GIS FOR MODELING CARTOGRAPHIC DESIGN

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The modeling of cartographic design based on the system approach allows to increase artistic expressiveness, ergonomics, reliability, technological effectiveness and competitiveness of the fundamental cartographic products. The main attention must be paid to the methods of computer-aided projecting of electronic maps and atlases and methodology of creating problem-oriented GIS intended to model the cartographic design.

In order to solve this problem we develop some concepts and computer-aided methods for projecting electronic maps and atlases, and create problem-oriented GIS for modeling the design of various cartographic products. The developed methods provide the system approach for projecting functions, images, form, composition of elements of electronic maps and atlases as well as for their engineer-psychological evaluation.

This problem plays an important role in the area of sciences about Earth. Theoretical statements and methods, approaches to solving this problem are stated for the first time in this sphere of knowledge. These theoretical statements and methods are now being developed within the Project 99-05-65087 that is being realized in the Moscow State University of Geodesy and Cartography and granted by the Russian Fundamental Researches Foundation (Russian Academy of Sciences). The anticipated results of the Project must have the principal importance for the development of this branch of knowledge. The Project directs to solve the problem of modeling cartographic design for creating cartographic products that are used in Earth sciences. It involves development of the main scientific statements of the theory of modeling cartographic design on the base of system projecting of electronic maps and atlases as a new scientific discipline in geoinformatics and cartography.

Cartographic design modeling must utilize certain design techniques and principles, namely: Classification of map symbols and fonts; Correlation between a design and means of expressing the information according to the purpose of a map; Accuracy of information mapping; Ergonomics; Compactness; Unification; Constructibility; Aesthetics; Reliability; Up-to-date methods.

Problems of designing of fundamental cartographic products are solved by composite-spatial means. The key element of a composition is the layout which determines relations between the elements of the design. The relations between the elements ensuring harmony of the composition are characterized by certain properties:

- Replication of the whole in its compounds as the basic feature ensuring composition integrity. It is provided by the shape, size and color;
- Coordination, i.e. the order of all elements or element groups ensuring certain sequence of composition perception;

- Proportionality i.e. establishing a common measure for commensurable symbols of elements or their groups in a composition for true perception of map parts and a whole;
- Balance of every part and the whole about symmetry axes;
- Unity and integrity of a composition as the most generalizing principle and property.

The main means of expressing composition on maps are symmetry (asymmetry), rhythm, contrast, proportion, scale, colour. Each part has its place among the others, and all the parts should match and submit to the main one. All the ideas of a composition structure should help logical organization of the main content and the elements of the arrangement to form a unity, aiming at the best functioning of a fundamental cartographic product. The composition of units of fundamental mapping products is determined by the size and configuration of a represented area. When modeling it is recommended to select several types of the composite solutions (layout versions of units of the content):
- The map takes up all the working space and is limited by a framework: internal or external. The supporting elements are placed outside the boundaries of the mapped territory. It is the main header that is the integrating element of the map;
- The map is inside a framework, and the supporting elements are wherever available. The external framework integrates the content;
- The map has a free ("floating") layout within the boundaries of the mapped territory. The remaining elements are placed where space avails.

To supply perceptive integrity of a cartographic product, some principals are necessary to be observed, namely:
- Coordination and harmony of all the compounds;
- Highlighting primary content elements by allocating them on the foreground and subordinating secondary elements to the primary ones;
- Rational allocation of mismatching elements and colour spots.

The following methods of modeling a cartographic design are created on the basis of the latter principles of artistic development and design:
- Method of system designing and creation of map symbols;
- Method of art designing using a modular grid;
- Method of a engineer-psychological estimation of visual perception.

The method of system designing is developed on the basis of a system approach and is used for the guidelines on creation of legends of thematic maps. When developing legends it is necessary to keep to the following principles:
- Units of the content of a legend should be systematized;
- They should be placed in the order defined by a theme of a map;
- Basic units should be organized in the hierarchy outline;
- Map symbols are elements of a structure and are in a close intercoupling both with each other and with all the structure of a legend.

The method of artistic designing with a modular grid uses the concept of a module as a certain unit of measurements of cartographic and other (textual, photo, illustration) information. The correctly selected value of a module ensures structural exactness and regularity of data positioned. The modular system helps organized arrangement of a material on the working field. The composite modular construction having symmetrical design is considered classical; it provides for orderly arrangement of the elements of the content and speeds up extracting information. The asymmetric arrangement of modules requires the presence of several vertical axes and gives dynamism to the compositions; it provides for active perception of the information. The rhythmic connection of modules shows when moving from section to section in colour decision, arrangement of headers, illustrations, schedules and pagination.

The method of an engineer-psychological estimation of visual perception is called to attract attention of the readers of a map. The efficiency of obtaining cartographic information depends on methods of representation of units of the content on a map and their features. The different means of mapping allow a cartographer to influence the process of reading of a map. A general estimation of perception of a map is made using certain criteria: readability, conspicuousness of elements, visual response to

colour\background and their matching. Reading of the cartographic information is a complex psychological process including sensation (nebulous vision), perception (discrete vision), recognition of a form (shape). The estimation of this complex psycho-physiological process of visual perception of maps should follow certain rules: the law of contrast, the law of harmonic ratio of part as whole, law of apperception, figure and background phenomena. Estimation of visual perception of electronic maps requires new methods and non-traditional means of representation of the cartographic information: animation, pulsation, dynamic colour changes and disappearing symbols.

Thus solution of these tasks demands adequacy of the structure of a map to one's actions during perception of the information, and necessity of coordination of external and internal means of activity. To create optimum maps optimum integrated criteria of an are established:

- Criterion of optimum content\elements correlation on a map;
- Criterion of an optimum graphic and colour design.

As separate criteria for designing optimum content as the amount of details are used timing (responsiveness) and quantity of errors in activity (accuracy in actions). The main requirement of the second criterion is that map symbols and the titles should single out the main objects of the content and dismember among themselves elements of the map, provide fast and exact study and estimation of geoobjects. The sizes of map symbols in angular values should not exceed minimum permissible ones which provide for their best visibility and conspicuousness on a display, being the necessary condition of their readability in view of physiological capabilities of an eye (acuteness of sight, contrast sensitivity and propulsion response). The colour design should provide for stable colour distinction and transfer of map symbols, matching with the colour range of existing maps.

Detection speed, ability of map symbols to be distinguished and recognized (identified), their minimum permissible sizes and colour differences serve as basic parameters for estimation of a graphic and colour design of a map. The dependence of the user's effective work on the content of a map can be evaluated by results of definition of speed and accuracy of reading a map by difference methods. A rather simple method of timekeeping does not allow to define precisely enough the beginning and the end of reading, to take into account switching-off user's attention from a display and requires a great number of experiments.

The most acceptable method is engineer-psychological method of estimation of visual perception of the cartographic image. It allows to study the information displayed and to determine basic psycho-physiological characteristic of the process of perception in actual conditions on the test-objects and on actual complex cartographic entity set models. The visual formation of images displayed on a monitor consists of three levels: sensation, perception and apperception. It comprises preliminary review of the map and obtaining of the initial information, refinement and detailing of primary images and final fixation of images and informative interpretation of the obtained information.

External development of the visualization process is the motion of an eye. It is known, that eyes, perceiving the visual information, combine steady fixation of map symbols and their structural units with different kinds of motion - fast short jumps (search of structural members), smooth and delayed drift (search and durable stop on a point of fixing) and sharp long jumps (search of map symbols). The reading of the information by a visual system takes place during an immobility of an eye and the position of a point of fixation characterizes a place of concentration of attention of the spectator on a map symbols. It is established, that all kinds of eye motions and the time of scanning of the map is substantially determined by the character of a solvable task, the amount of details and the quality of graphic and colour design. The research uses methods enabling to register eye motions in various tasks.

For modeling a cartographic design in problem-oriented GIS it is necessary to use general principles and methods of modeling. So far GIS has no sophisticated tools for map design. As for cartographic requirements until recently little attention has been paid to the problem of qualitative visualization of data. Instrumental GIS often contain built-in editors for creation of user's electronic libraries of map symbols, but their capabilities are rather limited or have inconvenient interfaces so to use them for creation of complex symbols is impossible. For solution of this problem some GIS are capable of

importing symbols created in other programs, which makes developing complex structural elements of a design possible.

Thus there are not very many sophisticated means for modeling a cartographic design in various GIS. On the other hand, GIS gives a number of valuable advantages for designing maps:
- Creation of electronic libraries of map symbols;
- Ranking elements of a design by themes;
- Creation of new symbols on the basis those in libraries;
- Saving certain sets (combinations) of symbols (legend) as separate files to be automatically used for any other data sets;
- Modeling three-dimensional surfaces using natural textures;
- Ruling the layout of units of a map with automatic generation of a legend;
- Creation of separate units of the model - frameworks, headers, text boxes, tables;
- Sewing together and cutting cartographic data in any format;
- Generation of different types of legends on the basis of sampling from databases;
- Insertion of multimedia units in an electronic map - video, audio, photo histories;
- Control of the cartographic map with the help of functional GIS-toolkits;
- Integration of maps having different scales;
- Control of one map as being an attribution to another.

So in GIS-applications cartographic design tools are to create and to analyze maps using precise mathematical methods, various projections and objects topological relations support. Besides, links with numerous attributes stored in databases are used to allow creation of various thematic maps " on the fly " on a unified basis, and the means of modeling and designing a project in GIS-applications are functionally controlled.

The combined method of modeling a design of cartographic products is based on integration of GIS-applications and graphic publishing systems. The combination of methods means, that the input and editing of the cartographic data is carried out by means of GIS-technologies, and for final design of a map graphic applications are used. There is a wide range graphic software products used in modern cartography - from elementary graphic editors to programs of modeling virtual surfaces using a huge graphic palette of textures and fills, as well as imitation of various types of paints and artistic tools - paintbrushes, pencils, pens.

When combining methods development of map symbols is carried out in several ways. Maps with complex symbols are recommended to employ conventional drawing of nomenclatures with their conversion to the digital format by scanning with subsequent delineating directly by mouse on the screen of a monitor. In this case usage of tracing necessarily requires caution, as superfluous lines, closed loops, etc. may appear. In some cases, especially if there are complex authorized models, usage of raster maps not only for out-of-frame design of maps, but also for insertion of raster artistic symbols is recommended. To input\create nomenclatures special data tablets and computer pens permitting introduction of pictures right from the desktop, without an intermediate process of scanning are used. For maps having simplified denotations map symbols are created directly in the environment of the used software product with their delineating on a screen. Thus, the wide range of graphic tools allows show on the screen of a monitor the author's plan of design. When zooming is used the detailing degree of small-sized objects appears higher than that on the paper.

For development of a design and designing electronic maps separate preparation stages require different in task program applications. This situation leads to certain technological difficulties when creating fully functional electronic maps:
- Necessity of conversion of data from one format in another;
- Increase of duration of cycle of creation of maps;
- Existence of two sets of cartographic data.

Creation of fundamental cartographic products, meeting all the requirements to modern maps results in that the map is created within the frames of an integrated technological complex. Thus the use of combined methods of modeling a cartographic design is recognized most effective. At creation of

electronic products the designing methods back up on general principles which have been worked out when developing traditional maps and (or) their computer variants, intended to be electronically stored. At the same time there is a number of differences connected with the type of the carrier of an electronic map (screen monitor) and the sphere of its application. Apart from the differences in ways of colour perception of a map on the screen monitor and on the hard carrier (additive/subtractive synthesis), the virtual use by a map has essential meaning. So, in these conditions the way of layout of the content and its units is determined by a dynamic plot and ways of navigating through the content. The ways of navigating reflect dynamic links between different structural units of the content, which consist of a set of components (text descriptions, animations, video, sound). Similar multimedia in modern cartographic products requires special approaches.

Several ways of navigation or types of structural layout used at the creation of electronic maps are distinguished. Linear: uses sequential transitions, from one frame (screen) to another or from one information block to another. Hierarchical: uses transitions on branches of a tree structure, which are shaped on the basis of logic of the contents. Non-linear: uses free transitions in the contents of the project, not limiting by the predetermined routes. Mixed: the users can freely select routes of transitions, but thus are limited to linear segments of representation of units of the content, which make logical sequences.
It is more preferable to use the schemes of navigating with non-linear structure, because they give users large freedom of choice. Besides he can go to the subject index, glossary, help sections or navigational map itself. However, too many versions of transition can make an impression of chaos to the user, he can be embarrassed by such multivariant environment, therefore their quantity needs be optimized.

Navigation methods and areas of transitions are part of user’s graphic interface. The navigation structure should have logically clear denotations, so that actions were intuitively clear to the user of an electronic product. It is achieved using symbols (icons) or explanatory comments. There are several basic types of areas of transitions: dynamic and static. Dynamic areas of transitions use radio-buttons, selection indicators, animated buttons. For decorating areas of transitions various representational means are used:
- Textual - various text formatting tools are used (colour, text adjustment along the curves, torsion, three-dimensional text);
- Graphic - contain the specific pictures or their parts;
- Icons - are the main character graphic objects for denotation of operations or objects.

A convenient user interface of an electronic cartographic product is determined not only by graphic quality of units, but also by other various details, for example, arrangement of interactive buttons and areas, highlighted buttons, dropping standard menu of an operating system.

For creation of an ergonomic interface the following artistic techniques are used:
- Symbolic denotations for the main theme of each unit;
- Creation of contrast (large - small, thin - thick, heavy - easy);
- Simple and light screens with large areas of white background;
- Special symbols-characters such as drop caps;
- Light and shadows of different shades;
- Gradient fills;
- Negative maps and text for allocation of important information-semantic units;
- Two-dimensional and three-dimensional objects and text;
- At development of a design of the interface for data management it is necessary to avoid:
- Usage of too many paints and fussy frameworks on a screen;
- Redundancy of screen objects (dense screen);
- High speed of displaying important plots or messages;
- Bulky text messages - they should be divided into parts (semantic units).

Having created a certain set of map symbols in graphic applications, they are stored in user's electronic libraries of characters based on TrueType fonts. Such character sets then are used for extension of means of design in GIS-applications. Universal electronic libraries of map symbols allow to reduce costs of a design, to automate engineering process of designing production maps, to unify user's libraries for thematical maps. Apart from just libraries of symbols there are libraries of basic structural elements and

sets of their possible combinations on the basis of language cartographic rules. The language of a map enables:

- Compact coding of large volumes of the cartographic information;
- Estimation of informational significance (self-descriptiveness) of a map;
- Economical way of storage and information transfer;
- Creation of means of automatic recognition (identification) of symbols.

The designing of a map symbols takes place at the integrated combination of simple components. By exhaustive search of structural members sets of their variations are designed for a single denoted object or phenomenon, which enables to expand and diversify specialized electronic libraries.

Thus there are using new methods of artistic construction of cartographic products. They include methods for computer-aided projecting of variants of compositions, optimal formats, map symbolization systems, elements of outer appearance as well as engineer-psychological methods and approaches for creating cartographic products. The industrial-implemented computer-aided technologies give us the great advantage in comparison with traditional ones that concludes in fact that they allow to operatively carry out modeling of cartographic design for the development of cartographic products using basic models and problem-oriented GIS. These methods can be implemented on the base of modern computer techniques, high-resolution canners, software, basic information maintenance. The backbone of such technologies are interactive workstations and expert systems. The results are planned to be used by cartographers from various countries in their scientific researches and practical work in the area of creation of fundamental cartographic products (electronic maps and atlases).