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Accelerating the Convergence Speed of Precise Point Positioning by Using Multi-mode GNSS ⋆

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Abstract The Precise Point Positioning (PPP) does not need the support of base stations, and it has broad application prospects. However, the convergence time of PPP is long. In order to accelerate the convergence speed of PPP, the PPP model using multi-mode GNSS (Global Navigation Satellite System) is discussed. The experiments show that the convergence speed becomes faster by using the multi-mode GNSS, the mean percentage of time reduction for converging to different precisions (10 cm, 15 cm, and 20 cm) is 42%, 78%, and 74%, respectively; meanwhile, in the severe regions, such as in the mountainous regions, the number of observable satellites becomes fewer, and the PPP sometimes cannot achieve positioning using a simple system. But the PPP using multi-mode GNSS can achieve positioning and accelerate the convergence.

Key words astrometry—Earth—techniques: miscellaneous— methods: data analysis

1. INTRODUCTION

Since the Precise Point Positioning (PPP) was proposed in 1997, it has achieved great development[1], and been gradually applied in practice. With the help of the precise orbit and clock product[2], the PPP corrects and estimates the various errors by using models, and then it achieves the high-precision positioning[2]. Compared with the network RTK and traditional RTK, the PPP does not require the support of base stations, and can achieve the high-precision positioning using only a single receiver, so it has very wide application prospects, especially on the sea and in mountainous regions where base stations are difficult

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to set. On April 1, 2013, the International GNSS Service (IGS) released the real-time precise orbit and clock product, which further promotes the application of real-time PPP[3]. However, the PPP has an unavoidable disadvantage, namely it needs a process of convergence to realize the high-precision positioning[4], generally in the order of several ten minutes, and if the observation condition is severe, the convergence time will be even longer. So how to accelerate the convergence of PPP is of great significance for users. Essentially, there are two reasons for the slow convergence of PPP[5], one is the low precision of pseudorange measurements, the other is the slow change of satellite space geometry. For ordinary users, the two reasons for the slow convergence of PPP cannot be completely eliminated. In fact, from the perspective of measurement, increasing the number of measurements can improve the estimation accuracy of parameters, and then can speed up the convergence of PPP. There are two ways to increase the number of measurements, one is to increase the number of frequencies, for example, from double frequencies to triple frequencies[6−7]; the other is to increase the number of satellites, for example, to increase the number of observed satellites by using the data of multiple GNSSs. This paper just discusses the latter, namely to increase the number of observations by use of multi-mode GNSS. There are many studies on the positioning of multi-mode GNSS[8−9]. Some studies make the combined point positioning by using the multi-mode GNSS[10−11], some studies make the precise point positioning and improve the positioning precision by use of multi-mode GNSS[12−18]. These studies mainly focus on enhancing the positioning reliability in the background of good observational condition. However, for relatively severe regions, such as the mountainous regions, the related research is rare. At the same time, the PPP can also be used to transfer time and frequency[19]. The Trimble company estimates the real-time precise orbit and clock product with the help of more than 100 stations distributed in the world, in most cases the PPP can realize convergence within half an hour, if the Galileo and BDS systems are joined in, the convergence time can be reduced to one half[20]. In addition, the Trimble RTX service, which estimates the tropospheric delay, ionosphere delay and the hardware offset, can realize convergence in a very short time (such as several minutes)[21], it has greatly promoted the application of real-time PPP. But the Trimble RTX service relies on a large number of ground reference stations (distance between each other is about 120 km), which greatly increases the cost. This paper uses mainly the multi-mode GNSS to accelerate the convergence of PPP. Firstly, the PPP model under the multi-mode GNSS is discussed, then an analysis on the experiments is given.

2. THE PPP MODEL OF MULTI-GNSS

The PPP generally uses an ionosphere-free combination model, the corresponding equations of observation are

$$P_{\mathrm{IF}}^{j} = \rho^{j} + c(\delta t_{\mathrm{r}} - \delta t^{j}) + T_{\mathrm{trop}} + \varepsilon_{P}^{j}\,, \tag{1}$$