

Method of Visualization of Geoinformative Data: on the Example of Reference Archaeological Objects

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Abstract

The article reveals the results of an interdisciplinary study aimed at improving laboratory methods for collecting, analyzing and synthesizing geodata necessary to expand the methodological apparatus in scientific fields for the study and preservation of cultural heritage sites in vast areas, using triangulation in building a geogrid with reference to satellite cards. Data visualization significantly complements natural and instrumental methods of collecting information, searching, fixing, systematizing and inventorying in areas that are difficult to access for field research methods.

Fixation and binding of control points to the geogrid by the triangulation method is due to a number of advantages: the accuracy of building and fixing the binding objects, the possibility of scaling the grid, the triangulation algorithm along the smallest diagonal of the quadrilateral.

As a result of assigning properties of modifiers to reference points, which were selected as reference archaeological objects - the ruins of fortified settlements on high-resolution satellite maps, layers of inter-object edge connections were formed, which, when certain properties of modifiers were turned on, were displayed as differently colored edges on the geogrid, fixing invariants patterns of these relationships.

In the final experiment, we obtained a hybrid visualization of layers based on the specified properties of modifiers for edge connections, between reference objects in the geogrid system, which made it possible to obtain more objective results under the given conditions than by methods of constructing linear links by coordinates, using tracing and routing.

As an implementation of the results of testing the method, a project of an interactive scalable cartographic scheme with visualization of data on the objects under study and their relationships in a large location has been developed.

Keywords: geodata visualization, Delaunay triangulation, parametric modeling, visualization in cartography, objects of cultural heritage, anchor reference objects.

1. Introduction

In solving problems related to the collection and analysis of archaeological data in the laboratory, in the search, fixation, revealing and inventory of new, previously not included in the cultural heritage sites (CHS) registers, various methods of analysis and decryption are used, when taking into account the exact fixation of objects on satellite and surface contour maps problem. Along with the well-known methods, auxiliary or ampliative methods are also used in cartography, which make it possible to expand the possibilities of revealing and fixing CHS, as well as the possibilities of studying identified objects under laboratory conditions.

Geoinformation data visualization essentially fills up the instrumental methods in research work under laboratory conditions for geology, archaeology, agrarian industry and other areas using geanalytics and GIS-technology. "Exploratory data analysis" (EDA) is most effective when working with infographics, analytical geodata diagrams [4, pp.19-58]. Methodological approach to visualization: on example of control sites fixation, that in fact, uses EDA, coupled with cartography and is aimed at obtaining concrete results during laboratory experiments with the retrieval of parametric indicators for further transfer into practice [19, pp. 99-109].

As an instrumental supporting for data visualization, polygonal construction of a highly precise coordinate grid of the coordinate reference points location, in our case, reference archaeological objects (hereinafter, RAO) is used.

For the initial coordination of such objects, linear Delaunay triangulation on HR satellite maps is used [12, pp. 14-39], hereafter a rigid polygonal frame of the coordination grid is created with an option to display linear relationships, assign parameters and properties to objects. Such method provides wide application possibilities for obtaining results in modeling interactive schemes on coordination satellite maps.

2. Research methodology

Google maps, a geogrid editor program, 2D graphic editor programs are used in the study. Aerial and topographic mapping of different years are used for precise coordination with regard to RAO and objects localization on satellite maps.

The whole process consists of successive steps:

Phase 1: RAO initial informative data retrieval: localized aerial photographs, satellite coordinates, lay of land archaeological maps and other auxiliary data;

Phase 2: satellite data receiving;

Phase 3: satellite data fine-tuning with aerial photographs and topographic maps with the RAO coordinates reference on a scale of 1:10000 layerwise overlay;

Phase 4: satellite maps objects localization on a scale of 1:500 - 1:1000 using coordinate reference and aerial photographs and topographic maps layerwise layer stacking, as well as RAO localization auxiliary and additional data retrieval relative to the nearest (control) inhabited localities and the terrain landmarks;

Phase 5: received data for geolocation on a scale of 1:10000 in a graphic editor program using the zoom function overlay;

Phase 6: data import for the specified RAO in Gridder2D [15], triangulation geogrid building;

Phase 7: fixation of obtained results by means of the triangulation grid and distances reference between the RAO in the metric coordinate system on a scale of 1:10000 fine-tuning;

Phase 8: RAO modifiers and edge connections parameters assignment;

Phase 9: visualization of received data in the form of graphical diagrams using 2D graphic editor programs;

Phase 10: obtained data processing.

It is worth taking into account that archaeological data may correlate in course of time, they need to be updated periodically. Based on specific examples for RAO, it is necessary to make a selection as for anchor coordinate objects.

Architectural and archaeological complexes sites located on vast areas and at a considerable distance from each other are considered as an example of this method practical implementation. Stabilized settlements, large mounds or any other significant objects can be the central objects of such complexes. RAO fixation center can be assigned as the zero coordinate anchor point.

The RAO edge connections model is proposed to be formed using GIS technologies [3] by the high-precision coordinate grid of anchor objects location polygonal construction method using Delaunay triangulation [11] on HR satellite maps. The need for using this method is due

to the necessity to determine the shortest connections between the anchor objects, the edge connections in the node points concentration that determines their number, where the framework condition is fulfilled – triangulation along the smallest diagonal of the quadrilateral.

This method makes it possible to check the node points parametric correlations, to form a rather accurate coordination grid of all objects localized on the satellite map with a light error in the anchor coordinates with a deviation up to 3-5 meters from the satellite coordinates. During the building process, the condition is checked: whether objects of certain types have edge connections with each other.

The Google Maps interface (HR satellite maps) is used as a workspace (Fig. 1.1). To work with geogrids, the GIS GeoLink 3.14.0013 software utility is used [5]. To work with RAO, a modified grid is used, built using the utility for 2D triangulation of complex two-dimensional regions Gridder2D [10]. The simulated cartogram grid makes it possible to visualize the cartogram contents against the background of a real geographical situation with reference to satellite maps. Thus, the cartogram displays the RAO localization in terrain conditions based on cartographic data - isolines, the earth surface and river levels marks (see Fig. 5). The source cartographic data detailing makes it possible to form and group layers that display typomorphology and isometric inter-object connections by RAO interpolation. Cartograms contain both the cartographic information results and the source data. 2D editors for cartographic images processing are used: CorelDRAW, 2017 Academic Edition, D-504-18 dated 25.04.2018 [18] and Adobe Photoshop CS 5 Academic Edition, K-113-11 dated 11.04.2011 [16].

In the course of laboratory work, with the view to fix objects points accurately on an HR satellite map, aerial photography of different years was used as an auxiliary data [9; 14. pp. 116-121], in particular cases, decrypted aerial photographs cartographic schemes and the archaeological atlas materials were used [1; 17, pp. 199-219], archaeological data of field and laboratory archaeological study [6, pp. 5-17].

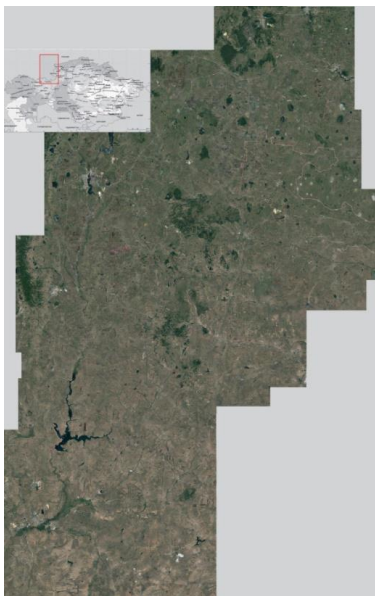


Figure 1.1. A territory for study fragment – an HR satellite image

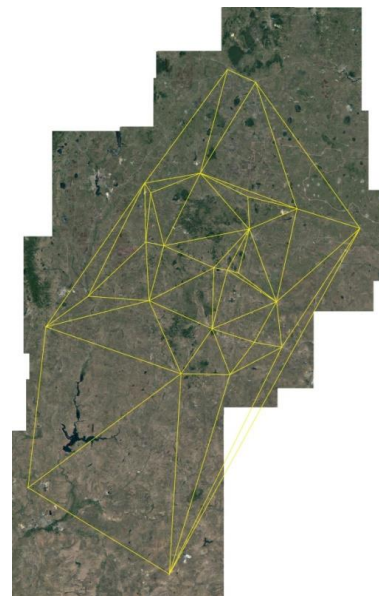


Figure 1.2. Triangulation of localized anchor points (RAO) in the satellite image

3. Algorithm for linear connections building

The method used includes the following algorithm for building a RAO localization geogrid (Fig. 1.2):

- 1) collecting data on RAO: aerial photographs, satellite coordinates, archaeological maps with terrain and other auxiliary data;
- 2) receiving data from a satellite map on a scale of 1:20000;

- 3) Transfer satellite images to a scale of 1:10000;
- 4) objects localization on satellite data on a scale of 1:500 - 1:1000 by informative data layer stacking and the available database of aerial photographs, coordinates, topographic maps analysis, fixing anchor objects relative to the inhabited localities and natural landscape points of detail indicated on the maps;
- 5) received data scale transfer;
- 6) triangulation algorithm startup of reference points with the supplied parameters: with division into layers, groups, subgroups of links between RAO;
- 7) the obtained results of the construction of a triangulation grid and the distances between RAO fixation;
- 8) analysis and collection of the received data with their entry into parametric tables.

The development of building linear links with reference to RAO method, allowed us to obtain more accurate results based on anchor reference points than the building on satellite coordinates basic method.

Such a triangulation scheme can be an example of triangulation built on the location of all cities in Russia (Fig. 2).

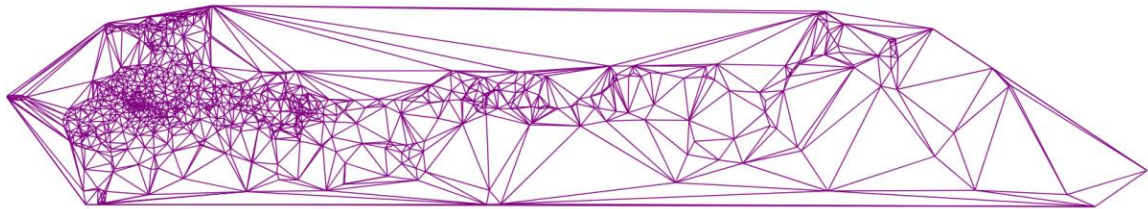


Fig. 2. A triangulation example built on the locations of all cities in Russia (modern cities of the Russian Federation are reference points) [2].

4. The geodata visualization method improvement

A Google map fragment - stabilized settlements of the Bronze Age in the border zone localization territory is taken as the basis for the grid building: the South of the Chelyabinsk Region, the Republic of Bashkortostan eastern borders, the northern borders of the Orenburg Region, on which reference points (the ruins of stabilized settlements locations) were previously plotted according to the given algorithm. Modifiers are assigned as reference objects.

As a result, analysis was conducted and a scheme combined by linear parameters, connections and RAO type-morphological characteristics was built (Fig.3.3).

RAO characteristics are assigned to the triangulation grid node points and consist of two modifiers:

- object morphological properties modifier (OMPM), assigned to a specific type of object: OMPM (1) – 1st type, OMPM (2) – 2nd type, OMPM (3) – 3rd type, OMPM (1..3) – indefinite;

- object typological properties modifier (OTPM), assigned to a certain object typical size: OTPM (1) - large, OTPM (2) - medium, OTPM (3) - small, OTPM (1..3) – indefinite.

According to previously conducted studies on the RAO type-morphology involved in laboratory research, a total of 10 morphotypes have been identified that combine the typical and specific parameters of modifiers: OMPM and OTPM. According to the number of detected morphotypes, the same number of linear-parametric RAO connections layers will be identified. Figure 3.3 shows the layer stacking of 4 triangulation grid edges layers that visualize chains of linear links.

RAO linear parameters and connections are assigned to the triangulation grid edge connections along the rectangle smallest diagonal and are visualized by means of color coding in the CMYK model (Cyan, Magenta, Yellow & Key).

It is worth adding that the number of RAO bound to linear parametric links may vary or be defined due to further research and laboratory experiments, with the inclusion of new or refinement of the uncertain reference points parameters.

Undefined OMPM and OTPM can be included or excluded in linear RAO chains "manually" or automatically. The inclusion or exclusion algorithm of undefined RAO is set depending on the tasks set in the laboratory research. In these works on the geodata visualization method improvement, algorithms for *undefined* RAO were not worked out, but added or excluded from the triangulation grid layers in "manual mode" taking into account one or another OMPM and OTPM.

The working out and inclusion of algorithms for the undefined RAO triangulation grid layers in automatic mode requires further development.

Further, edge connections are built between the anchor points, which are assigned their own color in the modifiers properties, thus, linear connections between similar and identical OMPM and OTPM are visualized. The RAO inter-object edge connections are visualized in a certain color in the triangulation grid system with the additional binding parameters inclusion and exclusion, depending on the tasks set.

At Figure 3.1, in Experiment No. 1, edge connections layers are visualized complying with the conditions for RAO linking without taking into account OMPM and OTPM, continuous lines building chains along river-beds.

Figure 3.2. Experiment No. 2 shows the results that fix the edge connections, complying with the conditions for RAO linking with analogous or similar OMPM and OTPM, without taking into account their location relative to river levels marks.

Figure 3.3 The results of combining the experiments No. 1 and No. 2 results are shown, in fact, through this process, we obtained layers hybridization (combination) according to all specified parameters of the RAO inter-object edge connections on the geogrid. As a result of layers combination, correlation in the RAO edge connections chains visualization is due to the framework condition – triangulation along the smallest diagonal of the quadrilateral: the program selects the smallest diagonal path and visualizes the edges with the smallest distance between RAO, including the specified commonality parameters of OMPM and OTPM and their location along river-beds. In the generalized visualization, Figure 2.3., linear connections chains between RAO with analogous or similar characteristics are shown.

As a result of the laboratory research, certain patterns in the RAO correlations with similar characteristics were revealed, taking into account the edge connections modifiers properties under given conditions.

Thus, depending on the given conditions, the edge connections visualization combination changes, displaying informative data on the linear edge connections systems formation between anchor points on scalable satellite maps.

An example clearly demonstrates the edge connections system between the reference objects and linear connections with the modifiers of the same type, that allows to formulate conclusions with respect to the settlement model within the certain territory boundaries and the development period, the formation dynamics, RAO functioning and development in this territory, but, in this case, the most important is the coordination vector definition of RAO linear connections and intervals dynamics between them. These data allow to simulate the possible reference points location coordination in the edge connections constructed model. That may contribute to the unknown RAO localization or the definition / refinement of the uncertain reference points parameters in the edge connections system in the future. The proposed method makes it possible to predict the new and previously unknown objects locations, the *planography* of which can be completely leveled in the natural landscape during agricultural activities or other natural or man-made environmental impacts.

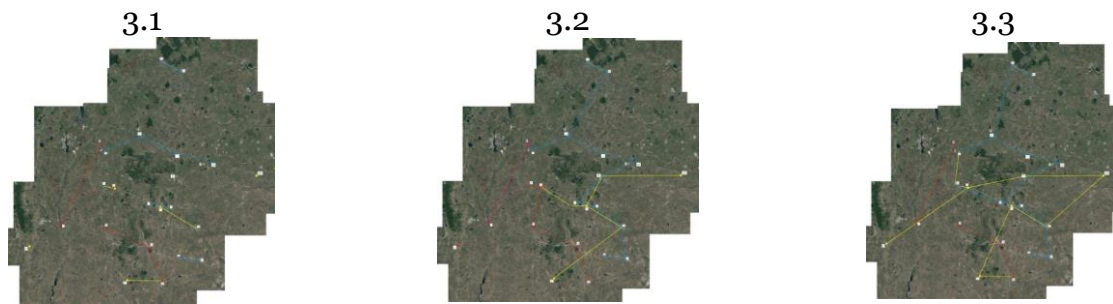


Figure 3. The edge connections visualization process between RAO typomorphological groups using stabilized settlements of the Southern Urals of the Bronze Age as a case study.

3.1. Edge connections visualization between RAO in the river-beds system without taking into account modifiers

3.2. Edge connections visualization between RAO taking into account only modifiers

3.3. Hybridization of the RAO edge connections visualization results for all specified conditions and parameters

In Figure 3 red, pink and yellow lines indicate the "Sintashta group" stabilized settlements connections, of various morphotypes, and the blue line shows the "Petrovsky group" stabilized settlements linear connections, presumably of a later period of functioning. A noticeable difference between the RAO localization in these groups is their concentration on a certain territory and the distances between objects segments.

5. Implementation results

As described in approbation, one of the main study practical results is the possibility to use this scientific visualization method in obtaining objective results in laboratory conditions of archaeological objects studying systems in the Southern Urals vast territory, namely the territories where Bronze Age stabilized settlements ruins or traces are located.

In the development of the South Ural system of the fortified settlements formation study hypothesis, there are certain gaps in the proof substantiation of all system elements integrity, as well as in determining the connections, factors, processes and other settlement system formation aspects. [7, pp. 7-29].

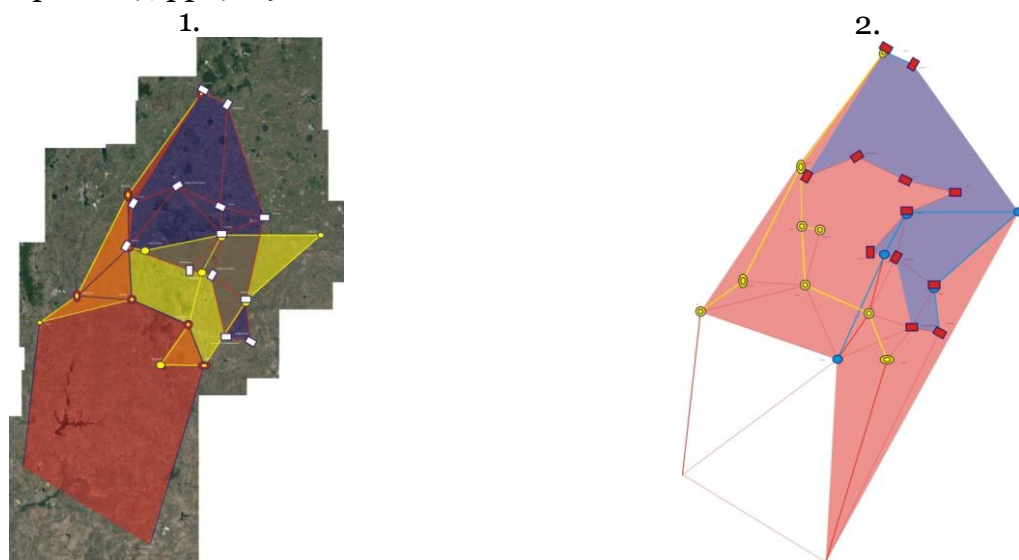


Fig. 4. Localized areas visualization by RAO type and morphological characteristics

4.1. Areas visualization on 3 RAO layers with layer stacking on a satellite map

4.2. Areas visualization along the boundaries of one of the RAO layers in a diagram form

The use of this method was necessary to evaluate and compare the obtained data with the archaeology data. It was necessary to find possible connections with similar settlement systems in adjacent and non-adjacent territories, or to find a possible reason for the lack of connections, where there are none.

In Figure 4 the edge connections layers visualization along the triangulation grid is supplemented: edge connections bordering areas obtained during experiments are highlighted in color. These diagrams show linear connections of stabilized settlements local groups, forming regions territorial locations according to the RAO characteristics.

The implementation result was an interactive scheme project with RAO advanced parametric and informative data with the possibility of this scheme layer stacking on a scalable satellite map (Fig. 5).

The software utility "GCRAO-1.0" ("Grid cartograms of reference archaeological objects. Version 1.0), designed for binding to satellite maps, as of this writing, is under development stage.

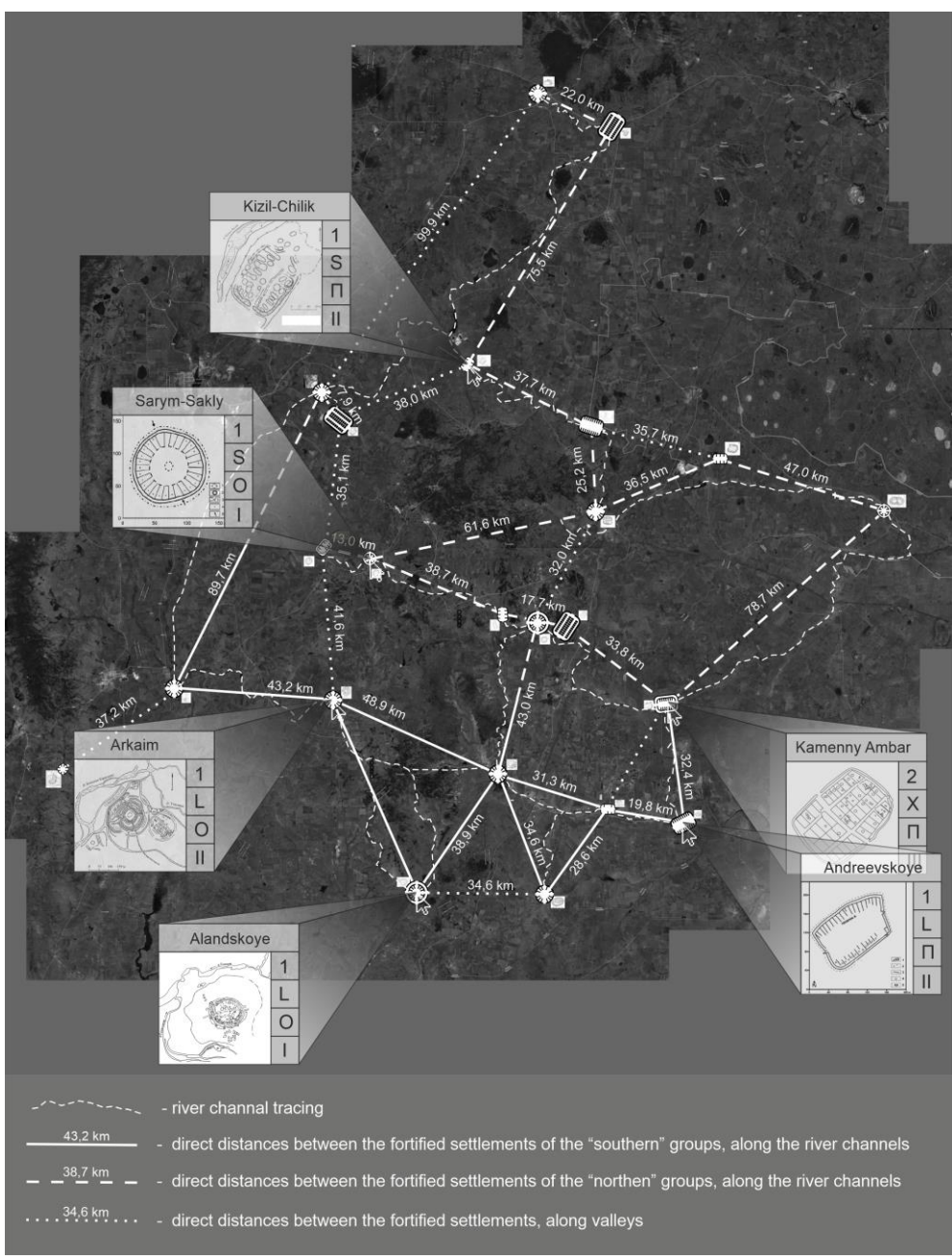


Fig. 5. Implementation result: an interactive scheme project on a satellite map.

6. Conclusion

At this stage of the study, a method that allows expanding the research possibilities in the geodata visualization field on example of fixing archaeological objects on satellite maps has been tested.

With the help of this method the linear connections distance parameters between the binding objects – RAO are most accurately determined and fixed, and the edge connections number and parameters are determined as well.

The proposed method allows:

- to check the nodal points connections;
- to determine the territorial frame linear-typological connections;
- to establish the shortest connections between RAO most accurately;
- to create a scalable polygonal grid for binding to satellite maps;
- to predict the RAO location in the binding system to the reference points.

Graphical information display on an interactive diagram provides an exhaustive amount of "single window" visual informative data with increasing the information visualization capabilities about anchor objects and navigation data.

This method was first put for the analysis and research of archaeological complexes and systems. The proposed method possibilities make it possible to widely use the developed schemes in satellite navigation and specialized applications for working with geodata. The approach given in the article can be applied to any areas and spheres of activity for static objects localization on the earth surface using the field of architecture and urban planing, historical geology, volcanology, geology of minerals, some areas of geography as a case study, etc.

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