Information support tools for regional security management in the Arctic

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Abstract. The research work is oriented to methodology and information technologies development for security network-centric control of regional socio-economic systems (by the example of Arctic zone of Russia). It is necessary to significant and relevant scientific problem solving of regional security decentralized control efficiency enhancement of the Arctic regions which are exposed to impact by the set of heterogeneous factors, that condition high risks of natural, technogenic and socio-economic emergency and crisis situations appearance. The main scope of our investigation is information infrastructure of the multi-level distributed system for Arctic regional security organizational management. For problem solving under research new models and methods, providing efficiency enhancement of that system functioning at the expense of activities adequate information and analytical support and coordination of the organizationally heterogeneous security control actors, have been developed. The article deals with the development problems of an integrated network-centric information infrastructure for regional security management support in the Arctic regions. For this type problem-solving application of the developed complex methodology, including a network-centric control model, simulation and conceptual modeling, multi-agent technologies, design and implementation methods of distributed information management systems has been proposed. The description of research and work-out results is given, namely the polymodel complex, the multi-agent modeling technology and the decision-making support system in the field of regional security by the example of Murmansk region. The received results constitute the foundation for regional security network-centric control system development. Research developments allow to operability and managerial decision-making efficiency enhancement in the field of Arctic regional security support and control subject to impact of heterogeneous factors. The represented results are applicable for new security distributed control system synthesis of various nature and scale complex objects, and for functioning operability and precision enhancement of the already existing security support systems of critically significant objects and infrastructures of Arctic region.

1. Introduction
In recent years, one of the research topics of the Institute for Informatics and Mathematical Modeling (IIMM KCS RAS) is the development of components of a single information space of regional development. Within the framework of this direction, the features of the organization of complex information support of security management in the region are studied.

Approbation of the research results is carried out on the basis of the Arctic zone of the Russian Federation (AZ RF). Recently, the Russian Arctic is a demanded macro-region of our country. The
interest in the AZ of the Russian Federation is due to its strategic importance for the geopolitical and economic goals of Russia's development. The consequence is to increase the attention of the international community who have their own interests in the development of the Arctic. Stakeholders include both government agencies and private businesses. The objectives of such participants on the use of transport facilities and the resource base of the Arctic are not consistent with each other, and are sometimes contradictory. Modern information management systems do not have a full set of functions for rational management in the presence of such contradictions. This is the reason for the creation of a comprehensive multifunctional information support infrastructure for regional security.

One of the historically formed springboards for the development of the Arctic is the Murmansk region. Research IIMM KSC RAS focused on the problems of regional development, characteristic of this strategically important region of the Russian Federation. The differences of the Murmansk region from other Russian regions are manifested in such characteristics as: harsh climatic conditions, border arrangement, concentration of objects of defense and industrial complexes. These factors significantly increase the vulnerability of the region through the emergence of different types of crisis situations of natural, technogenic and socio-economic nature. The process of neutralizing the consequences of crisis situations is characterized by the need for prompt rational decision. One of the ways to solve this problem is the development of integrated methods, tools and technologies for information support of regional security management. The isolation of decision making at different levels of decentralized security management increases the relevance of this task.

The research focuses on economic, social and environmental security. The main objects of research are methodical and software means of information support of functioning and development of regional socio-economic and natural-technical systems. The article describes some applied research results. They were used to solve real practical problems of ensuring the regional security of the Murmansk region.

2. Scientific and practical results
Recently, the scientific and practical results of IIMM KSC RAS, related to the organization of information support for the management of regional security, were conducted in the following areas:
- Development of computer models of various components of the regional security management system;
- Creation of information technology architectures for regional security management;
- Development of software components of an integrated information space to ensure regional security.

The interconnected results on each direction of applied research are given in the following sections of article.

2.1. Polymodel complexes
The analysis of the computer models previously developed in the IIMM was carried out to form the simulation tools for solving the problems of regional security management. The criterion of selection of models was their orientation on the study of different aspects of economic, social and ecological safety. The selected models were modified and adapted to create a uniform model complex. The model complex is designed to obtain different types of forecasts about the dynamics of regional security and its individual components. Forecasts are used to make recommendations to prevent potential crisis situations or reduce damage when they occur.

As a result, a polymodel complex for studying regional security problems was developed. The complex consists of problem-oriented simulation models of forecasting socio-economic development of the region. It allows to assess and investigate the dynamics of regional security indicators and its derivatives. The complex has a composite structure, dynamically formed from a finite number of typical model blocks - templates. According to the authors, this increases the correctness of model development and reduces the time of its adjustment.
The developed complex of simulation models is focused on the study of possible scenarios for the development of regional crisis situations of socio-economic nature. It serves as a tool to improve the quality of recommendations for the implementation of sound management decisions. The polymodel complex provides high variability of realization of computational experiments.

The complex is a library of problem-oriented computer models. Each model of the library is implemented programmatically as an independent Java-applet in the Anylogic simulation environment. In Figure 1 the structural scheme of the polymodel complex is shown. Simulation models grouped by a certain criterion are collected in structural blocks. Structural blocks of the complex are connected by two types of relations: the relationship of full or partial inclusion of one model into another; interaction relationships by passing individual parameters between models.

At the current stage of development, the polymodel complex consists of the following 20 model blocks: M1 «System-Dynamic model of demography of the city»; M2 «System-dynamic model of fuel and energy complex of the region»; M3 «System-dynamic model of the economic potential of a single-industry town»; M4 «System-dynamic model of the fishing industry in the region»; M5 «System-dynamic model of the agricultural complex of the region»; M6 «System-dynamic model of mining enterprise»; M7 «System-dynamic model of private enterprise development in a single-industry city»; M8 «System-dynamic model of the housing complex of a single-industry town»; M9 «System-dynamic model of environmental pollution»; M10 «System-dynamic model of food security in the region»; M11 «Simulation model of fuel and energy complex»; M12 «Simulation model of education quality management»; M13 «Simulation model of scientific and innovative enterprise»; M14 «System-dynamic model of staffing of the mining enterprise»; M15 «Complex of simulation models of personnel needs of the main branches of economy of the region»; M16 «Simulation model to estimate the number of graduates of universities and colleges»; M17 «Complex of system-dynamic models of market diffusion of innovations»; M18 «Polymodel complex of regional security»; M19 «Polymodel complex of innovative space of single-industry towns»; M20 «Complex of simulation models of life cycle management of projects in the field of regional security».

Figure 1. Structural scheme of the polymodel complex.
The developed polymodel complex is tested on practical problems of forecasting of regional social and economic crises [1]. For example, simulation models were used for long-term forecasting of personnel needs of economy of Murmansk region [2]. The library of problem-oriented computer models of regional security is the foundation for the development of information management systems with a simulation device. The following sections of the article describe examples of such application of a polymodel complex.

2.2. Technology of formation of multi-agent modeling environment for network-centric management of regional security

The modern world dictates increased requirements for information technology to ensure the security of regional socio-economic systems. Improvement of existing methods and mechanisms of organizational management of security continues to be a demanded task. Its solution is hampered by the presence of factors that complicate planning and operational accounting of crisis situations. Such factors include different nature, latent character, heterogeneity and slow growth of threats and dangers of regional development. Therefore, existing models and methods of automation and management of regional security [3, 4] require adaptation.

Neutralization of the consequences of socio-economic crisis situations is characterized by the adoption of sound management decisions in a short time. In such conditions, it is rational to use the network-centric control model [5]. The network-centric management of regional security implies the implementation of the networking structure of organizational management with dedicated control centers. The interaction between the centers is formed by their integration into a single regional information space. This concept eliminates closed hierarchical security management structures with rigid organizational relationships and centralized management and moves to open network virtual organizational structures with flexible connections and decentralized management [6]. As part of the implementation of this concept, a technology for the formation of a multi-agent modeling environment for regional security management problems is proposed.

The proposed technology is implemented in four main stages, presented in Figure 2.

Figure 2. Structural diagram of the technology of formation of multi-agent modeling environment for the tasks of regional security management.

The first step is to define a base set of agent classes for the synthesized system. Agents are split into classes based on their role. For example, for the task of modeling management processes in crisis situations were allocated classes: coordinator, performer, security expert. A set of system-wide and specific agent functions has been defined for each class.
In the second phase, coalitions are formed from instances of the selected classes. In some cases, it is possible the emergence of subjects of the conceptual model that perform several roles simultaneously. Instances of different classes are defined for them. In this case, the number of classes associated with the subject varies depending on the simulation progress. Agents are algorithmic executors of the non-terminal level. The agent knowledge base is populated based on the conceptual model.

The third stage is designed to develop components for the implementation of the simulation environment. It is proposed to present the modeling environment as a complex of system-dynamic models. Two types of models are used: environment simulation and agent activity simulation. The formation of the structure of simulation models is implemented by analyzing the conceptual model and information about the agents identified in the previous stages.

At the fourth stage, the synthesized components are combined into a single multi-agent modeling environment. Also, the modeling environment is configured for a specific task.

A distinctive feature of the proposed technology is the implementation of a new model of interaction of intelligent agents with imitation apparatus. The simulation machine recreates the model environment of the agent's functioning, recursively called in the modeling process. It is designed to obtain a local forecast of the results of the agent's activities. The simulation apparatus is based on computer models from the regional security research library presented in the first section of the article. The technology combines the phases of synthesis and qualitative assessment of the configuration of models of management structures, the dynamic formation of coalitions of agents and related information resource networks. The technology provides for the use of semi-structured incomplete source data.

The proposed technology has been tested on the tasks of ensuring environmental and economic security of the region [7]. In particular, it was used to solve the tasks of coordinating the activities of forces and means involved in the liquidation of emergency situations in the waters of the Northern Sea route. Also, to determine the participants in a public-private partnership and form effective innovative structures for the implementation of socially significant investment projects in the Murmansk region.

2.3. Decision support system in the context of regional crisis situations

The use of modern computer simulation tools allows organizing coordinated security management in all areas of the socio-economic development of the region. It also provides an opportunity to improve efficiency and effectiveness of management. To this end, a regional information system has been created and is being developed on the territory of the Murmansk region to support decision making on managing the security and development of the region in crisis situations of a socio-economic and natural-technogenic nature. It received the provisional name - decision support system for managing regional security of the Murmansk region - DSS RS MR. This information management system provides information support for the initial stages of development of regional crisis situations. To expand the functionality of the system, the issues of its integration with the regional subsystems of the region's system of emergency prevention and liquidation of the Murmansk region are being worked out.

DSS RS MR is focused on the following main tasks:
1) Automated collection, storage and analytical processing of information (on the impact of threats on the state of regional security; on crisis and emergency situations arising in the regional economy; on the socio-economic situation in the region; organizational structures of safety management, their resources and readiness for implementation of anti-crisis measures in the region).
2) Information monitoring of safety indicators of socio-economic and natural-technogenic environment of the region, aimed at diagnosis, prevention and neutralization of crisis situations.
3) Forecasting the dynamics of regional security indicators based on modeling scenarios for the behavior of subjects of regional security management in various crisis situations to plan their joint activities.
4) Comprehensive information support and coordination of processes of preparation and development of managerial decisions on ensuring regional security at all levels of management, control of implementation of the adopted decisions.

5) Coordination of inter-agency cooperation in a single information field.

It should be noted that for the solution of the third problem model complexes and information technology of the organization of the multi-agent environment of modeling which description is given in the first two sections of this article were used.

The main structural elements of the DSS RS MR are:
- the central information and analytical system of the situation center of the region (CIAS SCR);
- information and analytical systems of situation centers of municipalities (IAS SCM);
- information and analytical systems of crisis management centers (IAS CMC) of the main Department of EMERCOM of Russia in the Murmansk region;
- information and analytical systems of critical and potentially dangerous objects (IAS CPDO);
- a unified point of access to resources and services of DSS RS MR based on web technologies (Internet portal «RU-Arctic.net»);
- hybrid cloud service «Virtual cognitive center» for regional development and security management;
- virtual integration platform professional social network of security experts «BarentsNet»;
- service-oriented agent P2P-platform of portable type and multi-agent information support system for network-centric regional security management.

Problem solving in the system is provided by the interaction of the following functional subsystems of the DSS RS MR:
1) the system for planning anti-crisis measures for diagnosing, preventing and mitigating the effects of crisis situations in the region, implemented as a module for making management decisions;
2) the system of safety passports of the critical objects and infrastructures of the region;
3) crisis registration system;
4) the system for coordinating joint actions of organizational security management structures in crisis situations
5) the system for modeling and forecasting the development of crisis situations and assessing their consequences;
6) the monitoring system of regional security indicators and sources of threats of crisis situations;
7) the system of information and delivery of recommendations.

The formal basis of DSS RS MR (mathematical apparatus and control algorithms) is described in detail in [8, 9]. The functional structure and composition of the management decision-making module in the conditions of crisis situations, forming the operational core of the DSS RS MR, is presented in Figure 3.
The process of regional security management in crisis situations should cover the whole complex of problems of regional development. To this end, the DSS RS MR operates in the following three main modes: stationary (combining the mode of daily activities and high readiness); emergency (mode of neutralization of developing crisis situations); post-emergency (liquidation and mitigation of crisis situations).

Continuous information monitoring of regional security indicators plays an important role in management. It is accompanied by a systematic comprehensive measurement of security indicators of socio-economic development of the region and their subsequent analysis [10].

Since the time for decision making is usually limited, it is not always advisable to fully rely on the obtained monitoring data, since the reliability, relevance and completeness of the information collected is not guaranteed. Therefore, in the process of monitoring it is necessary to use modern methods and technologies for processing and analyzing incomplete semi-structured source data. As practice shows, the lack of reliable information is the main problem in the organization of early diagnosis of threats to regional security and, accordingly, the prevention of crisis situations. This is due to incomplete source data.

DSS RS MR also includes servicing software and hardware designed for information technology support of the functioning of the basic functional subsystems: integrated territorial system of communication and data transfer; administrative and security management system; regional geographic information system of the Murmansk region.

According to expert estimates, the practical implementation of the system will reduce the time and labor costs of relevant departments to develop and coordinate management decisions in crisis situations of socio-economic and natural-technogenic by 20-30% in terms of solving organizational issues for the planning and implementation of anti-crisis measures.

Figure 3. The functional structure and composition of the decision block DSS RS MR.

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The system is planned to be applied in the implementation of the "Strategy for the development of the Arctic Zone of the Russian Federation and ensuring national security up to 2020" in the Murmansk region for solving practical problems in the field of information ensure regional security.

3. Conclusion

The article presents outcome results of applied research, focused on the creation of software tools for information support of regional security management. In particular, the description of library of problem-oriented models, technologies of formation of multi-agent environment and system of decision-making support is offered. The considered results are interconnected and obtained in the course of a sequential transition from individual computer models of regional systems to large-scale integrated solutions for the formation of a unified information infrastructure to ensure regional security.

The distinguishing feature of the considered solutions is the integration of methodological, model and software tools for analysis and processing of various information about the impact of changing threats and hazards on the state of regional development. This provides an adequate current situation with information support and coordination of management decisions at all levels of regional security management and increases the validity of decisions made.

Along with simulation modeling, multi-agent technologies are used in the form of creating software agents for monitoring and forecasting the dynamics of regional security indicators. The offered complex software solution provides an opportunity of operative adjustment of a modeling environment on peculiarities of one or another task of management and high variability of realization of computational experiments.

According to the authors, promising directions of fundamental and applied research in the subject are:

- Generalization and development of separate results of the developed theory of network-centric management of spatially distributed complex objects of different nature and scale in relation to modern conception of acceptable risk.
- Development of an integrated methodology for modeling multi-level network-centric control systems for complex semi-structured dynamic systems for other relevant applications.
- Development of draft legislative acts of regional level for effective introduction of simulator-modeling complexes of support of decision-making in structure of systems of regional management.

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