THEORETICAL ASPECTS OF GEOINFORMATION MODELING

Tamara Kozachenko
Institute of Geography of National Academy of Sciences of Ukraine
44, Volodimirs'ka St., Kyiv-034, 01034, Ukraine
ba@geogr.freenet.kyiv.ua

Theoretical aspects of geoinformation modeling

The essence of geoinformation modeling. Geoinformation modeling is a way for intelligent processing and representation of spatial information for the purpose of gaining new knowledge. Computer-assisted electronic-graphic modeling, application of graphic, graph-mathematical and electronic-graphic models as well as GIS-technologies is the basis of geoinfomation modeling.

The theoretical foundation of geoinfomation modeling (particularly its computer-assisted electronic-graphic kind) is the conception of cartographic-cybernetic system functioning with use of cartographic data and modeling algorithms. They describe all processes of maps creation and use with involving digital and graphical information.

Cartographic-cybernetic system is considered as a specifically organized set of interconnected and interacted subsystems and their elements, which are being united during the process of dialogue between a cartographer and a computer into a single logical-mathematical system (special software). It functions as a comprehensive whole and is destined for projecting, creation and using maps and other geoimages. Such using is based on mathematical methods of geoimages research and on their purposeful and substantial transformations.

Geoinformation modeling is an integrative theory, which unites on the new methodological basis already known methods of projecting, creation, using and analysis of geoinformation models to research objects of the real world with the system of ordering and transformation of information about these objects. Geoinformation modeling is the ability of designing geoinformation models and their analyzing for the purpose of real world's objects research. In this sense it can be considered as a modern geoinformation technology, which in contrast to theoretical methods of modeling is a technological process, since it interacts with objects of GIS databases.

Therefore, geoinformation modeling is the spatial objects transformation, that use these object's organization, according to which each graphic object is linked with one or several database tables and transformation of graphic objects causes transformation of table data. This kind of modeling is a class of modeling of graphic objects, which are linked with databases.

The structural definiteness of geoinformation modeling object. The fundamental conceptions and basic categories of geoinformation modeling are its object and method. The object of geoinformation modeling can be defined by its three main characteristics. The structural definiteness of geoinformation modeling consists of its essential, spatial and temporal definiteness. The essential definiteness includes characteristics of different formations (objects, groups of objects, combinations, taxons), processes, their substantial properties and relations. Spatial definiteness consists in transformation of spatially coordinated discrete and continuous information, spatial characteristics of objects (their spatial position and relations), topologic-geometric forms of spatial structures. Temporal definiteness includes representation of objects in statics, dynamics, retrospection, in their current state and in forecast. Natural and socio-economic geosystems, their components and elements are the objects of geoinformation modeling.

The system of methods of geoinformation modeling. The methods of modeling are characterized by the scope of conditions and rules for transformation of geoinformation modeling objects. The methods of geoinformation modeling of geosystems and their components include spatial-temporal modeling of their structure, dynamics, interrelations and functioning. The properties of geosystem components are better described with cartographic models, and their relations – with methods of GIS analysis.

The system of methods of geoinformation modeling includes use of different kinds of methods: *geographic modeling* (classification, modeling of geosystems, structural-typological analysis), *cartographic modeling*, *mathematic-cartographic modeling*, *modeling on basis of remote sensing data*, *computer-assisted electronic-graphic modeling* (information-digital, GIS-technologies of geoinformation modeling, GIS analysis and modeling, graphical visualization).

Computer-assisted electronic-graphic modeling includes use of different kinds of methods: *information-digital modeling* (properties description, description of relations between properties, functional description of properties and relations), *GIS technologies of geoinformation modeling* (geogrouping, buffering, generalization, combining, geocoding, data generalization, creation of thematic maps and computer animations, creation of virtual geoimages, creation of diagrams and graphs), *GIS analysis and modeling* (overlay, simulation, mathematic-statistical analysis, trend-analysis, spatial correlation, clasterization), *graphical visualization* (electronic maps and atlases, transformed aerophotos and satellite images, 3D models, animation models, diagrams and graphs, tables), *application of expert systems and knowledge bases*.

The system of geoinformation models. The *"geoinformation model"* notion as a certain purposeful formalized representation of real objects has put into basis of most methods of information processing in geoinformation systems. Geoinformation model is an image and can be created for a separate object, a group of objects, and an information system. The system of geoinformation models must correspond to the current

knowledge about geosystems, understanding their essence, genesis, dynamics, integrity, functioning of geosystems in whole and their elements.

The research process consists in using different types of geoinformation models: *digital models of geospatial data organization* (conceptual models, models of data about geospatial objects, models of database objects, models of database management system), *information models* (information-descriptive, information-resource, intelligent), *verbal, mathematical, graphic images* (symbol-graphic, electronic-graphic, remote sensing ones). Spatial models (maps, electronic maps and remote sensing images) take a special place among them.

The essence of geoinformation modeling. Geoinformation modeling is a way for intelligent processing and representation of spatial information for the purpose of gaining new knowledge. Computer-assisted electronic-graphic modeling, application of graphic, graph-mathematical and electronic-graphic models as well as GIS-technologies are the basis of geoinfomation modeling.

The theoretical foundation of geoinfomation modeling (particularly its computer-assisted electronic-graphic kind) is the conception of cartographic-cybernetic system functioning with use of cartographic data and modeling algorithms. They describe all processes of maps creation and use with involving digital and graphical information.

Cartographic-cybernetic system is considered as a specifically organized set of interconnected and interacted subsystems and their elements, which are being united during the process of dialogue between a cartographer and a computer into a single logical-mathematical system (special software). It functions as a comprehensive whole and is destined for projecting, creation and using maps and other geoimages. Such using is based on mathematical methods of geoimages research and on their purposeful and substantial transformations.

Geoinformation modeling is an integrative theory, which unites on the new methodological basis already known methods of projecting, creation, using and analysis of geoinformation models to research objects of the real world with the system of ordering and transformation of information about these objects. Geoinformation modeling is the ability of designing geoinformation models and their analyzing for the purpose of real world's objects research. In this sense it can be considered as a modern geoinformation technology, which in contrast to theoretical methods of modeling is a technological process, since it interacts with objects of GIS databases.

Therefore, geoinformation modeling is the transformation of spatial features models that use these features' organization, according to which each graphic object is linked with one or several database tables and transformation of graphic objects causes transformation of table data. This kind of modeling is the class of modeling of graphic objects, which are linked with databases.

The basis of geoinformation modeling as a special technology is various transformations based on set-theoretic relations, laws of formal logic, image processing algorithms, technologies of computer graphics operation, DBMS technologies and many others.

The structural definiteness of the geoinformation modeling object. The fundamental conceptions and basic categories of geoinformation modeling are its object and method. The object of geoinformation modeling can be defined by its three main characteristics. The structural definiteness of geoinformation modeling consists of its essential, spatial and temporal definiteness. The essential definiteness includes characteristics of different formations (objects, groups of objects, combinations, taxons), processes, their substantial properties and relations. Spatial definiteness consists in transformation of spatially coordinated discrete and continuous information, spatial characteristics of objects (their spatial position and relations), topologic-geometric forms of spatial structures. Temporal definiteness includes representation of objects in statics, dynamics, retrospection, in their current state and in forecast. Natural and socio-economic geosystems, their components and elements are the objects of geoinformation modeling. The qualitative definiteness can be represented by absolute and relative indices, both statically and dynamically, in the wide range of spatial and time scales.

The system of methods of geoinformation modeling. The methods of modeling are characterized by the scope of conditions and rules for transformation of geoinformation modeling objects. The methods of geoinformation modeling of geosystems and their components include spatial-temporal modeling of their structure, dynamics, interrelations and functioning. The properties of geosystem components are better described with cartographic models, and their relations – with methods of GIS analysis.

The system of methods of geoinformation modeling includes use of different kinds of methods: *geographic modeling* (classification, modeling of geosystems, structural-typological analysis), *cartographic modeling*, *mathematic-cartographic modeling*, *modeling on basis of remote sensing data*, *computer-assisted electronic-graphic modeling* (information-digital, GIS-technologies of geoinformation modeling, GIS analysis and modeling, graphical visualization) (Fig. 1).

Geographic modeling consists in formation of the conceptual framework that can be used for description and explanation of the essence of objects, phenomena and processes. These concepts determine the possible scope of geographic information representation in computer environment. Its essence consists in classification, modeling, structure-typological analysis of geosystems. Classification and structuring of geographical information are the most important procedures of objects, phenomena and processes modeling.

Geoinformation modeling is based on geographical models, which characterize spatial distribution of objects, phenomena and processes. Geographical data models are the

foundation on which all GIS are created. A geographical data model works like a prism through which we perceive and interpret the infinite variety of the real world.

Cartographic modeling. The characteristic feature of cartographic modeling is the possibility of data analysis in addition to their spatial distribution. The potential of cartographic modeling is well corresponded with analytical tools of geoinformatics.

The maps, created on basis of GIS technologies, are more various and more informative, screen representation makes them more dynamic. Such maps can have both traditional forms (cartograms, maps of point density) and untraditional ones, e.g. three-dimensional computerized block diagrams; photoblock diagrams, where three-dimensional model of earth surface is overplayed with space image; three-dimensional maps (perspective computer models) created on basis of different methods of geographic space transformation and its mathematical formulation.

Mathematic-cartographic modeling is an integral part of GIS for a long time. Integration of mathematical and cartographical models allows using their strong points. Many such models have been created, including ones simulating various natural and social phenomena. This kind of modeling has been formed in consequence of mathematical methods use in thematic cartography in the early 1970s.

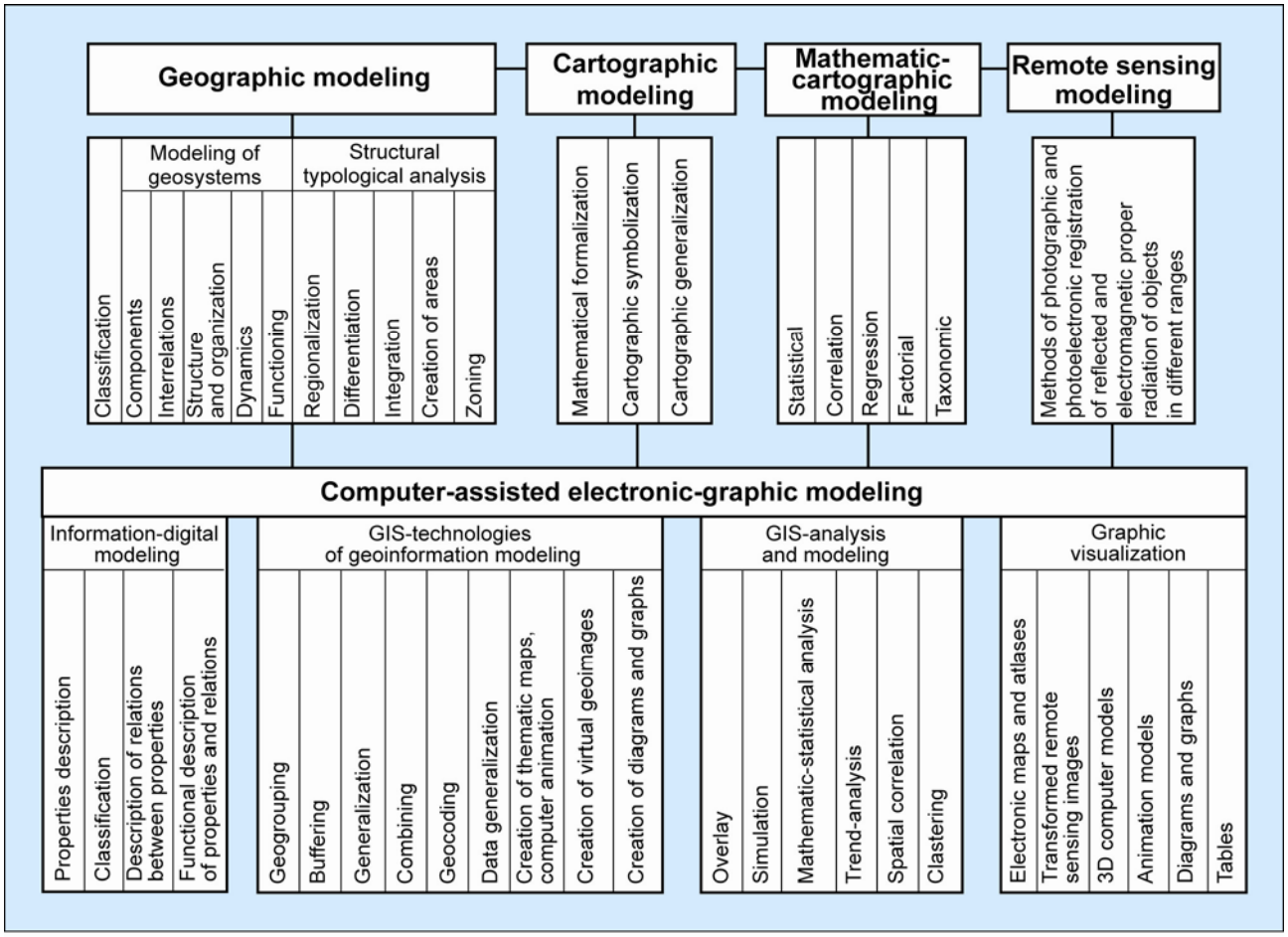

Fig. 1. The system of methods of geoinformation modeling

The crucial question in this process is the evaluation of mathematical algorithms reliability. One of the positive features of mathematic-cartographic modeling is its multivariance (the possibility of processing the same information array with different algorithms). Besides, the use of different arrays is possible at the stage of information support.

The development of computer technologies has led to including into geoinformation modeling the methods of computer graphics. The use of these methods along with methodology of mathematic-cartographic modeling has formed the basis for a new modern kind of computer (electronic-graphic) modeling.

The software and hardware improvement of GIS-technologies has caused further development of using ***remote sensing*** data as one of the main sources of information for GIS and geoinformation modeling, especially for efficient and dynamic mapping. Almost all modern GIS software packages have facilities for image processing – from

use of images as backing for interactive creation of vector maps to computer image interpretation for creation of thematic maps.

Computer-assisted electronic-graphic modeling includes use of different kinds of methods: *information-digital modeling* (properties description, description of relations between properties, functional description of properties and relations), *GIS technologies of geoinformation modeling* (geogrouping, buffering, generalization, combining, geocoding, data generalization, creation of thematic maps and computer animations, creation of virtual geoimages, creation of diagrams and graphs), *GIS analysis and modeling* (overlay, simulation, mathematic-statistical analysis, trend-analysis, spatial correlation, clasterization), *graphical visualization* (electronic maps and atlases, transformed aerophotos and satellite images, 3D models, animation models, diagrams and graphs, tables), *application of expert systems and knowledge bases*.

The system of geoinformation models. The *"geoinformation model"* concept as a certain purposeful formalized representation of real objects has been put into basis of most methods of information processing in geoinformation systems. Geoinformation model is an image and can be created for a separate object, a group of objects, and an information system. The system of geoinformation models must correspond to the current knowledge about geosystems, understanding their essence, genesis, dynamics, integrity, functioning of geosystems in whole and their elements.

The research process consists in using different types of geoinformation models: *digital models of geospatial data organization* (conceptual models, models of data about geospatial features, models of database objects, models of database management system), *information models* (information-descriptive, information-resource, intelligent), *verbal, mathematical, graphic images* (symbol-graphic, electronic-graphic, remote sensing ones) (Fig. 2). Spatial models (maps, electronic maps and remote sensing images) take a special place among them.

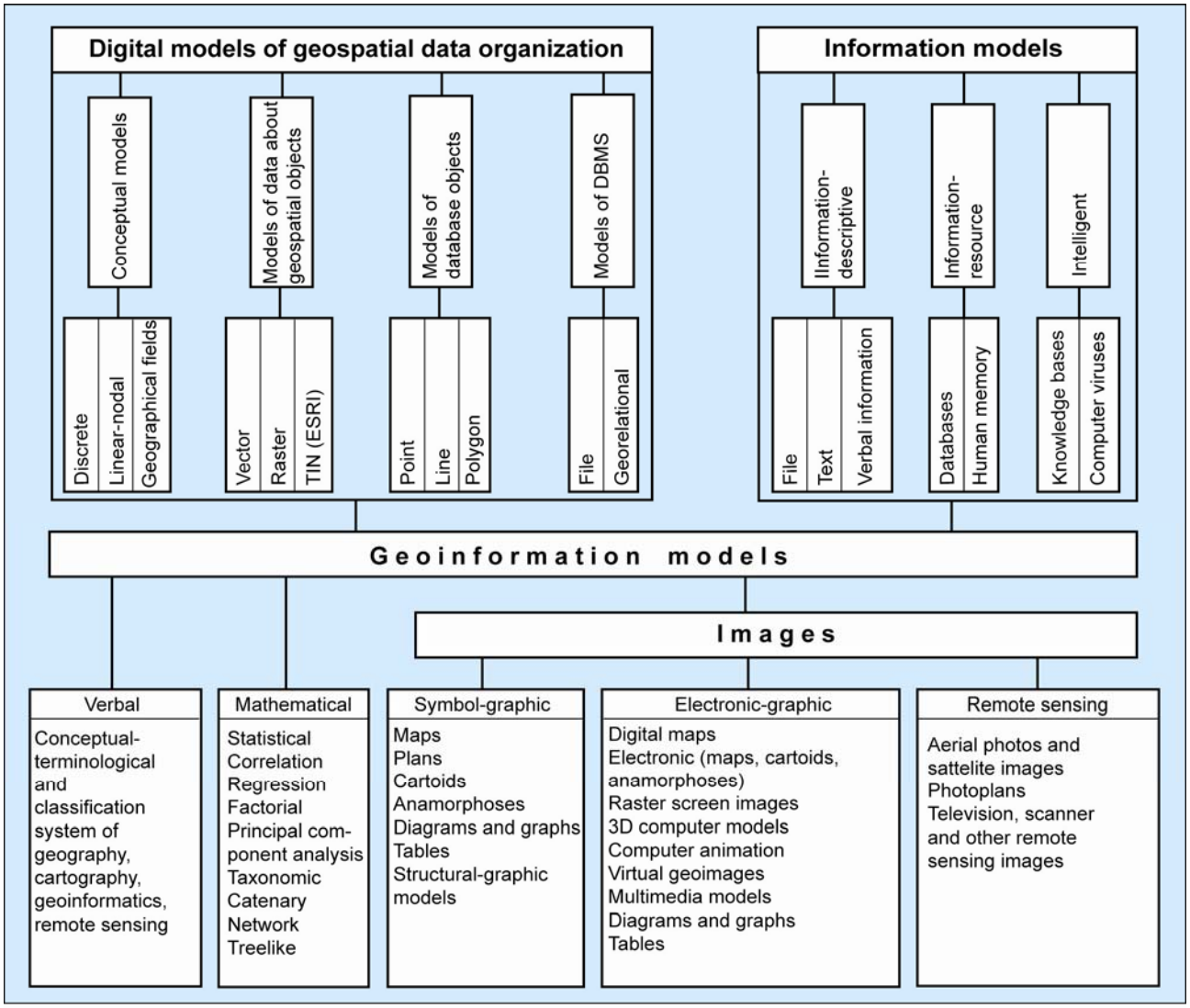

Fig. 2. The system of models of geoinformation modeling

Digital models. The development of automated methods of spatial information processing has determined emerging a new direction in modeling – digital modeling. In geoinformatics it consists in using mathematical methods and software tools for modeling of earth surface objects.

The main element of this kind of modeling is digital terrain model, which can be created by means of different technologies. Digital models can be kept in two ways: within a database and independently – in the form of file structures.

In computer cartography there are two kinds of models. The first kind is *digital model of cartographic representation*. This is the model represented in digital form, according to certain structure of digital description and coding in computer memory. The

necessary condition for digital map perception is visualization of coded cartographic representation by means of its displaying in monitor. The second kind –*analog model of cartographic representation* – is presented in graphic view. The information base of geoinformation modeling is formed by digital models of reality.

Information models. The last information revolution is characterized by qualitative changes of information. Information is turned from a means of knowledge transfer into resource of production, means of its changes, commodity. That means the transition from the set of disembodied data to the set of interconnected models, for which the property of resourceness is inherent.

Development of computer technologies has caused the broadening of "information model" concept. Three classes of information models have been defined – information-descriptive, information-resource and intelligent ones.

A certain set of digital data about spatial features forms *geospatial data*. They consist of two interconnected parts: coordinate positional (topologic-geometric) part and nonpositional (attributive) one. These two parts form the description of spatial location and thematic content of the data, respectively.

One of the main purposes of *coordinate models* is accurate mapping of objects' spatial properties. Spatial features are represented in graphic form that helps to solve two tasks:

– representation of objects positional relationship (topology);
– quantitative description of geometric characteristics of objects and their location in certain coordinate system (metrics).

The nonpositional part includes qualitative characteristics of spatial features (semantics) and statistics. This information is presented in the form of text or numerical parameters. The quantitative attributes are created according to nominal, ordinal, interval and proportional scales. It is important to know what scales are used for data, since it determines the possible ways of the data processing.

To create *attributive models* the data must be typified, divided into groups and associated (linked) with spatial features.

The object of information modeling in GIS is a spatial feature that can be represented in the form of digital reflection (model) of the real object with description of its location and properties (characteristics, attributes). The basic (elementary) types of spatial features operated by modern GIS are point, line, polygon.

Three groups of information models are distinguished in cartographic modeling. The content of the first group is determined by the essence of object, its properties and features; the second group – the systemic processing of information about the object;

the third group – properly cartographic form of representation and transformation of information.

Information model of geoinformation modeling object is the aggregate of logical and mathematical relations that represents in generalized cartographic form essential quantitative and qualitative features of the object and its internal structure.

Graphical displays, visual graphic images remain for human the main way of cognition, systematization of obtained knowledge, the important tool for creative work. The development of technology has caused creation of many new *graphic models of the Earth* (electronic maps, various remote sensing images, photomaps, computer animations, multimedia images, virtual models).