Conceptual model in the system of decision-making support for the critical informational infrastructure of the departmental information network

V A Spirin, A A Zenin, S A Pysin and D G Zybin

Information Safety Department Institute Of Penitential System Of Russia Voronezh, Russia

E-mail: zdg77@mail.ru

Abstract. The analysis of the functioning of dynamic models of real information systems was performed. It shown that randomness is caused by the manifestation of the basic property of environmental processes — their basic incomplete predictability. A systematic approach and relevant research principles have applied to ensure the scientific formulation and solution of the problem of ensuring the sustainability of critical information infrastructure of departmental information network functioning, its decomposition into particular research problems and aggregation of particular results obtained. The development trends and the construction considered and analyzed, which allowed us to suggest ways of practical implementation of the proposed synergistic approach.

1. Introduction

One of the main distinctive features of theoretical knowledge forms is the presence of one of the elements such as theoretical (conceptual) model of the investigated object, methodology of the quality estimation (efficiency) of a system (process) or a set of regularities concerning system characteristics allowing to synthesize a system (process) or distribute a systemic effect for a compound object for the benefit of its separate components according to the defined requirements.

Conceptual models designed based on synthesis of the generalized representations on some components of their processes and phenomena relying on the fundamental laws describing the behavior of the studied system (object).

Conceptual model for provision of cyber-stability of the objects in the critical informational framework of the departmental informational network (CIF DIN) integrated by the use of informational telecommunication network for public use (ITN PU) into the state informational network (SIN) and cyberspace reproduces stochastic dynamics of the destructive informational impacts (DII) on the objects of CIF. This model implies general schemes of CIF objects (automated management system (AMS of DIN, ITN PU) and the processes (functioning, impacts and provision of cyber-stability) investigated in cyber-stability theory demonstrating their most essential relations.

An inherent element in this management system is a sub-system of provision for decision-making that has its own self-reliant role in the complex system. Facilities for management and control of the stable performance in departmental informational network (DIN) depend in a direct way on the capabilities of system for provision of decision-making [1, 2], its ability to provide a decision-maker with a qualitative balanced information characterizing the real and predicted states for the objects of...
SIF and to ensure the valid choice for tracing of the goal achievement in the conditions of confrontation in cyberspace. Design of the system for provision of decision-making allowing to ensure an adequate management of CIF in such conditions is not possible without making analysis of not only the links between CIF objects and CIF as a whole but and the appearing emergent properties but also without revealing of their appearance, i.e. understanding their synergetic properties.

The issues of decision-making in the conditions when the influencing factors possessed as random values (i.e. in purposeless way), because of purposeful destructive informational actions are of a great complexity. The choice of a strategy allowing attaining the current aim requires a certain formalization of the situation for decision-making – namely, mathematical model formulation of the problem situation in the conditions of indeterminacy.

2. Analysis and conceptual model of a decision support system for critical information infrastructure of a departmental information network

Analysis of performance for the dynamic models of the real informational systems [3-5] demonstrated that the randomness caused by manifestation of the main property in the system processes – their principle incomplete unpredictability. This idea confirmed by the fact that the repetition of the same alike situations does not lead to an unambiguous result. Events with the ambiguous outcomes are named bifurcation ones [6].

Principal absence of the possibility to make a perfect prediction of the system behavior and its elements in future that is true for the complex active systems is their main distinct feature. This property determined by the fact that such kinds of the systems when interacting with the environment of performance participate in the “bifurcation events” by choosing their strategy and the outcome of these events cannot be unambiguously predicted beforehand.

Each of the bifurcation events fits not only one but also several or an infinite set of the possible outcomes with a certain probability of realization, and any of them can be realized after occurring of the event. These outcomes form a set the possible results for this event. If the event happened, then only one outcome realized from a set of the possible outcomes and a further development of the process takes place according to only one of the possible scenarios until a new event occurs with several possible outcomes.

Nominally, the model of the problem situation defined with the use of the following elements representing a set of the most essential factors from the viewpoint of a decision-maker [7]:

- \( N = \{1, 2, \ldots, n\} \) - a set of participants of the conflict;
- \( S \subseteq N \) - a subset of the conflict’s participants united by the common objective and cooperating with each other (coalition);
- \( \mathcal{R} \) - hierarchy relation in the coalitions;
- \( U^S \) - a set of strategies for \( S \)-th coalition;
- \( \Theta^S \) - information being in disposal of \( S \)-th coalition;
- \( X_U^S \) - Cartesian product of a set of strategies for coalitions – a set of situations;
- \( W^S(X_U^S) \) - gain function of \( S \)-th coalition;
- \( P^S \) - model corresponding preferences of \( S \)-th coalition on a set of situations in the model of problem situation.

For each of the coalitions in general it is necessary to set a binary preference relation on a set of situations. The objective of a coalition in the conflict is the achievement of the mostly preferred situation in one or another way. The situation is a result of the choice of their own strategies for all of the players. In general, the gain for i-th player does not coincide with the gain that he can ensure for
himself gaining single-handed since entering coalition S can get a greater gain. This can explain by the fact that:

\[ W^S() \geq \sum_{i \in S} W^i() \] (1)

Thus, the most common model of the conflict defined by a system of sets:

\[ \left\{ N, \{ U^S, \theta^S, P^S, W^S \}_{S \subseteq N}, R \right\} \] (2)

Mechanism H for the model of the conflict implies that participants of the conflict from a set of N affect some certain system that as a result leads them in getting of certain gains:

\[ H : U^{[1]} \times U^{[2]} \times \Lambda \times U^{[\theta]} \times T \rightarrow (W^{[1]}, \ldots, W^{[\theta]}) \] (3)

Where T – is a set of the points of time in the development of the conflict. Every of the participants in the conflict acts according to the quite certain rules tending to achieve its own aim. It assumed that all of the conflict’s participants get some kind of information on the state of a system. In many cases, information is concerned with the form of the functions associated with the gain of some players or of their coalitions as well as a set of admissible strategies for participants of the conflict and their coalitions.

Process of provision for stability of performance of CIF DIN in the conditions of DII inseparably connected with the determination of the vectors for variable of the state characterizing control object and the factors affecting this object that resulted in arising of the current situation. This requires complex consideration of as the character of the situation development as the measures directed at the elimination of its negative consequences.

In addition, the study of stability during operation of CIF DIN in case of DII occurrence inherently connected with the execution of attaining the objective function and this process can described by a tuple in the form of:

\[ Y(t) = \{ Y_0, X(t), F(t), U(t), S_U, S_F, \Theta, \Psi \} \] (4)

Where:

- Y - is the vector of objective function of CIF DIN;
- Y(t) - is a vector of the result of the objective function execution in the current situation
- V0 - is the initial state of the control object;
- X(t) - DII vector;
- F(t) - vector of variables used for description of the state of object where current situation emerged;
- U(t) – vector of the control actions aimed at the reducing (elimination) of the effects of external perturbations (environment), destabilizing factors and DII;
- SU - protection strategy;
- SF - onset strategy;
- \( \Theta \) - additional information on the problem information;
- \( \Psi \) - mapping which conforms the values of the fixed strategy for attaining of and the values of influencing factors for the objective function.

Goal achievement in CIF DIN corresponds to the execution of the objective function in a current situation.
\( C(t) - Y(t)_{\text{nuG}(t)} = 1 \) \( (5) \)

Where, is the vector of ability to execute objective function in the current situation.

Thus, one can make the following conclusions.

- Integration of multi-type information systems (IS) IS SIN through the use of ITN PU resulted in the accessibility of CIF through cyberspace and this emerges new vulnerabilities and threats thus making a provision of the national security in a dependence of their protection. Security of CIF implies the state of CIF protection providing its steady operation in the conditions of computer attacks. Obviously, in order to compensate these kinds of threats it is necessary to incorporate the corresponding management system with a steady operation that will consider CIF as a complex of interrelated functions, networks and technologies. However, this approach considerably complicates the problem of stability control and management. The basis for stability management in the system is a system of decision-making support.

- Provisioning of stability in operation of CIF objects in the composite automated control systems is possible only under complex solution of scientific problems concerned with the control of stability processes from the viewpoint of a systemic approach. Application of systemic approach and the corresponding principles to the carrying out of the investigations enables scientific character of the problem definition as well as its solution regarding provision of stability in CIF operation and its decomposition into specific tasks of investigations as well as the aggregating of the obtained specific results. It is clear that in this case a complexity in the applied methods of investigations creates qualitatively new scientific approach – a synergetic approach. Consideration of synergetic properties of CIF DIN enables to enhance controllability of the system due to the coordination of the control actions with the intrinsic trends in the system as well as by varying of the power connections between the parts of the system as a whole (it allows as to strengthen as to weaken connections that are already present).

- Analysis of the tendencies in the development and design of the prospective system of decision-making support made it possible to propose the ways of practical implementation for the proposed synergetic approach. Comparative analysis of the ways for designing of decision-making support system demonstrated that only in a thoughtful combination of the methods applied in a decision-making support system there could generate an emergence and synergetic effect when a complementarity will minimize specific imperfections and make it possible to solve difficult tasks in the practice of decision-making in an automated manner. To acquire parameters describing the states of CIF object it is required to arrange a corresponding subsystem of monitoring that is adequate to the objectives of decision-making support system and that is capable to account for the effects of external and internal, constructive and destructive informational impacts. The obtained description of the actual CIF state allows performing of the estimation for CIF capability to execute the objective functions in the given time instant and in certain conditions. Design of a decision-making support system that is able to implement a complete coverage of all the tasks to be solved including usually difficult for automation the planning and prediction tasks requires the application of the intellectual data analysis. The quality of the provided information after its processing in the decision-making support system will be first determined by the level of accumulated empirical data and the applied technique for the intellectual analysis of these data.

A necessity of empirical data accumulation in the specially designed informational storage favors formation of the continually augmented archive of the behavior activity for various objects, from technical facilities of the data processing CIF objects up to CIF system as a whole.

The choice of strategy allowing attaining the current objective requires formalization of the situation for decision-making, namely, a design of the mathematical model for the problem situation and simulation of behavior of the opposing parties.

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