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Precise point positioning technique with single frequency raw GNSS observations using different products on android smartphones

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Keywords
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PPP
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Abstract

In recent years, the proliferation of low-cost Global Navigation Satellite System (GNSS)-enabled smartphones, updates in GNSS systems, and advancements in positioning algorithms have led to increased research into the contributions of smartphones to positioning studies. The aim of this study was to test the positioning performance of single-frequency GPS/GLONASS observations using the Precision Point Positioning (PPP) technique with different products (Final, Rapid, and Real-Time) offered by Wuhan University. To provide a reference for comparison, post-process PPP solutions were obtained using geodetic-grade GNSS receivers and Final products, which have demonstrated centimeter-level accuracy in previous studies. The analysis of the GPS/GLONASS observations using the three different products revealed consistent the Root Mean Square Error (RMSE) values in the centimeter-level when all the observations in the epoch-differenced time series were examined. Moreover, after the convergence of the time series generated from the smartphone data, an improvement ranging from 76% to 98% was observed for the horizontal and vertical components at a level of 0.5 cm and 1 cm, respectively. These results suggest that GNSS-enabled smartphones using PPP techniques with appropriate products can achieve accurate positioning performance.

Introduction

The release of the first Android smartphones in 2008 marked the beginning of a new era in mobile technology, which has rapidly evolved to become ubiquitous in many application areas. The accuracy of smartphone positioning has improved in proportion to the advancements in satellite systems. However, until 2016, raw GNSS observations were not available to users, and only position, velocity, azimuth, and time information could be obtained from smartphones [1]. In 2016, Google announced the availability of raw GNSS data to users with the Android N (Nougat=Version 7) version, which was a significant milestone for positioning studies on smartphones [2].

Until 2018, positioning, navigation, and timing applications on smartphones were based on single-frequency GNSS observations. However, in May 2018, Xiaomi launched the Mi8 model smartphone, which was the first smartphone capable of collecting dual-frequency GNSS raw observation data [3]. This development opened up new possibilities for precise positioning performance evaluation using smartphones with different positioning techniques, such as Real-Time Kinematic and Precise Point Positioning [4-7].

In this study, using different satellite orbit and clock corrections produced by Wuhan University, solutions were produced with PPP technique, both with a smartphone and with a geodetic-grade GNSS receiver. Experiments were carried out to investigate the contribution of products produced by the same analysis center at different time intervals to the literature, to both single-frequency and multi-GNSS observations. In addition, it is aimed to evaluate the positioning performance in terms of the process by using post-process (Final and Rapid) and near-real-time (Real-Time) products in the experiments.

Material and Method

The solution of the PPP technique using the raw observation data (via Geo++RINEX Logger) collected from the Android smartphone and the satellite orbit and clock correction parameters provided via the internet is shown schematically in Figure 1 [8]. The satellite orbit and clock correction information required in post-process and near real-time solutions based on PPP technique is obtained via the internet by the WHU (Wuhan University) analysis center produced. In the RTKPOS application of RTKLIB software, raw GNSS observation data and necessary products are processed. In the experiment description, data was collected with a Xiaomi Redmi Note 8 smartphone, which can collect single-frequency GPS and GLONASS raw observation data with a sampling interval of 1 Hz. On the other hand, raw observation data was recorded under the same conditions with the geodetic-grade CHC I80 receiver to test the position accuracy of the smartphone. Experiments were carried out in Gebze Technical University, Department of Geomatics Engineering in November 2022 for approximately one and half hour.

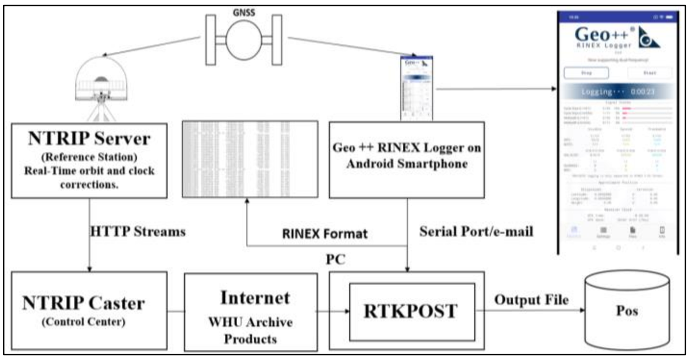

Figure 1. Schematic view of the PPP method with an Android smartphone.

Results and Discussion

In this section, the performance of positioning accuracy on Android smartphones is examined using 3 different products of both GPS and GPS/GLONASS satellite constellations. However, the epoch difference time series obtained using only real-time products and the histogram distributions related to these solutions are shown in Figure 2 and Figure 3. In Figure 2, the epoch differenced time series of the solutions generated from both the geodetic-grade GNSS receiver and the smartphone during the whole experiment are shown. In addition, statistical histograms of the epoch differenced obtained from the smartphone are given by taking the solutions obtained with the geodetic-grade GNSS receiver as reference. In the first row of the figure, the epoch differenced time series of the north, east and up components, respectively, based on only-GPS observations are shown. In the second row of the figure, with reference to the epoch differences obtained from the CHC I80 GNSS receiver, RMSE values and histogram distributions of the three different components of the epoch differenced produced from the Xiaomi 8 smartphone are given. Unlike the first line of the figure, the epoch difference time series of GPS/GLONASS observations is presented in the third line, and the statistical values of the observations obtained from the smartphone are presented in the fourth line. According to the results, due to the integer phase uncertainty due to the nature of the PPP-based solution, the convergence time causes fluctuations as seen in the time series. Despite being a static solution, these fluctuations persisted between approximately 800 (s) and 1000 (s) periods, although different for the three components. The reason for this short duration is that the measurement was made without recording data for about 15-20 minutes before the experiment. Therefore, from the instant that the fluctuations fall below 0.5 cm in the horizontal component and below 1 cm in the vertical component, the epoch differenced time series and statistical histograms are shown as seen in Figure 3. It has been observed that the RMSE values of GPS-only and GPS/GLONASS solutions, for which the post-convergence period difference is taken, have improved compared to the results obtained during the whole experiment. In addition, in Table 1, the position accuracy of the smartphone was evaluated by making both GPS and GPS/GLONASS satellite observations by using Final, Rapid and Real-Time products produced by Wuhan University at certain times. As a reference, the raw GPS/GLONASS observation data obtained from the geodetic-grade GNSS receiver and the solution obtained using the Final products were taken. The results showed that while the position accuracy was below about 10 cm in the solutions obtained throughout the experiment, the position accuracy decreased sub-centimeter after the convergence of the integer phase ambiguity. In this study, for a fair assessment, a single geodetic-grade GNSS receiver was used as a reference to the PPP technique, which has been proven to be at the centimeter level in many studies. However, after convergence, it was observed that the solutions obtained from 3 different products gave consistent and successful results at the millimeter level.

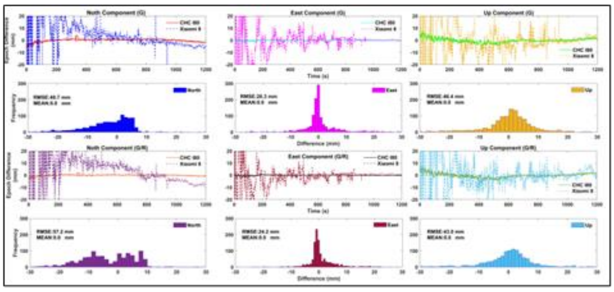

Figure 2. The epoch differenced time series and histogram distributions throughout the experiment

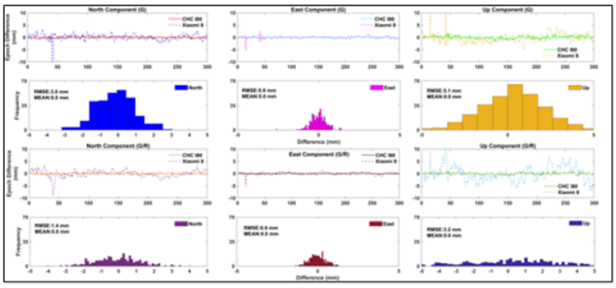

Figure 3. The epoch differenced time series and histogram distributions after convergence

Table1. RMSE values of North, East and Up components for Xiaomi 8 smartphone

	GPS			**GPS/GLONASS**		
	North (mm)	**East (mm)**	**Up (mm)**	**North (mm)**	**East (mm)**	**Up (mm)**
Real-Time	49.7	26.3	46.4	57.2	24.2	43.0
Rapid	47.8	28.1	85.4	62.7	22.3	81.9
Final	48.5	29.0	86.4	62.8	22.7	83.6
Real-Time	3.0	0.6	5.1	1.4	0.6	3.2
Rapid	5.8	3.2	20.8	3.8	2.9	14.9
Final	5.6	1.8	11.2	2.9	2.1	9.9

Conclusion

In this research, the positioning performance of the smartphone was evaluated in static mode by using the parameters of the single-frequency PPP-based solution produced by the same analysis center at different times. The results were tested with the raw data collected from the geodetic quality GNSS receiver, whose positioning accuracy has been proven at the centimeter level in many studies, simultaneously with the smartphone and with the PPP-based solution using the final products as a reference. According to the results, it was observed that the RMSE values obtained with the GPS/GLONASS satellite combination after convergence were better than the RMSE values obtained with only-GPS satellite observations. However, in the raw observation data collected according to the smart phone's geodetic GNSS receiver; It is seen that the positioning performance of smartphones is significantly affected due to disadvantages such as the number of satellites due to satellite locking, hardware-related data quality, signal-to-noise ratio and duty cycle. Therefore, in future studies, it is recommended to use smartphones with the developer option that disables the duty cycling feature in Android 9 and higher versions for continuous carrier phase measurement. This will contribute to faster convergence and improve positioning accuracy. In addition, it is considered to investigate the effect of different satellite system combinations in real-time positioning studies on smartphones with dual-frequency data collection feature.

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