Fresh approaches to Earth surface modeling

N S Kopylova¹, I P Starikov²

¹ St. Petersburg Mining University, 2, 21st Line of VO, St. Petersburg, 199106, Russia
² Academy of Military and Space after A.F. Mozhaisky, 13, Zhdanovskaya Str., St. Petersburg, 197198

E-mail: ans_natasha@mail.ru

Abstract. The paper considers modelling of the surface when fixing objects in the geocentric coordinate systems in the course of GLONASS satellite system development. The authors revealed new approaches to presentation of geographical data to a user, transformation of map properties and the leading role of ERS (Earth remote sensing) as a source of mapping information; change of scientific paradigms aimed at improvement of high-accuracy cartographic objects representation in the plane.

1. Introduction
Dynamic development and adoption of satellite technologies in all spheres of human life and activities predetermined the new stages of development of many branches of industry and practice. Cartography as technical service of scientific knowledge directly depends on the velocity and trends of development of space industry branch. Global high-accuracy positioning resulted in development of a high-accuracy geocentric coordinate system in solving a wide range of global and local mapping tasks, while global ERS from the space leads to the possibility of direct use of ERS data by a GNSS consumer. These facts predetermined the search for alternative means and techniques of high-accuracy object mapping based on the new research and development projects.

2. Materials and methods
The Decree of the Government of the Russian Federation [1] established the following State coordinate systems:
- the geodetic system of 2011 (GSK-2011) to be used for geodesic and cartographic works, established and distributed using the State geodesic network;
- the general Earth geocentric coordinate system “Earth parameters of 1990” (PS-90.11) to be used for geodetic support of orbital flights, navigation management and execution of geodetic and cartographic works for defense purposes, established and distributed using the Space geodesic network and the State geodesic network.

It was also established that the geodesic reference coordinate system of 1995 (SK-95), introduced by the Decree of the Government of the Russian Federation dated July 28, 2000, No.568 “On establishing the Uniform state coordinate systems” as the Uniform State Coordinate System and the Uniform Reference coordinate system of 1942 (SK-42), introduced by the Decree of the Council of
Ministers of the USSR on April 7, 1946, No.760 “On introduction of the Uniform reference coordinate and elevations system in the territory of the USSR”, will be applied until January 1, 2021 for geodesic and cartographic works performance with regard to the materials (documents) generated using them.

The 3D objects (3DO) can be described in the form of a digital data set in the geocentric coordinate systems while the actual earth surface is displayed in the form of the digital surface [2]. In accordance with Federal Law No.431-FZ [3], the basic 3D objects include: national and local motor roads; public railway tracks and railroad stations; moorings and seaports; aerodromes and airports; buildings and constructions; settlements; wooden terrains; specially protected natural areas; used restricted zones; land plots; surface water bodies and maritime zones of home jurisdiction of the Russian Federation and World Ocean water area.

As far back as the first half of the 20th century, M.S. Molodensky stated that the geodetic tasks including those for determination of the object coordinates could be solved on the physical surface of the Earth omitting reduction to geoid and spheroid [4].

M.M. Mashimov suggested using the actual Earth surface (Earth area) without additional transition to the reference surface that can be represented by the surface of spheroid of revolution or triaxial spheroid and actual surfaces projection can be used for mapping [2].

The long-range scientific task is finding new alternative types of cartographic projections of real surfaces in geocentric coordinates.

Transition is required from three-dimensional (geocentric) coordinates to surface coordinates in the plane for display of surface points in the plane. The point position in space in geocentric coordinates system is determined by the values of coordinates \(X, Y, Z\). The center of this spheroid coincides with the beginning of the geocentric system while the plane of the principal meridian coincides with the \(XOZ\) plane of the system [5], in case of a reduction of measurement results to the surface of a general Earth spheroid.

Such surface handling suggests using the improved cartographic projections to obtain high-accuracy metric measurement results [2].

The actual surface can be reconstructed upon 3D modeling using various means of information representation on natural objects and processes in the form of numeric data (physical surface) [6].

Adequate modeling of continuous Earth surface requires the infinity of points. But there are also the methods of digital continuous surfaces representation using the data finite number, for instance, upon digital surface modeling (DSM), including digital terrain modeling (DTM). Usually DTM notion is connected with a local network, frequently with a network of ordered elevations. Resolution is the most important parameter which is horizontal (the distance between the network adjacent points) and vertical. The resolution value depends on the scale and is characterized by the accuracy of heighting and other DTM indices [7].

The triangular irregular network \(TIN\) model (Triangulation Irregular Network) is often used. The irregular point network in \(TIN\)-models can be located in accordance with the territory characteristics (more points in high relief areas, less – in a flat terrain). Such irregular sampling highlights the surface pattern better. More complicated polygons, which can be divided into triangles, are sometimes used as tiles. Delaunay method of non-crossing triangles network construction is usually used for forming triangles. Three points form a Delaunay triangle by definition when and only when the circle passing through them does not contain any points not pertaining to such triangle, ensured by construction of Thiessen polygons. The triangles have vertexes (points) with coordinates \((X, Y, Z)\) and their network, and the surface formed by them is continuous.

DSM formation handles the problem of global mapping locally; data of the physical surface of considerable dimensions are practically designed using special mathematical methods and laws.

Recording of the mapping objects position in DMS is connected with their information provision in a digital form (catalogues) such as DSM, as well as digital maps. Bitmap geographic data representation is frequently used together with vector representation by means of remote sensing data enabling one to ensure the uniform metrically proved globe coverage. The above-mentioned fact offers exciting possibilities for all-aspect display of up-to-date geodata in various multi-scale representations.
erases the barriers between the limiting possibilities of cartographic projections and enables one to view a nonorthogonal metrically determined three-(3D) or four(4D)-dimensional image. The use of such materials is often connected with the issue of “big data” and application of cloud techniques [13,14] for data processing and transfer to the consumer, as well as results in displacement of cartographic load by geographic load. This happens because the space is perceived through the actually existing geographical systems (forest, swampiness, clearance, building, etc.) and not through their models. Situational load representation in digital images is not connected with significance; the value of image symbolics becomes irrelevant. Various logic-mathematical, calculation and other operations using such cartographic images prove to be rather challenging as working in GIS, ACS and other systems implies formalization, standardization, classification of the existing real-world objects [11].

Transformation of bitmap data (pixels) into digital data in the spatial frame of references is the task of the new neogeography trend; and usage of special mathematical laws is not obligatory for objects display within this trend.

The use of artificial intellect and neural networks is one of the attempts of solving an issue of computer-aided recognition of mapping information by bitmap images in cartography [15]. A neural network can be trained by decoded image objects in case the geographic terrain pattern is identical each time, which is a priori impossible when handling the real geographical space. That is why, no megamachine can replace the mapper brains, though it can in turn assist in optimization of a number of mapping processes. Besides, information in the map connected with historical and up-to-date specificity of territory development – objects toponymics – can not be represented in automatic mode. Transformation of map characteristics to simplification of its qualitative and quantitative content is observed.

Generally, the approaches to display of planimetric and location details in the map undergo significant changes, development of satellite techniques predetermines studying and development of new scientific and technical projects in the form of cartographic projections.

3. Resume

A number of principal conclusions can be made in connection with the above-stated information:

1. The dominant source of cartographic works includes remote sensing data (RSD) and digital maps with step-by-step replacement of analog maps and other cartographic works.
2. Map properties are transformed in connection with the change of formal data representation:
   - symbolics of the image was replaced by visual panoramic 3D, 4D-representation of real-world data;
   - systemacity of data presentation is connected not with the rules of objects cartographic representation in the map but with the existing real geographical terrain pattern;
   - map generalization is executed in an automatic mode due to a multi-scale representation of digital cartographic works against the background of the detailed meaningful manual process of generalization for all analog map succeeding scales. High-quality automation of this process is very complicated as it is connected with comprehension of information representation from the point of view of territory geographic features and the process does not always provide the true terrain pattern;
   - the mathematical law of digital cartographic works generation is connected with the prospective representation of 3D and 4D data without the use of the precise range of standard scales and cartographic projections of limiting character. Coordinate fixation of the spatial geographical pattern provides high-accuracy data on the objects (mainly by bitmap images), but does not enable one to quickly solve various calculation and analytical tasks as well as implement overlay operations. The map is a meaningful result of work of a geographer, a mapper, a geoinformation scientist and a programmer. Unfortunately, the modern erroneous idea of a map as of an artifact of only a geoinformation scientist and a programmer as a result of computing is completely wrong, and the source map loses its informative value. High-accuracy coordinate (geocentric) requirements for the
objects representation determine the scientific basis of improvement of cartographic projections generation and application procedures.

3. Neogeography as a new approach to development of geographical data representation for the user is based on integration of advanced information technologies and ERS. The cartographic information sources provided mainly in bitmap form evolve into the “big data” structure and “big data” efficient processing and obtainment are connected with the development of the Internet and Web technologies, thus setting the mandatory requirements for systems existence (for instance, navigation systems) and determining their performance capabilities. Limitations and locality (in case of removal to the territories of base stations, limited energy-saving system resources, etc.) of such data use and processing in space and time are obvious. Certainly, one cannot speak of inclusiveness and common usage of data.

4. Up-to-date methods and means of geographical data representation offer alternative information representation against the background of obligatory existing maps of digital and analog representation for solving a wide range of problems: domestic, scientific, industrial and state problems. The technical revolution of data representation specified the new vector of mathematic representation of cartographic data in the form of new cartographic projections search, the latest executed in the 20th century.

4. Conclusion

There is the tendency to “refract primary cartographic knowledge” from the prospect of the primary sources of geographical information – ERS data and etc., but it is completely non-promising and leads to the loss of full, complex and comprehensive display of geographical space, which is conveyed by a “geographical map”. ERS is the new primary prospective information source about the terrain and the vector data obtained in various geoservices (Google Maps, 2TomTom, Here Maps, OpenStreetMap.org and etc.) [16] involving Web technologies [17,18]. They obtained the new vector in cartography connected with neogeography [19], which is determined based on such source. The present-day consumer often uses only the information provided by the services without final qualitative map analysis being the focus of direct interest of departmental structures and governmental agencies.

That is why cartography involvement into such high technologies sphere as science suggests not only mastering of the new means, methods and techniques of initial environmental information display, but also the change of scientific paradigms of mathematical earth surface modeling in the plane by means of new methods for modern high-accuracy mapping.

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