Development of methods and tools to support regional management in the Arctic zone of the Russian Federation based on cognitive interfaces

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Abstract. This article discusses the creation of methods and tools for decision-making information support for regional management systems in the context of ensuring environmental and technological security in the Arctic region. To implement information support for regional management, we propose to use information technology for spatial data visualization. This technology is used to synthesize cognitive interfaces of multi-subject information systems supporting regional management in the Arctic zone of the Russian Federation. The article describes the methodological support, composition and structure of information technology to identify implicit conflicts of environmental management based on the use of methods of conceptual and ontological modeling of the subject area, system analysis and theory of management of complex systems. The key elements of the technology are the conceptual model of the conflict situation of environmental management, the ontology of the subject area, the knowledge base and the cognitive user interface of the multi-subject information regional management support system for the Arctic territories. A brief classification of conflicts among the stakeholders of the Arctic region (using the example of the Murmansk region) is also described. The proposed technology allows to identify potential conflicts of environmental management, including the detection and identification of environmental and technological safety problems in the Arctic regions of the Russian Federation.

1. Introduction
The management of large and complex spatially distributed natural-industrial complexes is a complex problem. This activity requires decision makers (DM) to take into account heterogeneous factors and to solve a number of particular tasks. One of the most difficult types of such tasks is to identify implicit potential conflicts of major stakeholders. The effective solution of such problems becomes especially important in the conditions of the Arctic regions, the ecological system of which is especially sensitive to anthropogenic impact, and the natural restoration of natural complexes occurs much more slowly than in southern latitudes. At the same time, it is impossible to completely eliminate the anthropogenic impact on the environment during industrial development of the territories of the Far North. [1, 2]Therefore, it is necessary to develop specialized systems that take into account environmental and technological safety issues. The most important functions of such systems can be implemented in the framework of multidisciplinary decision-making information systems (MDMIS) for the tasks of regional management in the Arctic zone of the Russian Federation (AZRF).
Despite the development of modern decision support systems (DSS) and the development of various information analysis tools to improve the efficiency of decision makers, managing large spatially distributed natural-industrial complexes remains a complex, difficult to formalize task. The most urgent need for an adequate, fast and effective solution of such tasks is manifested at the regional level. This article considers the territorial and administrative regions of the Arctic zone of the Russian Federation. From the point of view of regional management, the region is a large, complex bio-socio-economic system (BSES). To manage such a system, it is necessary to take into account a huge number of heterogeneous factors [3]. The biggest difficulty lies in the fact that these factors are difficult or impossible to predict, analyze and take into account their impact on the development of the system. In addition, the quantitative and qualitative composition of such factors, as a rule, cannot be determined in advance.

Regional management includes many aspects and subsystems, the mutual influence of which must be taken into account in order to make informed decisions. If we consider the region as a one bio-socio-economic system, it becomes obvious that it is a complex object, including many levels that require specific approaches and management methods [4]. Among the most significant and having a strong spatial reference to the territory, we can distinguish: social, economic, environmental and administrative levels. Incorrect control on any of them carries the potential danger of disrupting the normal functioning of the entire system [5, 6].

To improve the quality of management of spatially distributed natural-industrial complexes and prevent threats to sustainable socio-economic development of the region, [7] methods and specialized tools for systems analysis and information support for various activities in the Arctic are being developed [8, 9]. The method of dynamic visualization of spatial data, described in the paper, also refers to methods for improving the quality of management of spatially distributed natural-industrial complexes. Based on this method, it is possible to implement cognitive interfaces of multidisciplinary information systems, allowing to identify potential environmental and technological conflicts within the framework of regional management. For the effective functioning of the multidisciplinary support information system for regional management, it is necessary to provide opportunities for detecting, identifying and resolving conflict situations arising between the main stakeholders of the region.

2. Problem statement and methods

Our work is aimed at the creation and development of methods and tools to support decision-making in the field of regional management in the context of ensuring environmental and technological safety in conditions of incomplete or contradictory information. An important feature of managing a real regional system is that it is impossible in advance to unambiguously determine the full composition and exact number of interacting objects, as well as all possible ways and types of their interaction. Therefore, the system model and the modeling system are subject to significant changes in the modeling process, which complicates the process of creating correct and consistent models of region management.

Another important problem is the problem of correctly extracting expert knowledge, processing and formal presentation of this knowledge. Often there are situations associated with obtaining incomplete or contradictory data. This is due to the fact that experts participating in the process of extracting knowledge are drawn from different subject areas and have their own ideas about the surrounding reality, which can often not coincide with the opinions of other experts who have alternative experience of interacting with the outside world. To obtain high-quality knowledge, it is of great importance both the professional experience of a particular expert and his level of awareness in the field of methods of extracting expert knowledge. When combining, integrating knowledge gained from experts, to build a single, connected model, there is an inconsistency between the model elements and the connections between them, caused primarily by differences in the cognitive picture of the world of each expert. Therefore, when modeling real systems, it is necessary to use an additional tool that allows for the integration of heterogeneous data and knowledge obtained from various sources, even in case of discrepancies. This problem can be solved through the use of modern cognitive
technologies and formal methods of presenting information, which make it possible to limit the possible interpretations of knowledge and data obtained from experts from different subject areas. One of the widely used methods for creating formalized specifications of subject domains is the conceptual modeling method.

The above features of modeling real regional systems determine the high importance of improving existing and developing new methods and tools for creating conceptual models for various subject areas. The effectiveness of the development of tools, technological and scientific-methodical bases for solving problems of intellectual information support for managing complex spatially-distributed regional systems depends on the successful solution of this task.

The developed conceptual domain model (CDM) provides a formal presentation of heterogeneous activities in the region based on the analysis and identification of the main concepts and relationships used in the management of spatially-distributed socio-economic systems. Thus, CDM is a logical system that provides the ability to derive conclusions based on the rules for deriving facts from knowledge bases (Figure 1).

![Figure 1. The scheme of using the conceptual domain model for the reconcile of data and knowledge as well as for logical inference](image)

The conceptual model describes the composition and structure of the subjects and objects of activity in the region, which makes it possible to use it as a formal basis for solving problems of intellectual information support of regional management. The formalization of the conceptual model provides the possibility of automating the work with the model - from the implementation of procedures for analyzing the completeness and consistency of collective knowledge presented by experts to the design and formation of an executive modeling software environment. The declarative nature of the conceptual model makes it possible to use various modeling methods for processing this knowledge: logical, analytical, statistical, and simulation methods.

3. Types of typical for the AZRF environmental management conflicts
We conducted a detailed analysis and synthesis of information on the main activities of the most important stakeholders in the region. As an example, the Murmansk region of the Russian Federation was chosen. Murmansk region is part of the AZRF and has borders with other states. To formalize data and knowledge, we used the above-mentioned CDM. As a result, we identified potential conflicts of environmental management and identified the most significant types of such conflicts [10, 11]. The use of this knowledge in the management of the region allows to increase the level of ecological and technological safety of the bio-socio-economic systems of the region. All possible environmental management conflicts in the region (on the example of the Murmansk region) were divided into three types:

1. conflicts related to the implementation of various types of stakeholder activities, when these types of activities are fully or partially incompatible. That is, the implementation of activities by one stakeholder leads to the fact that another stakeholder cannot carry out his type of activity. For example, “protection of natural areas - mining”, “protection of maritime state borders - free water tourism”, “drinking water intake - discharge (leakage) of waste (technical) water”, etc.

2. conflicts associated with the use of certain resources of the territory. At the same time, a certain territory can also be considered as a special type of resource. Here both intrasectoral and intersectoral conflicts are possible. For example, the competition of various mining companies for the right to develop a single field, the competition of fishing companies for a quota or territory of catch, etc.

3. conflicts associated with the use or implementation of certain activities in a particular area. In such conflicts, the object is some “limited space” or part of it. In other words, it can be said that in this kind of conflict the object is the “right to use” some territory. Examples of such conflicts can be the closure of territory for military purposes or to ensure security, the organization of specially protected natural areas, etc.

A large number of subjects of social, economic, political and other activities in the region, as well as the complexity of bio-socio-economic systems makes the task of systematic representation of the composition and interaction of diverse subjects of conflicts relevant. This task is particularly relevant in assessing the impact of man-made activities in the Arctic zone, due to the high vulnerability of natural ecosystems in the conditions of the Far North.

In this paper, we use the generalized definition of conflict. Conflict is the interaction of two (or more) stakeholders who have different (incompatible) goals and (or) ways to achieve them. Such stakeholders can be called the subjects of the conflict or the players or parties to the conflict. And the conflict itself can also be called a conflict situation.

The Conceptual Conflict Model (CCM), which is a key element in identifying and solving environmental and technological safety problems within regional management and describing conflicts arising between stakeholders in the course of various types of economic activity, is presented in terms of set-theoretic relations as follows: CCM = <SC, OC, GSO, R>, where:

CCM is a conceptual model of a conflict situation, describing the entire set of conflict situations, defined by a tuple of sets <SC, OC, GSO, R>:

SC - set of subjects of a conflict. This set includes stakeholders who realize activities on the territory of the regional management. In fact, elements of the set of SCs can be not only the direct actors operating in the region, but other subjects of the bio-socio-economic system who may have an interest in different outcomes of a conflict. Or the actors on which one or another outcome of the conflict can significantly affect. Such subjects (actors) are called indirect participants in the conflict (for example, municipal, regional and federal authorities, environmental organizations, the local population, etc.);

OC - set of objects of conflict. This set includes those entities that are directly the object of the conflict. To solve practical problems in the field of regional management support, it is necessary to specify the main characteristics of the object of conflict. Thus, the set of conflict objects can be represented as: OC = <S, KA, Rs, RI>, where:
S is the set of spatial areas (in a geographic sense) or territories associated with the object of the conflict;

KA - a set of activities carried out (or planned for implementation) by stakeholders from a set of SC, which are associated with the object of the conflict;

Rs - the set of resources of the bio-socio-economic system used or necessary for the implementation of some activities by stakeholders from the set of SC, which are associated with the object of the conflict;

RI is the set of relations on the sets <S, KA, Rs>.

GSO - set of the goals of the subjects of the conflict (stakeholders), which they are trying to implement in the framework of their activities.

R is the set of relations defined on the <SC, OC, GSO> sets.

4. Methods, composition and structure of information technology to identify potential environmental and technological conflicts based on cognitive interfaces

The conceptual conflict model is used to identify conflict situations by a decision maker within the framework of information support system for the detection of potential conflict situations, taking into account the interests and contradictions of various stakeholders. A brief description of the composition and structure of this system is presented in Figure 2.

Figure 2. Information support system for detecting environmental and technological conflicts at the regional level

A generalized methodology for identifying potential environmental and technological conflicts can be described as follows. At the first stage, a knowledge base is created. For this purpose, knowledge of experts is used, structured and formalized on the basis of the proposed conceptual model of the subject area of regional management. The result of this stage of work is a formed, correct knowledge base, the volume of which is sufficient for solving practical problems of supporting the management of spatially - distributed socio-economic systems at the current stage.

At the second stage, the domain ontology is developed on the basis of a conceptual model, available data on the subject area and knowledge obtained from experts. Also, on the basis of the knowledge base, a set of axioms is formed for implementing logical inference on ontologies. Creating
an ontology is an iterative process. This process involves a constant return to previous iterations of development, analysis and possible revision of the structure and composition of the ontology. Also, the ontological description of the subject area is updated as the volume of data and knowledge about the subject area grows.

When the ontological model is formed sufficiently, it can be used to solve practical problems of identifying conflict situations. For this, the decision maker must formulate his request in accordance with the structure defined by the conceptual model of the conflict situation. After setting the basic parameters, the formalized request is passed to the reasoner (solver). The reasoner, using data and knowledge presented in the ontology and a set of axioms, determines whether the described situation belongs to the class of potentially conflicting environmental or man-made (technogenic) situations. It is clear that the effectiveness of the reasoner is completely determined by the adequacy of the domain ontology built, and the knowledge about the domain that has been formalized in the form of inference rules (axioms) in the system for supporting the detection of conflict situations, taking into account the interests and contradictions of various stakeholders.

At the fourth stage of work, the system issues a DM response to his request. In the main part of the answer, the system uniquely relates the situation described in the request to either a set of potentially conflict situations or a set of non-conflict situations. If the situation described by the decision maker has fallen into set of conflict situations, the additional part of the answer is also issued. This part contains an ontology fragment describing the situation (visual image and formal description), as well as the set of axioms that was activated in the process of logical inference, as a result of which the situation was attributed to a set of potentially conflict situations.

Thus, the decision maker has the opportunity to analyze in detail all the components of a potential conflict situation and decide on how to change the composition of subjects, objects and connections in the conflict situation in order to transfer it into a set of conflict-free situations.

5. Conclusion and discussion

All environmental and technological conflicts and related threats to the socio-economic development of the region have territorial and temporary connections. This suggests that within the framework of the decision support system for regional management a promising tool for identifying and analyzing potential conflicts will be methods and technologies for dynamic visualization of spatial data. The basis of such methods and technologies can be based on the formal model of conflict situations arising between the subjects of the socio-economic system of the region. Further development of work in this direction provides for the development of a methodological basis for constructing cognitive interfaces of multi-subject information systems based on cognitive visualization of spatial-temporal data.

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