International Cartographic Association
Association Cartographique Internationale

Fast high accuracy kinematic smartphone positioning for location-based services

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Keywords: GPS/GNSS, location-based service, Android mobile devices, smartphone positioning and mapping, real-time kinematic positioning, fast positioning convergence

Abstract:

High accuracy smartphone positioning is a research topic under extensive investigation driven by the availability of raw GNSS (GPS, Galileo, GLONASS, Beidou) carrier phase observations to Android smartphones users and great value to location-based services (van Diggelen et al, 2018; Zangenehnejad & Gao, 2021). Location-based services are to find out the geographical location of the mobile user and then provide services based on the given location information and they can touch almost every aspect of our daily life from health care, transportation, emergency and rescue services, public safety, to homeland security.

High accuracy spatial location information is a vital component in developing location-based service to mobile devices, including government mandates that cellular operators must provide location of emergency callers within a certain degree of accuracy. Today, nearly every new smartphone contains a GNSS chip. While the accuracy of standard GNSS positioning with smartphones usually in the range of 5 to tens of meters, improved positioning accuracy is expected to enable many new location-based applications. This is because high accuracy will make it possible to deliver personalized services of great value to mass market applications. Better positioning accuracy, for instance, can provide new experiences in lane-level navigation and augmented reality with sensor fusion. Professional apps such as surveying could also take advantage of high accuracy positioning using much cheaper multi-constellation and multi-frequency smartphones.

The feasibility of much higher accuracy with smartphones has been frequently demonstrated in published literature. For instance, cm-level accurate positioning has been shown obtainable with smartphones using real-time kinematic (RTK) techniques in static and open sky environments, but the accuracy would be significantly degraded in operational environments. There are also commercial products providing sub-meter positioning accuracy in sub-urban environments. In 2021 and 2022, the Google hosted two Google Smartphone Decimeter Challenges (GSDC) during which various smartphone GNSS datasets from land vehicle applications were used to assess smartphone positioning accuracies using different techniques (Fu et al., 2020). As was revealed, meter-level positioning accuracy was achieved by the leading participants but only in post-mission. In addition to further accuracy improvement, kinematic positioning performance in real-time operational environments must be addressed in order to support location-based services using smartphones.

This paper will discuss several issues related to high accuracy smartphone positioning and critical to location-based services.

1) Quality Assessment of Smartphone GNSS Observations: The data logging and GNSS observation generation are a critical part in smartphone positioning algorithm development which should be evaluated. This includes issues associated with the raw GNSS data accessible through Google's application programming interface (API) and the conversion of the raw GNSS data to GNSS observations (pseudorange, carrier phase and Doppler) for position determination. For raw GNSS data conversion, various open source Apps have been developed, e.g. the GnssLogger App from Google and the RINEX Logger App from Geo++ (Geo++ GmbH, 2018). Although being widely used, the quality of GNSS observations output from the GnssLogger and the RINEX Logger was found inconsistent including biases after analysing datasets from the Xiaomi Mi8, Google Pixel 5 and Samsung S20 smartphones (Zangenehnejad et al., 2022). This indicates the importance of proper understanding of the observation conversion algorithms implemented within the data logging Apps. Otherwise, the quality concern would affect the GNSS data processing such as cycle slip detection, code smoothing and ultimately positioning

Abstracts of the International Cartographic Association, 6, 67, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa.
https://doi.org/10.5194/ica-abs-6-67-2023

performance. A newly developed conversion software (UofC CSV2RINEX) at University of Calgary will also be introduced which provide improved performance.

2) Fast Wide-lane Ambiguity Resolution: Fast positioning convergence is a requirement essential for real-time location-based services such as vehicle navigation and mapping using smartphones. The positioning algorithms with smartphones have been mainly based on RTK or precise point positioning (PPP) techniques in a float ambiguity mode. Fast ambiguity resolution however is a difficult task to smartphone positioning for two reasons. One is the use of low-cost GNSS chips in smartphones and another is the challenging environments in kinematic positioning. Both factors will affect the quality of the GNSS observations and subsequently the obtainable accuracy and reliability of the position solutions. Different strategies exist to achieve fast positioning convergence which can be a trade between the convergence speed and the desired accuracy. We have seen industry efforts in developing instant kinematic PPP system at sub-metre accuracy to support land vehicle lane-level navigation and mapping. Various efforts have also been made by researchers to ambiguity resolution with multi-constellation and multi-frequency GNSS signals (Geng & Li, 2019; Heßelbarth & Wanninger, 2020). While mostly tested in open sky environments for existing work, fast wide-lane ambiguity resolution seem more realistic for kinematic positioning with limited measurement quality and redundancy. It will be discussed along with operational feasibility in the field.

3) Evaluation of Smartphone Real-time Kinematic Positioning Performance: Given that most test results so far in literature are obtained either in open sky environments or in post-mission mode, evaluation of smartphone real-time kinematic positioning performance will be conducted using datasets acquired from land vehicle navigation applications including datasets from GSDC and field tests conducted in Calgary, where open-sky area, sub-urban and dense-urban environments are fully included. The analysis will focus on real-time PPP and RTK processing with Android smartphones including Google Pixel 5 and Samsung Galaxy S20. The accuracy analysis will demonstrate that an improved real-time positioning performance can be reached with PPP and RTK.

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https://doi.org/10.5194/ica-abs-6-67-2023