CREATION OF ALGORITHMS FOR THE AUTOMATED CONSTRUCTING RELIEF MAPS BASED ON REMOTE SENSING DATA FOR A VARIOUS MORPHOSTRUCTURAL COMPLEXES OF THE RUSSIAN FEDERATION

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ABSTRACT: Relief plays the most important role among all the elements of the terrain, because it affects the state and position of other elements: hydrography, historical formation in the area of human settlements, vegetation, etc. At present, the relief can be displayed in many ways: it depends on the further using of visual models. These are perspective images, stroke methods, hypsometric methods, the construction of isolines (isohyps), symbols, block diagrams, shadow plastic techniques and others. The basis of modern computer relief mapping is the construction of digital elevation models (DEM) - models that reflect heights of a relief, without considering heights of the objects located in the territory. They allow restoring (visualize) the relief in contours using interpolation, extrapolation or approximation techniques. Automated methods for constructing relief models (maps) accelerate the receipt of visual images and ultimately allows to users to make the right decisions during the analysis of the territory. More and more administrators from the economic and social spheres want to evaluate their territory based on the DEM and more and more specialists can work with the DEM. The Russian Federation has a huge area of territory. The size of individual administrative regions (subjects of the Federation) can also be very large and sometimes includes inside its borders a variety of morphostructural complexes. Depending on the size of the territory, fluctuations in the amplitude of elevations, geographic location and various relief visualization algorithms are used. The article discusses the algorithms for the automated construction of visual relief models (maps) for various territories of the Russian Federation. These territories have different structural forms of relief. From an economic point of view, these lands also have different economic purposes. Different methods of the final image processing are proposed, depending on the morphological structure, the size of the topographical picture and the choice of the user who owns the data and remote sensing of relief construction software. As a result, methods for processing remote sensing data and construction relief maps in two scenarios are proposed: the most spectacular and the simplest. Control managers of these and other regions may subsequently choose the most suitable processing algorithm and use it.

1.   INTRODUCTION

Among all the elements of the terrain relief plays the most important role. It affects the state and position of other elements: hydrography, historical formation in the area of human settlements, vegetation, etc. There is a relationship between all these elements, that is affected by topography.

The following requirements are imposed on the image of a relief on hypsometric maps:

- metricity (measurability) of the image, which makes it possible to obtain absolute heights and excesses on the map, characteristics of tilt angles, dissection, etc.;

- the plasticity of the image, i.e., the visual transmission of the unevenness of the relief, forming the visual image of the area for the reader;

- morphological correspondence of the image, which is manifested in the desire to emphasize the typological features of the relief forms, structure.

Scientists always sought to take these requirements into account. And these desires go through the whole history of the mapping of the relief methods development. And not only in the relief maps, but also in compiling other maps of nature. (Isachenko, 1960), (Bozilina et al., 2016). (Zaruzkaja et al., 1989)

At present, the relief can be displayed in many ways: it depends on the further using of visual models. These are perspective images, stroke methods, hypsometric methods, the construction of isolines (isohyps), symbols, block

diagrams, shadow plastic techniques and others. The application of a relief image method depends mainly on the type of map, purpose and scale. (Zaruzkaja, 1958)

The basis of modern computer relief mapping is the construction of digital elevation models (DEM) - models that reflect heights of a relief, without considering heights of the objects located in the territory. They allow restoring (visualize) the relief in contours using interpolation, extrapolation or approximation techniques. Based on DTM, specialists perform various calculations and transformations, automatically compile derivative morphometric maps: slopes and expositions of slopes, dismemberment, visibility / invisibility zones, etc. In automatic mode, river thalwegs and the entire erosion network can be restored. In additional DEM are used to form block diagrams, panoramas, and other three-dimensional relief images, including dynamic models rotating on a computer screen. Detailed DTM allow to create a relief shading at a given lighting. Based on DEM digital relief maps are obtained.

Automated methods for constructing relief models (maps) accelerate the receipt of visual images and ultimately allows to users to make the right decisions during the analysis of the territory. The using of remote sensing data to formation digital elevation models makes it possible to reduce the time required in comparison with traditional technologies for obtaining elevations from topographic plans.

The Russian Federation has a huge area of territory. And Russia relief is varied: dominated by plains and plateaus but mountain systems are mainly concentrated in the south of Siberia, north-east and east of the country. The size of individual administrative regions (subjects of the Federation) can also be very large and sometimes includes inside its borders a variety of morphostructural complexes. On the territory of one administrative region, plains, plateaus, and high and medium-high mountains can be found. The presence of various morphostructural complexes complicates decision making on territorial management. The regional leaders must think through the issues of industrial and agricultural facilities based on the conditions of topography. So, most regional managers are ready to cooperate with scientists and specialists in order to introduce modern computer technologies in the process of economic management, which allow to obtain visual models of their territories.

In order to develop the most profitable algorithm for constructing a relief map using remote sensing data operating on various morphological structures, our team selected the Samara region of the Russian Federation.

These territories have different structural forms of relief. It is in the southeastern part of European Russia, on both sides of the Volga River in its middle reaches. The Samara region includes three parts: the Right Bank (Pravoberezh'ye), the North Left Bank (Severnoye Levoberezh'ye) and the South Left Bank (Yuzhnoye Levoberezh'ye). In the north of the Left Bank there is a flat plain and the Bugulminsko-Belebeyevskaya Upland and its spurs (Soksky Yars, Kinelsky Yars, Sokoli Mountains). The south of the Left Bank is a gentle wavy plain; in the south of the region there are sections of the Upland General Syrt (Blue, Middle, Stone, Perelyubsky Syrts). The Right Bank is the higher lands, there are the Zhiguli Mountains. On the territory of the Samara region there are many entities that have arisen in the process of human economic activity: quarries, dumps, excavations, soil dams, dams, as well as ravines that are constantly growing and are a big problem for agricultural production.

As a result, we propose an algorithm for constructing a relief map using remote sensing data in two scenarios. The result is a visual model, the construction scheme of which can be used by regional managers not only of the studied region, but also of other large regions of the Russian Federation in order to accelerate decision-making in the field of economic planning.

2. PROPOSED METODS

The task of compiling a relief maps based on remote sensing data has been solved by many authors. (Seger, 1989), (Kennelly, 2008), (Schovengerdt, 2010), (Metelka, 2018)

The first task is data acquisition. There are several sources of open source data where we can find the right tiles (SRTM): United States Geological Survey [Earthexplorer.usgs.gov, 2018a, b] or Shuttle Radar Topography Mission [Srtm.csi.cgiar .org / srtmdata, 2018] and others. We have tried to use other data, but these were inconvenient to use in our context and often incorrect.

Each tile is a jpeg or png image and is stored in a file with a unique name, which is determined by the scale and coordinates of this tile along the X and Y axes, with X starting from 0 (which corresponds to 180 ° W) to 2zoom - 1 (180 ° E), and Y has values from 0 (85.0511 ° N) to 2zoom - 1 (85.0511 ° S) in the Mercator projection (Web
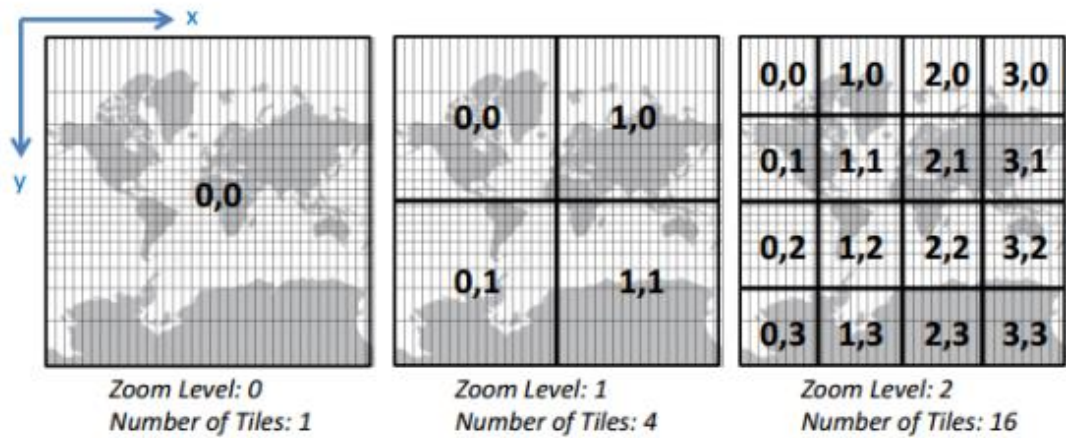
Figure 1. The most common version of a tile structure.

Mercator). (Stefanakis, 2015) (Figure 1).

The second task is the construction of isolines (isohyps). The distance between them must be chosen considering the peculiarities of the territory and "with excess". For example, if the topography is flat, then it makes sense to choose a smaller section. If the scale has been uneven, then chose the smallest of the sections; during the further analysis, it is possible to remove excess isohyps.

The next stage – the color scale development and the formation of a color relief. We will need to create a file with the txt extension of the following format:

< height level 1> <R> <G> <B>
< height level 2> <R> <G> <B>
…………………………………………...
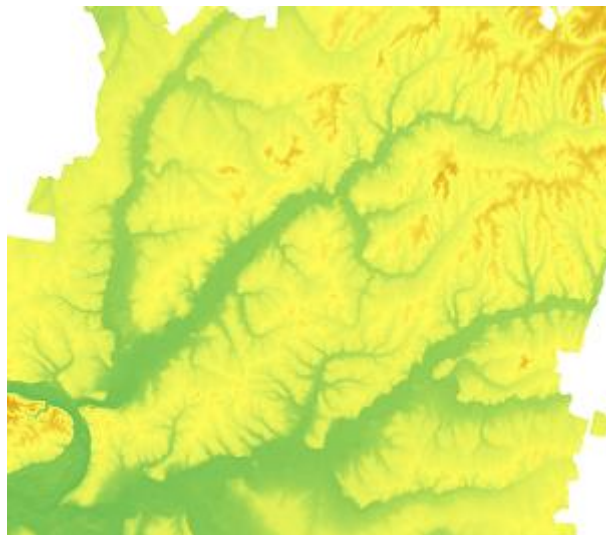< height level n> <R> <G> <B>

Figure 2. The results of the colorized relief construction.

Here <height level k> is the height of the level, <R> is the red component of the color, <G> is the green component of the color, <B> is the blue component of the color (the color in which the current level will be painted [k: k + 1]).

High-altitude steps need to be built only after working with contours, because they determine their number and borders.

During the creation of colorized relief, it is better to use the tool "Color relief". The basis of this operation - the creation of layered coloring. Unlike traditional options, where a discrete representation of the color scale is possible,

in this algorithm it will represent a continuous (linear scale). (Figure 2.)

The fourth stage is the creation of relief shading. The relief analysis tool "Shadow Relief" was used. With the help of this tool was made shadow relief, representing a bitmap, which contains information on the distribution of sunlight on the territory.

The method of relief shading is the creation of a grayscale image with a given lighting of the area. The greatest volume and expressiveness are given by the methods of black and white plastic. They enable the smoothest transition from light to dark. In classical cartography, there are three washing options: with side (oblique) lighting; in sheer lighting; in combination lighting. The construction of relief shading has been studied by many scientists throughout the history of the development of methods for displaying relief. (Castner et al., 1979), (Fremlin et al., 1998), (Hurni, 2006), (Kennelly, 2008), (Lyons, 1914)

It is possible to adjust the direction of the light source ("Sun") and its height above the horizon. If the absolute elevations are insignificant or there is relatively flat terrain, then it is permissible to set a vertical scale greater than "one". The resulting shading will correspond to the relief forms exceeding the real picture a specified number of times. (Figure 3)

The fifth stage is the post-processing of the shading. After the construction of the relief shading it is necessary to clarify what values it takes. If the majority is below 150 - 190, it is necessary to bring the raster to a new range of values in such a way that the spread of values is no more than 100 and the whole range lies as close as possible to 255. To this end, we offer the following steps:

$$\text{Shadow\_raster} * k + q, \qquad (1)$$

Shadow_raster - shading, k - the scale factor, the approximate value of which can be taken equal to:

$$k = 100/\max \llbracket - \min \rrbracket , \qquad (2)$$

max/min – maximum / minimum value raster Shadow_raster; q – a shift whose value is equal to:

$$q = \lfloor 254 - k * max \rfloor, \qquad (3)$$

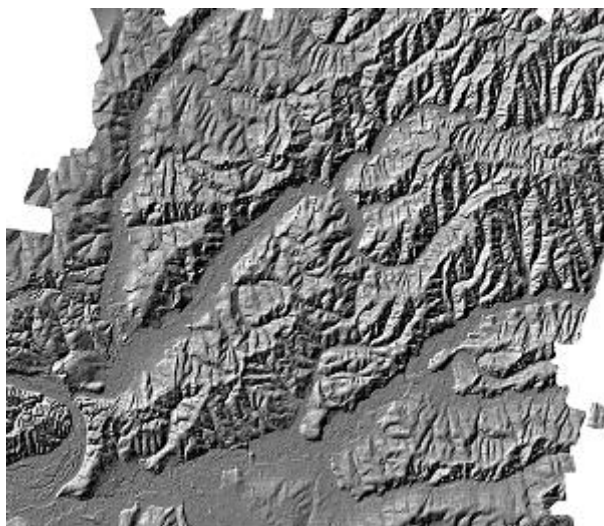Operator $\lfloor \quad \rfloor$ means rounding from the bottom.

Figure 3. The results of the relief shading construction

The final stage is the creation of the final image. We offer two options.

Option 1: merge relief with shading and color relief. (Figure 4) The essence of this method is that the original colorized relief is converted from the RGB color system to HSV. Thereafter, the value of H is replaced by a value H relief shading. And then converted to RGB again. This approach allows you to get the color relief in the same tones, but darker depending on the light. During the post-processing of shading should be careful not to get too dark.

Figure 4. Merge relief with shading and color relief

Option 2: overlay layers with transparency setting. A color relief serves as a substrate, on which a layer of shading is superimposed. The latter can be set up any transparency. (Figure 5)

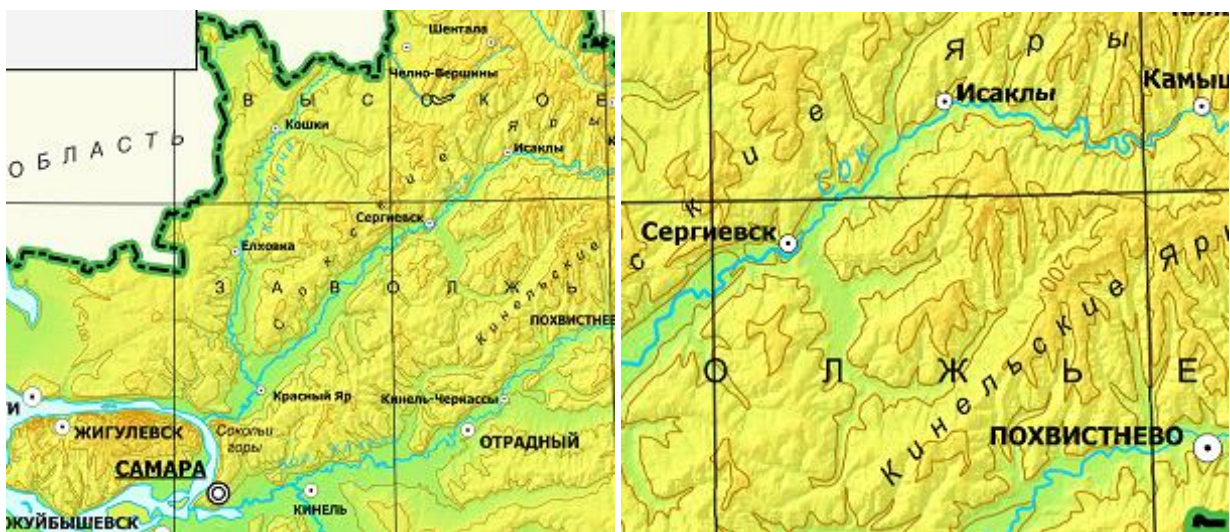Figure 5. Overlay layers with transparency setting

Figure 6. Fragments of different scales of the final Samara Region relief map (Russia)
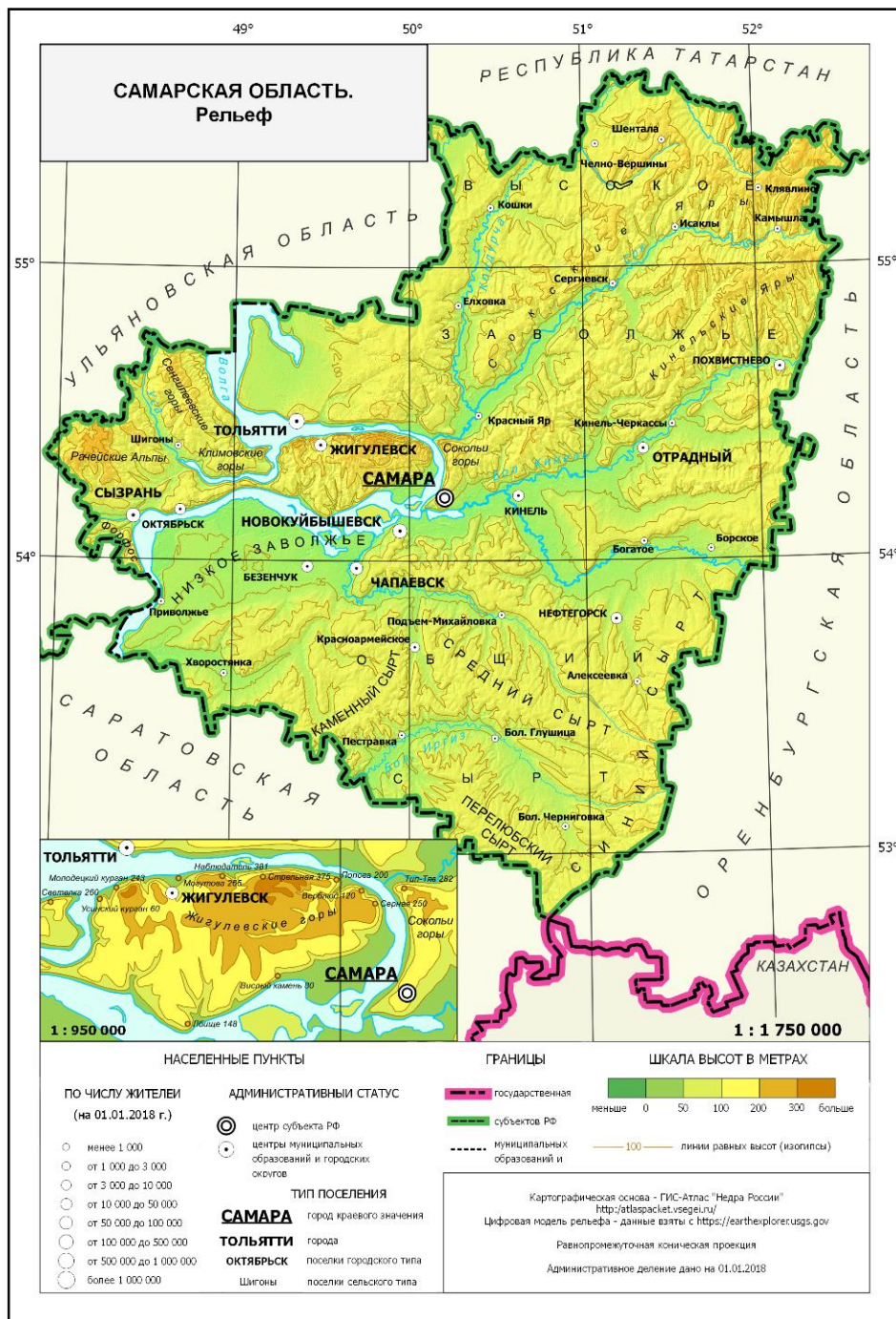
Figure 7. Final relief map of Samara Region (Russian Federation)

The second method is simpler, but the most expressive and spectacular is the first one.

For the final image, which is positioned as a real geographical map, based on the laws of classical cartography, it is necessary to add horizontals to the resulting image. (Figure 6, 7)

The algorithm was implemented in the QGIS program. Relief construction can be carried out in different computer programs, however, currently there is a tendency to simplify technical equipment both from a financial point of view and from the point of view of personnel training. The QGIS program is quite easy for training, has a free access code, and can be used directly in the technical departments of regional administrations.

3. RESULTS

As a result, we propose an algorithm for creating a visual model (map) of the relief of the Samara region (Russian Federation) based on remote sensing data. This region has various morphostructural complexes; therefore, the algorithm can be used in other territories as an instrument of economic management.

4. CONCLUSIONS

1. Creation of relief maps plays an important role in modern management of administrative regions. The most relevant methods - construction of relief maps based on remote sensing data.

2. The Russian Federation occupies vast spaces and includes various morphostructural complexes. Our team chose the Samara region for the development of the algorithm for constructing the relief map based on remote sensing data. This region also includes various morphostructural complexes and may be used as an example of working with the administrative areas.

3. Our algorithm consists of several stages and has two ways of constructing the final image.

4. We offer to work with QGIS as the most loyal program in order to use it not only by narrow specialists, but also by employees of administrations and municipalities.

5. We believe that the final model should be a real geographical map in order to improve visual perception. This map can be used by managers at various levels to make decisions in the field of spatial planning of regions.

6. Our algorithm can be used for other areas having different morphostructural complexes.

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