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PRINCIPLES OF GNSS

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Abstract: *The most direct method for obtaining spatial information in digital form is the use of data from Polish geodetic measurements obtained from the global satellite location identification system. Global location systems GNSS belong to non-photographic recording systems of the group of remote methods for Earth measurements. The most popular system is GPS (Global Positioning System), designed and controlled by the US Department of Defense.*

Key words: *receiver, coordinates, accuracy, location, monitoring*

GNSS technology and complementary GIS become the basis of modern mapping design and production. With the astonishingly rapid advancement of information technology, it can be assumed that GNSS in the near future will be the most common and unique method for collecting cartographic information. GNSS consists of 27 NAVSTAR (Navigation System with Time and Ranging) satellites orbiting certain orbits around the Earth (Fig. 1) [1].

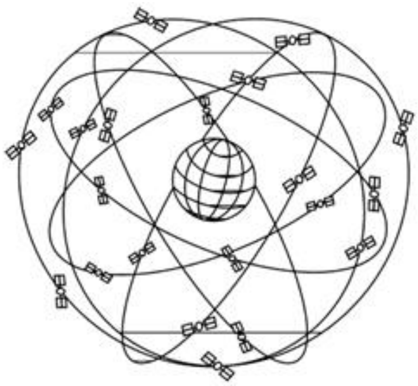

Fig. 1 Configuration of GPS satellites

The orbits of the satellites are at an altitude of 20200 km from Earth. They are calculated in such a way that at least four satellites are connected to any point on the Earth's surface. The positions of satellites are known for high accuracy and defined in a global geocentric coordinate system. The current system used for GNSS is designed in the US, although the European Space Agency also has a similar system called Galileo, and the Russian version of GNSS called the GNASS (GLYObalynaya NAvigation Sputnikova System) offers similar coverage and accuracy. For military safety reasons, the U.S. government regulates the resolution of GNSS satellite transmissions intended for the public. For civilian purposes, the first code C/A (Coarse / Acquisition - code) is available, and the second P – code (Precision - code) is reserved for the US military services and other authorized users.

Initially, practical accuracy is within 3 to 30 meters and is not enough to collect accurate map data. Since then, the manufacturers of these tools have continuously improved the design and accuracy of coordinate definitions. Today, geodetic GNSS receivers are theoretically accurate about a centimeter for x and y coordinates and a few centimeters per h.

Modern GNSS receivers are as small as cell phones (Fig. 2), have a simple LCD (Licuid Cristal Display) screen similar to electronic calculators and a simple input keyboard. These tools can be programmed to record and display the exact position of the station, the speed and direction of the travelling user and the design time of arrival at some points along a selected path. With the continuous improvement of geoinformation technologies, it is already proposed to combine appliances consisting of an external laptop with a GIS solution and gNSS component. This allows topographical measurements to be carried out entirely digitally and for objects to be entered on site.

Fig. 2 GNSS receiver

The system can quickly and accurately determine the spatial position (latitude, longitude and height or spatial decartes coordinates) of points on or above the Earth's surface. The accuracy achieved is centimeter for geodetic applications if two receivers are used simultaneously. This option reduces the price of the special data collected for the cards. At the same time, it increases the accuracy of mapping information.

A major problem in the use of GNSS to collect data are trees and steep terrain, which make it difficult to receive signals from satellites. The use of GNSS in aircraft and ship navigation and some vehicles is the most widespread and rapid.

Car manufacturers, taxi and transport companies install GNSS to monitor cars individually and provide secure control for drivers. Despite these current limitations, the use of GNSS in cartography is also increasing. The latest GNSS models with very high accuracy in coordinate definitions allow for the execution of topographical pictures, which are the basis of all medium-scale and small-scale maps. Among the many applications of GNSS is also to check the locations of the state border lines.

There are numerous applications of GNSS in GIS in the management of regional and local resources and control activities in certain areas. An example of the sharing of the two technologies is monitoring global changes over a long period of time, such as measuring deformations of the Earth's crust, volcanic ascent, movement of tectonic plates and earth rotation. GNSS provides the powerful geodetic tool for measuring and studying these processes.

Mathematical model for determining locations with GNSS

Global navigation satellite systems are means that determine coordinates of earth points based on the reception of special satellite transmissions. GNSS operates according to the following simple principle. Satellites constantly transmit coded radio signals that indicate their exact location and time in space [2].

Take into account the time for which the signal travels from the satellite (Fig. 1) to the receiver (Fig. 2) placed on a point on the ground.

Figure 3 shows the determination of the position of the ground point by four measured distances R1, R2, R3 and R4.

The location of the receiver (earth point) shall be determined by triangulation based on the mutual positions of at least four satellites. The exact spatial position of the earth's points is determined by the descartes coordinates X, Y, Z, by the measured distance Earth – Satellite:

$$R_i^j(t) = \sqrt{\left(X^i(t) - X_j\right)^2 + \left(Y^i(t) - Y_j\right)^2 + \left(Z^i(t) - Z_j\right)^2} \quad (1)$$

where R is pseudo-distance, i=1,2,3 and 4 is an indication of the satellite and j at the ground point.

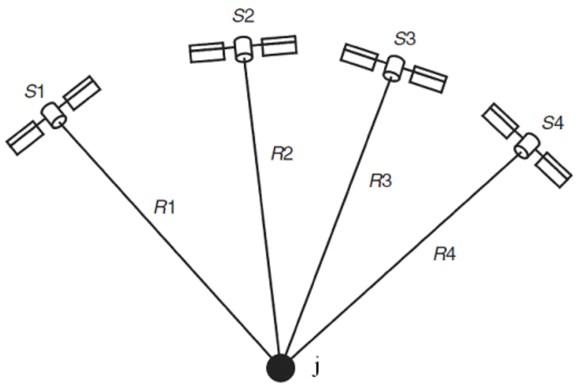

Fig. 3 Absolute positioning

The coordinates of the receiver placed on the determinable ground point shall be calculated by the three known locations of the satellites and the measured distances in a common coordinate system. However, four satellites are needed due to the lack of synchronisation between the satellite's clocks and the receiver. For this reason, the fourth unknown Δd – repair of the clock of the GNSS receiver appears. By Δδ, correct the pseudo-distance R:

(2) $$\rho_i^j(t) = R_i^j(t) + \Delta\delta_i^j(t)$$

The calculated spatial coordinates X, Y, Z of the Earth point can be transformed into projection coordinates x and y or ellipsoid (geographical) coordinates j and λ.

Most often, data from direct measurements obtained with GNSS geodetic receivers are used to transform the resulting graphic in the required national (local) coordinate system. The GNSS coordinate system is the WGS-84 global geodetic coordinate system, which is geocentric (the beginning of the coordinate system is in the mass center of the Earth) [3].

When GNSS is used, the coordinates of the ground points are obtained in the same system with high accuracy. To move to the local coordinate system, it is necessary to perform some transformations that we have already mentioned. For this purpose, the coordinates of common points of the model identified in the two coordinate systems, e.g. "Bulgarian Geodetic System 2005" (national coordinate system used in our country) and "WGS 84" are used. Geodetic points (mainly high-end triangulal points) determined by GNSS are defined by the coordinates X, Y and Z and are in the WGS-84 system. Their assistance shall determine the coordinates of all other model points in the relevant national coordinate system, which is usually assigned to the reference ellipsoid adopted in the country.

Differential GNSS

The differential GPS -DGPS method uses two receivers (Fig. 4). One receiver is stationary (also called a reference station) and the other is mobile (rover station) and is used to collect data by crawling different points from the ground. Measurements shall be carried out at the reference station over a long period of time, ensuring that its spatial position is accurately determined. By comparing the exact location of the reference station with the location of the rover station standing at any other point, an assessment of the accuracy of the measurements shall be ensured. This method of processing measurements, called the Smallest Square Method (MNMK), makes it possible to adjust the measurements made at each point. This improves accuracy in determining the coordinates of unknown ground points.

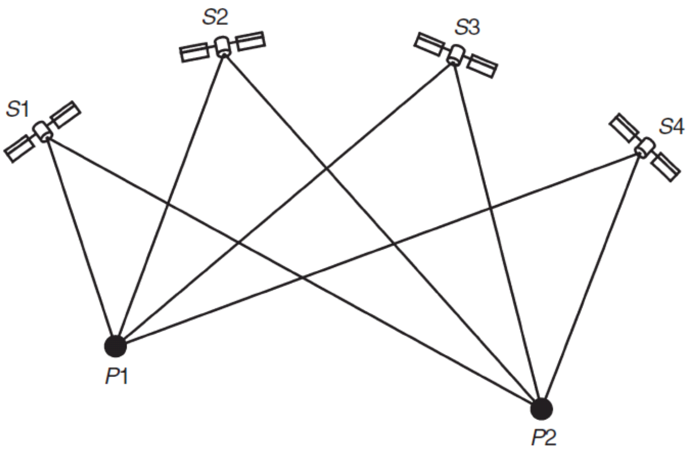

Fig. 4 Relative positioning

Conclusion

In many ways, GNSS has revolutionised the collection of primary data, especially since differential GNSS stations have been developed, with which the accuracy of measurements has significantly increased. GNSS methods are also used after drawing up the map and creating the GIS database. To match the reality map, changes and corrections must often be made to update the database. It is excessively expensive to perform a new geodetic filming or flying and mapping of the area. With the help of GNSS measurements, the coordinates of only additional points to be entered into the database can be determined [4].

GNSS and related technologies will play an increasingly important role in collecting cartographic data, and the accuracy of their satellite-based locations will also continuously increase.

The disadvantage of DGPS observations lies in the fact that the two receivers have to work simultaneously. In many countries, there is a tendency to base a network of permanent stations that offer DGPS correction to the mobile station. In Bulgaria, a network of GNSS base stations of various operators is also built, which constantly receive signals from satellite systems GPS, GLONASS, GALILEO and COMPASS. For example, the NAVITEQ operator builds and maintains its own infrastructure network of 25 permanent GNSS base stations across the country, on the basis of which it provides high-precision location identification services.

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