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Comparison of different algorithms with a single GNSS receiver

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Abstract

In Nowadays, many terrestrial or satellite-based positioning techniques have developed systems and methods to obtain the needed location information at low cost, real-time and precisely Nevertheless, each technique has undergone significant refinement and evolution, effectively converting the drawbacks of prior methods into notable advantages. In this study, the position accuracy of Network-RTK (Network-Real Time Kinematic) and PPP (Precise Point Positioning) techniques, which are trending in positioning techniques with GNSS, are examined and their advantages and disadvantages are revealed. Root mean square errors (RMSE) were calculated to test the point location accuracy. The findings of the study indicate that the N-RTK technique exhibited superior performance over the PPP technique in all three components: North, East, and Up. However, it is worth noting that the PPP technique showed significant improvement in RMSE values after convergence, as the convergence of integer phase ambiguity took place. Additionally, by increasing the utilization of satellite observations and obtaining more accurate satellite orbit and clock correction information, the accuracy of PPP-based results approached that of the N-RTK technique. These results suggest that with enhanced data combinations and refined correction information, the PPP technique has the potential to achieve comparable position accuracy to that of the N-RTK technique. Nonetheless, it is important to acknowledge the initial superiority of the N-RTK technique in the specific aspects studied.

Introduction

In Nowadays, numerous institutions and companies, particularly those involved in geomatics engineering, have been effectively employing the Network-RTK (CORS) technique, also known as Continuously Operating Reference Stations (CORS). This technique enables the precise determination of point locations using a single GNSS receiver, without the requirement of any fixed ground point. Furthermore, these locations can be determined instantly, showcasing the high accuracy provided by the CORS technique [1-3].

However, the Network-RTK technique has a limitation in that it relies on the availability of GNSS infrastructure and bidirectional data communication (such as GSM or GPRS) between the reference stations and the mobile receiver. In situations where such communication is not possible, the point location cannot be determined using the Network-RTK technique.

On the other hand, the Precise Point Positioning (PPP) technique offers a strong alternative to Network-RTK. It allows for the calculation of point positions with high accuracy using a single GNSS receiver, without requiring raw measurements or correction information from a known reference point, and without dependence on any specific GNSS infrastructure. This makes PPP a valuable method in scenarios where the Network-RTK technique is not feasible or practical [4,5].

During the determination of point location using the PPP technique, certain external parameters are required, including solid earth tide, ocean loading, and accurate satellite orbit and time information. Moreover, the PPP method operates on the fundamental principle of treating the phase initial ambiguity as unknown. This characteristic often results in an extended measurement time for achieving centimeter-level sensitivity in PPP solutions, compared to relative positioning methods. To address the issue of convergence time stemming from the resolution of integer phase ambiguity in the PPP technique, several methods and models have been developed. These techniques aim to optimize the time required to obtain reliable solutions [6-10].

In this study, the position accuracy and comparative advantages of the CORS-TR (CORS-Turkey) and RT-PPP (Real-Time-PPP) techniques, which utilize a single GNSS receiver, have been investigated.

Material and Method

In this section, GNSS receiver and observation data sets used in static experiment design with different algorithms are introduced. In addition, the quality of GNSS observation data and the algorithms used for position determination are explained. Within the scope of this study, GNSS observations were made at the N.211 and G.22012 triangulation points, whose coordinates are known, in static mode, simultaneously at 1 Hz sampling interval.

In N.211, where GNSS observations are made, instant location information is provided by receiving corrections from the CORS-TR system. However, due to internet quality, location information could not be produced in some epochs. On the other hand, a static session was held at the G.22012 point and the observation data were recorded for post-process. The experimental design, which was made in a static session, lasted approximately 2.5 hours on the campus of Gebze Technical University on May 9, 2023. In addition, in the RT-PPP technique used in this study, satellite orbit and clock correction information produced by CNES (National Space Research Center) in real-time conditions was used. All process steps of N-RTK during the experiment and RT-PPP techniques after the experiment are shown in Figure 1 and Figure 2 in detail, respectively. During the experiment, GNSS raw observation data was recorded via the CHC I80 GNSS receiver/antenna. With the satellite orbit and clock correction information obtained over the internet from the CNES archive of the experiment day, solutions were made with the static-PPP technique in real time in the rtkpos application of the RTKLIB software. On the other hand, the point position was obtained by N-RTK technique, with the help of the corrections obtained by the GNSS receiver via the internet and the satellite observations made by connecting to the CORS-TR system during the experiment.

Results and Discussion

In this section, point positions are compared in the time domain by making simultaneous 2.5-hour observations at the N.211 and G.22012 triangulation points with known velocities at epoch 2005.0 in the ITRF 20 ((International Terrestrial Reference Frame-2020)) datum, by applying Network-RTK and RT-PPP techniques, respectively. In the experiments, with the Network-RTK technique applied at the N.211, position components were obtained at the sampling interval of 1 second during the experiment. However, the obtained position components are at epoch 2005.00 in the TUREF (Turkish National Reference Frame) system, that is, the ITRF-96 datum. In addition, the raw GNSS observation data used to determine the point location belong to the GPS and GLONASS system. In this case, velocities were calculated in the ITRF-2020 datum and the measurement epoch to compare the point location components with the referenced coordinates. During the experiment, as a result of receiving the corrections from the CORS-TR network via the internet, it caused data loss in some epochs depending on the internet speed.

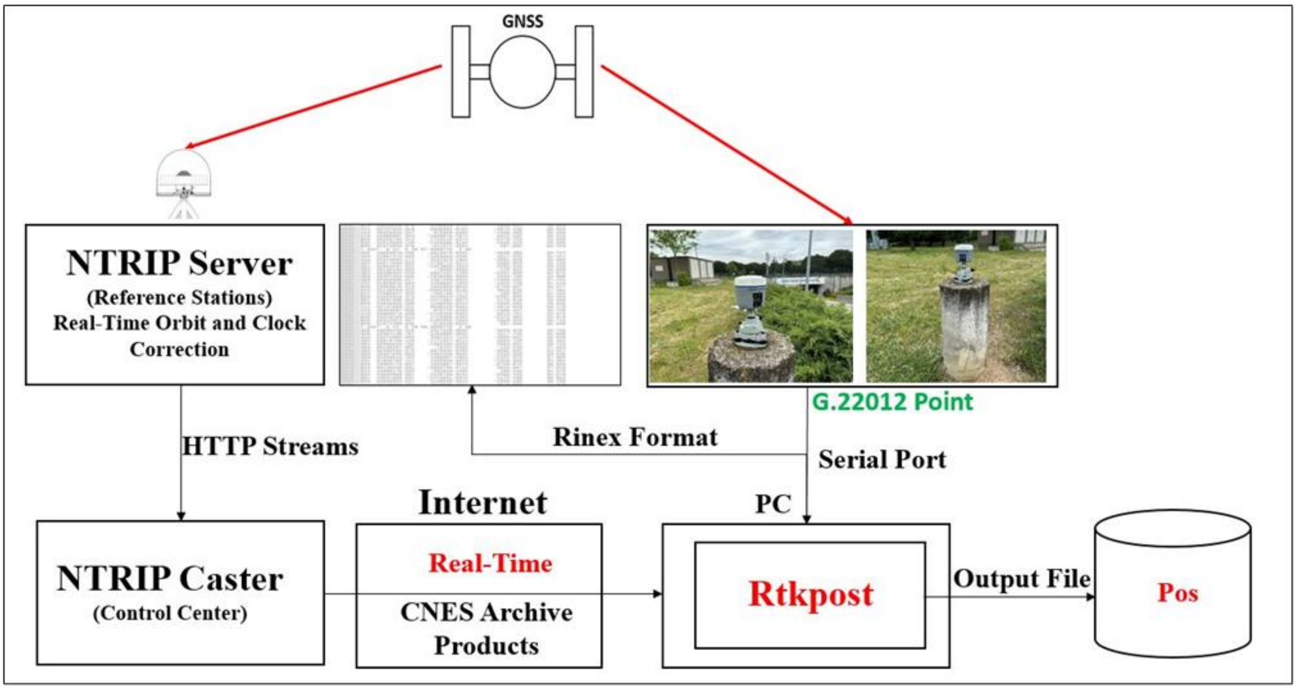

Figure 1. Schematic view of the static-RT-PPP method with a GNSS receiver/antenna

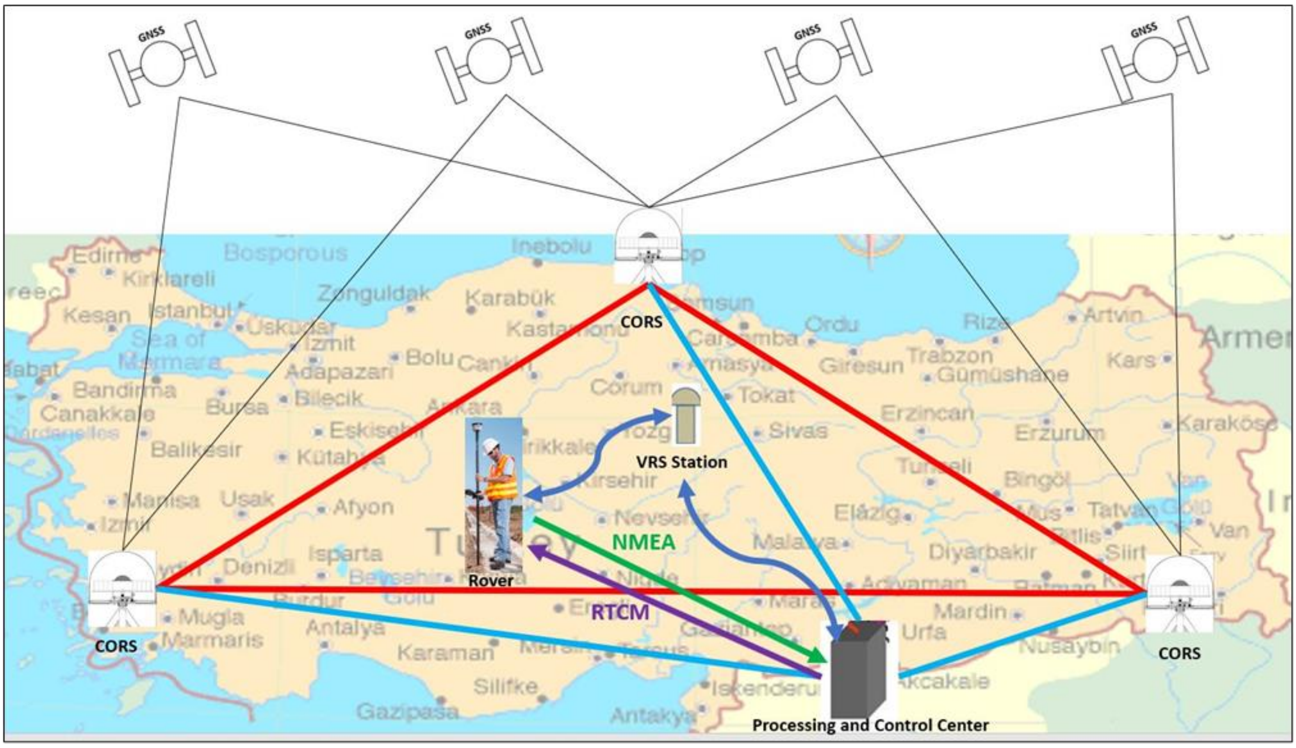

Figure 2. VRS method in Network-RTK technique

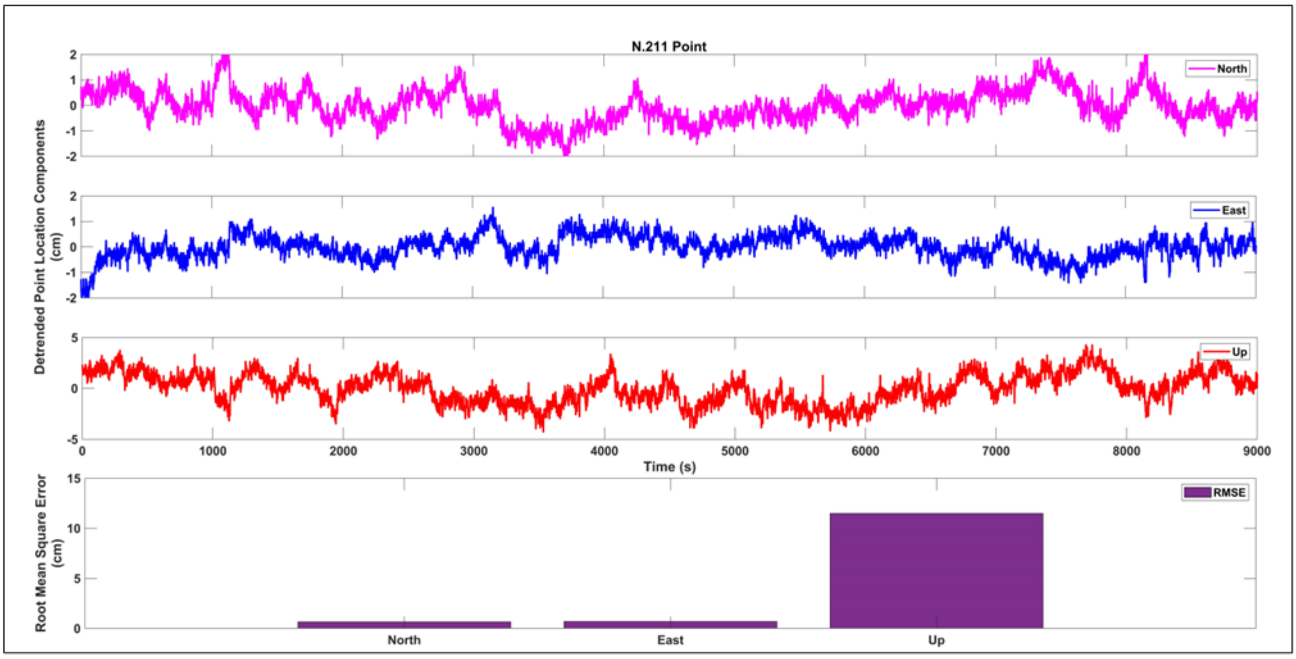

Figure 3. Time series and RMSE of point location components of Network-RTK solution of N.211

This data loss is compensated for by using nearest neighbor interpolation. The North, East and Up components of the N.211 point in the time domain of the Network-RTK solution, respectively, are shown in Figure 3. Detrend was applied to extract the offsets and linear trends seen in the position components obtained throughout the experiment. The time series in lines 1 and 2 in Figure 2 show the North and East components, respectively. Static measurements show a displacement between -2 and +2 cm for both horizontal components. Looking at the up component, this value varies between -5 cm and +5 cm, and the position accuracy in itself is lower than the horizontal component. In the last part of the figure, it is ±7 mm in the horizontal component and ±10 cm in the vertical component, according to the referenced coordinates. On the other hand, the time series of the point position components obtained by the PPP technique using the satellite orbit and clock correction information produced under real-time conditions in static mode of the raw satellite observations obtained from the GNSS receiver installed at the G.22012 Triangulation point is given in Figure 4. The evaluation after the time taken for the convergence of the integer phase ambiguity in the PPP technique is also shown on the same figure. In the right part of Figure 4, the displacements in the time domain after convergence range from -2 to 2 cm for the horizontal component and -4 to 4 cm for the vertical component. While the mean square error value in the northern component was 35 mm throughout the experiment, it was calculated as 5.5 mm after convergence. While it was 80 mm during the whole experiment for the eastern component, it decreased to 71 mm after convergence.

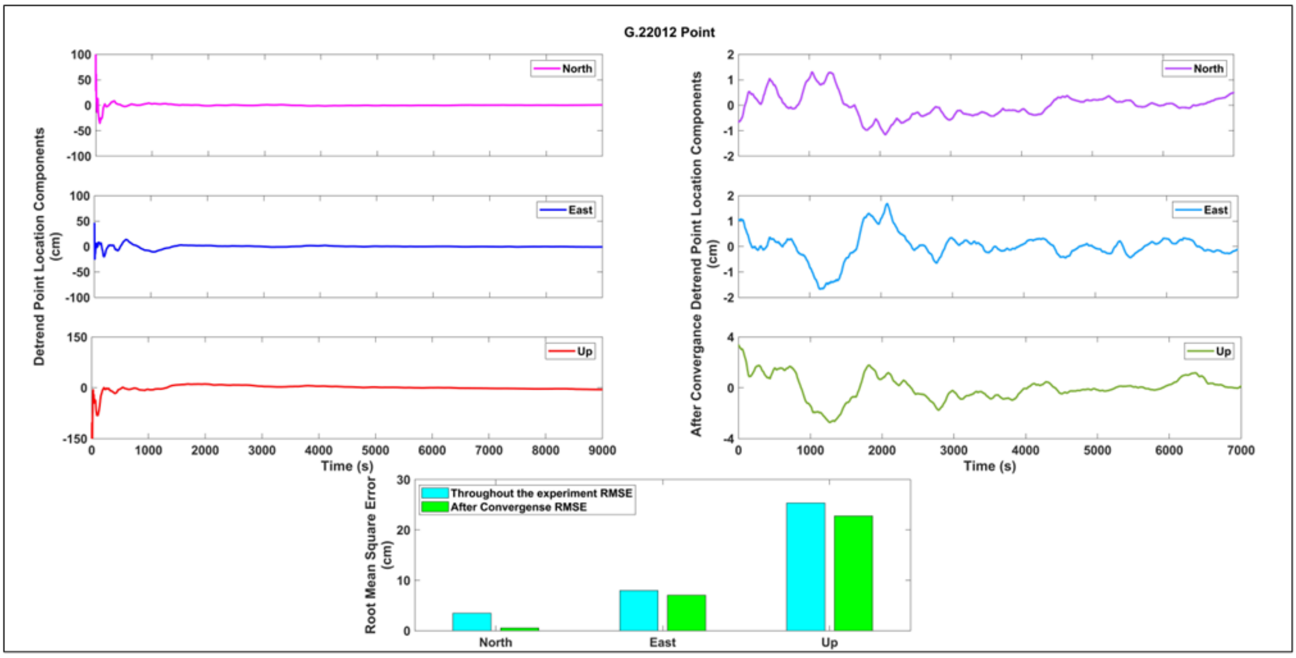

Figure 4. Time series and RMSE of point location components of RT-PPP solution of G.22012.

While the vertical component was 25.4 cm during the whole experiment, it was found to be 22.8 cm after convergence. In real-time static-PPP solutions, after convergence, there is a decrease of approximately 1 to 3 cm in the mean squared error values in the horizontal component, while a decrease of about 1 cm in the vertical. However, considering the coordinates referenced at two points, it was found that the RMSE values of the solutions made with the Network-RTK technique had the lowest values both horizontally and vertically compared to the other points.

Conclusion

In this study, the performances of the methods were tested by making simultaneous observations at 2 triangulation points with known coordinates to compare different algorithms with a single GNSS receiver under the same conditions. During the experiment, point locations whose coordinates and velocities were calculated by the static method were taken as reference in order to compare the Network-RTK and RT-Static-PPP methods with each other. When the solutions obtained during the whole experiment were compared, the best result was obtained from the Network-RTK solution. It was also observed that there was a significant improvement in RT-PPP solutions after convergence. In addition, the high cost of the infrastructure and necessary equipment of the CORS-TR system, and the inability to receive corrections by mobile receivers in limited regions where internet/GSM data transmission means are weak are the major disadvantages of the method. However, these needs are not required in solutions based on PPP technique. Due to the nature of the PPP technique, a certain period of time must be waited for the integer phase uncertainty to converge. Although the PPP-AR technique was developed for this problem, it could not be applied within the scope of this study. Because the signals received from the satellites of the GNSS receiver/antenna used and the analysis centers affiliated to IGS are not included in the bias file produced for the corrections brought to the satellite signals. Looking at the Network-RTK results throughout the experiment, there are epoch losses due to internet speed. Although this problem is solved by the interpolation method in the analysis part, the quality of internet/GMS tools, which are data transmission tools, should be increased at every point in the network for the corrections coming from the Tusaga-Aktif system. However, in the CORS-based Tusaga-Active system, the inclusion of the necessary correction information for the solution of GPS, GLONASS satellites as well as Galileo and BeiDou satellites will affect the result more accurately.

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