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PRECISE POINT POSITIONING TECHNIQUE VERSUS RELATIVE POSITIONING

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Abstract
Precise point positioning is a GNSS based positioning method that is known to regaining more precise information about major systematical errors in its functional model. This method is seen as an advanced version of the conventional absolute positioning method that is able to offer higher accuracy of the estimate parameter. Contrarily, the relative positioning method is able to achieve high precise of the estimated parameters by using two or more receiver. Nowadays because of this development, the PPP technique it started to grow on the detriment of the relative GNSS positioning. PPP, it is able to offer point determination by processing undifferenced dual frequency receiver, combine with precise orbit and clock corrections offered by JPL to obtain centimeter/millimeter accuracy. The aim of this paper is to make a comparative study between Precise Point Positioning (PPP) versus relative positioning under different conditions.
Keywords: GNSS, JPL, Precise Point Positioning, relative positioning, GipsyX, accuracy.

Introduction

Two approaches are possible to achieve a high level of accuracy in coordinate provision with the help of Global Navigation Satellite System (GNSS). In the presence of a permanent reference GNSS stations network that spans a specific region territorially, the relative method of positioning is most common (Hofmann-Wellenhof et.al., 2008). This method allows determining the accurate coordinates of the rover receiver using observations from reference stations, position of which is known. At the same time using either continued static GNSS observations with their further processing (post-processing) or GNSS observations in real time mode (RTK technology). The main feature of the relative method is that the communication "reference station - rover receiver" is affected by common disturbing effects in the form of systematic errors, to eliminate or mitigate most of them is using the principle of double difference of observations (DD-double-differencing). Since the creation of the global positioning system in the late 1970s, the relative method of observation and processing has prevailed in the field of the use of satellite technologies in geodetic projects. Even more recently, it would be true to say that the relative method had a monopoly on high-precision positioning. While this approach is relatively simple, it also has some significant disadvantages. Thus, due to the limitation of distances between the reference and rover receivers, a dense network of permanent GNSS stations is required, which significantly complicates (organizationally and financially) the process of their installation and operation.

All this changed in the late 1990s, when some competition to the relative positioning method entered the market in the form of accurate positioning of the point (PPP - Precise Point Positioning) (Zumberge et.al., 1997). Precision Point Positioning (PPP), based on non-difference two / multi-frequency phase observations, almost immediately became an alternative to relative positioning. From the early 2000s to the present, the PPP approach has evolved in precision from decimeters to millimeters, using observations from a single GNSS receiver. This was made possible by the use of high-precision ephemeris-temporal information (orbital parameters and satellite clock corrections) in the framework of the processing and modeling of systematic effects that influence on the determination of pseudoranges between satellites and receivers (Chen et.al., 2009). With PPP technology, using the ephemeris-temporal information, the obtained coordinates of the observation point are automatically "tied" to the highly accurate International Terrestrial Reference Frame (ITRF). This approach was originally used almost exclusively for scientific tasks such as studying the state of the ionosphere, studying the movement of continental plates, determining the parameters of the troposphere. Recently, the PPP method has become popular in topographic surveying, accurate positioning, and even in high-precision agriculture (El-Mowafy A., 2009). This is mainly due to the simplification of processing with the help of numerous PPP software packages or automatic PPP-online-services of observation point coordinate calculation.

In this way, technological advancements and constant modernisation of GNSS make it possible to increase the final positioning accuracy. An important step in improving the accuracy, accessibility and

operationality of using the PPP method is the free provision of actual ephemeris-temporal information in real, or close to it, time by international research centers via the Internet (Kouba, 2009).
In this study, using the comparative accuracy characteristics of the PPP method and the relative positioning method, it is analysing the possibility of using the absolute method in tasks requiring the highest accuracy. The PPP method was implemented by GipsyX software, and the relative method - GAMIT / GLOBK, using constellations relating to Multi-GNSS (GPS + GLONASS + Galileo + BeiDou).

Methodology of research and materials

The vast majority of scientific or commercially available programs of GNSS observations processing have used the principles of relative positioning. With the reliability increasing of the PPP method, as well as the quality and availability of softwares, significant changes have taken place in the area of high-precision satellite positioning and related fields. The PPP method, in the case of achieving comparable in accuracy parameters with the relative method, which is traditionally considered as more reliable, will increasingly be chosen as the main because of its convenience and low cost.
In the case of GNSS measurements at only one point, the phase ambiguities cannot be corrected, so a significant disadvantage in the PPP method was the long period of accurate convergence, which is determined by the time from cold start to reaching the decimeter level. Conducted studies show that a typical convergence time lasts about 30 minutes under standard conditions and will be significantly longer for weak satellite geometry (Collins et.al., 2010). To overcome this inconvenience, it is using the Integer PPP method (PPP-AR). It allows to solve the ambiguities of phase measurements for high-precision absolute coordinates. The essence of this method is that a decoupled clock model is used at the output frequencies of the correction information generated by the GNSS measurements results on a IGS permanent stations network. Thus, in PPP-AR mode, separated satellite clock corrections are considered known from the network solution. Besides, for code and phase measurements must be compensated in advance the systematic offsets, which are related to relativistic and gravitational effect, antenna phase center variations, tidal effects, windup effect, atmospheric delays, etc.
The PPP method is implemented using various algorithms and models in online services and software packages. As late as the 1990s, the Jet Propulsion Laboratory NASA (JPL) introduced a new processing technology that did not require formation the differences to obtain accurate positions. It was named Precise Point Positioning (PPP), and JPL implemented it in its software for processing, at that time, GPS data - GIPSY / OASIS II (Official web-site of GIPSY-OASIS software package). This software has undergone nearly 30-years period of formation and improvement. During this time took place its evolution from processing only GPS to multi-GNSS observations. Ephemeris-temporal information was improving in the form of JPL products. It should be noted that JPL products (orbital parameters and clock corrections) are for scientific and educational purposes only. In 2019, an updated version of GIPSY / OASIS, called GipsyX, was released.
This study presents a accuracy comparative assessment of the PPP method implemented by the GNSS observations at 10 stations in Eastern Europe with the GipsyX software package, version 1.0 of 2019. The control values were the processing results of these observations with GAMIT / GLOBK (GG) software, version 10.70 of 2018 (Herring et.al, 2018), which implemented the relative positioning method, as well as the processing results from the EPN Analysis Center conducted by Bernese software (B).

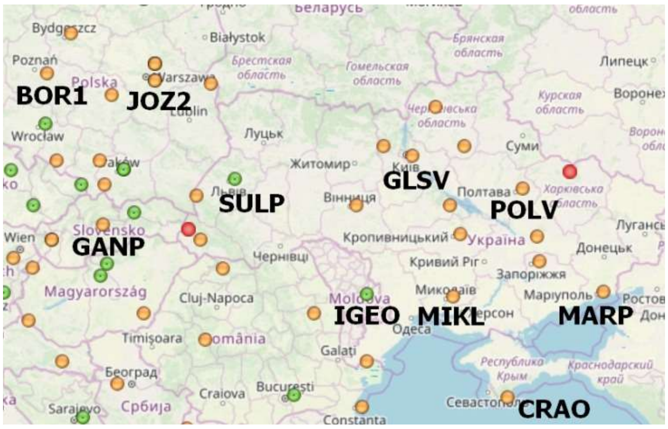

Fig.1. Location scheme of permanent GNSS-stations

To determine the coordinates we used stations of global and regional GNSS networks located closest to the territory of Ukraine. The GNSS observations data of 10 permanent stations of IGS / EPN network from April to June 2019 were selected. A total of 20 days were selected from the specified period, which was related to the availability of data from all stations at the same time (Official EPN server). Figure 1 shows the location of the GNSS stations selected for research.
It should be noted that fully multi-GNSS observations were conducted only at stations GANP, GLSV and, partly, IGEO, MARP (GPS + GLONASS + Galileo). At the other stations, these observations concerned only constellations GPS + GLONASS. Table 1 lists the main parameters, models, and processing strategy used to estimate the coordinates of GNSS observation stations.

Table 1

Parameters, models and strategy of experiments

Processing Strategy		
Software	GipsyX, 1.0	GAMIT/GLOBK, 10.70
Strategy	PPP-AR	DD-double-differencing
Orbit, Clocks and Satellites Biases		
Orbits and clocks	JPL's Precise Orbit and Clock in GipsyX Forma	IGS final
Satellite biases	MGEX wide-lane satellite biases	MGEX wide-lane satellite biases
Elevation cut-off	7°	7°
Models for Processing		
Antenna phase center corrections	ANTEX14	ANTEX14
Troposphere model	Saastamoinen/GPT2/VMF1	Saastamoinen/GMF
Ionosphere model	Ionosphere-free combination and second ordercorrections	Ionosphere-free combination
Ocean loading effects	FES2012	FES2004
Earth orientation modelling	IERS Conventions 2010	IERS Conventions 2010
Earth orientation parameters	EOP C04	EOP C04
Estimated Parameters		
Troposphere	ZTD/30 min	ZTD/2 h
Station coordinates	X, Y, Z transformed to East, North, Up	X, Y, Z transformed to East, North, Up

The PPP strategy underlying GipsyX software involves pre-processing GNSS observations, followed by actual processing and parameters estimation by by least squares method. During pre-processing, after selection of adequate data, each observation is being inspected for "outliers" and "cycle slips" detection using linear combinations (LC) and statistical tests. The ionospheric-free combination applied in processing uses dual-frequency GNSS pseudorange and carrier-phase observations. When the JPL orbit and clock products are applied (JPL's Satellite orbits and clocks), satellite clocks can be considered as known. The zenith tropospheric delay (ZTD) can be divided into an easily-predictable, thus easy-to-eliminate a priori, hydrostatic delay - ZHD, and an estimated in processing wet troposphere delay – ZWD. In GipsyX, the zenith tropospheric delay (ZHD) is computed using the Saastamoinen model with pressure and temperature from the Global Pressure Temperature (GPT2) model. The resulting ZTD is subsequently mapped using the dry Vienna Mapping Function (VMF1). Other corrections used in this study are: tidal displacement related to solid Earth, pole, ocean and atmospheric tides compliant with the International Earth Rotation and Reference Systems Service (IERS2010) standards, phase wind-up and relativistic effects.

Discussions and results

Table 2 presents statistics on the differences between the results of PPP solutions using JPL final products and control coordinates with EPN (B) in the measurement epoch, as well as the average differences in PPP coordinates with our solution by relative method (GG).

Table 2

Global RMS for PPP-B and PPP-GG for the entire stations examined

GNSS-station	North (mm)		East (mm)		Up (mm)	
	PPP-B	PPP-GG	PPP-B	PPP-GG	PPP-B	PPP-GG
BOR1	1.4	1.2	4.4	2.4	5.2	6.1
CRAO	-2.5	-1.2	6.2	3.3	-4.6	-9.6
GANP	-1.8	2.0	2.1	3.0	4.2	-0.2
GLSV	-4.1	3.2	2.6	2.3	4.0	3.2
IGEO	-0.5	2.7	2.8	3.1	-6.2	-8.0
JOZ2	2.0	-3.1	3.5	4.3	4.9	5.3
MARP	3.4	3.6	3.4	4.3	-5.1	-10.3
MIKL	-2.3	1.4	2.7	2.1	-3.1	-5.2
POLV	-0.7	2.1	2.5	2.3	-6.1	-7.2
SULP	2.9	1.1	3.8	3.2	5.8	5.1

Both approaches are characterized by the high precision of differences of horizontal coordinates: from 0.5 mm to 6.2 mm for Bernise and from 1.1 mm to 4.3 mm for Gamit / Globk. According to the well-known fact about PPP processing, the northern component (N) is determined somewhat more accurately than the eastern component (E). However, this principle is not so obvious for the solutions using JPL products (see Table 2). According to the statistics of determining the height component U, the comparison results are less satisfactory than the results of the horizontal components: the differences between the two approaches were approximately 5-8 mm, and in some cases slightly higher than 10 mm.

Conclusions and proposals

In the present study, PPP and DD positioning methods were used to determine high accuracy coordinates. During 2019, 20 days of simultaneous GNSS observations at 10 IGS / EPN stations were selected and processed using GipsyX, 1.0, and GAMIT / GLOBK, 10.70 software packages. The results of PPP and DD multi-station solutions have shown that the current accuracy of the absolute positioning method is practically similar to that of the relative method. Based on the results obtained from the combined EPN network solution using Bernese software, horizontal coordinates accuracy on the level of 3-5 mm for all stations and solutions can be characterized, and vertical component accuracy is changing depending on the specific station and varies by about 5-10 mm. In the analysis of daily values, the vast majority of mean differences in horizontal coordinates did not exceed ± 10 mm during the whole year. As for the vertical component, there are some fluctuations from -2 cm to 2 cm, which may be associated with seasonal atmospheric processes. This seems most likely because it applies to all stations at appropriate times. However, for the area covered by the selected observation stations, the results of the PPP solutions will satisfy the requirements of many surveying and engineering applications where the position is to be gotten in an ITRS reference system with an accuracy of 1 cm or less.

The benefits of combining signals from different GNSS when processing daily observation files are debatable, since this does not significantly improve positioning accuracy (up to 10%). The results obtained show that the improvement of accuracy from the use of combined GNSS observations can only take place in cases of weak satellite geometry and short observation sessions.

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