Performance Evaluation of Real-Time Precise Point Positioning Method

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Abstract. Post-Processed Precise Point Positioning (PPP) is a well-known zero-difference positioning method which provides accurate and precise results. After the experimental tests, IGS Real Time Service (RTS) officially provided real time orbit and clock products for the GNSS community that allows real-time (RT) PPP applications. Different software packages can be used for RT-PPP. In this study, in order to evaluate the performance of RT-PPP, 3 IGS stations are used. Results, obtained by using BKG Ntrip Client (BNC) Software v2.12, are examined in terms of both accuracy and precision.

1. Introduction
The Precise Point Positioning method, first introduced by Zumberge et al [1], is based on the processing of zero difference GNSS observations of a single receiver. Following studies proved that this method can be used in many study areas in terms of providing sufficient accurate and precise results [2-8]. Over the last decade researchers have focused on Post-Processed static/kinematic PPP. However, thanks to real-time service (RTS) of International GNSS Service (IGS), officially launched on April 2013, it is possible to access IGS products in real time. These products include broadcast ephemeris, GNSS satellite orbit and clock corrections which enable real-time PPP applications.

Ahmed et al [9] examined the suitability of real-time precise point positioning zenith total delay estimates using three different software packages. Results were assessed through a comparative analysis using IGS final troposphere product and real-time service data as reference. According to the results, the best agreement with these were achieved from the G-Nut/Tefnut software solutions. In addition, while de Oliveira et al [10] performed a study about modelling tropospheric wet delays with dense and sparse network configurations for PPP-RTK, Shi et al [11] examined the performance of GPS real-time PPP for aerial triangulation.

In this study, the positioning performance of RT-PPP method is examined in terms of both accuracy and precision using BKG Ntrip Client (BNC) software v.2.12.

2. RT PPP Software Packages
Recently, in order to perform PPP applications in real time, software packages have been produced. Among them, four software packages are well known and used by the researchers. They are;
- The BKG Ntrip Client (BNC), developed by the Bundesamt für Kartographie und Geodasie (BKG) [12].
- The G-Nut/Tefnut software library, developed at the Geodetic Observatory Pecny [13].
The PPP-Wizard, developed by the Centre National D’Etudes Spatiales (CNES) [14].
- The P3 software, developed by the Geomatics department at the University of Calgary [15].
All the above-mentioned four software packages use the kalman filter approach. The kalman filter approach requires a few minutes convergence time to reach full accuracy [16]. Besides the web addresses, authors refer to Ahmed et al [9] for the details of the BNC, G-Nut/Tefnut and PPP-Wizard and refer to Shi et al [11] and [17] for the details of the P3 software.

3. RT Data and Results
In order to examine the performance of RT-PPP method, three of IGS RTS stations (AZU1, KIR0, ULAB), which provide RT observation data, were selected. The location of these stations and details of them are given in figure 1 and table 1, respectively.

![Figure 1. Location of the IGS RTS stations used in this study](image)

| Station | Net  | Country | Latitude  | Longitude | Height (m) | Receiver     | Antenna       | Radome |
|---------|------|---------|-----------|-----------|------------|--------------|---------------|--------|
| AZU1    | RTS  | US      | 34.1258   | -117.8964 | 144.75     | TRIMBLE      | ASH701945B_M | SCIS   |
| KIR0    | RTS  | Sweden  | 67.8775   | 21.0600   | 497.90     | JAVAD        | JNSCR_C146-22-1 | OSOD   |
| ULAB    | RTS  | Mongolia| 47.6700   | 107.0500  | 1611.70    | JAVAD        | JAV_RINGANT_G3T | NONE   |

In this study, an open source multi-stream client program (BNC) version 2.12 data were used. While using this program, RT correction product stream IGS03, which includes GLONASS correction in addition to GPS, was registered. In addition, RTCM3EPH broadcast ephemeris stream was used. A data set containing RT-PPP coordinates for these stations and a time period of 1 hour were obtained using BNC v2.12. Coordinate results were derived at intervals of 1 second. Accuracy of the derived
coordinates for each interval were tested based on ITRF 2008 measurement epoch coordinates (true coordinates) of IGS RTS stations, obtained based on ITRF 2008 reference epoch coordinates and velocities. Estimated coordinate values of the stations in the topocentric coordinate system, indicating the differences between derived coordinates and true ones, are given in figure 2-4. As depicted in figures, about 20 minutes after the start, the results reach better than 10 cm in all components.

**Figure 2.** Differences of RT-PPP coordinates and true ones for station AZU1

According to the figure 2, each component of the AZU1 exhibits sub-decimetre accuracy after the first 20 minutes. Similar condition is observed 15 minutes after the initial time of KIR0 (Figure 3).

**Figure 3.** Differences of RT-PPP coordinates and true ones for station KIR0
During this time period, results corresponding to north components are better than 5 cm, whereas they are at 10 cm level in the east and up components. Comparing to the AZU1 and KIR0, differences corresponding to ULAB station are in similar level.

![Figure 4. Differences of RT-PPP coordinates and true ones for station ULAB](image-url)

Besides the accuracy analysis, in an attempt to further enhance our evaluation in assessing the precision of the results, some statistical values, including maximum (max), minimum (min), mean and standard deviation (std), corresponding to the differences were computed and given in table 2.

| Stations | North (cm) | East (cm) | Up (cm) |
|----------|------------|-----------|---------|
| AZU1     | 16.8       | 159.9     | 29.0    |
|          | -258.1     | -14.5     | -691.2  |
|          | -0.7       | 12.2      | -4.3    |
|          | 27.8       | 27.2      | 41.4    |
| KIR0     | 167.6      | 29.2      | 665.3   |
|          | -19.9      | -140.4    | -26.8   |
|          | 2.0        | -7.9      | 1.9     |
|          | 15.3       | 5.9       | 44.3    |
| ULAB     | 255.3      | 96.3      | 303.6   |
|          | -4.2       | -59.2     | -48.0   |
|          | 9.4        | -7.1      | 10.3    |
|          | 27.8       | 15.2      | 30.8    |

According to the table 2, maximum and minimum values illustrates the starting period of the results. Mean values of the KIR0 are better than the others which are less than 2 cm for the north and up components and better than 8 cm in the east components. In terms of standard deviation (std), which
indicates the precision of the differences, results are relatively large for all components. The possible reason of the large std values are directly related to the first 5 minutes of the obtained results.

4. Conclusions
This study examines the performance of RT-PPP method using three IGS RTS stations, which provide RT data. BNC v2.12 was used for estimating the coordinates. The obtained results were examined in terms of both accuracy and precision. The results obtained after 20 minutes exhibits sub-decimetre level accuracy. However, std values that indicate the precision of the results are generally large, which is related to the initial results.

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