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Comparison of Network-RTK and PPP Technique in terms of Position Accuracy

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Abstract

In Nowadays, in addition to terrestrial measurements, satellite based GNSS (Global Navigation Satellite Systems) sensors (Geodetic quality, low cost and chipset GNSS receivers) are widely used in many applications in determining the point location. Together with GNSS technology, it has created the need to calculate the point location with high accuracy, low cost and in real time. Therefore, different positioning techniques and GNSS sensors have been developed to date. In many developed countries in the world, with the help of Continuously Operating Reference Stations (CORS), the point location is detected in real time and with high accuracy by the Network-Real Time Kinematic (N-RTK) technique. In recent years, point location without the need for limitations such as data transmission infrastructure and reference GNSS stations has been determined in many studies with Precise Point Positioning (PPP) technique in real time and with high accuracy. Within the scope of this study, N-RTK and PPP techniques, which are widely used in engineering studies, especially in the field of Geomatics Engineering, were compared in terms of positioning accuracy relative to each other. For this purpose, the position accuracy of Network-RTK, Post-Process (PP)-PPP and Real Time (RT)-PPP techniques were examined, and their advantages and disadvantages compared to each other were revealed. Point position accuracy is better in the solution made with N-RTK technique in all three of the North, East and Up components, followed by PP-PPP and RT-PPP. In addition to the combination of satellite observations used, it is seen that the satellite orbit and clock correction information can be obtained more precisely, and the PPP-based results can be approached to the position accuracy obtained by the N-RTK technique.

1. Introduction

Today, with the developments in GNSS satellite and receiver technology, different algorithms have been developed to increase the location accuracy without the need for a real-time reference station. One of these methods is to calculate the point position with the N-RTK technique by making continuous observations with the help of reference stations. The Network-RTK technique, which has examples in developed countries in the world and is called the CORS system, started in our country as CORS-TR Project in May 2006 by Istanbul Kultur University, General Directorate of Land Registry and Cadastre and General Directorate of Mapping. This project was supported by TUBITAK and was completed in May 2009 (Uzel et al., 2011). The basic principle of the CORS system is GNSS receiver/antennas placed on reference stations with known coordinates and raw GNSS observation data is sent to the control center via ADSL (Asymmetric Digital Subscriber Line) and GPRS/EDGE (General Packet Radio Service/ Enhanced Data rates for GSM Evolution). Errors calculated in the center are modeled and RTK corrections are calculated in real time and sent to rover GNSS receivers via GPRS/EDGE in RTCM (Radio Technical Commission for Maritime Services) format (Yıldırım et al., 2011). Network-RTK technique, unlike the Classic-RTK

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technique, determines location using multiple reference points, not with a single reference point. CORS-TR system has 168 base GNSS stations and 2 control centers throughout Turkey and the TRNC (Turkish Republic of Northern Cyprus). In the Network-RTK technique, it is aimed to eliminate the disadvantages of a single reference point by using multiple reference points and to increase the accuracy. In this method, three main methods are used to transmit the corrections calculated in the control center to the receiver. These; VRS (Virtual Reference Stations), FKP (Flaschen Korrectur Parameter) and MAC (Master Auxiliary Concept) techniques. Thus, the position accuracy is increased (İnal et al., 2014).

Precise Point Positioning (PPP) technique, which is a special case of absolute position determination with a single receiver, has been investigated for its performance, reliability and accuracy in many application areas for about 20 years. This method has become a trend today, as a single receiver is sufficient and provides high accuracy. The PPP technique aims to determine the location with a single receiver with high accuracy using precise orbit and time information (Zumberge et al., 1997; Kouba & Heroux, 2001). The PPP technique is conventional-PPP where the phase initial ambiguity is estimated as a fractional number; when it is estimated as an integer, it is called PPP-AR (PPP-Ambiguity Resolutions) technique (Atiz, 2021). In this method, the precise orbit and clock information used are published on the internet as real-time or post-process via IGS and many analysis centers affiliated to this center. The evaluation of the data obtained after the data collection stage for high accuracy positioning is called post-process (PP). For this purpose, many paid or free software has been developed (Atiz, 2021).

Within the scope of this article, it is aimed to determine the location accuracy of the Network-RTK, static PP-PPP and RT-PPP techniques according to the reference coordinates, and to reveal the advantages and disadvantages of the N.211, N.210 and G.22012 triangulation points, whose point locations are certain. Simultaneous 2.5-hour measurements were made at the triangulation points whose coordinates are known on the campus of Gebze Technical University. Point positions were obtained with the static-PPP technique by using the instantaneous point position with the Network-RTK technique during the experiment, and the satellite orbit and clock correction information produced in real time after the experiment and for post-process. The results are compared together with reference to the coordinates obtained by adjustment the point positions based on statically base station points beforehand.

2. Method

In this study, the mathematical model of the network-RTK, which is a kinematic measurement method with phase measurements, and the precise point positioning technique, which is a special case of absolute position determination, are explained from the satellite-based positioning techniques.

2.1. Network-RTK (CORS-TR)

Network-RTK technique, which was developed to overcome the limitation of the single reference receiver brought by the classical-RTK technique, is one of the most widely used measurement methods today. In order to contribute to applications requiring high accuracy, the CORS system has been implemented since the 1990s (Yıldırım et al., 2011). The RTK technique is based on phase observations to satellites and correction or raw measurement data from reference stations. Reference stations send correction information to rover receivers via communication means such as GSM (Global System for Mobile Communications), internet or radio transceiver antenna. The mathematical model of the Network-RTK technique includes calculating the position of the rover receiver based on measurements taken from multiple reference stations within the network. As stated before, phase observations and correction information made to satellites are used in Network-RTK technique. In Network-RTK, 3 different techniques are used in the calculation of correction information, these are; VRS, FKP and MAC are techniques. These techniques allow modeling of the observation space (Kahveci, 2017). In this study, VRS technique is explained because VRS model is used for Network-RTK technique. The Virtual Reference Station (VRS) technique, also known as virtual base station (VBS), was first proposed by Vollath et al. 2000 (Kahveci, 2017). The VRS is a virtual station located just a few meters from the rover receiver. In this technique, there is two-way communication between the rover receiver and the control center (Yıldırım et al., 2011). The rover receiver sends its approximate coordinates to the control center and the control center generates the VRS reference data for the rover receiver. The generated VRS corrections are generally sent to the surfing receiver with RTCM (İnal et al., 2011). By calculating the correction parameters valid for the rover from multiple reference station data, some systematic effects (ionosphere, troposphere, etc.) in the RTK measurements are minimized (Kahveci, 2017). In Figure 1, the background processing steps of the VRS model are shown schematically (Altintas et al., 2023).

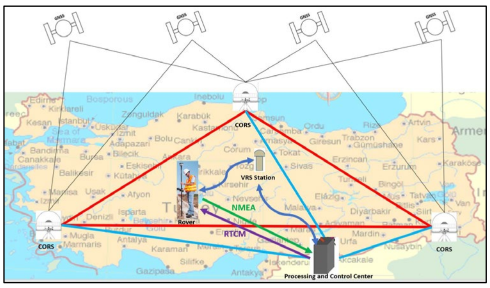

Figure 1. VRS Method in Network-RTK Technique.

After the rover receiver sends its approximate location to the control center in NMEA (National Marine Electronics Association) format, the VRS data calculated in the control center is sent to the rover receiver in RTCM (Radio Technical Commission for Aeronautics) format. Then, the point location is calculated by performing the standard RTK solution on the rover receiver (Kahveci, 2017).

2.2. Precise Point Positioning (PPP)

In the PPP technique, the point position of a dual-frequency single GNSS receiver is calculated using products such as carrier phase and code observations and satellite orbit and clock information for external real-time or post-process purposes. In this study, point location was calculated with two approaches using both post-process and real-time products. The RT-Satic-PPP and PP-Static-PPP approaches are shown schematically in Figure 2.

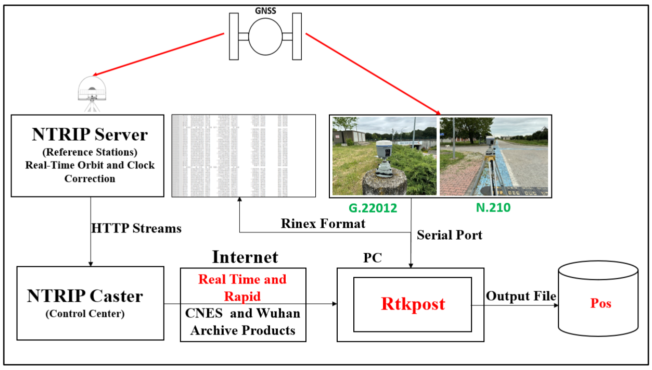

Figure 2. Schematic View of The Static-RT-PPP/PP-PPP Methods With a GNSS Receiver/Antenna.

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3. Results

In Nowadays, with GNSS receivers used in many engineering activities, positioning sensitivity studies are carried out with different satellite systems and positioning techniques. The main purpose of these studies is to perform instant and reliable position determination studies at low cost, at high speed and without the need for external parameters. In this article, the accuracy of the point location was analyzed by applying three different positioning approaches, namely CORS-TR, RT-PPP and PP-PPP, with a single GNSS receiver. In the experimental design, besides using a single GNSS receiver, three different approaches were evaluated by making simultaneous satellite observations for a fair assessment. For this, simultaneous measurements were made in Gebze Technical University Campus at the N.210, N.211 and G.22012 triangulation points, which are close to each other, in the ITRF2020 datum and in the 2005.0 epoch, as the 6° UTM coordinates are given in Table 1 and as seen in the Google Earth image in Figure 3. During the experiment, the CHC I80 GNSS receiver/antenna with the same type of GNSS receiver/antenna was used. The epoch epoch position of the point position components during the measurement was calculated by the Network-RTK method of the raw observation data collected with the GNSS receiver at the N.211 point throughout the experiment. On the other hand, satellite observations were made in static mode simultaneously with the CHC I80 GNSS receivers located at the N.210 and G.22012 triangulation points. All experiments were completed on 09 May 2023 with approximately 2.5 hours of simultaneous observation.

Figure 3. Triangulation Stations with GNSS Measurement in The Experiments.

Table 1. Referenced coordinates of the position components of the triangulation points.

TRIANGLE POINTS	6° UTM Coordinates at ITRF2020 Datum 2005.0 Epoch		
	NORTH (m)	EAST (m)	UP (m)
G.22012	4520147.46801	698860.78829	44.2445
N.210	4519711.23128	698983.78935	44.7835
N.211	4519720.20295	699203.41743	44.0856

After the measurement process, the simultaneous start and end times of the calculated position components at all 3 points were taken together and an evaluation was made. All of the calculations and graphics made in the analysis part were made in the MATLAB program. In addition, the fact that the GNSS receiver/antenna used in the experiments has the same feature has been a fair evaluation for the comparison of all 3 points according to the reference positions in the simultaneous measurements made at the points. The reference coordinates were calculated using the same method and program for the 3 points. The velocities at the time of measurement of these points were calculated in milimeter/year unit by interpolation as a result of the velocity estimations made by taking the existing geodynamic, tide gauge GPS points in TUTGA (Türkiye National Basic GPS Network), TUSAGA-Active, General Directorate of Mapping and the stations of some institutions and municipalities with the clustering analysis method within the scope of the Project for the Determination of the Speed Zone of Türkiye carried out by the General Directorate of Mapping and Yıldız Technical University.

In the experiments, with the Network-RTK technique applied at the N.211 point, position components were obtained during the 1 second sampling interval during the experiment. However, the obtained position components are at epoch 2005.00 in the TUREF 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 Tusaga-Active network via the internet, it caused data loss in some epochs depending on the internet speed. This data loss is compensated for by using nearest neighbor interpolation. The North, East and Elevation components of the N.211 point in the time domain of the Network-RTK solution, respectively, are shown in Figure 4.

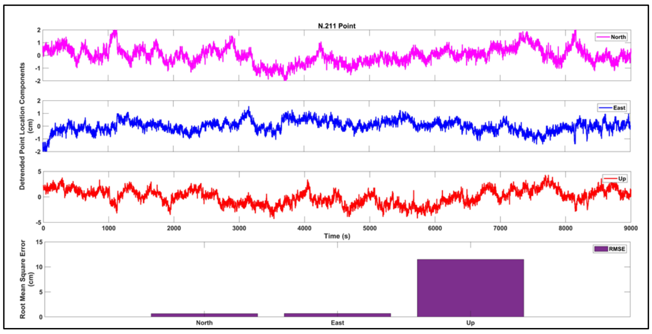

Figure 4. Time Series and RMSE of Point Location Components of Network-RTK Solution of N.211.

Detrend was applied to extract the offsets and linear trends seen in the position components obtained throughout the experiment. The time series in rows 1 and 2 in Figure 4 show the North and East components, respectively. Static measurements show a displacement between -2 and +2 cm for both horizontal components. Looking at the vertical component, this value varies between -5 cm and +5 cm, and the position accuracy in itself is lower than the horizontal component. Looking at 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 position components obtained by post-process in the RTKLIB software of the simultaneous satellite observations made with the GNSS receiver installed at the N.210 point is shown in Figure 5. For post-process, a solution was realized with the PPP technique in static mode using Rapid products produced by Wuhan University. Considering the results of the static-PPP solution, fluctuations are observed in the position components due to the convergence time of the integer phase ambiguity due to the nature of the PPP technique. The time series of the position components of this point throughout the entire experiment are given in Figure 5 on the left, and the point position components after convergence are given on the right. While the displacement occurring in the horizontal position component after convergence is between -2 and 2 cm, it varies between -4 and 4 cm in the vertical. In order to test the accuracy of the position components obtained from the post-process static-PPP solution according to the reference coordinates of the N.210 point, when the root mean square errors (RMSE) were examined, it decreased to 8.8 mm after convergence, while it was 9.4 mm for the North component throughout the entire experiment. Looking at the east component of this point horizontally, it was calculated as 19.7 mm throughout the experiment and 19.5 mm after convergence. The vertical component is 12.9 cm during the whole experiment, while it is 12.8 cm after convergence. 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 fit observations obtained from the GNSS receiver, which is the last point in the experiments and installed at the G.22012 triangulation point on the concrete block, is shown in Figure 6. Similar to the solution of satellite observations of point N.210, but different types of data were used in terms of the products used. The evaluation after the time taken for the convergence of the integer phase ambiguity in the PPP technique is also shown on the figure. In the right part of Figure 6, the displacements in the time domain after convergence range from -2 to 2 cm for the horizontal component, as at N.210, and from -4 to 4 cm for the vertical component.

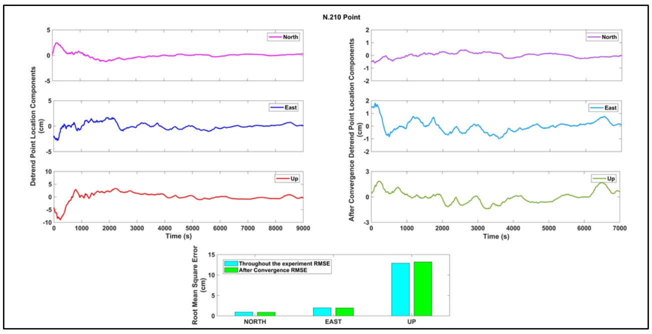

Figure 5. Time Series and RMSE of Point Location Components of PP-PPP Solution of N.210.

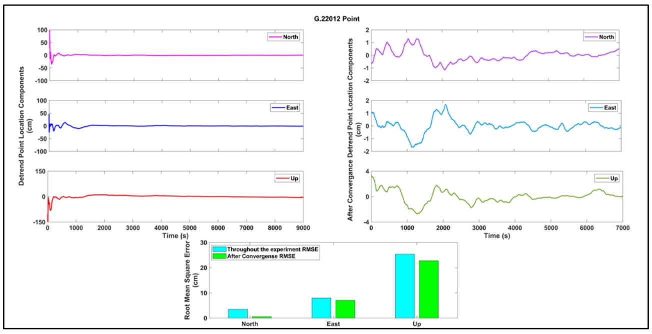

Figure 6. Time Series and RMSE of Point Location Components of RT-PPP Solution of G.22012.

The reference coordinates of the G.22012 point are shown with the bar graph at the bottom of the figure by calculating the RMSE in order to test the accuracy of the solutions obtained by the real-time static-PPP technique. While the RMSE value in the north 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 east component, it decreased to 71 mm after convergence. While the vertical component was 25.4 cm during the whole experiment, it was found to be 22.8 cm after convergence. In this case, there is no significant change in the post-process static-PPP results, but there is a decrease of approximately 1 to 3 cm in the RMSE values in the horizontal component after convergence in real-time static-PPP solutions, while a decrease of 1 cm in the vertical is observed. In addition, considering the coordinates referenced at three 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. However, Network-RTK results are more sensitive, followed by PP-Static-PPP and RT-Static-PPP.

4. Conclusion

In this article, the performances of the methods are tested by making simultaneous observations at 3 triangulation points with known coordinates to compare different algorithms with a single GNSS receiver under the same conditions. During the experiment, point positions whose coordinates and velocities were calculated by the static method were taken as reference in order to compare the Network-RTK, PP-Static-PPP and RT-Static-PPP methods with each other. The reference coordinates of all three points were calculated using the same method and simultaneous measurements. The calculated coordinates of the point location components in Network-RTK solutions are in ITRF 96 datum, 2005.0 epoch. However, satellite orbit and clock correction information used in PPP-based solutions has been calculated by analysis centers in ITRF2020 datum after December 2022. In this case, the coordinates of the location components obtained from the Network-RTK solution were recalculated in the ITRF 2020 datum and the current measurement epoch to ensure datum integrity. In addition, GPS and GLONASS satellite observations are also discussed in PPP-based solutions, where coordinates are produced with the help of GPS and GLOANSS satellites in Network-RTK technique, for a fair evaluation. When the solutions obtained during the whole experiment were compared, the best result was obtained from the Network-RTK solution, followed by PP-Static-PPPP and RT-Static-PPP. In the results based on PPP, rapid satellite orbit and clock correction information produced for post-process was more sensitive than real-time satellite orbit and clock corrections. It was also observed that there was a significant improvement in RT-PPP solutions after convergence. According to the results, it is seen that the precision of the point position components resolved by the PP-PPP technique is closer to the Network-RTK solution. This suggests that the satellite orbit and clock correction information will be produced more precisely, and the results of the models and parameters used may be similar to the accuracy of the position components calculated in the Network-RTK technique. 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 ambiguity to converge. Although the PPP-AR technique was developed for this problem, it could not be applied within the scope of this article. Because the signals that the used GNSS receiver/antenna received from the satellites and the analysis centers affiliated to IGS are not included in the bias file produced for the corrections to the satellite signals. During the experiment, there are epoch losses due to internet speed according to the Network-RTK results. 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-Active system. However, the inclusion of the correction information required for the solution in the CORS-based Tusaga-Active system, as well as the GPS and GLONASS satellites, as well as the Galileo and BeiDou satellites, will increase the positioning accuracy. Today, according to the literature studies, the coordinates produced for the Network-RTK should now be given in the ITRF 2020 datum. For this, studies should be carried out on the quality of satellite systems used in the Tusaga-Active system, GNSS receiver/antenna in base stations, current datum and data communication tools. The use of GPS and GLONASS satellite observations for Network-RTK caused us not to use other satellite systems for PPP-based solutions. In addition, PPP-AR solution could not be made due to the GNSS receiver/antenna feature. However, in future studies, it can be decided beforehand which signal type the GNSS receiver/antennas record and whether it is suitable for the method to be applied.

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Author contributions

1st Author: Data curation, Writing-Original Draft Preparation, Validation, Control and Validation
2nd Author: Conceptualization, Methodology, Software, Data curation, Writing, Visualization
3rd Author: Investigation, Software
4th Author: Investigation, Software

References

Altintas A F, Usta S, Karadeniz B & Pehlivan H (2023). Comparison of Different Algorithms with a Single GNSS Receiver. *7th Advanced Engineering Days (AED'2023)*,22-26, Mersin, Türkiye.

Atiz Ö F (2021). Investigation of Positioning accuracy of AR approach on PPP Method. Master's Thesis, Necmettin Erbakan University, Institute of Science, Konya, 84p (in Turkish).

İnal C, Bülbül S & Yıldırım Ö (2014). Repeatable of Network RTK Measurement. *Afyon Kocatepe University Journal of Science and Engineering*, 02550.

İnal C, Gündüz A M & Bülbül S (2014). Comparison of Classic RTK and Network-RTK Methods. *Selcuk University Journal of Engineering Science and Technology*, 2(2), 19-29.

Kahveci M (2017). Kinematic GNSS and RTK CORS Networks. Nobel Academic Publishing. ISBN: 978-605-320-720-7 (in Turkish).

Kouba J & Heroux P (2001). Precise Point Positioning using IGS orbit and clock Products. GPS Solutions, 5 (2), 12-28.

Uzel T, Eren K, Gülal E, Dindar A A, Tiryakioğlu İ & Yılmaz H (2011). Monitoring Plate Tectonics by TUSAGA AKTİF (CORS-TR). TMMOB Chamber of Survey and Cadastre Engineers 13. Türkiye Scientific and Technical Mapping Congress, Ankara, Türkiye.

Yıldırım Ö, Mekik Ç & Bakıcı S (2011). TUSAGA-Active (CORS-TR) System, Contributions to The General Directorate of Land Registry and Cadastre. Journal of Geodesy and Geoinformation. 11(2), 134-139.

Zumberge J F, Heflin M B, Jefferson D C, Watkins M M & Webb F H (1997). Precise point positioning for the efficient and robust analysis of GPS data from large networks. *Journal of Geophysical Research Solid Earth*, 102 (B3), 5005–5017.