if there are no feedbacks.

If in the class of systems satisfying axioms 1-3, a subset of systems φ is distinguished, then the normalization condition is satisfied:

$$\theta(S) = 0 \; \forall S \in \phi. \qquad (11)$$

Thus, the complexity of CAS elements is a multi-valued concept that includes *static* and *dynamic* components. Static complexity is determined by the complexity of subsystems, and dynamic complexity is determined by the generation of control signals. Management software is supported by a level of *computational complexity*. A group of operators "interpretation - action" forms a structure of transformations on a set of generated management decisions in order to develop a General concept of managing a complex system of conflict interaction. Complexity theory is a prerequisite for understanding learning and development processes, and a hierarchical structure defines management under conditions of time delays, noise and uncertainty.

Since a CAS system can be represented as sequentially-parallel or cascaded (hierarchically) connected subsystems, including subsystems with feedback, the axioms of connectivity explain the structure of such decompositions. Thus, the hierarchical system in question is complex and organized. Complexity is defined as the minimum number of operations required to restore the system, and organization is defined as the ability to "compress" information generated by a cascade of bifurcations that lead to symmetry breaking, and after the onset of chaos - by a cascade of iterations that increase the resolution of the display at a given time interval.

Within the framework of the axiomatic approach, the recognition of abnormal behavior of the CO during the operation of the CAS based on the UCS concept is implemented using the following procedures:

Procedure 1. Classes of abnormal behavior of objects in a conflict situation are identified and the corresponding reference interactions are studied using the use-case knowledge base.

Procedure 2. An analysis of the conflict situation under study is performed, based on which fragments of interacting objects are formed that are close to classes of abnormal behavior.

Procedure 3. For the selected fragments, an axiomatic basis is formulated in the form of a sequence of axioms corresponding to the reference trajectories.

Thus, the problem of recognizing abnormal CO behavior based on UCS s reduced to the problem of fuzzy search for fragments of reference interactions of abnormal behavior in the observed system evolution.

The mathematical theory of functional space in UCS is defined by a system of objects and relations within the framework of an ontological basis, and the logical structure of the interpretation of the dynamics of the interaction system is based on fundamental provisions (axioms) that determine the *evolutionary complexity* of the CO. In this case, the analytical component of the dynamic catastrophe theory is represented by interpretation models, while the geometric component is represented by various visual models in the form of cognitive images and fractal maps. The problem of space-time is considered taking into account a measure of complexity, taking into account the interaction of elements of a conflict situation, as well as the relationship of the concept of analytical synthesis with the physical laws of interaction.

The task of predicting CO behavior in a conflict situation is a chain of transformations:

$$X_1(T,S) \Rightarrow Y_1(\mathrm{Out}),\ldots,X_n(T,S) \Rightarrow Y_n(\mathrm{Out}), \qquad (12)$$

where the components $X_1(T,S),\ldots,X_n(T,S)$ define the interpretation functions at each step of performing information transformation operations using the control function, a and $Y_1(\mathrm{Out}),\ldots,Y_n(\mathrm{Out})$ are the results of predicting the studied characteristics of the interaction system.

One of the features of the CAS structure *is a hierarchical organization that* defines management in conditions of time delays, noise and uncertainty. Strategic planning of operations and conceptual decisions in a hierarchical organization is presented in the form of a dynamic hierarchical network [12] (figure 2), which reflects the fundamental result of integrating components of a dynamic disaster model based on intelligent technologies and high-performance computing [4].

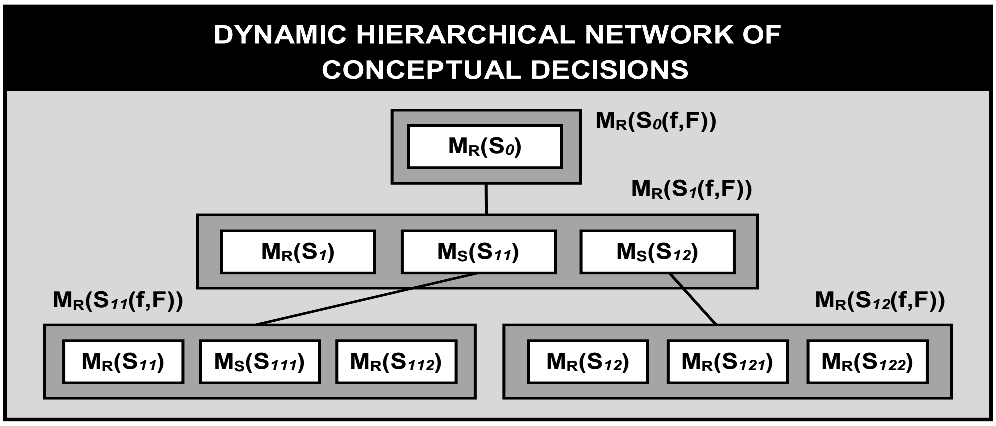


Fig. 2. Structure of a dynamic hierarchical UCS network

The hierarchical model allows describing the dynamics of a conflict situation at various levels of abstraction: reflections of elements, properties, and characteristics that determine the functions of managing *f* interpreting *F* the development of the current situation. When decomposing, *the concept of* connectivity is realized, assuming the representation of the original model $M_R(S_0)$ in the form of a set of sublevel models connected by a tree relation. The formation of hierarchy levels is carried out using the standard basis decomposition. At any level of the hierarchy, the CAS subsystems and relationships between them are distinguished, while ensuring the level of complex and not losing the levels of direct analysis.

The task of constructing an optimal hierarchical structure is to construct a set Ω hierarchical structures (hierarchies) with a given functional

$$\mathrm{argmin} G \in \Omega\ P(G), \qquad (13)$$

$$P: \Omega \rightarrow G\ [0,+\infty]. \qquad (14)$$

The concept of hierarchical structure implies the asymmetry of connections and the impossibility of cyclic subordination, i.e., the oriented graph and its acyclicity.

As a tool for describing C_i CAS tasks and the order of their distribution on the basis of the functional space of behavior of the dynamic theory of catastrophes, the matrix of strategic decisions is used, which is an extension of the functionality of the presentation [13]:

$$\begin{array}{c} \\ X_1 \\ \cdots \\ X_j \\ \cdots \\ X_m \end{array}
\begin{array}{c} \begin{array}{ccc} \{A_1\} & \{A_i\} & \{A_n\} \end{array} \\ \left[\begin{array}{ccc} (x_{11})^* & (x_{1i})^* & (x_{1n})^* \\ \cdots & \cdots & \cdots \\ (x_{j1})^* & (x_{ji})^* & (x_{jn})^* \\ \cdots & \cdots & \cdots \\ (x_{m1})^* & (x_{mi})^* & (x_{mn})^* \end{array}\right] \end{array}. \qquad (15)$$

Matrix (15) is obtained on the basis of the transformation of the initial data (functional elements of the CO) using the Cartesian product {m×n} of sets of alternatives A and features X, which form a representation of the dynamics of interaction in the current conflict situation. The system of alternatives in the resulting matrix of strategic decisions is reduced to a single scale using the transformation

$$(x_{\mathrm{ji}})^* = (x_{\mathrm{ji}} - x_{\mathrm{min}j})/(x_{\mathrm{max}j} - x_{\mathrm{min}j}) \qquad (16)$$

with display

$$x_{\mathrm{ji}} \rightarrow x^* \in [0,1]. \qquad (17)$$

Matrix (15) is used to construct matrices that display interpretation functions in behavior spaces (Int-Beh) and control spaces (Int-Cont) at a given implementation interval:

$$\begin{array}{c} \{A(\mathrm{Int}-\mathrm{Beh})\} \\ \begin{bmatrix} f_1 & \cdots & f_i & \cdots & f_n \\ f_{11} & \cdots & f_{i1} & \cdots & f_{n1} \\ & & \cdots & & \\ f_{1m} & \cdots & f_{\mathrm{im}} & \cdots & f_{\mathrm{nm}} \end{bmatrix} \end{array} \qquad (18)$$

$$\{A(\mathrm{Int}-\mathrm{Cont}\}$$
$$\begin{bmatrix} F_1 & \cdots & F_i & \cdots & F_n \\ F_{11} & \cdots & F_{i1} & \cdots & F_{n1} \\ & & \cdots & & \\ F_{1m} & \cdots & F_{\mathrm{im}} & \cdots & F_{\mathrm{nm}} \end{bmatrix}$$

The initial information for constructing the matrix of strategic decisions is the information transformation model M (Inf), which contains the following data sets [3, 4]:

$$M(Inf) =< Cond(D), V(D), M(C) > \qquad (19)$$

where Cond (D) is a vector of terms that defines a set of conditions for the existence of solutions X = $\{X_1, X_n\}$; V(D) is a vector of decisions that includes the set of solutions Y =$\{Y_1, ...,Y_m\}$; M(C) - matrix of compliance specifying model relationships between conditions and decisions.

This interpretation of data reflects the *principle of* complementarity, according to which conditions are provided in which there is a continuous change in the behavior of objects in the conflict environment. The formal model of information transformation opens up the possibility of finding solutions using hierarchical structures that are characteristic of the tasks under study. This model does not depend on the content of the problem and is a universal tool for analyzing and finding solutions. This opens the possibility of "compressing" information, since only the information that is minimally necessary for managing a conflict situation is extracted from the source data.

Thus, the CAS is considered as *an active system* functioning in a complex dynamic environment of interacting objects. Management of MTC is to establish the procedures, *minimizing* an objective function that ensure *the maximum effectiveness of* management in the current situation. Active elements are defined as *CAS objects* whose functions are aimed at modeling and visualizing the dynamics of a conflict environment within the framework of the UCS concept . When generating alternatives and developing control actions, a collective strategy is selected*,* taking into account the strategy of the active elements of the system. The hypothesis *of independent behavior* of active elements of the CPU is considered within the framework of the paradigm of information processing in a multiprocessor computing environment. The synthesis of *an optimal* control function for active elements of the CPU ensures maximum efficiency of information processing procedures. The set *of implemented* actions is determined by the set of PPR procedures. *Planning actions* when assessing the state of the CO and predicting its development consists in choosing effective planning procedures based on optimal criteria

The task of modeling CO dynamics is to construct scenarios (situation models) with a dynamically changing class of strategies and manage the scenario. To solve the problem, a scenario S_C is formed, the execution procedures of which consist in representing S_C as a combination of strategies (alternatives) S_c^{tj} and control moments t_j, (j=1,...,N)

$$S_C = \underset{t_j}{Y} S_C^{t_j}. \qquad (20)$$

Transitions between P_S strategies are described by mapping the set of effective strategies as two sets, the first of which corresponds to the set of arcs, and the second to the set of benefits of these strategies in the set of arcs.

The crucial rule for choosing alternatives in the multi criteria optimization problem is represented by the intersection of fuzzy goals G_i and constraints C_j or a convex combination taking into account their relative importance:

$$D = G_1 \cap \ldots \cap G_i \cap C_1 \cap \ldots \cap C_j \ldots ; D = \sum_i \alpha_i G_i + \sum_j \alpha_j G_j , \sum_i \alpha_i + \sum_j \alpha_j = 1, \qquad (21)$$

where α is the importance coefficient.

4. Strategies for interpreting CO behavior based on the UCS concept

In accordance with the concept of dynamic catastrophe theory on the basis of a supercomputer complex CAS a strategy for interpreting the evolution of the CO is implemented as the ability to transform a set of input signals into a set of output signals in the form of a formal model:

$$G(\mathrm{Attr}) = \langle G(\mathrm{Stab}), G(\mathrm{Cap}) \rangle, \qquad (22)$$

where G(Attr) - attractor sets, displaying a model of interaction in a hostile environment Oh; G(Stab) - many, forming a movement CO to the target attractor; G(Cap) - set, characterizing the behavior of the CO in the loss of stability of the environment.

The CAS computing complex implements the input-output operator behavior functions and provides solutions to identification, approximation, and prediction problems that determine the behavior of the CO in the process of evolution. The interaction space within the framework of dynamic catastrophe theory *defines the interpretation and control* functions, which are used to carry out operational control of the characteristics of an aggressive environment in the course of evolution (Fig. 3).

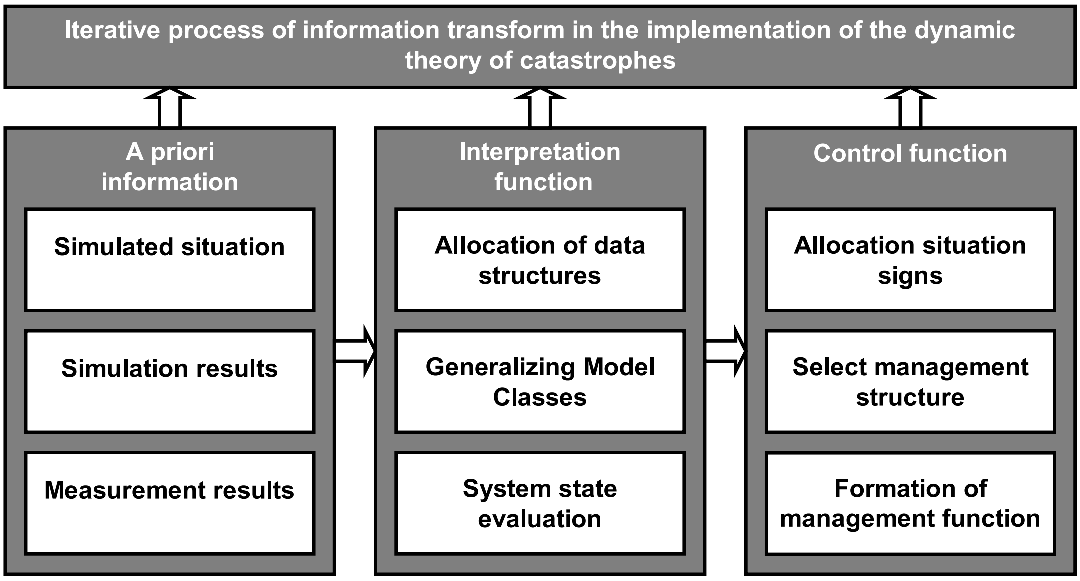


Fig. 3. Converting information based on the UCS concept

The General formal knowledge model integrating the used classes of conflict situation interpretation *functions*based on UCS is presented as a functional:

$$\Phi_1\{f_1(\bullet)|\mu\},\ldots,\Phi_5\{f(\bullet)|\mu\}, \qquad (23)$$

where $\Phi_j\{f(\bullet)|\ \mu\}$, (j=1,..., 5) - functions that define classes of interpretation models: $\Phi_1\{f(\bullet)|\mu\}$ and $\Phi_2\{f(\bullet)|\mu\}$ - computational and diagnostic models; $\Phi_3\{f(\bullet)|\mu\}$ - models defining the strategy of dynamic catastrophe theory; $\Phi_4\{f(\bullet)|\mu\}$ - models for analyzing and predicting the current situation; $\Phi_5\{f(\bullet)|\mu\}$ - models of a dynamic knowledge base.

The construction *of the control function* at each step of the iterative procedure is based on the synergetic paradigm π(S) in the form of a sequence of actions:

$$\pi(S)=f_j(\bullet)\big|\Delta t_1,\ldots,f_n(\bullet)\big|\Delta t_n, \qquad (24)$$

where $f_j(\bullet)$ is the control law defining the expansion and contraction phases depending on the state interpretation function at the j-th stage of the system evolution (j=1,...,n); Δt_j is the duration of the stages.

The implementation of interpretation and control functions is carried out when modeling the behavior of an CO based on the UCS concept (Fig.4). The CO behavior model is constructed using MAC and neuro-dynamic systems (ND-systems) oriented to parallel processing of information in a supercomputer environment of the CAS [3, 4].

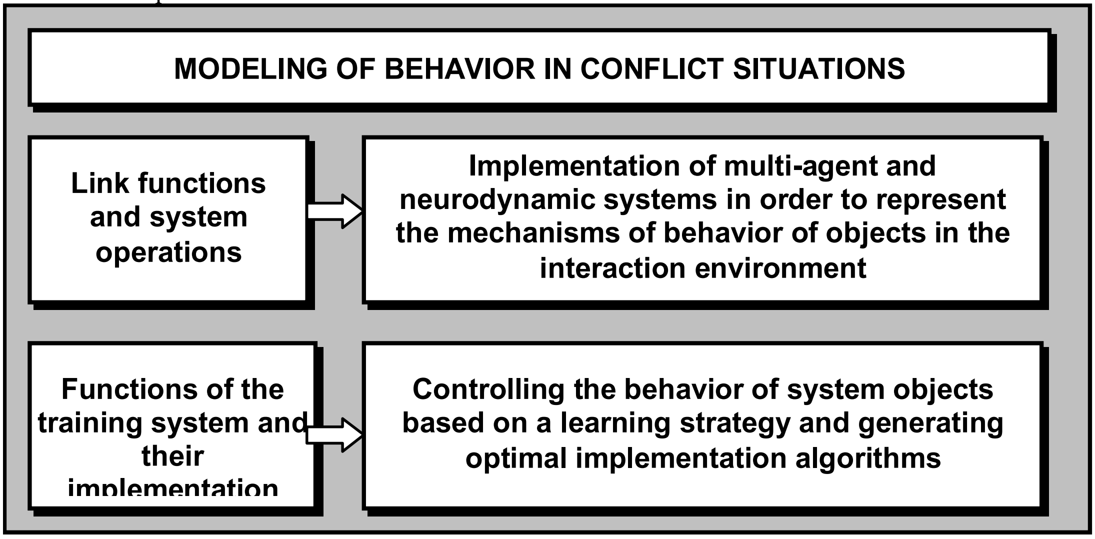


Fig. 4. Modeling behavior in CO interpretation based on UCS

The theory of strategic decisions in managing CO behavior provides for a transition from situational management to management with modeling. Relationships in graph-based interpretation of network models allow us to take into account the consequences of decisions being made and control the behavior of the CO not at the level of actions, but at the level of chains of events. To perform simulation procedures in the created virtual space, abstract symbols of various classes of elements of the structure of an aggressive environment are formed and the ability to interpret its behavior within the framework of the theory of synergetic control is formed.

The facts and phenomena of CO modeling are related to various interpretations of activity in solving behavior training tasks using simulations of the physiological and mental functions of objects in a conflict situation. The functions of sensory systems are implemented in the construction of algorithms for information processing based on the concentration of "consciousness" on the most important aspects of the development of the interaction process, which reflects the evolution of the conflict environment within the framework of a dynamic model of catastrophes (Fig.5) [3].

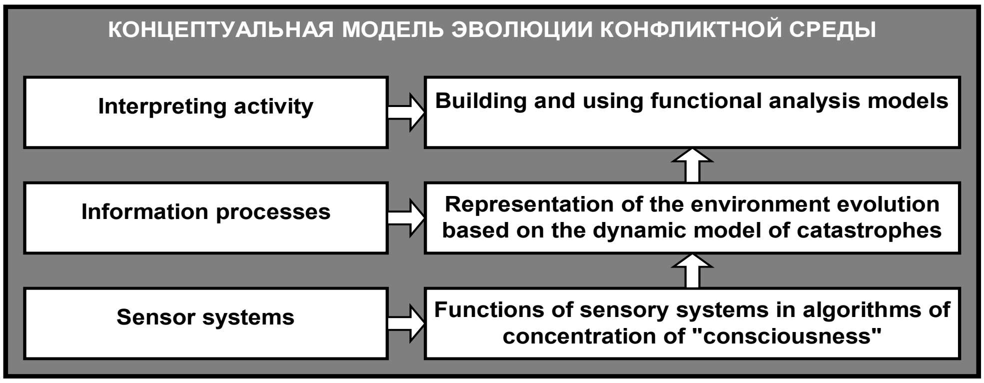


Fig. 5. Evolution of the interaction system based on dynamic catastrophe theory

The concept of a training model as a mechanism for coordinating the activity of interaction processes of conflict objects and the overall balance of information processing procedures of a supercomputer CAS ensures the fulfillment of the main modeling. It's task is to create a computing environment for virtual modeling of information-physical processes that run in parallel and ensure the organization of information exchange between processes (synchronization), and also decision support in a complex dynamic environment. The controlling influence that changes the state of the CO in accordance with a given law is described using the relations:

$$y_0(\Lambda(\pi)_0),\dots,y_k(\Lambda(\pi)_k). \qquad (25)$$

Here $y(\Lambda(\pi))$ $-(\pi)$ is a vector of parameters $(\pi_0,\dots\pi_k)$ that define the characteristics of the environment and perturbing influences for a given CO evolution in accordance with the operating modes of the CPU within the permissible "input - output" region.

5. Assessing the adequacy of conflict situation interpretation models based on the UCS concept

Let's consider the features of the functioning of the CAS software complex based on the dynamic theory of catastrophes. The conceptual model of assessing the adequacy of mathematical models describing the system of interaction of objects in conflict situations formalizes the processes of constructing problems and criteria functions for interpreting the evolution of the CO in the implementation interval. For rice.6 presents a sequence of information processing operations that determines the criteria basis for evaluating the adequacy of mathematical description of interaction processes in conflict situations.

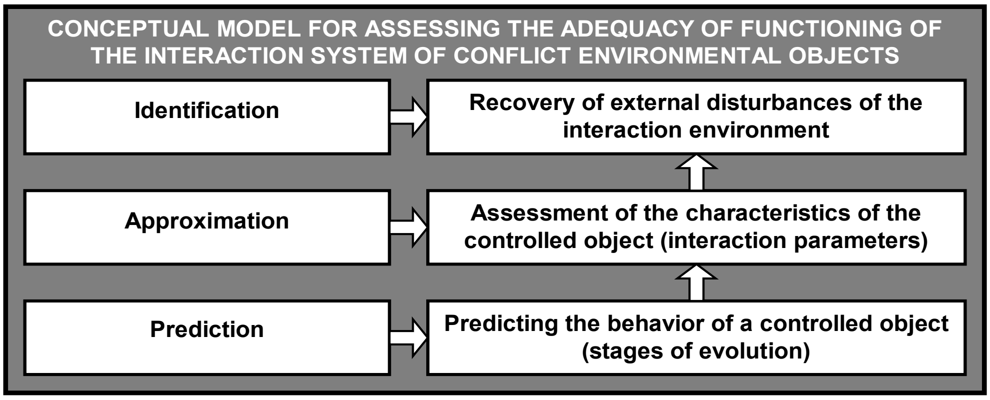


Fig. 6. Criteria basis for implementing UCS procedures in a conflict situation

Here the main stages of implementation of computational technology for determining the parameters of an aggressive environment, dynamics of interaction of environmental objects, as well as the stages of evolution in predicting the behavior of elements of the modeled system are highlighted.

The strategy for assessing the adequacy of UCS procedures in the functioning of the computing complex (figure 7) defines the formalization of the conflict situation based on the factors that characterize a priori information, the concept of the minimum description length (M DL), and the problem of complexity. Here the sequence of stages of forming an adequate UCS model within the framework of the MDL concept [14] and complexity theory [15] is indicated.

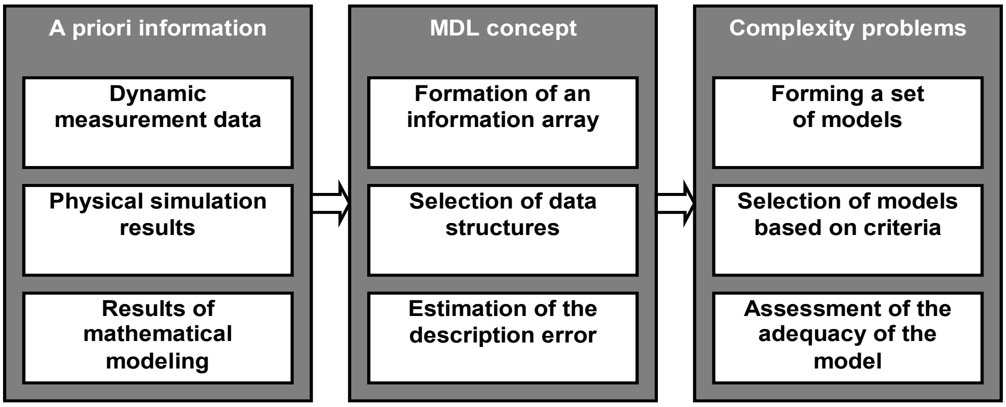
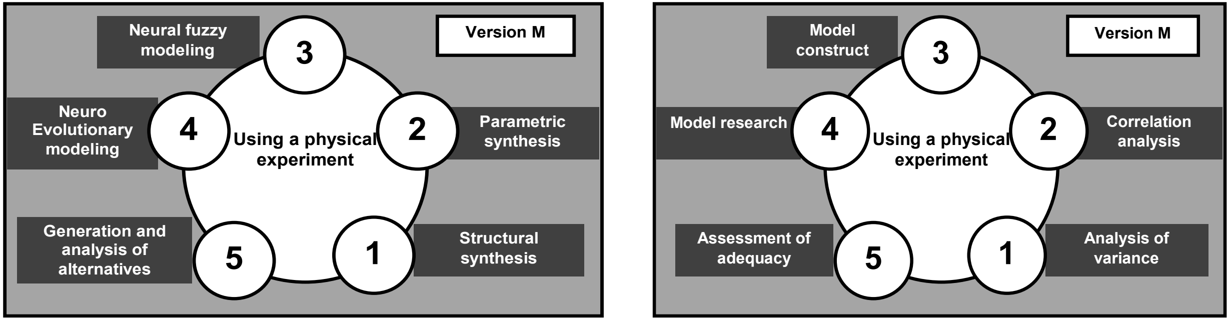


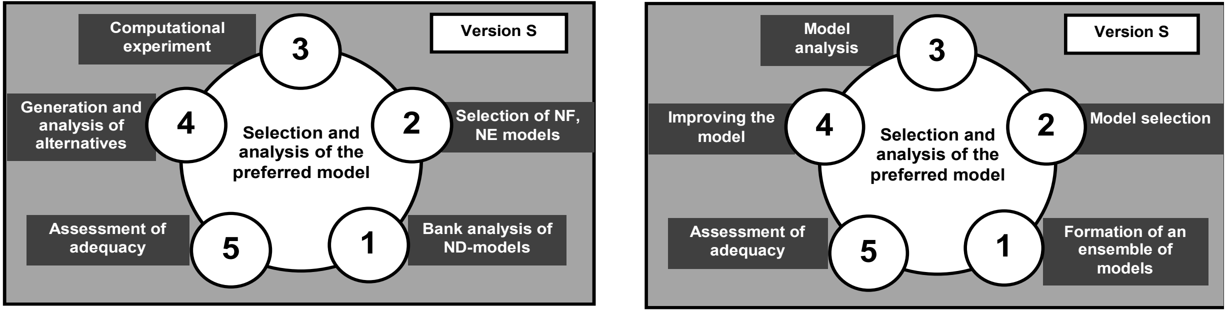
Fig. 7. Information flow that determines the strategy for evaluating the adequacy of the interaction model when interpreting dynamic situations based on UCSUCS

As follows from this figure, the problem of adequacy is solved by integrating a priori information, the concept of MDL and the problem of complexity, which determines the choice of a solution in accordance with the conceptual model of dynamic catastrophe theory [16], which is adapted in relation to the problem under consideration.

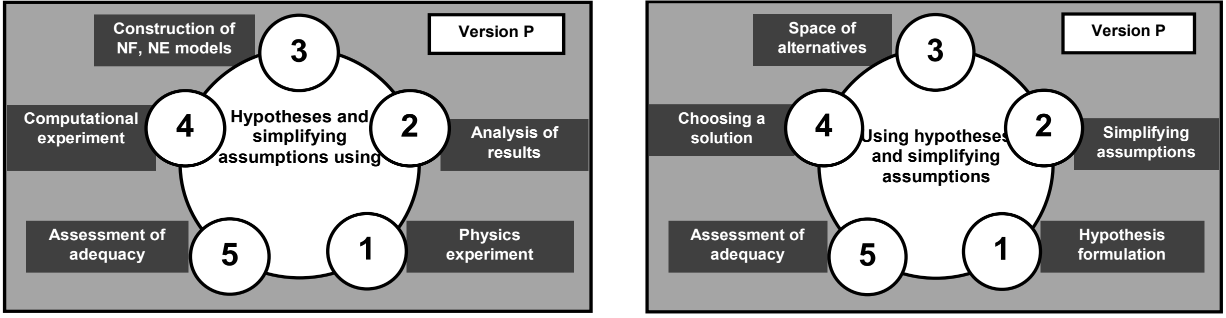
The assessment of UCS adequacy is based on a modified scheme of O. Balchi [4] for a specific application of the conflict situation in order to take into account the data of physical, neuro-fuzzy and neuro-evolutionary modeling (Fig.8).



Cycle M – ND-model **Cycle M – standard model**



Cycle S – ND-model **Cycle S – standard model**



Cycle P – ND-model **Cycle P – standard model**

Fig. 8. Graph-interpretations of O. Balchi's modified scheme, in which M,S,P are cycles of information transformation

At the same time, the improvements consisted in considering UCS as an integral part of a practical application based on it - the task of modeling conflict situations in the functioning of the software complex of the CAS based on the principle of competition.

The first cycle is associated with the development of competing models (modeling- M), implemented on the basis of the ND-system and methods of classical mathematics. In the course of this cycle, the structural and parametric synthesis of the neural network is implemented in the tasks of neuro-fuzzy NF and neuro-evolutionary modeling, and for the competing model, the assessment of the overall structure and components within the framework of sequential statistical analysis procedures.

The second cycle refers to the implementation of appropriate mathematical (simulation) experiments performed with competing models (simulation- S) for given initial conditions and input vector elements. Here NF and NE models of data Bank analysis are formed, on the basis of which a computational experiment is implemented, generation and analysis of alternatives and assessment of adequacy. Construction and analysis of the competing model is carried out in accordance with the formalization of the problem in conditions of significant uncertainty in accordance with the algorithm [3].

The third cycle is the most important. It consists of conducting physical (physical- P) experiments, on the basis of which models are formed that provide an assessment of adequacy under conditions of complete uncertainty. During ND this cycle, the components of the NF and NE models are formed in the ND- и NE system using physical modeling data, a computational experiment is implemented, and the adequacy assessment is performed.

Intelligent support for M,S,P procedures is provided by the calculation management system and visualization of modeling results. As estimates of the adequacy of fuzzy, neural network and competing models, we should adhere to the recommendations that determine the use of UCM procedures in complex dynamic environments [4].

6. Conclusion

Thus, the development of the CAS software package and demonstration of its functionality in various conditions of interaction of objects in a conflict environment is carried out on the basis of supercomputer technologies for modeling and visualizing interaction situations using multi-mode ADS. In order to achieve this goal, the following main tasks are envisaged:

- formation of a scientific and technological Foundation for the dynamics of the CAS functioning in UCS mode on the basis of supercomputer technologies for modeling and visualizing interaction processes using the results of fundamental and applied research;
- solving qualitatively new problems in terms of volume and complexity of conflict situations interpretation in order to increase the effectiveness of management decisions to ensure the safety of critical facilities;
- ensuring the integration and effectiveness of research and development, creation and practical application of a modern set of applied tools for analyzing and predicting the development of targeted organized antagonistic conflicts in conditions of uncertainty based on CAS and high-performance information processing tools.

The solution to these problems will achieve the goal of creating MTC - improving the efficiency of FFD-based simulation and visualization of the dynamics of interaction between the elements of the conflict environment on the basis of supercomputer technologies. The conceptual solutions that define the problem of connectivity, complexity and stability based on the UCS concept are aimed at ensuring the principle of adaptability and reflect a single trend - an adequate description of the hierarchical organization and the identification of significant functionally significant elements of interaction in a conflict situation. The above analysis is crucial in the search for mechanisms that ensure the formation of collective properties of interpretation of an aggressive dynamic environment, leading to the formation of hierarchical systems and the emergence of the possibility of their mutual modeling. Compression of the mathematical description of conflict situations is a necessary prerequisite for the formation of collective properties of interaction models in UCS through the organization of cross-correlations between the corresponding variables.

References:

[1] Barseghyan A. A., Kupriyanov M. S. Stepanenko V. V., Kholod I. I. Methods and models of data analysis: OLAPand Data Data Mining. Saint-Petersburg: BHV-Petersburg, 2004. 336 p. (in Russian)

[2] Tikhonov A. N., Arsenin V. Ya. Methods of solving ill-posed problems, Moscow: Nauka, 1979, 284 p.

[3] Nechaev Yu. I. Theory of catastrophes: a modern approach to decision-making. - Saint Petersburg: Art-Express, 2011, 391 p.

[4] Nechaev Yu. I. Topology of nonlinear non-stationary systems: theory and applications. Saint Petersburg: Art-Express, 2015, 325 p.

[5] Baluta V. I., Osipov V. P., Chetverushkin B. N., Yakovenko O. Yu. Adaptation of intellectual agents in a neoconflict environment / / SCVRT2019 Proceedings of the International scientific conference. 2019. Pp. 28-35.

[6] A.Kh. Khakimova, O.V. Zolotarev, M.A. Berberova. Visualization of bibliometric networks of scientific publications on the study of the human factor in the operation of nuclear power plants based on the bibliographic database Dimensions. Scientific Visualization, 2020, volume 12, number 2, pages 127 - 138, DOI: 10.26583/sv.12.2.10, E-ISSN:2079-3537.

[7] M.A.Berberova, S.S.Zolotarev, «NPP risk assessments results dependence study on the composition of the population living around the NPP (on the example of Rostov and Kalinin NPP)», GraphiCon 2019 Computer Graphics and Vision. The 29th International Conference on Computer Graphics and Vision. Conference Proceedings (2019), Bryansk, Russia, September 23-26, 2019, Vol-2485, urn:nbn:de:0074-2485-1, ISSN 1613-0073, DOI: 10.30987/graphicon-2019-2-285-289, http://ceur-ws.org/Vol-2485/paper66.pdf, p. 285-289.

[8] M.A.Berberova, K.I.Chernyavskii, «Comparative assessment of the NPP risk (on the example of Rostov and Kalinin NPP). Development of risk indicators atlas for Russian NPPs», GraphiCon 2019 Computer Graphics and Vision. The 29th International Conference on Computer Graphics and Vision. Conference Proceedings (2019), Bryansk, Russia, September 23-26, 2019, Vol-2485, urn:nbn:de:0074-2485-1, ISSN 1613-0073, DOI: 10.30987/graphicon-2019-2-290-294, http://ceur-ws.org/Vol-2485/paper67.pdf, p. 290-294.

[9] The synergetic paradigm. Variety of searches and approaches. Moscow: Progress-Traditsiya Publ., 2000. 535 p.

[10] Sevryugin N. N., Yudin A.V., Kuznetsov A.V. About the methodology of choosing technical solutions / / automation and modern technologies. 2005. no. 3, pp. 27-30.

[11] Casti Jnr. Big systems: connectivity, complexity and catastrophes. Moscow: Mir, 1982, 216 p.

[12] Smolentsev, S. V. Application of dynamic semantic network for identification in intelligent measurement systems // Collection of reports of the International conference on soft computing and measurement SCM-2000. Saint Petersburg: 2000. vol. 2, pp. 82-83.

[13] Tikhomirov V. A., Tikhomirov V. T., Makushkin A.V. the Principle of constructing an information-probabilistic method for implementing a long-term forecast // Software products and systems. No. 2. 2004, pp. 10-15.

[14] Kolmogorov A. N. Information theory and theory of algorithms. - M.: Nauka, 1987, 304 p.

[15] Solodovnikov V. V., Tumarkin V. I. Theory of complexity and design of control systems. Moscow: Nauka, 1990, 168 p.

[16] Lazarson E. V. Modern technology of automated solution of multivariate problems // Automation and modern technologies. 2009. No. 11, pp. 23-29.

[17] Golitsin G. A., Petrov V. M. Harmony and algebra of the living. - Moscow: Znanie, 1990, 128 p.

[18] Gubko M. V. Mathematical models of optimization of hierarchical structures, Moscow: LENAND, 2006. 264 p.

[19] Mesarovich M., Takahara Ya. Obshchaya Teoriya sistem: Matematicheskie osnovy [General theory of systems: mathematical foundations], Moscow: Mir, 1978, 312 p.

[20] Moiseev N. N. Selected works, M. TyRex Co., 2003, 376 p.

[21] Nikolis J. (Ed.) Dynamics of hierarchical systems: an evolutionary view, Moscow: Mir publ., 1989, 488 p.

[22] Figueira G., Almada-Lobo B. Hybrid simulation-optimization methods: A taxonomy and discussion // Simulation Modelling Practice and Theory. - 2014. - T. 46. - C. 118-134.

[23] 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

[24] E. Gallopoulos E.N. Houstis and J.R. Rice, «Computer as Thinker/Doer: Problem-Solving Environments for Computational Science» IEEE Computational Science & Eng., Vol. 1, No. 2, Summer 1994, pp. 11-23.

[25] Szalay A. Extreme data-intensive scientific computing // Computing in Science & Engineering. - 2011. - T. 13. - No. 6. - CPp. 34-41.

[26] Zadeh L. Fuzzy logic, neural networks and soft computing // Commutation on the ASM-1994. Vol.37. № 3, p.p.77-84.

About the authors

Nechaev Yuri I. - Doctor of Technical Sciences, Professor, Saint Petersburg state Maritime technical University. E-mail: nyui33@mail.ru

Osipov Vladimir P. - Candidate of Technical Sciences, leading researcher Institute of applied mathematics. M. V. Keldysh, RAS, E-mail: Osipov@keldysh.ru

Baluta Viktor I. - Candidate of Technical Sciences, senior researcher, Keldysh Institute of applied mathematics of the Russian Academy of Sciences, Plekhanov Russian University of Economics. E-mail: Vbaluta@yandex.ru