Precise Point Positioning (PPP) Technique versus Network-RTK GNSS

Reha Metin ALKAN, İ. Murat OZULU, Veli İLÇİ, Turkey

Key words: GNSS, PPP, CSRS-PPP, Network-RTK, CORS, TUSAGA-Aktif

SUMMARY

The aim of this study is to make an accuracy comparison of the Network-RTK and the PPP techniques in a dynamic environment. In order to assess the accuracy performance of the both techniques, a kinematic trial was carried out. The Network-RTK-based coordinates of the vessel were recorded from the National Turkish Network-RTK System, called as TUSAGA-Aktif network, in real-time. The collected data in the kinematic trial were sent to a commonly used online processing service, Canadian Spatial Reference System-Precise Point Positioning Service (CSRS-PPP) operated by Geodetic Survey Division of Natural Resources Canada (NRCan) and PPP-derived coordinates were obtained. The Network-RTK and PPP-derived coordinates were compared with those of differential technique results, i.e. to the reference coordinates, epoch-by-epoch.

The results show that the Network-RTK, TUSAGA-Aktif, provides a cm-level of accuracy when the solution can be fixed, while it decreases dramatically to even a meter-level of accuracy if the fixed solution cannot be provided. Concerning the PPP technique, the kinematic test results showed that the PPP-derived coordinates converge to the relative solutions with also a cm-level of accuracy. In general, it concludes that both of the techniques can be used for the several marine applications as a strong alternative to the conventional differential methods. In this study, the test procedures and their results are discussed.

Precise Point Positioning (PPP) Technique versus Network-RTK GNSS

Reha Metin ALKAN, İ. Murat OZULU, Veli İLÇİ, Turkey

1. INTRODUCTION

Major developments in the world of informatics have led to the development of different solutions with various algorithms, and major changes in numerous professional fields as well as in satellite-based positioning. Although; in the 1990's, it was necessary to obtain positioning with Global Positioning Systems (GPS) using at least two receivers; nowadays an accuracy of within a centimetre level of positioning has become possible using a single receiver and advanced techniques.

One of which is Network-RTK (or commonly known as Continuously Operating Reference Station-CORS) used extensively in the world, producing economical and rapid solutions for the users. Network-RTK systems have been set up to provide data collection, processing and be transmitted to users and thus it needs reliable and robust communication links, high-cost infrastructure including relatively expensive network-capable GNSS receivers and usage fees. According to the results obtained the Network-RTK has been used quite widely all over the world due to it many advantages like accurate and fast positioning, it can easily be used by one person and its cost-effectiveness. On the other hand, it has some restrictions and this limits its usage in some cases and remote places. The most important restriction is; this technique, similar to all of the differential techniques, needs additional data, i.e. correction, from at least one reference station and the distance between the rover and its reference station is not un-limited (should be about 50-100 km). This requires the need of a data line to transmit to the receiver. The uses of such services are restricting, especially, in developing counties where there are no sufficient frequencies of a reference points and GSM station.

In Turkey, TUSAGA-Aktif Network was completed and opened for civilian use in 2009 sponsored by the Turkish Scientific and Technical Research Agency-TUBITAK (Bakıcı and Mekik, 2014). The network consists of 146 reference stations with an average spacing of 70-100 km covering the entire country of Turkey including the Turkish Republic of Northern Cyprus (Figure 1). The users of this system can obtain his/her position within a few cm-level of accuracy even in a couple of seconds, fast, easy and cost-effectively, 365/24/7 in real-time. In addition to position determination, the system aimed to model the atmosphere (troposphere and ionosphere), to predict weather, to monitor plate tectonics and to determine datum transformation parameters between the old system and ITRF*yy* (Bakıcı and Mekik, 2014).

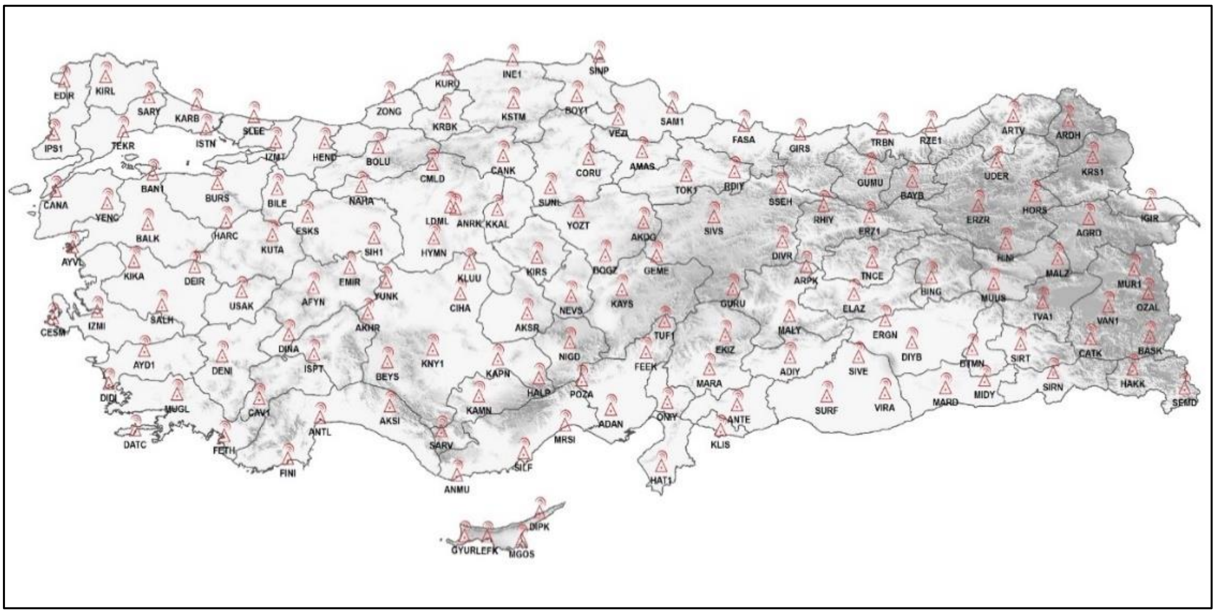

Figure 1. Location of TUSAGA-Aktif Reference Stations (Bakıcı, 2015)

Over the past decade, researchers have made studies to develop more economical, convenient, reliable, and worldwide precise positioning solutions, which do not have the disadvantages that exist in the conventional differential GNSS techniques, including CORS-like. One of the commonly used methods is Precise Point Positioning (PPP). PPP provides positioning without the need for a reference station using a stand-alone GNSS receiver. With this method, it has become possible to reach a cm to dm level of positional accuracy in the static or kinematic mode (Zumberge et al. 1997; Kouba and Heroux, 2001; Huber et al. 2010; Martin et al. 2011; Grinter and Janssen, 2012; Junping et al. 2013; Zhizhao et al. 2013; Abdallah and Schwieger, 2015). Although the usability of the PPP technique is increasing day by day in different scientific and practical application areas, it has some restrictions including the need of long convergence time and the unavailability of the PPP processing mode in common commercial GNSS processing software. On the other hand, studies on the PPP method still continues with an increasing interest because of its ease of usability for user communities. It is believed, as a result of these studies, real-time and more accurate positioning will be possible in the near future.

The PPP coordinates can be derived from sophisticated scientific GNSS processing software (like Bernese), and more recently from the online services developed by many institutions, research centers or organizations. The user of the online system only need a computer with an Internet connection and web browser without the need to know detailed knowledge of the GNSS and any data processing package.

In this study Canadian Spatial Reference System-Precise Point Positioning Service (CSRS-PPP) operated by Geodetic Survey Division of Natural Resources Canada (NRCan) online service was used to obtain PPP-derived coordinates. The service was introduced in November 2003. The

NRCan’s CSRS-PPP provides unlimited access and is free of charge but requires registering to the system. The service estimates the PPP coordinates from single or dual-frequency GNSS data (GPS and if available GLONASS) in Static (“fixed” GNSS receiver) or kinematic (“moving” GNSS receiver) modes. In CSRS-PPP, the quality control procedure is carried out by a series of automated verifications and then the results are sent to the users (Mireault et al. 2008). The service uses the best available Final, Rapid or Ultra-Rapid GNSS satellite orbit and clock correction products (URL 1). The usage of the service is very simple and serves with minimal input requirement. The user, after logging in to the service need to;

- enter user’s e-mail address,
- select the processing mode as static or kinematic,
- select the desired reference frame of the output coordinates in either NAD83 or ITRF,
- select vertical datum,
- select ocean tidal loading (OTL) (as a more option)
- upload the RINEX observation file (in *.zip, .gzip, .gz, .Z, .??O* format)

and then click “Submit to PPP” (URL 1). After the submission is completed, the service will automatically start processing. The processing results including the PPP-derived coordinates and some additional information (like graphs, text outputs) are sent back to the users via a URL link provided in an e-mail that given during the submission. More detailed information about the NRCan’s CSRS-PPP service processing procedures can be found in Tétreault et al. (2005), Mireault et al. (2008) and at URL 1.

In this study, the accuracy performance of the Turkish National Network-RTK, i.e. TUSAGA-Aktif, and the PPP techniques in dynamic environments are compared. In order to this, a kinematic trial was conducted. The test procedures and their obtained results are given in the following chapters.

2. TEST MEASUREMENT

In order to compare the TUSAGA-Aktif Service and PPP technique in terms of accuracy in a dynamic environment, a kinematic test was conducted at the Obruk Lake Dam, in Çorum, Turkey in October of 2015. The kinematic part of the study was started with static initialization for a short time and the receiver was then moved to the vessel and data was collected for approximately 1.5 hours at 1-second interval with an elevation mask of 10° (Figure 2).

The mentioned static initialization was carried out to calculate the precise coordinates of the vessel for each epoch with the differential (relative) GNSS method using both the GNSS data collected to the vessel and at the reference station on the shore that was occupied on a reference point with a known coordinate in ITRF. This allows us to calculate the reference trajectory of the vessel (known coordinates for each epoch) using a relative positioning method to compare the attainable accuracy of the Network-RTK and PPP-derived coordinates. All processes were carried out with Leica Geosystems AG commercial GNSS processing software, Leica Geo Office (LGO) and vessel coordinates were calculated within a cm-level of accuracy.

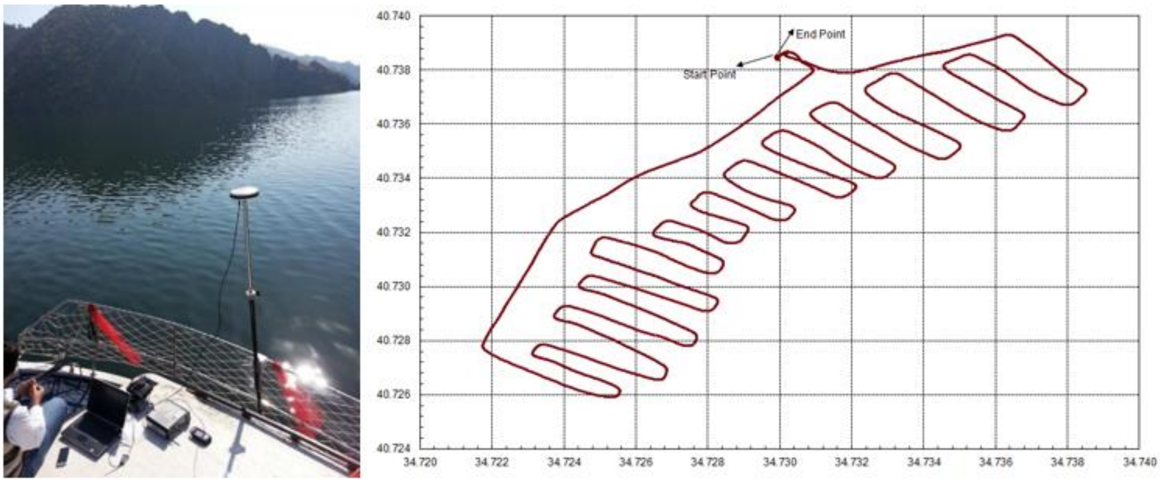

Figure 2. Test Measurement and Trajectory of the Vessel

In this test study, ProFlex 500 GNSS receivers with geodetic–grade antenna was used. ProFlex 500 is a 75 channel (GPS L1 C/A L1/L2 P-code, L2C, L1/L2; GLONASS L1 C/A, L2 C/A code, L1/L2) receiver with having up to 20 Hz of raw data and position output. Accuracy specifications of the receiver given in Table 1.

Table 1. Accuracy Specifications of ProFlex 500 Receiver (URL 2)

REAL-TIME POSITION ACCURACY	**Autonomous** - CEP: 3.0 m - 95%: 5.0 m **SBAS Differential** - 0.9 m (RMS) **Differential (Local Base Station)** - CEP: 40 cm - 95%: 90 cm **RTK (kinematic)** **Fixed RTK** - Horizontal 1 sigma: 1 cm + 1 ppm - Vertical 1 sigma: 2 cm + 1 ppm **Flying RTK** - CEP: 5 cm + 1 ppm - CEP: 20 cm + 1 ppm	**POST PROCESSING ACCURACY (RMS)**	**Static, Rapid Static** - Horizontal 5 mm + 0.5 ppm - Vertical 10 mm + 1 ppm **Long Static** - Horizontal 3 mm + 0.5 ppm - Vertical 6 mm + 0.5 ppm **Post-Processed Kinematic** - Horizontal 10 mm + 1.0 ppm - Vertical 20 mm + 1.0 ppm

While the kinematic measurement was lasting and the data was logged in kinematic mode, at the same time, the Network-RTK coordinates were recorded for each measurement epoch in real-time from the nearest TUSAGA-Aktif Network's point, i.e. CORU. The coordinates were calculated from the TUSAGA-Aktif network via GSM connection in ITRF datum. The calculated coordinates were investigated in terms of solution type and 69.7% of the measurements were obtained as fixed solutions while 9.5% and 20.8% of them were obtained as float or DGPS solutions, respectively.

The collected data from the vessel was sent to the CSRS-PPP service the day after the data collection date, using the service's interactive web page by choosing the kinematic processing option. The kinematic PPP coordinates for each measurement epoch with solution reports were retrieved a short time later via e-mail from the service.

The coordinates of the vessel determined with the TUSAGA-Aktif Network and NRCan's CSRS-PPP online service were compared with those of differential solution of the LGO software, i.e. to the reference coordinates, epoch-by-epoch. Figure 3 illustrates the differences in north, east, 2D position and ellipsoidal heights.

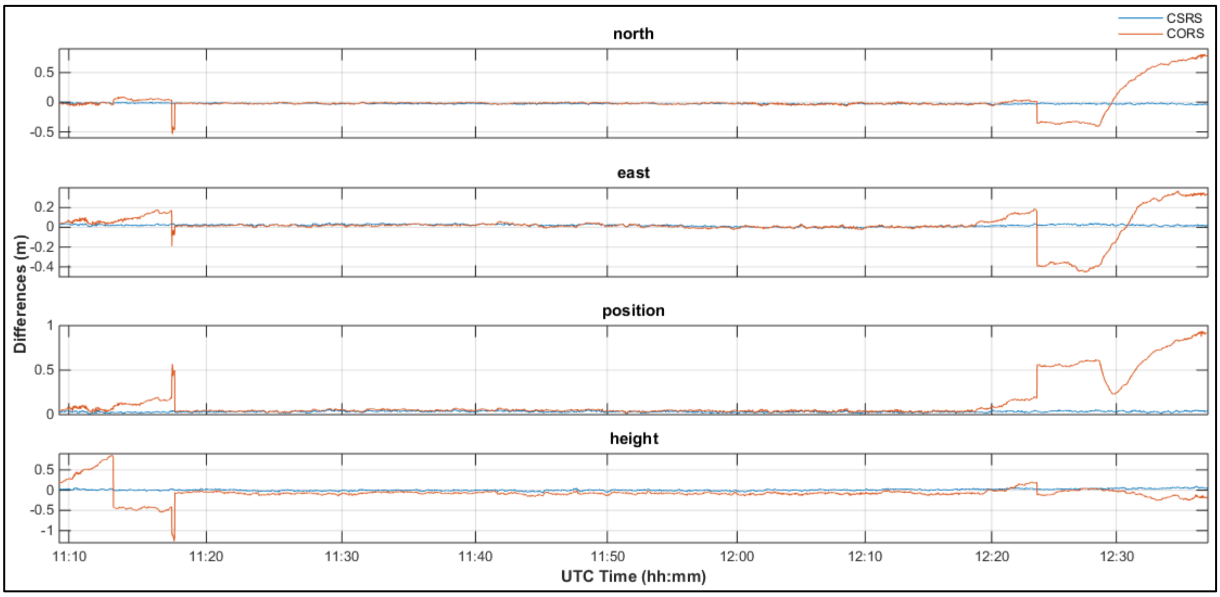

Figure 3. Differences between Known-coordinates (Differential Solution) and
NRCan's CSRS-PPP & TUSAGA-Aktif Network
(*blue line*; CSRS-PPP, *red line*: CORS or TUSAGA-Aktif Network)

The results were also investigated statistically and the minimum, maximum, mean differences and Root Mean Square Error (RMSE) for the differences are summarized in Table 2.

Table 2. Statistical Comparison of the Results

	Position (m)				Height (m)			
	Min.	Max.	Mean	RMSE	Min.	Max.	Mean	RMSE
NRCan's CSRS-PPP Service								
	0.01	0.06	0.03	±0.03	-0.07	0.10	0.01	±0.02
TUSAGA-Aktif CORS Service								
Whole Results (including Float/DGPS/Fixed Solutions)	0.01	0.94	0.14	±0.26	-1.26	0.86	-0.07	±0.19
Results from Only Fixed Solutions (69.7 % of whole of the solutions)	0.00	0.05	0.01	±0.01	-0.08	0.03	-0.02	±0.03

It's clearly seen from Figure 3 and Table 2; TUSAGA-Aktif Network provides a cm level of accuracy when the solution can be fixed whilst the PPP-derived coordinates converge to the relative solutions with also a couple of cm of accuracy. The results revealed that the accuracy decreases dramatically to even a meter-level of accuracy if the fixed solution was not provided from the Network-RTK.

3. RESULTS

In this study, a kinematic trial was carried out to assess the accuracy performance of the Network-RTK and the PPP techniques in a dynamic environment. The results of the test measurement show that, the Network-RTK provides a cm level of accuracy when the solution can be fixed. Otherwise, the accuracy decreases dramatically to even a meter level of accuracy if the float/DGPS solution occurs due to problems in the communication link, outside the coverage area of the GSM network or where the absence of data transmission is poor.

Concerning the PPP technique, the kinematic test results showed that the PPP-derived coordinates converge to the relative solutions with a cm-level of accuracy. This accuracy has allowed the technique to be a viable alternative to conventional differential GNSS techniques in terms of accuracy, easy-use and cost-effectiveness while reducing labour and equipment costs. Although Network-RTK offers many advantages over conventional differential GNSS techniques, PPP techniques needs a single receiver and this removes the necessity for the base (reference) station(s) or data from the CORS-like networks. Thus PPP is still useful in areas that are not covered by a

CORS infrastructure due to low population density, economic reasons, or operational constrains (Rizos et al. 2012).

REFERENCES

Abdallah, A. and Schwieger, V. (2015). Kinematic Precise Point Positioning (PPP) Solution for Hydrographic Applications, *Proc. On FIG Working Week 2015 from the Wisdom of the Ages to the Challenges of the Modern World*. Sofia, Bulgaria, 17-21 May 2015.

Bakıcı, S. (2015). Geoinformatik Teknolojilerinin Tapu ve Kadastro Genel Müdürlüğünde Kullanımı. *1. Konum Belirleme ve Uydu Navigasyonu Zirvesi-2015*, 20 Mart, İstanbul (In Turkish).

Bakıcı, S. and Mekik, Ç. (2014). TUSAGA-Aktif: Delivering Benefits to Turkey. *Coordinates*, X(02), pp.19-26.

Grinter, T. and Janssen, V. (2012). Post-Processed Precise Point Positioning: A Viable Alternative? *Proc. of the 17th Association of Public Authority Surveyors Conference (APAS2012),* Wollongong, New South Wales, Australia, March 9-21, 2012.

Huber, K., Heuberger, F., Abart, C., Karabatic, A., Weber, R. and Berglez, P. (2010). PPP: Precise Point Positioning-Constraints and Opportunities. *XXIV FIG International Congress*, Sydney, Australia, April 11-16, 2010.

Junping, C., Haojun, L., Bin, W., Yize, Z., Jiexian, W. and Congwei, H. (2013). Performance of Real-Time Precise Point Positioning. *Marine Geodesy*, 36, pp. 98-108.

Kouba, J. and Héroux, P. (2001). Precise Point Positioning Using IGS Orbit and Clock Products. *GPS Solutions*, 5(2), pp. 12–28.

Martin, A., Anquela, A.B., Capilla, R. and Berne, J.L. (2011). PPP Technique Analysis Based on Time Convergence, Repeatability, IGS Products, Different Software Processing, and GPS+GLONASS Constellation. *Journal of Surveying Engineering*, 137(3), pp. 99-108.

Mireault, Y., Tétreault, P., Lahaye, F., Héroux, P. and Kouba, J. (2008). Online Precise Point Positioning: A New, Timely Service from Natural Resources Canada. *GPS World*, 19(9), pp. 59–64.

Rizos, C., Janssen, V., Roberts, C., and Grinter, T. (2012). GNSS: Precise Point Positioning PPP versus DGNSS. *Geomatics World*, 20(6), pp. 18–20.

Tétreault, P., Kouba, J., Héroux, P. and Legree, P. (2005). CSRS-PPP: An Internet Service for GPS User Access to the Canadian Spatial Reference Frame. *Geomatica*, 59(1), pp. 17-28.

Zhizhao, L., Shengyue, J., Wu, C., and Xiaoli, D. (2013). New Fast Precise Kinematic Surveying Method Using a Single Dual-Frequency GPS Receiver. *Journal of Surveying Engineering*, 139(1), pp. 19-33.

Zumberge J.F., Heflin M.B., Jefferson D.C., Watkins M.M. and Webb F.H. (1997). Precise Point Positioning for the Efficient and Robust Analysis of GPS Data from Large Networks. *Journal of Geophysical Research*, 102(B3), pp. 5005-5017.

URL 1: Natural Resources Canada, Precise Point Positioning.
Available from: http://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/tools-applications/10925 [accessed 12/12/2015].

URL 2: ProFlex 500 - Igage Mapping Corporation.
Available from: http://www.igage.com/mp/proflex500/ProFlex500_Br%28Len%291.pdf [accessed 12/12/2015].

BIOGRAPHICAL NOTES

Reha Metin ALKAN is a Professor in Geomatics Engineering Department at Istanbul Technical University (ITU) in Istanbul, Turkey and he is currently being as President of Hitit University in Çorum, Turkey. He holds MSc and PhD in Geodesy and Photogrammetry Engineering Department from the ITU. His research area mainly covers satellite positioning and navigation, and engineering surveying.

İ. Murat OZULU graduated from Yıldız Technical University (YTU) in 1991 as Geodesy and Photogrammetry Engineer. He obtained MSc degrees from Anadolu University, Turkey in 2005. He is currently being as PhD candidate in YTU and working as a Lecturer at the Vocational School, Department of Technical Programs Map and Cadastre Department of the Hitit University in Turkey. His areas of research include geodesy, GNSS, engineering surveying and geodetic documentation studies at archaeological sites.

Veli İLÇİ graduated from Istanbul Technical University in 2006 as Geodesy and Photogrammetry Engineer. He obtained MSc degrees from Afyon Kocatepe University, Turkey in 2013. He is currently being as PhD candidate in Yıldız Technical University and working as a Lecturer at the Vocational School, Department of Technical Programs Map and Cadastre Department of the Hitit University in Turkey. His areas of research include geodesy, GNSS, indoor positioning, engineering surveying and GIS.

CONTACT

Prof. Dr. Reha Metin ALKAN

Hitit Üniversitesi Rektörlüğü
Kuzey Kampüsü, 19030 Çorum / TÜRKİYE

Telephone : +90 364 219 1926
E-mail : alkan@hitit.edu.tr