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METHODS OF AUTOMATED SELECTION OF ELEMENTS FOR MATHEMATICAL BASIS OF ATLAS MAPS

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ABSTRACT

In the era of digital mapping, it is possible and necessary to automate labor consuming manual operations related to the development of a mathematical basis for atlas maps. The concepts of automated selection of mapping scales, cartographic projections, spacing of cartographic grids, and development of composites have been implemented with the use of the automated development of mathematical basis of certain atlas maps. In order to select mathematical basis of maps in the system of an atlas, the following terms have been considered: determination of succeeding scales, coordination of cartographic projections, and retention of cartographic grid spacing ratio for maps of different scales during atlas mapping. Possibilities of geoinformation systems are considered upon the development of maps for integrated and regional atlases. Automation of the considered mapping procedures facilitates rapid and high-quality designing of the mathematical basis of atlas maps.

Key words: Atlases, Mapping Automation, Mathematical Cartography, Cartographic Projections.

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1. INTRODUCTION

At present, maps and atlases are printed in digital form [1]. Digitalization of map printing made it possible to simplify labor consuming stages. First of all, this relates to the stages of compilation of specific maps for atlases [2]. However, the development of a mathematical basis for atlas maps in digital form has not been sufficiently studied. The decision on selection of mathematical basis is made exclusively by the cartographer. Automation of processes related to the mathematical basis for atlas maps would make it possible to accelerate compilation of atlases, to ease mapping procedures, and to improve the quality of maps and atlases.

Obligatory and fairly complicated initial stage of map compilation is the selection of elements of mathematical basis, namely: mapping scale, optimum cartographic projection, development of layout and cartographic grid. These issues are not completely solved by means of modern geoinformation systems (GIS), though, they can compile certain elements.

Numerous maps of integrated atlases require various combinations of projections, layouts, scales, etc. Under such conditions, it is crucial to consider mathematical elements of maps not independently but in combination with other elements [3]. Regarding atlases, the issue of the interrelation is especially important because coordination should be performed not only in the frames of a single map but of the overall complex. Hence, this article discusses not only an automated selection of optimum mapping projections but the automated selection of other elements of the mathematical basis for atlas maps as well.

2. DETERMINATION OF SUCCEEDING SCALES

Compilation of high-quality maps requires for a reasonable selection of scale which depends on map function and topic, its format and layout. It is possible to highlight three main approaches to map scaling resulting from the map functions and application:

- The first approach: selection of large scales used for mapping. The main requirement is the provision of accurate measurements of point position and line length using the map;
- The second approach: if the requirements to accurate measurements using the map are not determining, then the scale is computed on the basis of map format and sizes of mapping area;
- The third approach: for small-scale maps, the requirements to accurate measurements are not so important, their main properties are completeness and details of map content. Thus, while compiling derived small-scale maps, the equation is proposed for scale computing considering quantitative and qualitative aspects which are reflected in the form of graphic load coefficient.

The second approach is used for map compilation most frequently.

Map format is determined by overall dimensions of the map. Selection of map format is based on its dimensions along internal and external borders, along the edge with margins, as well as paper size.

In general, the map scale is determined by its format, scope of the mapped area, specifications of projection, orientation of cartographic representation, convenience of map application under conditions for which it is intended, technical and economic factors.

Scale selection is especially important for the representation of a specific area (continent, country, sea) in predetermined frames stipulating sizes of the map, atlas [4].

Development of the main map scale which provides a presentation of an object or phenomenon in the frames of the preset mapped area can be based on the algorithm illustrated in Figure 1.

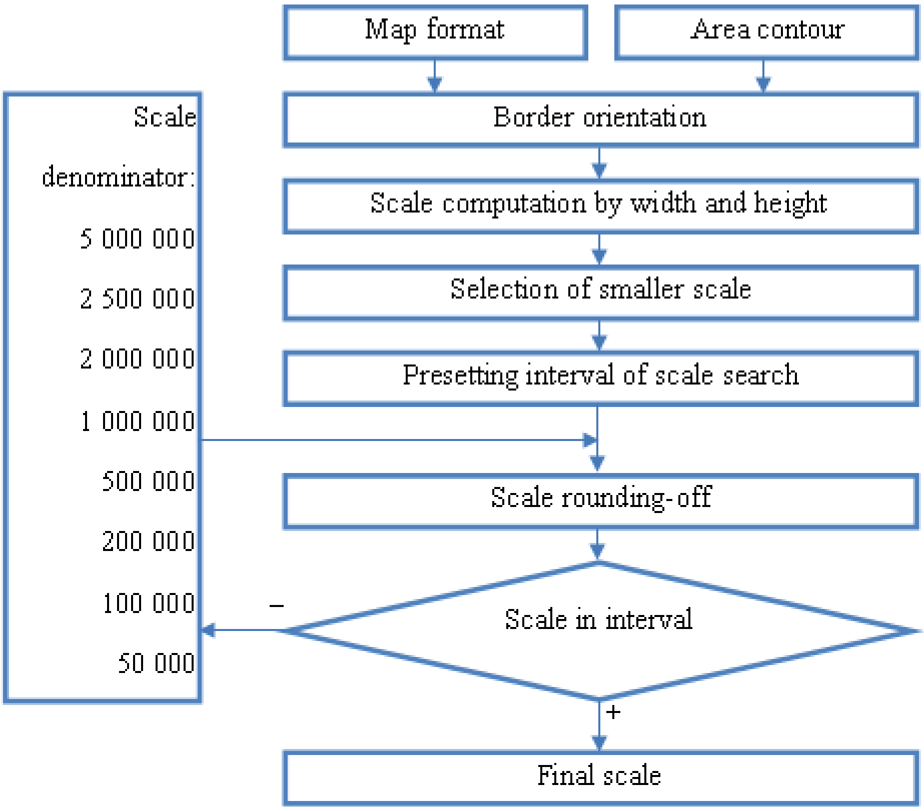

Figure 1 The algorithm of scale computation by map format

The proposed algorithm facilitates selection of the main scale of certain atlas maps. In order to determine succeeding scales of all atlas maps, it is required to determine the scale of each map, however, sometimes it is impossible upon the development of a new atlas because the atlas format was not preset. While designing atlas and determining succeeding scales of small-scale maps the requirements to measurement accuracy are not so important, their main properties are completeness and details of map content. The equation is proposed for scale computing considering quantitative and qualitative aspects which are reflected in the form of graphic load coefficient.

$$M_K = \sqrt{\frac{K_N S_M}{N}}, \qquad (1)$$

where M_K is the named scale in km per 1 mm; K_N is the coefficient of the total graphic load; S_M is the mapped area in km^2; N is the total map graphic load in mm^2.

This is a strict equation of scale determination of a developed map. Unfortunately, it is highly difficult to determine the totalgraphic load of the developed map. In this regard, it is sufficient to use its simplified variant based on optimum graphic load coefficient of localities K_{N_L}=15% and average locality surface area (signature and cartographic symbol) S_L=8.62mm^2,determined empirically:

$$M = 0.13\sqrt{\frac{S_M}{\sum L}} \qquad (2)$$

Equation (2) has been verified upon computing scales of fundamental atlases of Russia and the USSR. Analysis of the performed computations showed good convergence of computed and actual scales in the atlases (Fig. 2), especially for medium, low, and sparsely populated regions of the Russian Federation which amount to more than 65% of entities of the Russian Federation. Of course, there are significant differences in the scales of entities related to sparsely populated regions, because in the atlases these entities are presented in small scales but are characterized by the minimumgraphic load which differs significantly from the optimum. In this regard, it is proposed for such empty territories to bring up the graphic load to the optimum by means of scale decrease. This would permit to retain the information content of maps and to reduce significantly consumption of mapping paper.

When selecting the scale, it is necessary to consider the following issues: correlations between the scale of developed map and the scales of relevant maps – in order to preserve scale equality of ratio; economic considerations comprised of efficient usage of mapping paper of standard sizes, the most complete use of effective area of printing forms; issuing aggregate maps on minimum number of sheets, etc.

Figure 2 Correspondence between the computed atlas map scales and map scales in the published atlas of Russia in 2002

3. SELECTION OF CARTOGRAPHIC PROJECTION

An important and complicated stage of map compilation is correct and substantiated selection of cartographic projection [5]. Map making companies quite often prefer to ignore this difficult stage using the projections of initial mapping documents for completion of new maps even to the disadvantage of map accuracy and layout. In the context of the intensive application of digital maps for various commercial and research problems, including the development of various GIS projects, specific and topic-related maps, an urgent necessity to solve this problem automatically has emerged.

Selection of cartographic projections depends on the sizes of mapped territories. For maps of the world [6], hemispheres, continents, and Russia, a set of cartographic projections has been determined. Therefore, for automated selection of projection to such territories an appropriate library has been developed which has been verified using the maps of the Russian Federation. When mapping territories with longitudinal extend less than 9º, the Gauss-Kruger projection is selected [7]. Hence, let us consider the automated selection of cartographic projections for all Russian territory and for territories of medium sizes covering certain entities of the Russian Federation or its large parts. In addition, while developing an automated selection of cartographic projection the map content is considered.

This work considers the automated selection of cartographic projections for the Russian Federation.

While selecting projections for all Russian territory it should be considered that, depending on the functions, content, and method of application, the requirements can be varied not only with regard to the projections but also to layout, in particular to the inclusion of segments of adjacent territories into the map borders. By now the set of projections is determined used upon compilation of maps of the Russian Federation. We developed the graph facilitating automated selection of projection from the set of existing ones with consideration for map function, distortion pattern, and layout features (Figure 3).

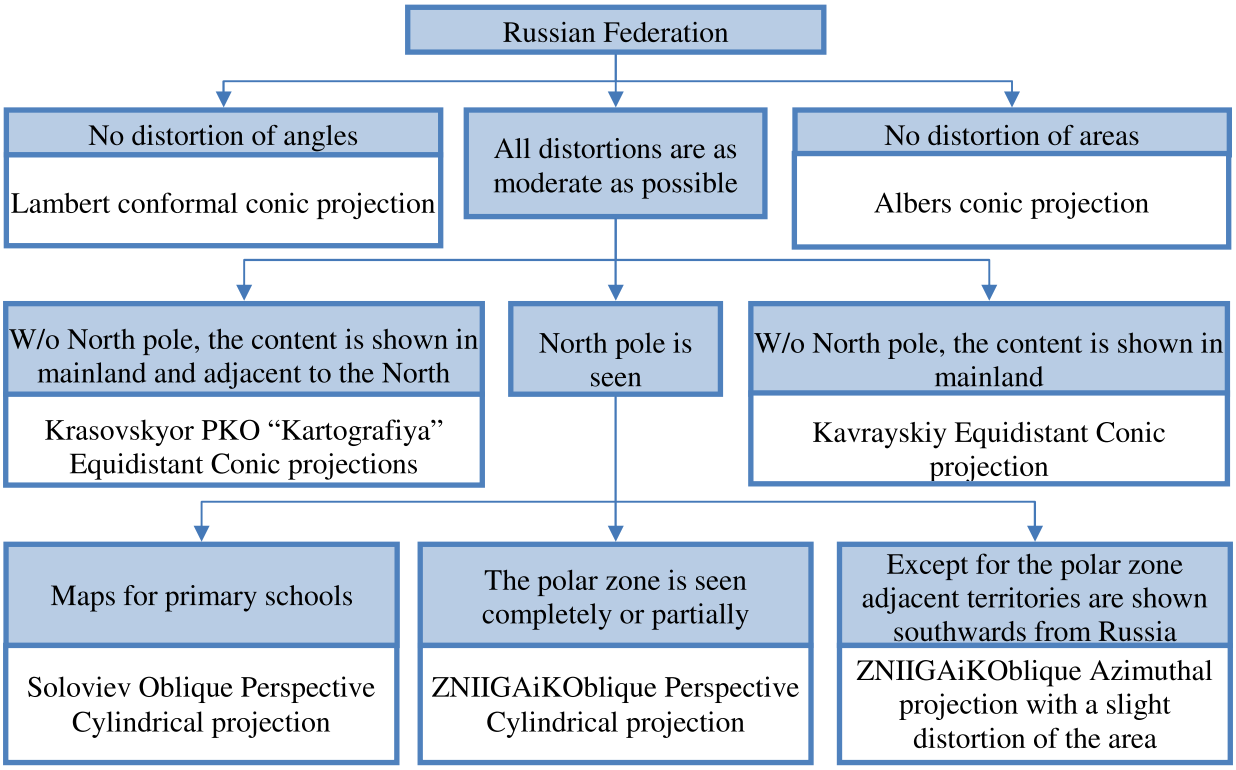

Figure 3. Selection graph of cartographic projection for maps of the Russian Federation

For the maps of medium-sized regions of the Russian Federation, the cartographic projections are selected stage-by-stage (Fig. 4). At first, a projection set is predefined for subsequent reasonable selection. Then the selected projections are estimated by partial functionals and the most suitable projections are proposed, then the layout of the cartographic grid with distortions is compiled. Then the user determines the required projection. The stages of the procedure were considered in detail elsewhere [8].

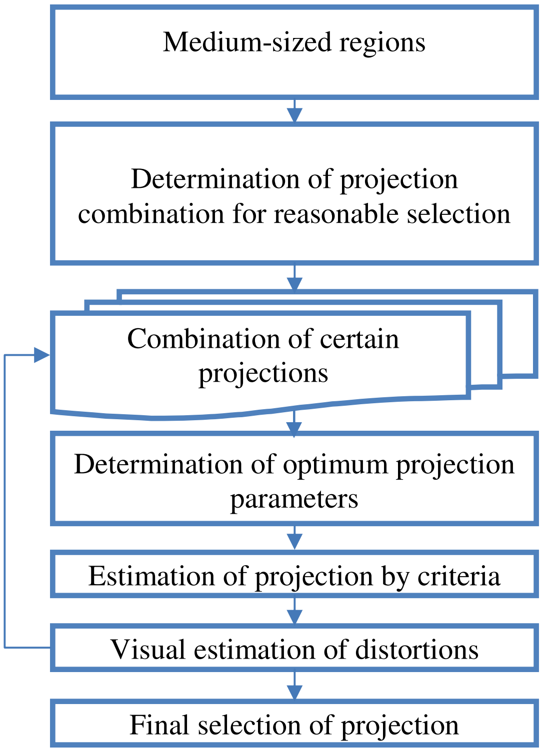

Figure 4. Selection of cartographic projection

4. DETERMINATION OF OPTIMUM SPACING OF THE CARTOGRAPHICAL GRID

The published maps were analyzed, and mapping grid spacing was determined as a function of the map scale. Political-administrative, geographical and physical maps were analyzed. The results are summarized in Table 1.

Table 1. Selection of mapping grid spacing as a function of scale and geographic position of cartographic territory

Scale	**Mapping grid spacing**		
	φ_S<40°	40°<φ_S<60°	φ_S>60°
Less than 1:150 million	30°×30°	30°×30°	30°×30°
1:50 million – 1:150 million	20°×20°	30°×20°	30°×20°
1:15 million – 1:50 million	10°×10°	12°×8°	20°×10°
1:5 million – 1:15 million	5°×5° 4°×4°	6°×4°	10°×5°
1:2 million – 1:5 million	2°×2°	3°×2°	4°×2°
1:1 million – 1:2 million	1°×1°	1°×1°	2°×1°

As follows from Table 1, mapping grid spacing depends both on the map scale and position of territory. The length of the meridian arc of 1º is always the same on the sphere, whereas the length of the parallel arc of 1º depends on the latitude. Thus, at the equator these arcs are equal, and at the latitude φ = 60° the length of the parallel arc is twice as short as the length of the meridian arc. At an equal spacing of cartographic grid along longitude and latitude at the equator, the grid will subdivide the Globe into segments close to squares whereas near poles the segments will be narrower in the longitudinal direction. In order to obtain more uniform mapping grid, it is required to modify the grid spacing along the longitude as a function of the latitude of the south border of the map. The table shows three ratios of mapping grid spacing: 1:1, 2:3, 1:2.

For the map scales of 1:5000000 – 1:15000000 and for the territories southward from 40º two variants of mapping grid spacing are given. This would permit to meet the requirement of retention of mapping grid spacing for maps of different scales upon atlas mapping.

5. COMPOSITE LAYOUT OF ATLAS MAPS

When developing layout, all the considered elements of mathematical basis are used. They are mutually coordinated. At this stage, it is possible to vary parameters of other elements. In addition, such approaches are considered as violations of map frames, frame rotation. In order to develop mapping basis of layout for the Russian Federation, the mapping database 1:8 000 000 is used, thus providing development of layouts for the map scale of 1:1 500 000 and smaller. Mapping objects are selected by means of mathematical apparatus developed at the Department of Cartography, MIIGAiK [9]. The layout can be implemented in geoinformation systems.

The map layout is developed on a virtual page. A cartographer can preset any page format, however, capabilities of printers used for amp printing should be considered. In order to arrange the mapping data on a page of a specificformat, there are specialized objects: data frames of any form and any size for location in any position of the page. The number of frames is not limited, they can be used in the form of inset maps or several maps on one page. When developing a data frame, the cartographer should consider the size of mapped territory, scale, format of the map page. Therefore, each frame can contain maps of different content or maps of different scales. Frame contour can be decorated by various borders.

In addition to the dataframe, it is possible to locate other map elements, such as map header, north direction, legend, scale, diagram, text, and other graphic elements. An important task of a cartographer is to distribute the map elements on the page aiming at map suitability.

Some elements of the map, such as north direction arrows, scale rulers, and legends, are closely related to the content of the data frame. The north direction arrows define map orientation. The scale rulers are visual indicators of dimensions and distances between the objects shown in the map. The legend explains the meaning of mapping symbols used for the presentation of various objects. When varying the scale, the north direction or map content, the appropriate layout components are also varied.

When compiling a set of maps, it is important to arrange them in a uniform style. This is aided by layout patterns which save time, provide standardization and unification of layout of map series.

Modern GIS programs provide wide possibilities for development of elements of mathematical basis. Herewith, selection of cartographic projection and determination of its parameters, computation of mapping scale by map format, determination of geographic grid spacing, and, to some extent, determination of indices of the geographic grid, development of map border with the digitalization of map grid should be performed by the cartographer. Therefore, automated selection and development of elements of mathematical basis is a prioritized trend in mapping researches aimed at the accurate and rapid compilation of maps.

6. CONCLUSIONS

Development and verification of the concept stages will be performed mainly for the case study of integrated atlases of certain regions of Russia. This work is a stage of the concept of automated atlas mapping developed by the Department of Cartography, MIIGAiK [10]. This work will provide rapid and high-quality designing of the mathematical basis for maps and atlases.

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