

**THE DEVELOPMENT OF A CONCEPT AND METHODS  
FOR CREATING AN INTERNATIONAL SYSTEM OF GEOGRAPHIC MAPS  
AS A UNIVERSAL BASIS OF THE EARTH KNOWLEDGE**

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**Abstract**

The integration of European and other countries has set a purpose to develop the concept and methods of creating the International System of Geographical Maps (ISGM) unified in the mathematical basis, graphic means and, mainly, geographic basis of contents.

The concept includes the development of a system of requirements to the ISGM as an universal basis of the Earth knowledge, noted for its high accuracy and content complexity, the methods of agreement, unification and modification of maps, suggestions on standards, terms and definitions. In GIS it is realized through the system approach while developing computer methods of analysis and synthesis, of map information-quantity control, of models and algorithms of map creating, of aerospace imagery interpretation, and of researches into identification and generalization of images.

The ISGM is compiled of 1:10 000, 1:25 000, 1:50 000, 1:100 000, 1:200 000 (1:250 000), 1:500 000 and 1:1 000 000 topographic maps in the traditional form (on the paper) and in the form of electronic maps (on optical disks).

The creation of the ISGM will be a basis for promoting geographical investigations, the theory of cartography, geoinformation mapping as a new direction. It will contribute to the development of the Earth's knowledge basis, to the increase of GIS efficiency, to the extension of international cooperation.

**1 Introduction**

Modern world is now coming into a period of global informational development that is characterized with universal character of informatization processes, computerization of all kinds of human activities, creating integrated information networks and systems that are intended to provide users with access to all information resources of the society.

Today it becomes possible to create an informational space of humanity through the united base of knowledge about the Earth. Such base of knowledge integrates all kinds of human activities oriented to the acquisition of new information about surrounding world. It can be realized as a united network of centers distributed on regions and interconnected by whole info-computing network.

It is important to stress the priority of complex investigation of our planet. There is a need to collect "under the same roof" all the main knowledge about the Earth which have common roots. Methods, technologies and data that are obtained by various branches of human activities, must serve to the common affair of creating system of knowledge about the Earth. Base of cartographic knowledge provides a possibility to construct cartographic models adequately to real world with minimum of data excess.

The main task of the base of knowledge about the Earth is to accumulate not only cartographic sources, but also knowledge which exists in the world, for example, in Barcelona.

Barcelona with its more than 2000-years history is the important part of knowledge about the Earth. Most ideals of humanity, thirst to investigation of the world have found their highest reflection in this history.

The wonderful world of Picasso is close to Russian tradition of thought which always aims at the truth in its expression.

Global informatization of the human society provides an important role of a new direction in science, that is of creation and implementation of GIS and electronic maps systems.

As a beginning of this direction in Russia one may consider the development of an experimental digital terrain model (1961) and of experimental example of automated cartographic system that had some functions of GIS (1964). The analysis of works done in this area allows to detect the main stages and to show the increasing value of geographic and cartographic theory, mathematical modelling in cartography, system approach, generalization and image processing in cooperation with interactive methods and artificial intellect. Most attention was paid to the methodological and systemotechnical principles, notions, as a scientific background for creating and development of automated cartographic systems and databanks. The synthesis of these components allows to create GIS which tasks are not only spatial data acquisition, storing up and retrieving, but also its analysis and processing, as well as collecting knowledge about the Earth. The development of EMS concept and technologies of its creation had been completed in 1992.

The implementation of these works resulted in the Digital and Electronic Maps Transfer Standard (1994). This Standard contains specifications describing structures and organization of spatial data of digital and electronic topographic maps (scales: 1:25 000, 1:50 000, 1:100 000, 1:200 000, 1:500 000 and 1:1 000 000). It consists of: The Unified Classification and Coding System of the Cartographic Information; Conceptual and Logical Data Models; The Rules for the Digital Data Description (definition of features, structure and content of object-oriented and attribute data, spatial relationships, annotations); The Description and Content of Symbol Libraries. The Standard is intended to provide procedures of acquisition, storing up, processing and exchange of spatial data between GIS as well as separate users.

But one or some of these maps themselves cannot be the universal tool for those users who need to solve problems in industry, agriculture, transportation, communication, geology, meteorology, oceanology, tourism, defence etc. It is necessary to collect electronic maps of various scales, projections, coordinate systems, content, arrangement in the united system, to establish logical and mathematical dependencies between these maps, and to write them down to data media (optical discs). So it is equal to create an unified computer-aided model of the Earth, composed from thousands electronic maps of various intent, but under the unified system of map symbols, content and mathematical base.

The further development of electronic maps seems to be the way of creation of spatial (3-d) terrain models produced analytically or by means of TV-scanning of relief maps "from a bird-flight height". Using such models in a computer "movie" allows to see the terrain from various points of vision or to "fly" over it.

Today our aim is to develop methods for the automatization of the recognition of map symbols and for the cartographic generalization.

The level of research and development of the automation in cartographic generalization does not comply with modern and perspective requirements. The main obstacle arises while solving this problem is caused by creative nature of mapmakers' activities. The work of cartographer seems to be easy, but it is impossible to construct the complete mathematical description of all processes in order to make them clear to the computer. Existing

algorithms of generalization do not involve features of the terrain, spatial relations between objects, qualitative and quantitative attributes and other parameters which are used by cartographers in generalization. These algorithms do not provide unification of various elements of the cartographic image.

Modern systems also have no algorithms to produce complete series of map scales. Existing algorithms are too simplified and do not correspond to the intent and content of projected maps. The development of methods for the computer-aided recognition of objects and phenomena should be considered as an important theoretical basis for the creation of perspective map-scanning systems and cartographic bases of knowledge.

The solving of these problems seems to be found in a new look at the concept of cartographic generalization, more deep investigation of it as a creative process, mathematical modelling of all the amount of generalization processes, development of methods for the recognitions of map symbols, implementing elements of the artificial intellect (expert systems).

For mapping, where the bulk of intellectual creative activities of professionals is rather great, works on creating expert systems on the base of artificial intellect are the subject of high interest. Theoretical and practical results of the research in area of cybernetics, computing, mathematics and cartography can be the main ground for the development of such systems.

Today we do create the portrait of the Earth, its continents and oceans. This portrait will be clear not only to the specialists, but to any user at all. The concept of the Electronic Maps System and experience collected in the process of its creation is now put to the basis of the project called "Sum of Technologies" that is being developed nowadays by Russian cartographers. Possibly, phisicists and philosophers who investigate the real world, will consider not only mass and energy, but also the geographic and cartographic information, for it is impossible today to solve problems of the human society beyond such a kind of data.

## 2 Methodology for creating GIS

Every scientific theory has its own subject of investigation which attracts the research activities. So the necessary condition for formulating GIS theory is the precise definition of its subject, directions and methods of scientific research.

Nowadays GIS theory is a relatively independent area of knowledge with its own basis and principles. Its subject can be defined by means of deep investigation of entity and intent of GIS, sum of its tasks and conditions of their solving, including technical and technological ones.

The entity of GIS is the activities of groups of specialists (cartographers, mathematicians, programmers, system analysts etc.) in area of acquisition, systemized processing, modelling and analysis of spatial data and its implementation to solving tasks, prognosing and adopting decisions.

The main intent of GIS is the formulation of knowledge about Earth and certain territories as well as current retrieving necessary and sufficient spatial data by users' requests in order to reach maximal effectivity of their activities. This can be achieved by the following ways:

- analysis and generalization of experiance collected in area of supply users with spatial data;
- development of key notions and definitions, detection and research of objective laws of information supply, and formulation of basic principles of designing and exploiting GIS;

- investigation and development of general concept for creating the system of cartographic models, hard- and software, technology of automated production, storing up and retrieving electronic maps and problem-oriented terrain models;
- formulation of criteria and methods for evaluating GIS effectivity and practical recommendations for GIS implementation.

Successful solution of all these problems can be reached only under the condition of development of the methodological basis which is necessary for the effective research, understanding and rational using the laws of informatization, for the development and implementation of scientific principles of creating and using GIS.

Hence, the subject of GIS theory includes laws of informational supply; principles of creating systems for spatial data acquisition, storing up, processing, modelling and analysis; principles of data retrieving; hard- and software; development of necessary organizational structures.

The analysis of subject and tasks of GIS theory allows to detect the following parts of it:

- GIS (general statements);
- cartographic information for GIS (spatial data, digital and electronic maps, spatial terrain models);
- hardware and software, technologies of creating, storing and retrieving cartographic information;
- methods of spatial data processing, modelling, analysis and visualization;
- methodology of evaluating the effectivity of GIS;
- organization of GIS informational supply, recommendations for GIS creation and implementation.

According to these parts, it is useful to detect and systemize the main concepts that compose GIS theory as a new area of knowledge.

These concepts must reflect the entity of GIS and laws of its informational supply, investigate and show the mechanism of their action. These concepts allow to detect the most essential dependencies and relations between GIS and external environment (i.e. users), to investigate relations between subsystems inside GIS. Unexact explanations of notions, lacks in terminology make impossible to reach unification in explanation and implementation of GIS theory.

The principles of creating and implementing GIS are those links which connect GIS theory with practice. They seem to translate the objective laws of information supply into the language of practice. On the basis of these laws there can be formulated the general principles concerning GIS in whole, as well as principles concerning its subsystems.

In accordance to intent of GIS, it must have branched structure, complex parts, large bulks of transferred information. Such a system is characterized by continuous increasing of complexity, development of technological processes, growing quantity of sources of information.

At the first stage of creation of such a complex system, the main problem is to choose its most rational structure and principles of creation.

The most important of these principles is that of correlation between GIS structure and its technical parameters, and the requirements of users. According to this principle, GIS must satisfy the main requirements concerning not only to system's content and to its subsystem interrelation, but also to the cartographic models, and especially to electronic maps created for using in GIS. This principle can be realized as a result of development of several variants of GIS's structure and technical parameters, and choosing the most appropriate variant. The structure of GIS with given technical parameters is realizable, if its choice involved only those variants which was oriented to the existing hardware or to the perspective means of automatization industrial production of which can begin in nearest times.

Another basic principle of GIS creation and implementation is the system approach. It involves consideration of the subject of research as a whole complex system consisting of series of subsystems linked by mutual functional dependencies. System approach provides unification while creating of informational, mathematical, technical, linguistic supply, their compatibility, defines methods for GIS research and projecting its structure. System approach is the generalized methodology of solving problems based on the concept of such systems.

The increase of effectivity of users' work should be the final result of GIS implementation. It can be reached by current providing users with necessary and sufficient information about terrain by means of creating topographic, geographic and special-purpose maps (including digital and electronic maps). By the sense, it needs to solve the problem of creating (updating) the unified system of cartographic models, for instance, electronic maps system.

Usage of system approach helps to detect bottlenecks and "white spaces" in the GIS's informational supply being created and to save efforts, time and money while creating and implementing GIS.

Hence, it is useful to regard ways of using system approach to GIS creation as three interconnected aspects:

- system approach as a conceptual ground for creating and implementing unified system of cartographic models;
- system approach as a scientific method of developing computer-aided technologies and effective work of GIS;
- system approach as a methodology of research and projecting GIS, its structure.

Modelling is the main tool in system approach. By modelling we understand such a way of reflecting reality which involves usage of some specially constructed model reproducing essential properties and attributes of investigated real object (or group of objects) and phenomenon.

So, in the light of latest achievements in using modelling for management, projecting and system researches in geography and cartography, it seems to be useful to create and implement mathematical models for solving GIS's problems in the following ways:

- modelling as a way to create unified system of cartographic models and to define their parameters;
- modelling as a tool for choice and projecting automated technological processes, their parameters and establishing main dependencies between these parameters and parameters of cartographic products;
- modelling as a methodology for research and projecting GIS, interrelations between its subsystems and evaluation of GIS's effectivity.

Establishing the criteria for the evaluation of GIS's effectivity is one of the most important stages in the process of creating and implementing GIS.

The effectivity of GIS is inflied by its intent, results of work and expences made for GIS creation and exploitation. Evidently, the effectivity of GIS of the same intent will be the higher the greater is the result and the lower is the expences. While developing methods for the evaluation of GIS effectivity, one should use methodological principles that propose evaluation from the point of view of system approach, private evaluations, provide flexibility and sensibility of methods in relation to changing modes of GIS's work, correct establishing of the criteria for the evaluation of every subsystem's effectivity, and creating strict system of criteria on this basis.

### **3 Concept and methods of the cartographic data support of GIS**

GIS Is one of the main means of intensifying processes of society informatization, a main source of information for them is geographic maps. The general purpose is to develop the concept and methods of creating the International System of Geographic Maps (ISGM) unified in projections, scales, coordinate systems, intermap relationship division and signs and symbols, graphical means and, the last but not the least, geographic bases of contents. This approach is to be extended to topographic maps of the following scales: 1:10 000, 1:25 000, 1:50 000, 1:100 000, 1:200 000 (1:250 000), 1:500 000 and 1:1 000 000. The project envisages to design maps included into the ISGM both in the traditional form (on the paper) and in the form of the electronic maps (on optical disks).

At present topographic maps designed in the various countries cannot, unfortunately, serve as a necessary and sufficient information basis to make various GIS compatible, as they are not in agreement in the mathematical bases, elements of their contents, the signs and symbols, they do not correspond exactly to the scientific principals of designing cartographic products. All these are obstacles in the way of integrating and creating international networks of GIS and, consequently, international cooperation in information exchange. An attempt to unify maps was undertaken in the relation to 1:1 000 000 map under the decision of the V International Geographic Congress (Bern, 1891). But specifications of this map adopted at the UN Technical Conference (Bonn, 1962) were not tight to the map-sheet unification.

There are some prerequisites of realizing the project suggested on the basis of theoretical developments in the fields of map designing and computer technologies. The ISGM may be come an important part of national mapping programs of Russia, as well as of the USA, Canada, Great Britain, Germany, France, Spain, Japan, Australia and other countries, and it may need to widen researches inside the countries and cooperation among them. It will also need the support of the UN and the International Cartographic Association.

The ISGM will contribute to the promotion of geographic researches, land-, sea-, air- and space-navigation, the theory of cartography, and in particular, its new development - geoinformational mapping, of increasing GIS efficiency. It will be a basis for creating international thematic maps, including ecology ones, and, mainly, for deepening international cooperation in numerous fields of map applications.

As a result of previous investigations there were developed scientific bases for topographic land-and-coastal map contents for classifying maps and objects represented on them and for methods of their designing. There were carried out researches into interpreting aerospace imagery, identifying and generalizing objects of mapping, into map updating, automated designing of cartographic models (both basic and derivative ones). There were investigated prerequisites of and developed the new types of cartographic products, formats of digital and electronic maps, technical means of automating map-design process (scanners, interactive working stations, plotters), its software, cartographic expert systems.

The development of requirements to the ISGM with their further coordination with organizations concerned all over the world will be the starting point of the project. The concept of the ISGM envisages the creation of wholly unified products characterized by intrinsic unity, which is provided with the following:

- agreement and unification of mathematical map basis;
- agreement of contents and the system of map symbols;
- methods promoting both topography depiction of territories by necessary topographic maps and their actual state, as well as updating of these maps.

Maps designed by various countries, latest aerospace imagery with a great resolution and other sources of information on territories are considered to be used as source materials. The agreement and unification of the mathematical basis is supposed to be carried out through using a single scale series which will make it possible to represent territories with necessary detalization and accuracy and through projections providing complete mapping, without gaps, of any territory of the Earth with minimal distortions in a proper coordinate system. Projection equations are to provide simplicity and reliability of information control with accuracy required. It is needed to develop transformation algorithms in order to connect maps with different projections and coordinate systems. It is also possible to use equations of universal conformal projection.

For agreement and unification of map contents it is supposed to develop a Project of General System and Structure of Contents of Topographic Maps of one and the same scale series, it is being based on modern classifications adopted in the sciences on Earth, including nature, its protection and economic development of the territory.

Under this Project it is supposed to create a whole hierarchy organized dynamic system of great importance both for developing and unifying map language and solving the problem of automatizing the process of creating GIS.

The ever widening range of application of maps demands the increase of their informational quantity and contents. It leads to the fact that the Project pays great attention to the directions of improving maps, to the increase of their contents by new objects and characteristics and to the reflection various phenomena dynamics, which is important in applying maps to the cause of nature-protection investigations.

There will be considered problems of designing topographic coastal- and hydrographic-maps on a unified mathematical basis with land-maps and in genetic interrelations with them. It is supposed to develop principles of mapping of main contents components of topographic maps of sea bottom and shelf, bottom sedimentations, water properties, plant and animals.

One of the purposes of the Project, according to the authors, is to make a theoretical basis for a new type of topographic maps and their particularization for various branches of practice.

Theoretical basis of mapping is closely connected with the methods of learning geographical environment. That is why the development of the Project will be conducted with account of the system approach, i.e. a general scientific method considering phenomena in their unity, versatility, interrelationship and dynamics.

Interpretation of aerospace imagery, its geographical basis and general methods of landscape interpretation while designing and updating maps is considered to be taken as the main method to increase information load of maps.

For agreement and unification of contents and map symbols it is supposed to develop computer methods for their analysis and synthesis, for controlling map information quantity, for processing (identification and generalization) spatial data, for estimating map perception from engineering and psychological point of view.

The investigation program of generalization is to create a theoretical basis for mathematically defined rules of selection and generalization taking account of the value (weight) and dimensions of objects and their details, comparison of the obtained results with the stated qualification and taking the decisions on delusion and simplification of outlines, increase, integration, smoothing or constant preservation of symbols.

The Project includes the development of methods, models and algorithms for creating electronic maps in linear, vector, matrix and raster formats.

For logic and compact representation of spatial data the principals for arrangement of a classification system and cartographic information coding will be suggested. Semantic aspect of objects will find its reflection in them. Each object is the basis for information-logic unit, corresponding to terrain objects and preserving constant values of qualitative and quantitative characteristics.

Realization of the methods being developed is provided on the basis of the multimedia program means, providing effective use of video-, audio- and other means of operative access to spatial data (first of all space ones) to increase of communicative possibilities of the system.