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GEOINFORMATION METHODS AND TECHNOLOGIES IN THE STUDY OF NATURAL-SOCIAL-PRODUCTION SYSTEMS

S. A. Yamashkin

Ph.D. (Engineering), Associate Professor, Institute of Electronic and Lighting Engineering, National Research Mordovia State University - 430005, Saransk, Russia

A. A. Yamashkin

D.Sc. (Geography), Professor, Geography Faculty, National Research Mordovia State University - 430005, Saransk, Russia

O. A. Zarubin

Lecturer, Geography Faculty, National Research Mordovia State University - 430005, Saransk, Russia

O. V. Tsibakov

Postgraduate, Geography Faculty, National Research Mordovia State University - 430005, Saransk, Russia

V. A. Gurin

Postgraduate, Geography Faculty, National Research Mordovia State University - 430005, Saransk, Russia

A.E. Kodulev

Postgraduate, Geography Faculty, National Research Mordovia State University - 430005, Saransk, Russia

ABSTRACT

The article discusses aspects of the application of geographic information principles, methods and technologies in the construction of project-oriented spatial data infrastructures (SDI). It gives a detailed description of the key challenges in creating effective SDIs, issues of analyzing and forecasting the state of natural-social-production systems, identifies key problems and directions for the development of SDIs. It was emphasized that the problem-oriented SDI is a complex of specially organized spatial databases in computer systems equipped with a special control system and a set of application programs for solving target problems.

Key words: Spatial Data Infrastructure, Project-oriented System, Geoportals, Cloud Technologies, Spatial Data.

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1. INTRODUCTION

The need to analyze the functioning, dynamics and development of natural-social-production systems exists in various fields of science and practice. First of all, control structures, whose tasks include the development of pre-investment, urban planning, pre-project, design, organization and maintenance of environmental monitoring of the state of geotechnical systems, in order to predict emergency natural and man-made environmental situations. Modern practice shows that spatial data infrastructures (SPIs) are flexible and versatile tools for solving many environmental management problems, ensuring the collection, processing, storage and visualization of spatial information on the state of natural, social and production systems and their interaction [1].

Currently, problem-oriented SDIs are being created both within the administrative-territorial units and within the boundaries of natural regions. Their practical relevance lies primarily in the speed of information submission and in the exact spatial data binding. SDIs are a flexible tool for the continuous accumulation and operational presentation of extensive, multi-dimensional information about territories.

The key challenges in creating effective SDIs include:

- development of the theory and methods of organizing databases of spatially distributed data and their control systems [2];

- improvement of information technologies for receiving, processing and presenting spatial data; tools for analysis, modeling, synthesis and production of new cartographic models [3, 4];

- development of systems of rational organization and use of information resources of the territory to support management decision making [5].

Modern life and the development of society, the increasing activity of public opinion, especially in the field of ecology, put forward to science and practice new problems that must be solved quickly and fundamentally. It can be argued that in addition to the fundamental problems that have traditionally been resolved in the field of environmental management, new ones have emerged that require special attention. [6]. If the traditional tasks included the disclosure of the essence of the studied phenomena, then the new tasks are associated with the effective use of scientific and practical knowledge that has been accumulated throughout the previous stage of its development. This knowledge covers the origin, history of development and the current state of nature, the economy and the population that exist and interact with each other.

2. GEOPORTALS OF SPATIAL DATA INFRASTRUCTURES AS AN INSTRUMENT FOR MANAGING DECISIONS

Changes in the natural environment in conditions of spontaneous development or as a result of human production can turn into local, regional or global environmental problems. In this regard, it is obvious that for studying, reliable assessment and getting an answer to these or similar questions, geoportals are necessary - information systems that reflect the properties and state of natural, social and industrial systems [5]. Geoportals can be built on a regional basis and include a complex of information, a rational volume of which should provide a timely and scientifically based assessment of environmental, social and economic processes. Ideally, a decision taken at any level should be based on the necessary and sufficient amount of information. These decisions can be operational or strategic - to represent a specific link or a system of targeted long-term changes. Naturally, the volume of information, the principles of its processing and evaluation in each case should be rationally selected and scientifically sound.

The work on the creation of regional portals will be effective if we are accurately aware of the priority geo-ecological problems and how the information should be prepared so that it becomes the basis for making certain management decisions. The ecological approach to the analysis of the decisions taken inevitably leads to the fact that each natural-social-production system enters the field of vision of a certain subject of management. And, probably, for each object there is a finite number of possible, alternative made decisions. It is obvious that the types of economic activity, one way or another, are connected with the territory and territorial objects. Consequently, the decisions made in their course, one way or another, are connected with the natural-geographical territorial objects. Any decision is made on the basis of processing and analyzing information that may have a different kind of map, table, observation results, remote sensing data. The experience and knowledge of specialists can also be considered as information in one form or another, accumulated and verified by practice. Therefore, one of the tasks of geography, when analyzing the problems of managing the national economy, is the processing of geographic information as a basis for decision-making support.

3. SDI AS A MODEL OF NATURAL, SOCIAL AND PRODUCTION SYSTEMS

Natural, social and production systems, differ in a certain regional coverage, with the growth of the size of the territory and the structure of decisions [7]. Already at the oblast level, territorial coverage is significant, since the number of land users reaches several hundred thousand. Because of this, there is a clear need for systematization, typing and optimization of geo-information materials as a basis for supporting decisions made. To solve these problems, obviously, a special geographical analysis of these problems is needed based on modern computer and geo-information technologies. In connection with the ever-increasing influence of man on the natural environment, the need for a comprehensive study of the territory and the specifics of the established territorial environmental management has sharply increased in recent times. The deterioration of the human environment, the development of natural processes, the reduction of natural resources and the deterioration of their quality dictate the need for farming on a resource-conservation basis [8, 9]. For its successful implementation, it is necessary to know the specifics of regional environmental management, the compliance of the territorial organization of the economy with the resource and environmental capabilities of the region, which opens ways to improve and optimize the territorial structure of environmental management and the functioning of economic systems [10]. The creation of special problem-oriented geo-information systems based on spatially specific information, cartographic methods for its processing and evaluation, as well as probabilistic-statistical methods for analyzing this information in order to manage the national economy can contribute to solving these problems.

Spatial heterogeneity of natural conditions and resources, different history and nature of the development of the territory led to regional differences in environmental management and predetermined differences in the organization and functioning of regional SDIs. In addition to the development of technical means for obtaining and processing spatial information, a special geographic basis is needed, including a wide range of issues - from identifying objects of study, a range of information users at various territorial levels to determining the types and content of output, creating a geographic information database, applied GIS analysis methods for thematic processing of spatial information. In the system of various types of information used in management, a special place is occupied by geography, which covers the territorial spheres of resources, natural conditions, organization of functioning and production results. In the administrative management system, information on the long-term processes of the spatial and temporal dynamics of economic objects, resources and development conditions is used mainly for the purposes of forecasting, medium and long-term planning and relevant types of control, i.e. focuses on the needs of strategic management. On operational management, the use of geographic information is limited to certain types of spatial information averaged over the territory.

In the emerging economic management system, the role of geographic information increases dramatically. Solving strategic tasks imposes more stringent requirements on the focus, consistency and objectification in the spatial-temporal context of traditional forecasts, recommendations, reference data, assessments [11]. Simultaneously with the increase in the economic independence of primary production units, the need for geographic information for operational management purposes increases, i.e. information must respond to changes in resources in a timely manner, covering all aspects of management in specific territories. Operational information services should be carried out within the strict framework of the production regime, and the information received by consumers should have a form allowing it to be used for decision-making (quantitative characteristics of resources and conditions in economically significant ranges, variant recommendations, etc.).

New directions and models of research and practical activities in the field of analysis and assessment of the state of natural-social-production systems are born as part of the development and operation of various information and geo-information systems and technologies. They involve the development of cartography of ideas and methods of computer science, as well as the convergence of the actual cartographic research methods with new forms and means of accumulating, organizing, storing, processing, interpreting and distributing various spatial and other information, including in the electronic environment. Prospects of integrating all spatially-defined and temporal data into complete information systems, integrating the processes of creating and using maps are associated with geo-information methods and technologies. In connection with the above, it should be noted the selection of the phenomenon of the so-called "geographic information mapping". Its essence lies in the information-cartographic modeling and research of natural and socio-economic systems based on digital databases, GIS technologies, geographical and specialized knowledge. In the framework of this direction, active searches for effective computer methods of analysis and modeling are underway, operational and multi-variant mapping is being developed, new types of cartographic works and products are being created.

The large amount of data with which environmental decision makers have to deal has a spatial aspect, i.e. they characterize objects or phenomena in terms of their geographical location [12]. The presence of huge amounts of data implies the need to use modern means of processing and analysis. First and foremost, geographic information systems should be referred to such means.

4. MAIN DIRECTIONS AND PROBLEMS OF SDI DEVELOPMENT

At the present level of social development, the role of geographic information systems in earth sciences is not exhausted by the collection, processing, and storage of information. SDI becomes the main tool for modeling natural, economic, social processes and situations, tracing their connections, interaction in space and time, and most importantly a means of providing (supporting) decision-making of a managerial nature. It is possible to formulate the basic requirements currently imposed by cartographers and geographers on SDI.

First, the geographic information system involves a whole range of machinery and programs needed to fully provide scientific research. It should carry out technical, programmatic, informational support for conducting surveys on the study and management of the development of territories.

The second requirement is the "modularity" and "openness" of the system; The SDI should be represented by a set of modules responsible for performing specific operations, which can be easily transformed or modernized at the request of the user.

Geographers, cartographers or other specialists can formulate the requirement for support in SDI of conducting complex queries for processing, analyzing or receiving new information. In addition, a geographic information system must have a complex of mathematical, mathematical-cartographic or other models to ensure the construction and interpretation of a picture of geographic reality. A prerequisite for completeness of the SDI is to support work with spatially coordinated databases. It is advisable that modern SDI supports work in local and global networks. Thus, access to information of various users can be regulated and rational organization of their work is ensured.

The above requirements are classified as general. At the same time, each user, as research is conducted, presents its own conditions for the correct operation of the SDI, depending on the particular task, required level of automation, qualification of the contractor, etc.

As prescribed, SDI can be classified into:

- multipurpose (for example, designed for system monitoring);
- problem-oriented (aimed at solving one type or set of tasks);
- highly specialized.

Nowadays, when solving practical problems, the issue of the need for specialized means for analyzing and transforming data to develop solutions is becoming increasingly common. The list of such tasks is extensive: planning the construction of structures, problems of hydrological orientation (area and volume of flooding), predicting the risk of some types of emergency situations (landslides, landslides, avalanches, mudflows); assessment of human impact on the environment and the dangers of pollutants accumulated in various natural environments; problems of geological and hydrogeological nature (fields of depth, filtration rate, porosity of rocks). The experience of using SDI over the past decades has shown that the most frequently resolved issues are:

- planning (for example, survey work, designing the optimal development of the city, designing military and civilian facilities);
- maintenance of cadastre (conducting and improving the accounting and rational use of the land fund);
- monitoring of various types;
- complex and highly specialized studies of the state of various components of the natural environment and the national economy (environmental, physical-geographical, economic-geographical research);
- management of territories (environmental protection, maintenance of buildings and structures, taxation, etc.).

Problem-oriented SDIs intended for the study and evaluation of environmental facilities include a multidimensional spatially-distributed database. Their peculiarity is that the analysis and synthesis of information is carried out in space. A large number of maps and photographic images with various metrics are used as initial information for the database. This greatly complicates the structuring of information arrays and methods for their processing.

As a result of the research, the following architecture of a problem-oriented SDI was proposed for assessing natural and man-made factors.

Automation in the study of geosystems requires the integration of many branches of knowledge directly related to scientific and technical progress and based on a systems approach. A systematic approach to the study of geosystems is, first of all, an in-depth understanding of environmental facilities. The functionality of the problem-oriented SDI often refers to the modern methods of other sciences, such as mathematics, cybernetics, information theory, etc. This contributes to a comprehensive, integrated approach to the study of the real world picture. The cybernetic approach to SDI consists in modeling with the help of program complexes of separate geographic phenomena and natural processes.

The object of system spatial analysis in SDI are geosystems with a complex structure and a large variety of connections. The geosystem model is the main tool for spatial analysis. The properties of the components of geosystems are most rationally described by cartographic models, and the relationships and relations between them are described by numerical methods of analysis. The latter require a digital representation of information about the geographic environment, which inevitably leads to the creation of digital geo-information models, which can actually be implemented as databases of geographic and cartographic data in automated systems for their processing.

At present, the issue of creating sectoral and territorial SDIs that are capable of providing economic and scientific organizations with information on the state and dynamics of environmental components is particularly acute. The quality of management of sectors of the national economy related to environmental management depends largely on the timeliness and accuracy of obtaining information, on the basis of which they make the best administrative and economic decisions. Problem-oriented GIS should be an effective means of accumulating information (taking into account its updating and replenishment), prompt processing and analysis of multidimensional spatially distributed information and issuing documents to the consumer in the prescribed form or optimized management decisions.

Automation of research in the field of environmental management is divided into 4 main problems:

- automated information support, in which spatial databases occupy a central place;
- logical-mathematical processing of spatially distributed information, in which a special place is given to mathematical-cartographic modeling;
- automated creation of mathematics and cartographic models of environmental facilities, natural processes and phenomena;
- automated use and analysis of mathematics and cartographic models to support decision-making in territorial environmental management.

If the first problem is aimed at creating a spatial database, then the subsequent ones depend on it functionally. The organization of a spatial database as a prerequisite for the automation of research work is naturally considered as one of the stages of decision support, consisting of collecting, systematizing and preprocessing spatial information to bring it into a single system. But the spatial database not only provides automated creation of cartographic models, it is used at all stages of spatial analysis. For example, mathematical cartographic modeling can be conducted both at the stage of creation and at the stage of using cartographic models. Many cartometric characteristics, which are usually obtained as a result of map processing, can be directly calculated from digital data using a spatial database.

Spatial database is a relatively new concept in the field of storing and processing geographic information, which is becoming more and more widespread. A spatial database is an unambiguous structured set of data that most closely reflects the state of geographic objects, their properties, relationships, and relationships. A spatial database is essentially a digital information model of an object stored in the memory of a computer system. There are logical and physical data structure. The logical structure is formed by the relationships that exist in the totality of data and between them. The physical structure corresponds to the relations existing in the organization of data recording on the storage devices of computer systems. A physical description of the data is created and used for a problem-oriented SDI database management system. Researchers are mainly interested in information about nature management objects, in which ways this information is formally described, and which spatial and temporal connections between geographical phenomena are taken into account.

The core of any database is its model. It plays a crucial role in the development of specific problem-oriented SDIs. There are three main approaches to the choice of data model: hierarchical, network and relational. Any data representation can be reduced to two-dimensional tables of properties and relations (relational model). For the description of such tables there are exact mathematical notation. In addition, the relational approach does not contradict the other two and is suitable for describing any data structure. From a practical point of view, the preference of the relational model is as follows:

- it is easily implemented in software packages due to the fact that the data are presented in a matrix (tabular) form;
- the vast majority of data for thematic cartography is presented in the form of two-dimensional tables associated with a cartographic basis.

Thus, the central problem of creating problem-oriented SDIs is the organization of specific spatial databases. Problem-oriented SDI is a complex of specially organized spatial databases in computer systems equipped with a special control system (interface) and a set of application programs (functional modules) for solving target problems.

In [13] an architectural solution of project-oriented SDI has been proposed that can be decomposed and expanded for a specific problem area (Figure 1).

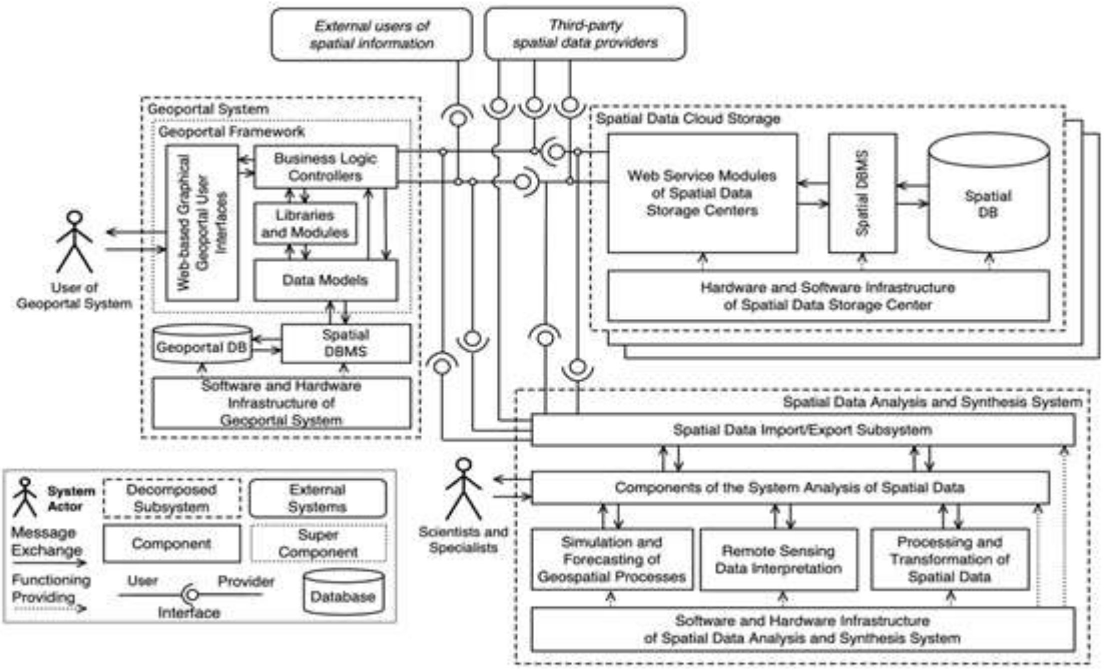

Figure 1 Structural component scheme of SDI

The structure of the platform solution is determined by the hypothesis that, in order to optimize the storage processes and the practical use of spatial data, project-oriented SDI should contain system components: spatial data storage, data analysis and synthesis subsystems, geoportal; external objects in relation to the SDI should be key actors (users of geoportal systems, scientists and specialists), as well as external consumers and third-party providers of spatial data and information.

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