Coordinate support of geographic information space

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Abstract. Today, the transition of mankind to the information society era is becoming an important state problem. Coordinate support of the space around us, timely and high-quality recording of the changes taking place in it, a thorough results' analysis and reflection is ensured by geodetic technologies, and their innovative development, continuous improvement ultimately contribute to the successful and dynamic development of modern society. However, today we are witnessing contradictions and inconsistencies between the technological geodetic processes and the regulatory documents governing the methodology for performing geodetic work to support various sectors of the economy. To everyone’s surprise, the existing instructions have not been revised since the last century and do not include the use of modern digital technologies for geodetic activities. This methodology should include a global process for the search, collection, storage, processing, including analysis and distribution, and as a result, the information provision concerning the objects and processes to the end user.

Introduction
The modern society development is inextricably linked with improving the population life quality, which is due to the living conditions’ improvement, and they, in turn, depend on the effective functioning of administrative, economic and social management resources, namely:
- urban development;
- creation of conditions for the production development;
- regulation of the city planning and development;
- improvement and engineering arrangement of the city;
- housing and municipal services reform.

These conditions are directly related to the information space development.

The information technology development has led scientists to separately isolate and study the information space. Information space is commonly understood as the totality of objects that enter into information interaction with each other, as well as the technologies themselves that provide this interaction.

The ability to work with spatial information using computer technology is inextricably linked with the geography and computer science development, which determined the emergence of a new science, the object of study of which was the geographical information systems.

Gradually, with the help of geographic information systems, electronic and digital maps, various databases and geodatabases, three-dimensional models of the surrounding space were created. Thus, the geographic information space started being formed.
Main part
Geoinformation space is a combination of geodata, geoinformation and geoinformation models formed on their basis, presented in two-dimensional and three-dimensional forms, covering ground, underground and above-ground spaces, interconnected by a single coordinate base.

By geodata we mean the information about a geographic location stored in a format that can be used in geographic information systems. The organization of geographic information space is based on a layered description in the spatial objects’ database. A layer is a collection of features used to display the geographic datasets. In this case, all information should be presented, stored and combined with the existing or predicted data. It can be either very simple or more complex, including the models that mimic the real world, combining a variety of different information layers.

The layers of geographic information space include the layers about hydrography, terrain, settlements, road network, etc., which ultimately form a multilayer electronic map. Such a map gives an opportunity to store a large volume of geodata.

Spatial data can be discrete, continuous and area-generalized phenomena. For discrete point, linear and areal objects, their actual location on the ground should always be determined. The point objects, for example, have one coordinate pair, lines (roads, pipelines and other engineering objects) and are represented by a series of coordinate pairs, and the areal objects are outlined with borders in the form of closed polygons. Continuous phenomena, in contrast to the discrete ones, describe not separate geodata, but the territory of the same type of information (temperature and precipitation region). The phenomena generalized by the area reflect the generalized characteristic or the individual objects’ concentration within a given area (the number of schools in a specified district of the city).

As we can see, spatial information is different in its structure and theme, but at the same time it should be integrated in geo-space on a single spatial-temporal basis. This integration should be based on uniform principles and satisfy the common requirements, excluding disunity and discrepancies. Localization and coordinate support, detailed measuring and graphical information, without which the geo-space cannot function, are carried out using the geodesy methods, or rather an interdisciplinary geodesy complex:
- geodesy;
- cartography;
- remote sensing;
- geo-informatics.

Thus, the geographic information space is a complex organizational and technical system in which the created spatial connections and relations play a major role.

Modern technological advances about the field of geodesy, the widespread use of various measurement methods with the possibility of modeling them, the ease of use make it possible to say that geodesy has significantly expanded the boundaries of its field of action, being introduced into various areas of the national economy. Any spatial problem is solved only by the geodetic methods, regardless of industry.

Conceptually, the geographic information space formation can be stated as follows. Spatial-temporal changes are recorded by geodesy, taking the form of geodata. On the basis of their quantitative and qualitative characteristics, the development patterns of the observed objects, processes or phenomena are highlighted, this information is evaluated and a forecast is given on further development. The result is a space model that combines geodetic and thematic information. And this process is constant, it cannot be stopped and requires constant modernization and modification.

The programs included in the methodology for the geographic information space formation can be the simplest, for example, creating a topographic plan of the area using tachometric surveys, or more complex, the results of which can be simulated by imitating the real world around us. The key issue is the choice of the appropriate program to get the necessary and the right quality information. It is necessary to clearly understand what initial information we possess and which as a result we obtain or
model; what are the criteria for evaluating the objectivity and need for information; how it will be placed in a particular layer or organize the new layers of information.

Localization and coordinate support of the proposed methodology should be carried out using the satellite geodesy methods, the regulatory requirements for which are fixed in the relevant documents [1] and [2]. All geodata layers should be created in a single coordinate system. Otherwise, it will be impossible to combine them and juxtapose in a single space. In the standard database, there are no problems with combining data. Another thing is if information is collected from various sources. There are questions about the definition of cartographic projection and coordinate system, the permissible degree of the areas and line lengths’ distortion. The appropriate recommendations’ development will avoid such difficulties.

On the Earth’s surface, the points position is determined in various coordinate systems. The main document regulating the application in their territories along with the state coordinate system of the LCS (local coordinate system) is [4].

One of the fastest and fairly accurate ways to obtain and recalculate from satellite-derived data to the local coordinate system is the method using GPS / Glonass equipment.

To date, there are the following ways of recounting:
- Molodensky transform;
- Helmert transform;
- Molodensky-Badekas transform.

Various manufacturers of modern satellite equipment have converted the received (calculated) coordinates in the WGS 84 system to the local coordinate system (LCS).

Today, one of the fundamental documents for observation and conversion to the local coordinate system are [1] and [2].

To go from one coordinate system to another (local) using GPS measurements, we need:
- the presence of at least 4 points with known planning and elevation coordinates (depending on the manufacturer and software features);
- strong points should be evenly spaced along the border of the work area.
- items should be of the same precision.

The following factors influence the accuracy of determining coordinates by satellite methods:
- distance from the base (points with known coordinates) to the rover (coordinate point should be obtained);
- the number of satellites used for the observation simultaneously located in the observation zone;
- geometrical arrangement of satellites relative to the observer;
- station observation time.

To get a better result, i.e. in order to exclude the measurement errors’ influence and to minimize them, it is recommended to perform the observations in the “fast statics – statics” mode.

Single-frequency receivers are not recommended for use on baselines of more than 20 km.

Today, when making the measurements with a rover receiver in the “static” mode, it is recommended to make the observations for at least 1 hour, according to clause 5.5.3.1 [2].

If the “fast static” mode is used in the production of shooting, then the observation time with a rover receiver is recommended for 15-20 minutes.

The instructions for the development of the shooting rationale and the shooting of the situation and terrain using global navigation satellite systems and GPS provide temporary recommendations for observing in the “fast statics” mode (Table 1).

| The number of satellites observed | Observation duration |
|----------------------------------|----------------------|
| 4                                | up to 20 min         |
| 5                                | 10-20 min            |
| 6 and more                       | 5-10 min             |

Table 1. Recommended observation time in the “fast statics” mode.
However, when shooting using various methods and taking into account the instruction requirements, it is nevertheless necessary to adhere to the recommendations contained in the documentation for the operation of the satellite equipment used during operation.

Let us consider several ways to observe the data receipt for conversion to a local coordinate system. We set up the base station at point C (it is necessary to start the first one) (Fig. 1.). Then, with a rover (portable) receiver, make observations at the points with known coordinates and heights (points 1-5) and at points which coordinates we want to get in the local coordinate system (A and B). Clause 3 shows a satellite backlash diagram for determining the coordinates of a point.

As mentioned above, the satellite equipment manufacturer’s program itself will recalculate the transition parameters to the local coordinate system.

Another way is that we install the base receiver at the point C with unknown coordinates. We turn on the base station first and make the observations at the points 1-4 with known coordinates (local coordinate system), and also coordinate the points A and B that we want to get in the local coordinate system. As a result of processing (conversion in LCS), the base station C, as well as the points A and B that we wanted to get in the local coordinate system, will be automatically converted to the desired coordinate system.

It should be noted that if the software on a PC or field controller does the conversion from one coordinate system to another, then it calculates the transition parameters. For further work (in order not to perform the above recounting methods), it is necessary to save in the program, while creating the coordinate system.

It should be noted that the base station always turns on first and turns off last, otherwise, the results processing is impossible.

One of the main drawbacks of the transition from one coordinate system to another is the destruction of strong points with known coordinates and heights. One solution to this problem is to monitor the points’ safety, as well as to explore the possibility of using the points of different accuracy and at different distances from the base station.

**Figure 1.** The satellite data conversion scheme to the local coordinate system (the base coordinates are known):
- the points with known coordinates in the LCS (rover points 1, 2, 3, 4, 5);
- the points which coordinates should be determined in the LCS (roving points A and B);
- the point C with known (unknown) coordinates in the LCS (base station);
- the satellite.

Summary
As a result, we obtain the information about the space around us (capital buildings, engineering structures, phenomena, processes and conditions) in a single electronic cartographic basis, the so-called electronic set of spatial data: systematized, mobile, dynamic, constantly updated. All information is an interconnected and interdependent array of natural and artificial objects of the space surrounding us, geodata about these objects and, finally, geodata information (metadata) generated by the methodology, through which the information is identified in the geographic information space.

Visualization will require the additional camera's work on processing and data input, but will significantly facilitate the process of grouping them. However, choosing the colors or characters to display the areas of attention can help to manage this data.

Forecasting, planning, regulation, analysis, control should be understood in this aspect management.

Constant updating is considered a necessary condition for the geo-space functioning, and the requirements for its frequency should be established. Legislation, this frequency is at least once every ten years [3]. However, in the proposed methodology, in the process of which information about space objects is collected not only of an informational nature, but also of a technical condition, physical property. As practice shows, this kind of information can change not only during the decade or one year, but also during the day. Another important reason for increasing the frequency of updates can serve as the purpose (end user) of geodata. For example, the data for the cadastre or for providing urban planning and architectural activities, for spatial analysis or forecasting modeling, for administrative and law enforcement organizations or the ordinary users. Of course, the accuracy and completeness of such information will be different, which in fact will allow the authors to develop the appropriate recommendations.

The cost of performing geodetic works in the view of the work complexity and the principle of continuous execution often overlaps the economic effect laid down in this initiative. Sometimes the cost of work per 1 sq. km on average is about 5 million rubles. It is easy to calculate how much it will cost to carry out these works on the territory of the Rostov-on-Don city or the entire Rostov region.

Moreover, simultaneous work is not possible. Even one period of a complex of geodetic works can take several years. In this regard, the application of a risk-based approach to the work implementation, which consists in increased attention in the areas where constant monitoring is required, and reduction or minimization where increased attention is not required, will be justified. Such an approach and the use of modern spatial and digital technologies will make it possible to understand where the full range of geodetic works will give the best economic effect, and where local shooting will be sufficient. The result of the research can be formulated as follows: labor and financial resources are distributed evenly.

References
[1] GOST 32453-2017 Global Navigation Satellite System. Coordinate systems. Methods of transformation of coordinates of defined points (as Amended).
[2] GKINP (ONTA) -02-262-Instructions for the development of shooting justification and shooting the situation and terrain using global navigation satellite systems and GPS.
[3] Federal Law of December 30, 2015 No. 431-FZ (as amended on August 3, 2018) “On Geodesy, Cartography, and Spatial Data and on Amending Certain Legislative Acts of the Russian Federation”.
[5] Government Decree from 03.03.2007g. No. 139 “On approval of the rules for establishing local coordinate systems”.