*Journal of Global Positioning Systems (2025)*
***Vol. 21, Issue 1: 99-99***



# Precise Smartphone Positioning Based on PPP-RTK Techniques

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**Defense Date:** April 10, 2025

## ABSTRACT

The proliferation of smartphones in recent decades has driven advancements in technology for navigation applications. The traditional positioning methods to enable precise positioning service are precise point positioning (PPP) and real-time kinematic (RTK) techniques. But without precise corrections to the atmospheric effects, PPP has long convergence time and RTK requires high-rate data. It has been extensively demonstrated that PPP-RTK technology can realize fast or even instant ambiguity resolution for users with precise atmosphere information from the reference station. Previous approaches, such as Continuously Operating Reference Stations (CORS), are characterized by high installation and maintenance costs. This thesis therefore focuses on this issue and evaluating smartphone precise positioning using PPP-RTK techniques.

First, a designated framework for PPP-RTK processing algorithm on smartphones is proposed, utilizing real-time satellite orbit and clock corrections provided by the Galileo High Accuracy Service (HAS) and atmospheric corrections derived from a single reference station. Moreover, smartphone PPP-RTK and PPP are validated with accuracy and convergence time, which underscore the efficacy of PPP-RTK in significantly improving convergence times and positioning accuracy compared to traditional PPP methods.

Second, this thesis proposes wide-lane (WL) integer ambiguity resolution (IAR) method that combines integer rounding and the Least-square AMBiguity Decorrelation Adjustment (LAMBDA) methods for smartphone applications. The float ambiguities that are with significant confidence function values are first processed with integer rounding. Then in the second step, the rest of float ambiguities are handled by the LAMBDA method.

Third, this thesis proposes a collaborative PPP-RTK method for smartphone precise positioning to eliminate the need to deploy fixed reference station as required in the traditional PPP-RTK systems. In the new method, the atmospheric corrections for a smartphone are generated by other smartphones running uncombined PPP. Such smartphones turned reference stations are established in real-time and together, they form a real-time network of collaborative reference stations for smartphone precise positioning.

Finally, an improved slant ionospheric correction model based on spherical harmonics combined with a quality control method for collaborative smartphone-based PPP-RTK positioning is introduced. The model was evaluated using random, boundary, and sparse datasets, demonstrating significant enhancements over existing methods, including the triangle interpolation method, single-source method, and float PPP.