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Near-Real-Time Precise Point Positioning Technique with Single-Frequency Raw GNSS Observations on Android Smartphones

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Abstract

In this study, positioning performance was evaluated by making single-frequency GNSS (Global Navigation Satellite System) observations under real-time conditions with a smartphone. In experiments, GNSS observations were recorded with the Xiaomi Redmi Note 8 Pro via the Geo++ Logger application. Measurements were made with the geodetic-grade CHC I80 GNSS receiver to evaluate the performance of the smartphone. In addition to the collected raw observation data set, solutions were realized with the Near-Real-Time Precise Point Positioning (N-RT-PPP) technique by using satellite orbit and clock correction products produced under real-time conditions from the CNES (Centre National D'Etudes Spatiales) archive. When all the observations with the epoch difference are examined, it is observed that the root mean square error (RMSE) values of the GPS/GLONASS observations give better results than the only-GPS solutions. In addition, in the epoch differenced time series produced from the smartphone, an improvement between 92% and 98% was observed for the part below 1 cm horizontally and 2 cm vertically after the fluctuation.

1. Introduction

Recently, with the development of satellite constellations and modernized signals in global satellite systems, and innovations in satellite-based positioning theory and algorithm, studies on geodetic-grade GNSS receiver/antenna(s) as well as low-cost GNSS receiver/antenna(s) and even smartphones have increased (Banville and Diggelen 2016; GSA 2017). Smartphones initially provided position information with a single-frequency, single constellation of satellites. In the beginning, smartphones produced single-frequency, single-satellite constellation and position information without open access to GNSS raw data. However, based on the raw GNSS observations from the satellite, Google announced at the "I/O 2016" conference in 2016 that with the Android N (Nougat=Version 7) version, raw GNSS data will be made available to the user on Android-based smartphones (Banville and Diggelen 2016; Gül et al. 2021). This statement has been a milestone for many studies on positioning on smartphones. Smartphones, which are widely used by most people in the global community for their needs and have a large mass market in the mobile smart device market, have now become a subject that is researched in precise positioning studies for different applications in the GNSS market. The first GNSS data evaluation study by Banville and Diggelen (2016) recorded raw multi-GNSS code, carrier-phase and Doppler observations at L1 frequency with a Samsung Galaxy S7 smartphone. However, single-frequency only-GPS raw data quality was studied. According to the results, they stated that the main problems of smartphones for precise positioning are GNSS antenna quality and cycle slip. A similar study evaluated the quality of the raw measurements and the obtained position accuracy with the linear polarized antenna and external GNSS antenna in order to evaluate the antenna quality with the Huawei Mate 9 smartphone with the GNSS chip (Broadcom 4774) of the same model (Siddakatte et al. 2017). While positioning, navigation and timing applications with smartphones were made through single-frequency GNSS observations until 2018, Xiaomi produced and marketed Mi8 model smartphone that can collect dual-frequency GNSS raw observation data for the first time in May (Chen et al. 2019). This event has been a start that will lead to the evaluation of precise positioning performance using different

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positioning techniques (Real-Time Kinematic, Precise Point Positioning, etc.) and many studies in engineering applications on smartphones (Chen et al. 2019; Liu et al. 2021; Odolinski and Teunissen 2019; Robustelli et al. 2019; Wu et al. 2019). In the literature, the positioning performance of smartphones has been evaluated by using geodetic-grade receivers as a reference to relative positioning or differential positioning technique, or by using a smartphone as a reference station (Gao et al. 2019; Geng and Li 2019; Paziewski et al. 2021). Although the positioning studies with smartphones are low cost, due to the GNSS antenna/chip feature used, the signals reflected from the objects in the environment are sensitive to the multipath effect, which causes the collection of low quality GNSS measurements. GNSS receiver/antenna(s), which are high cost and designed to minimize the multipath effect, have advantages over the antenna/chip(s) used in smartphones. In addition, many positioning applications use carrier-phase observations for high positioning accuracy. However, due to the GNSS antenna/chip structure used in carrier phase observations on smartphones, it causes interruptions in phase observations (Paziewski et al. 2019; Zangenehnejad and Gao 2021).

In Nowadays, with a single GNSS receiver, position determination studies with PPP technique under real-time conditions have gained great momentum. In this context, it has eliminated the need for a simultaneous reference receiver, a network or an infrastructure compared to previous methods. Along with the dual-frequency raw GNSS data collection of smartphones, PPP-based point positioning performance in both static and kinematic mode has been evaluated in many studies. In the studies, it was stated that the position accuracy can be determined at the decimeter level in static mode and with an accuracy of a few meters in kinematic mode (Aggrey et al. 2019; Elmezayen and El-Rabbany 2019; Kulikov et al. 2019). In this study, single-frequency GNSS raw observations were collected using both smartphone and CHC I80 GNSS receiver/antenna, and evaluation was carried out with the N-RT-PPP method.

2. Method

This study includes the N-RT-PPP technique based on multi-GNSS code and phase observations. In this context, the equations can be written as:

$$P_r^s = \rho_r^s + c.\delta t_r - c.\delta t^s + T_r^s + I_r^s + m_r^s + \varepsilon_{r,P}^s \quad (1)$$

$$\Phi_{r,j}^s = \rho_r^s + c.\delta t_r - c.\delta t^s + \lambda N_r^s + T_r^s - I_r^s + m_r^s + \varepsilon_{r,\Phi}^s \quad (2)$$

In these equations, the subscript r represents the receiver, while the superscript s represents the satellite; The pseudorange and carrier-phase measurements of the receiver relative to the satellite in P and Φ length units, respectively; ρ is the geometric distance between the receiver and the satellite; c is the speed of light in vacuum, δt_r and δt^s are receiver and satellite clock corrections, respectively; T_r^s indicates tropospheric delay along the path between receiver and satellite; I_r^s is the ionospheric delay along the path from the satellite to the receiver; λ is the carrier-phase wavelength; N_r^s is the initial phase ambiguity; m_r^s and ε_r^s represent the multipath and noise of the code and phase observations, respectively.

3. Results and Discussion

In this section, information and observation data sets of GNSS receiver/antenna used in the experiments are introduced. In addition, the observations collected on GNSS receiver/antenna(s) are demonstrated by the N-RT-PPP method. Finally, the results of the positioning performance of N-RT-PPP solutions obtained from the data collected from different GNSS receivers/antenna(s) are presented.

3.1. Experiment design and data processing

Within the scope of this study, observations were made with a total of 2 GNSS receiver/antenna(s) at a sampling range of 1 Hz using CHC I80 GNSS receivers and Xiaomi Redmi Note 8 Pro model smartphone. Experiments were carried out in Gebze Technical University campus in the Department of Geomatics Engineering in November 2022 and lasted for about 1.5 hours. During the experiment, GPS and GLONASS satellite observations were collected with 2 GNSS receiver/antenna(s). With the IGS (International GNSS Service)-RTS (Real-Time Service) service project initiated by IGS, RTS products can be broadcast over the internet in RTCM/SSR (Radio Technical Commission for Maritime Services/ State Space Representation) data format with NTRIP (Networked Transport of RTCM via Internet Protocol) data transmission protocol, and real-time satellite orbit and clock correction information can be obtained (Elsobeiey and Al-Harbi 2016). In a similar role to IGS-RTS, satellite orbit and clock correction products for GPS and GLONASS are routinely provided by the CNES. N-RT-PPP solution was realized by using satellite orbit and clock correction information generated under real-time conditions from the CNES archive. In this study, a solution was made with the rtkpost application module of the RTKLIB software to the point positioning and to monitor it in real time using the N-RT-PPP method.

3.2. Positioning performance with RT-PPP method

In this section, the raw GPS/GLONASS observations obtained from the Xiaomi Redmi Note 8 smartphone are processed with the N-RT-PPP technique in static mode, together with the satellite orbit and clock information produced under real-time conditions. Single-frequency GPS and GPS/GLONASS solutions were evaluated in the study. In this context, N-RT-PPP solution was made in static mode using a single GNSS receiver (CHC I80) to fairly evaluate the positioning performance of smartphones with single-frequency GNSS observations. In Fig. 1, 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 GPS-only observations are shown.

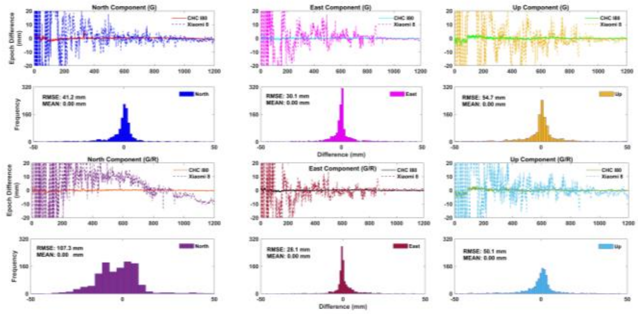

Figure 1. The epoch differenced time series and histogram distributions throughout the experiment.

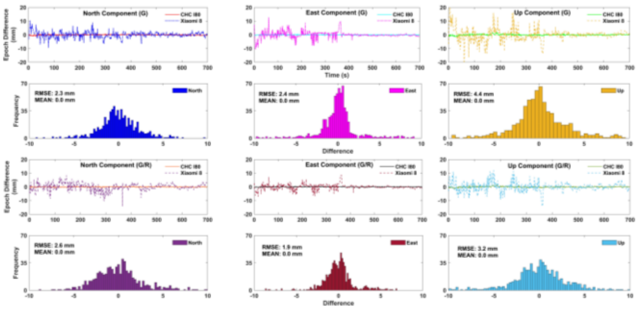

Figure 2. The epoch differenced time series and histogram distributions after fluctuation.

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. In the 3rd row of the figure, unlike the first row, the time series of the epoch differences obtained using GPS/GLONASS observations, and the statistical values of the observations obtained from the smartphone are presented in the 4th row. According to the results, there were clearly fluctuations in the solutions obtained from the smartphone. Despite being a static solution, these fluctuations persisted between approximately 600 (s) and 800 (s) epochs, although different for the three components. Therefore, from the instant that the fluctuations fall below 1 cm in the horizontal component and below 2 cm in the vertical component, the epoch differenced time series and statistical histograms are shown as seen in Fig. 2. According to the results, it was observed that the RMSE values of GPS and GPS/GLONASS solutions, whose epoch differenced were taken after fluctuation, were improved according to the results throughout the whole experiment. In Table 1, the RMSE values of the epoch differenced measurements of the GPS and GPS/GLONASS solutions during the all experiment (A) and after fluctuations (B) are given.

Table 1. 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)
A	41.2	30.1	54.7	107.3	28.1	50.1
B	2.3	2.4	4.4	2.6	1.9	3.2

4. Conclusion

In this study, near-real-time positioning performance of GNSS observations collected statically with a smartphone was evaluated. In the experiment, the data set collected with the Xiaomi Redmi Note 8 smartphone was solved with a single-frequency combination of both GPS and GPS/GLONASS satellites. In order to evaluate the results fairly, observations were also made with a single geodetic-grade GNSS receiver. It has been observed that the results obtained with the combination of GPS/GLONASS satellites give better results than the only-GPS observations. Considering at the epoch differenced time series after fluctuation, 94.4%, 92.0% and 92.0% improvements were shown in the north, east and up components, respectively, in the solutions realized by only-GPS observations. This assessment showed an improvement of 97.6%, 93.2% and 93.6% in the GPS/GLONASS satellite combination, respectively. In this context, it is clear that the addition of GLONASS satellite to single-frequency GPS satellite observations collected in static mode with smartphones improves real-time positioning performance. It has also been observed that the smartphone's static positioning accuracy improves significantly under real-time conditions after approximately 600 (s) to 800 (s) epochs. In addition to this study, it is considered to evaluate the positioning performance of smartphones capable of dual-frequency multi-GNSS observations with current technological developments in different satellite combinations in real-time.

References

Aggrey, J., Bisnath, S., Naciri, N., Shinghal, G., & Yang, S. (2019). Use of PPP processing for next-generation smartphone GNSS chips: key benefits and challenges. Proceedings of the 32nd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2019), 3862-3878.

Banville, S., & Diggelen, F. (2016). Precise GNSS for everyone: precise positioning using raw GPS measurements from Android smartphones. GPS World, 27(1), 43–48.

Chen, B., Gao, C., Liu, Y., & Sun, P. (2019). Real-Time Precise Point Positioning with a Xiaomi MI 8 Android Smartphone. Sensors, 19, 2835.

Elmezayen, A., & El-Rabbany, A. (2019). Precise point positioning using world's first dual-frequency GPS/GALILEO smartphone. Sensors, 19(11), 2593.

Elsobeiey, M., & Al-Harbi S. (2016). Performance of real-time Precise Point Positioning using IGS real-time service. GPS Solutions, 20(3), 565–571.

Gao, R., Xu, L., Zhang, B., & Liu, T. (2021). Raw GNSS observations from Android smartphones: Characteristics and short-baseline RTK positioning performance. Measurement Science and Technology, 32(8), 084012.

Geng, J., & Li, G. (2019). On the feasibility of resolving Android GNSS carrier-phase ambiguities. Journal of Geodesy, 93(12), 2621-2635.

GSA, European GNSS Agency (GSA) GNSS Raw Measurements Task Force 2017, Using GNSS raw measurements on Android devices (white paper) (http://doi.org.10.2878/449581).

Gül, C., Doğan, A. H., & Öcalan, T. (2021). Investigation of PPP performance with dual frequency raw GNSS observations obtained from smartphones. Journal of Geodesy and Geoinformation, 8(2), 120-130.

Hadas, T., & Bosy, J. (2015). IGS RTS precise orbits and clocks verification and quality degradation over time. GPS Solutions, 19(1), 93–105.

Kulikov, R., Chugunov, A., & Zamolodchikov, V. (2019). Investigation of collision warning possibilities by means of GNSS receivers of Android smartphones. IOP Conference Series: Materials Science and Engineering, 695(1), 12013.

Liu, Q., Gao, C., Peng, Z., Zhang, R., & Shang, R. (2021). Smartphone positioning and accuracy analysis based on real-time regional ionospheric correction model. Sensors, 21(11), 3879. https://doi.org/10.3390/s21113879.

Odolinski, R., & Teunissen, P. (2019). An assessment of smartphone and low-cost multi-GNSS singlefrequency RTK positioning for low, medium and high ionospheric disturbance periods. Journal of Geodesy, 93(5), 701-722. https://doi.org/10.1007/s00190- 018-1192-5.

Paziewski, J., Sieradzki, R., & Baryla, R. (2019). Signal characterization and assessment of code GNSS positioning with low-power consumption smartphones. GPS Solutions, 23(4), 1-12. https://doi.org/10.1007/s10291-019-0892-5.

Paziewski, J., Fortunato, M., Mazzoni, A., & Odolinski, R. (2021). An analysis of multi-GNSS observations tracked by recent Android smartphones and smartphone-only relative positioning results. Measurement, 175, 109162.

Robustelli, U., Baiocchi, V., & Pugliano, G. (2019). Assessment of dual frequency GNSS observations from a Xiaomi Mi 8 Android smartphone and positioning performance analysis. Electronics, 8(1), 91.

Siddakatte, R., Broumandan, A., & Lachapelle, G. (2017). Performance evaluation of smartphone GNSS measurements with different antenna configurations. Proceedings of the International Navigation Conference, Brighton, 27-30 November 2017.

Wu, Q., Sun, M., Zhou, C., & Zhang, P. (2019). Precise point positioning using dual-frequency GNSS observations on smartphone. Sensors, 19(9), 2189.

Zangenehnejad, F., & Gao, Y. (2021). GNSS smartphones positioning: Advances, challenges, opportunities, and future perspectives. Satellite Navigation, 2(1), 1-23.