Using Satellite Measurements by Means of Rompos Within a Geographic Information System

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Summary This article presents the use of satellite measurements within a Geographic Informatic System with the inherent advantages, with the steps to be taken and with concrete examples.

Using satellite measurements by means of **ROMPOS** within a Geographic Informatic System is a necessity, as well as a current and future issue, and within this article one has described a means of integrating measurements with typical and suggestive examples.

One presents comparative studies of measurement methods, cinematic stop&go and RTK and the GPS differential on the one hand, and **ROMPOS** on the other hand, as well as their use within a geographic informatic system.

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1. INTRODUCTION

The current tendency to accumulate as much information as possible for people comes along with new discoveries in the field of GIS inter-operational land measurements, as the advantage of their technological and computer-based character opens wide perspectives for a better understanding of the environment and the phenomena within it.

The evolution of specialized GNSS technology, starting from its initial aspects and up to current geodesy, based on the automatic processing of satellite data, reflects once more man's wish to impose its domination over the concepts of time and space and to use science in order to bring about the progress of a society it primarily represents.

It is under these circumstances that GNSS Global Positioning Systems create new tools for geodesy specialists and their profession, supplying a very large range of beneficiaries.

Among the special applications that make use of this state-of-the-art technology, one should mention the ones pertaining to the field of land surveys, agriculture, mining, air and sea navigation, and mainly land navigation: creating geodesy and cadastre networks, creating surveillance networks for areas affected by mining works and their environmental impact, monitoring instability phenomena in such areas, prediction studies for underground mining, impact studies, etc. The two systems, namely the GNSS positioning system and the GIS system interact quite well and they are largely inter-operable due mainly to the data provided by remote detection satellites and land and aerial photogrammetric devices.

Currently the global positioning system (GNSS) is being used on an increasingly larger scale also due to the spectacular progress of the products in this field.

Furthermore, technological progress entails both institutional and organizational changes, which will have a strong impact on the users of such technologies, but also on the whole community.

2. DEVELOPMENT DIRECTIONS AND TRENDS OF ROMPOS APPLICATIONS WITHIN GIS SYSTEMS

- The GNSS system will facilitate the company's access to data regarding the location and will provide useful and shared information in the activities involving GIS geographical informational systems that are used at all levels by the society we live in;

GNSS-based navigation – development directions and inter-operable character:

- Diversifying the range of applications while reducing the costs of GNSS equipment and GIS software;
- The GNSS system, combined with the GIS, will be the main tool for directing aerial, land and sea navigation;
- Extending the use of the GNSS system on the markets for land vehicles, for ITS applications – from autonomous navigation to navigation management and integration within the GIS system;
- The DGNSS system will continue to expand through the multiplication of the fixed stations that send out such data over Romania's territory;
- The GNSS system and the map-representation technology will converge towards new navigation tools– for instance ITS, electronic map systems, etc;
- Satellite communication will play a major role in GNSS and DGNSS applications – in particular in aerial and sea applications and GIS applications;
- The DGNSS system will be redefined for extended areas outside the local DGNSS system;
- There will be an increase in the use of low-cost receivers utilized for capturing data in support of GIS applications;
- There will be an increased integration of the GNSS system with other navigation systems.

GNSS based measurements

- The GNSS technology will be the most utilized one for land measurements, in particular for distances that exceed 5 km;
- The applications of GNSS measurements will become extended to engineering and cadastre, as well as agriculture, and they will all be integrated in GIS systems;
- An increase in the use of non-conventional positioning techniques;
- Fixed stations will become increasingly important – real-time post-processing and modelling;
- The internet will become increasingly involved in transmitting GNSS data, including access to fixed station data, base reduction services, etc;
- GNSS measurements will be extended to deformations-engineering structures, earthquake or volcanic areas, underground mines, agriculture, aerial, land and sea navigation, etc;

GNSS-based geodesy

- The usual estimated precision will be lower than 0.01ppm;
- GNSS geodesy will play an important part in geodynamic studies;
- The GNSS system will be used for non-positional applications such as monitoring the ionosphere and determining troposphere conditions –GNSS based meteorology;
- GNSS geodesy will be achieved using permanent support GNSS networks, as well as classical measurements of the campaign type;
- Improvements in the devices, defining the reference system (ITRS), global surveillance, (IGS), observational modelling and network design;
- All of these will require a partnership between theoreticians, researchers, government organizations and equipment producers– GNSS-based geodesy will no longer be dedicated to a single group of experts and government agencies will become more involved;

- Developing software to make data processing easier;
- There will be several networks of GNSS receivers that will operate full-time – at a global, continental, national and local scale, for various applications.

Real-time GNSS measurements are beginning to be an essential part of geodesic calculation. The RTK acronym – Real Time Kinematic, stands for kinematic measurements completed in real time. In this case the permanent station comes with a radio connection and retransmits data received from the satellites to the mobile receiver.

The mobile receiver (rover) has another radio connection in its turn and is able to receive information directly from satellites too, by means of its own antenna.

In recent years the RTK has become the most effective method for GNSS measurements due to its high precision on small areas, and is also used for similar applications that previously used total stations.

Over the last years several Real-Time methods have been introduced. One of the most complex ones, the VRS – Virtual Reference Station, uses a GNSS network to reduce systematic errors in positioning. Measurements can be completed at a centimetric precision, provided that certain factors are taken into account, such as: initialization time, number or geometry of satellites, influence of obstructions, length of bases, influence of the ionosphere and others. The reference station uses a technique that calculates corrections for systematic errors based on real time data. It presents the structure and functioning of a virtual reference station, as well as the means for integrating it in networks of permanent stations. Because of that, perhaps the most visible tendency is to continuously diversify and extend the applications based on GNSS technology.

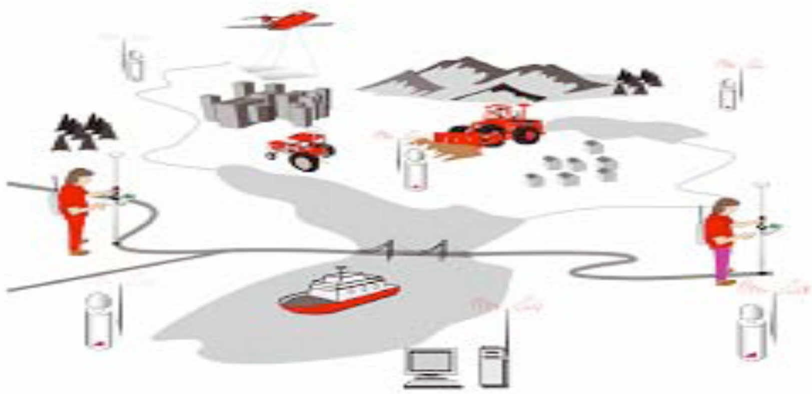

Fig. 1 Applicability of GNSS reference stations

In accordance with the tendency of developing services to a global and European level for the GNSS technology, after 1990 the GNSS system was also implemented in Romania.

For the perspective requirements of geodesy, specialists have designed and completed a National Network of Permanent GNSS Stations (RN-SGP). The increasing requirements of GNSS applications have led to the apparition and development of stations specialised in acquiring satellite data. In the beginning (1990-1999), these stations functioned in temporary mode, and reception was only meant to help solve punctual problems, as the range of extension of GNSS applications was smaller. Beginning with 1999, while preparing the assimilation of the new technologies provided by the European navigation system (Virtual Reference Station, GALILEO), permanent GNSS stations were established in Romania too, aiming to collect satellite data in full-time mode. Currently, there are over 70 permanent stations that are operating, and plans are made to increase their number.

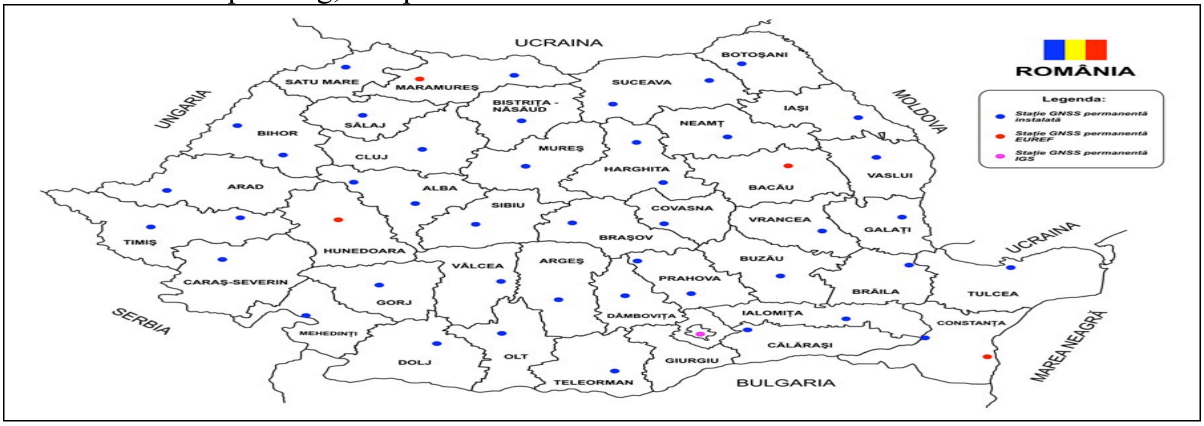

Fig. 2 National Network of Permanent GNSS Stations in Romania

The data acquired through satellite observation are provided through the VRS - Virtual Reference Station. It takes the observations transmitted by receivers, which can be operated with modern equipment for real time measurements (RTK). The runways used by the calculation algorithms within the network's server are private. The aim is to develop standardized interfaces for the software between the reference stations in the network and the mobile receivers (rovers). The concept of a virtual station involves the existence of a GNSS reference station permanently connected through data links to a control centre, where a computer records information from all the receivers and creates an active data-base of such regional corrections.

The mobile receiver interprets and uses such data as if they were provide by an actual reference station.

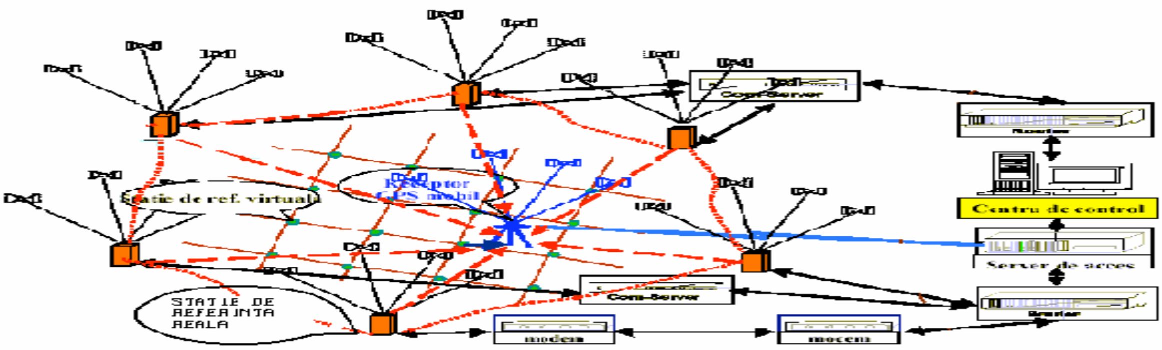

Fig. 3 The concept of a Virtual Reference Station within ROMPOS

Reference stations ensure all the required information for which precise measurements are available, with all kinds of RTK rovers, and transmits them further on through radio, phone or internet connections. Implementing the VRS concept in a functional solution of the system entails mainly the principle of connecting to the networks' server as many reference stations as possible, by means of communication links.

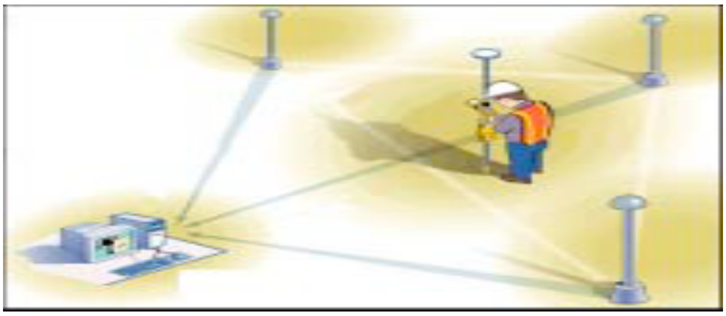

Fig. 4 Scheme of the network using ROMPOS

The GNSS rover transmits its navigation position through a standard NMEA message (National Marine Electronics Association), to the control centre operating GNSSNet. This format is available for most of the receivers.

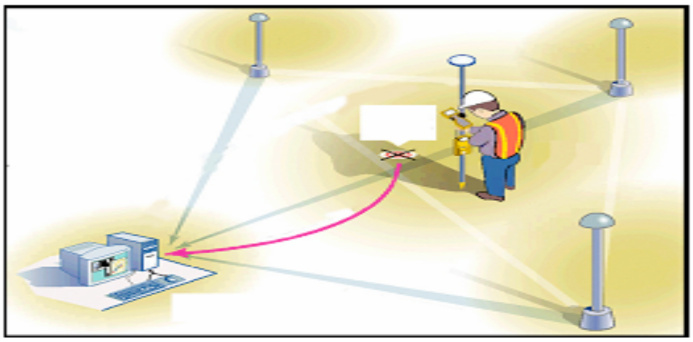

Fig. 5 Transmitting the ROMPOS message from the rover to the network's server

The control centre will record the rover's position and provide the corrected RTCM data (Radio Technical Comission for Maritime (services).
Using these data, it will process a high-precision DGNSS solution to correct its position. subsequently, the mobile station will transmit its new position to the control centre.

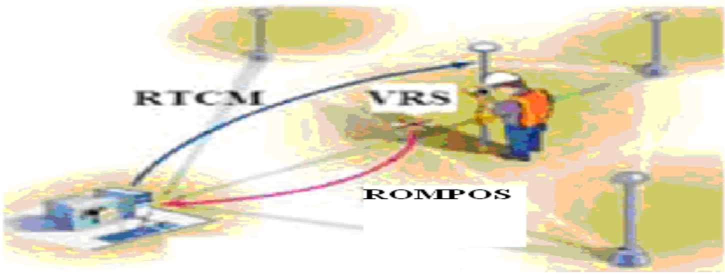

Fig. 6 Transmission flux for ROMPOS corrections

At this stage the network's server records the new corrected information. The recording rate can be selected to be between 0.05 and 300s. The data is recorded on special cards with a memory of 1 GB, enough for 7 weeks of recording GNSS data of 1 Hz L1+L2.

The memory can be split into primary and secondary files (ring buffer) for different recording rates. The files can also be recorded as unprocessed data in RINEX format. The GNSS receivers within the permanent reference stations operate on a full-time basis. The unprocessed data are recorded inside receivers in files of pre-defined length. The software ensures control over receivers and automatic data download at pre-established time intervals.

Also, the receivers send fluxes of unprocessed data directly to the server, without recording them in the internal memory.

Once they reach the server the unprocessed data are checked, validated, compressed, and converted to RINEX formats. The unprocessed data and RINEX files are then sent to a FTP server where they become accessible to users in various domains. The software monitors the settings of the GNSS receiver, data quality, communication connections, the functioning of the entire network and, as need be, generates warning messages and/or reports. The system's administration has full control over the receivers and the entire network. Also, a component of the software installed on the server continuously calculates the RTK/DGNSS corrections and converts them to standard RTCM formats, then sends them out to their users.

The use of a network of virtual GNSS reference stations makes it possible to create models that allow correcting system-specific errors (multi-path, cycle-slip, ionosphere). By means of an analysis software for the flux of data collected within a network, it becomes possible to establish regional correction parameters. If the RTK receiver has the right algorithm embedded, the received correction parameters can be used. There is also the option of introducing correction parameters in the server of the reference station, and then transmitting the corrected data to the RTK receiver. In both cases the operable distance between the RTK receiver and the GNSS reference station increases significantly, maintaining a high precision in the calculation.

The measurement's precision depends on the following factors: number of received satellites, their geometry, observation time, accuracy of received ephemeredes, ionosphere conditions at the time of the reception, etc. The approximate precisions estimated for positioning are as follows:

For 1km: 10mm + 2mm = 12 mm
For 10km: 10mm + 12mm = 22mm
For 30km: 10mm + 35mm = 45mm

For each location the RTK software chooses the closest reference station, interpolates and applies ephemeredes, troposphere, and ionosphere corrections, generates RTCM correction messages and transmits them to the mobile receivers (rovers). These RTCM messages allow for an improvement of the real time position pre-defined by the network. The estimated horizontal error is of 2- 3.5cm for distances of about 45-55km between the reference stations in the network area.

The communication systems of a permanent station are particularly important, their purpose being that of transmitting or receiving data. Communication is usually bidirectional. The amount and quality of data transmitted/received depends on several factors such as: the type of data transmitted (primary observations, archived or un-archived; meteorological data; differential corrections), the recording interval (1s, 5s, 15s, 30s), the number of satellites take into account at one time. A method that's being increasingly used for disseminating RTK and/or DGNSS corrections entails using IP-based communication networks. The main advantage stands in the considerably lower costs, as opposed to using phone connections, and the fact that its effective range is basically unlimited. A possible drawback stands in the instability that may occur with standard internet connections. Access to the internet requires a modem (whether through a phone line or broadband), a ComServer or an Ethernet port and an IP address for the receiver or server of the GNSS reference station.

RTK and GIS receivers must be equipped, in their turn, with devices that can access the internet. In the case of only one permanent GNSS reference station the connection via Internet is made directly between the station's server and one or several RTK or GIS receivers by means of software that runs on the station's server. Such software allows several RTK and GIS receivers to access the IP port at the same time. A permanent GNSS reference station can transmit RTK data through a radio connection directly to the mobile receivers. The station will be monitored by a programme running on a computer, which will also allow downloading and archiving the recorded data. The effective range of approximately 30km is usually sufficient in this case and ensures required precision. For special cases it is possible to install a second station or even multiple permanent GNSS reference stations, to ensure that the RTK receivers obtain two independent positions when determining certain critical points. If that is the case, a single computer (server) can ensure control for all the GNSS reference stations. They are utilized by a wide range of users, the optimal distance between the reference stations and the rover being between 25 and 40km.

This technique would also be a solution for achieving observations in geodesic points of higher level, located in forests, where normal real-time measurements are not possible, for sites located in inaccessible spots, sites that have been destroyed, etc.

3. ADVANTAGES OF USING ROMPOS APPLICATIONS IN GIS

The advantages consist of:

- lower expenses, inter-operable character with ROMPOS and GIS.
- processing observations with minimum effort and using them directly within the structure of GIS system
- ensuring control over data quality and unrestrained usage of such data within GIS systems.

4. CONCLUSIONS

To increase the precision in establishing surveyed points it is recommended that two vectors be determined for each detail point, preferably by running the points with a mobile receiver from one end of the area, and with a second receiver from the other end of the area, so that each point is stationed twice, which provides independent vectors and eliminates possible errors associated to the mobile receiver. Thus, GNSS measurements based on ROMPOS will be high quality and able to be used within GIS systems.

The use of GPS devices in combination with total stations is no longer restrained by the type of area, and the efficiency increases both in terms of precision and cost.

Given the current developments and trends in the evolution of geographic computer-based systems one may argue that a close connection to the GNSS system and in particular to the ROMPOS service is one of the main directions of development and research. Therefore this paper has attempted to describe the guidelines in this field of activity and the future close cooperation between GNSS and GIS.

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