KINEMATIC POSITIONING USING ONLINE SERVICES

Mustafa Berber[1], Mevlut Yetkin[2], Aydin Ustun[3]

[1]Dept. of Civil and Geomatics Eng., California State University, Fresno, CA, USA
[2]Department of Geomatics Engineering, Katip Celebi University, Izmir, Turkey
[2]Department of Geomatics Engineering, Kocaeli University, Kocaeli, Turkey

Abstract: The ability of GNSS (Global Navigation Satellite System) to set points without the need for a clear line of sight between points is a valuable asset in meeting the need for placing construction reference points. In construction projects, the application of Kinematic GNSS technique has increased over the years. Nowadays, Kinematic GNSS data processing can also be done using online services. Recently, many organizations have begun providing online GNSS data processing services. Currently, some of these organizations also provide kinematic data processing option. To take advantage of this option, users only need to specify the mode of processing. Nonetheless, it seems that since there is not enough data to resolve the integer ambiguities using the engines kinematic data processing services use, the results generated by kinematic online data processing services are in the order of decimeters.

Keywords: Global Navigation Satellite System, online data processing services, horizontal coordinates, vertical coordinates

1 Introduction

GPS (Global Positioning System) and GLONASS (Global Orbiting Navigation Satellite System) were developed by early 1970's, and with the inception of GALILEO (Europe's upcoming Global Navigation Satellite System) a new name to encompass all these three systems has born that is GNSS (Global Navigation Satellite System). Using GNSS, positions on the surface of the earth can be determined utilizing point positioning or relative positioning. One of the relative positioning techniques is kinematic method.

In many areas of surveying, speed and productivity are essential elements to success. In satellite surveying, the most productive form of surveying is kinematic method (Ghilani and Wolf, 2012). Kinematic surveying provides positioning while the receiver is in motion. Kinematic method is done either using Real Time Kinematic mode in the field or in the office using the Postprocessed Kinematic mode.

Construction surveys provide line, grade, control elevations, horizontal positions, dimensions and configurations for construction operations. They also secure needed data for computing construction pay quantities (Ghilani and Wolf, 2012). Kinematic GNSS technique can provide answers for all these applications quickly and economically.

Nowadays, Kinematic GNSS data processing can also be done using online services. It means that data collected in kinematic mode can be submitted to online data processing services and within a short period of time the coordinates of the points surveyed are returned to the user. Thus, these services significantly reduce the equipment and personnel costs, pre-planning and logistics compared to conventional approaches (Ebner and Featherstone, 2008).

As yet, only Tsakiri (2008) researched on kinematic GNSS data processing using online services. In her study, to assess the capabilities of the kinematic data positioning service, Tsakiri (2008) used two data sets. First one is 24h 30s RINEX (Receiver Independent Exchange Format) files from two static IGS (International GNSS Service) stations and second data set is a vehicle kinematic test for mobile mapping applications. Her results indicated that kinematic service can deliver solutions between 5 and 10 cm level in the horizontal and in the vertical when good quality data are supplied by the user. She suggested that further study using controlled samples of data are required in this area of kinematic positioning before firm conclusions can be drawn.

In this study, kinematic measurements are made at seven NGS (National Geodetic Survey) points along Road 714 in Martin County, FL, USA and these measurements are processed using two online services and this is explained in the following sections.

2 GNSS Data Processing Using Online Services

Currently, there are seven online GNSS data processing services freely available to users. These are: OPUS (Online Positioning User Service), APPS (Automatic Precise Positioning Service), SCOUT (Scripps Coordinate Update Tool), CSRS-PPP (Canadian Spatial Reference System Precise Point Positioning Service), GAPS (GPS Analysis and Positioning Software), AUSPOS (Geoscience Australia Online GPS Processing Service) and Magic GNSS. In addition UNB's PPPSC (Precise Point Positioning Software Centre) compares solutions from online PPP applications. Auto-Bernese provided by GPS Solutions requires payment for its service. The URLs of these services are given in Table 1.

Table 1. URLs of online GNSS data processing services

Service	URL
OPUS	http://www.ngs.noaa.gov/OPUS/index.jsp
APPS	http://apps.gdgps.net/
SCOUT	http://sopac.ucsd.edu/cgi-bin/SCOUT.cgi
CSRS-PPP	http://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php
GAPS	http://gaps.gge.unb.ca/index.html
AUSPOS	http://www.ga.gov.au/bin/gps.pl
Magic GNSS	http://magicgnss.gmv.com/
PPPSC	http://gge.unb.ca/Resources/PPP/SubmitData.html
Auto-Bernese	http://www.gps-solutions.com/online.html

To date, among these online services only four them; namely, APPS, CSRS-PPP, GAPS and Magic GNSS provide kinematic data processing option. While this paper was being prepared, Magic GNSS service was not responding and APPS did not return any kinematic data solution. Therefore, in this study, only CSRS-PPP and GAPS are used for positioning determinations.

To benefit from online GNSS data processing services, a single GPS receiver and a single field crew are needed. Thus, these services significantly reduce the equipment and personnel costs, pre-planning and logistics compared to conventional approaches. They also lessen the need to learn to use scientific GNSS processing packages (Ebner and Featherstone, 2008). With just one dual-frequency receiver, the observations taken are postprocessed based on differential methods using reference stations or precise point positioning using globally available precise satellite orbit and clock data.

Online processing services deliver solutions to users without any cost and with unlimited access. At most the users are required to get an account. The basic requirements that the user needs to take advantage of these different services are almost the same: access to the Internet and a valid email address. Users send a RINEX file or compressed RINEX file to the service and within a short period of time the estimated position of the GNSS system used to collect the data is sent back to the user in the form of e-mails or report files (Ghoddousi-Fard and Dare, 2006). In this process, disadvantages are that the quality of the solutions might be affected by the availability of precise orbit and clock data. In addition, the results that are returned to the user may be delayed by server processing speed and the internet connection.

Online processing services provide the coordinates in a recognized datum. However, it should be mentioned that while producing these coordinates, all services depend on the quality of the data and the length of data span supplied to them by the user (Tsakiri, 2008). Generally, these services produce coordinates in ITRF (International Terrestrial Reference Frame) or in their national geodetic reference frame. Transformation of coordinates is possible from one reference frame to another either using the published transformation parameters or using available online software from governmental organizations such as NGS.

3 Applications and Results

In this study, kinematic survey is conducted by collecting measurements for 2 minutes at seven NGS points along Road 714 in Florida using triple frequency GNSS (Leica GX1230) receivers (see Fig. 1). The data are processed using LGO (Leica Geo Office) software.

Figure 1. Seven NGS points along Road 714 in Martin County, FL, USA (image from Google).

With the first survey, to begin with kinematic surveying, the base station was set up over point AJ8524 and the rover was initialized on point AJ8514 for 13 min because this point is the closest to the base station. And then other points are visited for 2 min only. Since with the first survey more than 2 min data were collected at points AJ8524 and AJ8514 a second survey is carried out. With the second survey, the base station was set up over point AJ8516 and the rover was initialized on point AJ8515 for 14 min. This way all points had 2 min data only. Next, the coordinates of these points are determined using LGO and these coordinates are listed in Tables 2 and 3. By performing the survey as described, always the farthest point visited was three miles away from the base station.

In order to be able to make use of online data processing services, the rover is initialized close to AJ8516 for half an hour and then all these seven points are visited for 2 min only. This file is converted to RINEX and submitted to two online data processing services and received coordinates are also listed in Tables 2 and 3. The discrepancies are portrayed in Figures 2 to 5 for easier interpretation.

Table 2. Comparison of LGO produced kinematic results against CSRS-PPP results.

	LGO			CSRS-PPP		
	Latitude	Longitude	Ellip. H.	Latitude	Longitude	Ellip. H.
AJ8516	27 9 43.68570	-80 25 56.70100	-18.530	27 9 43.68156	-80 25 56.70474	-18.189
AJ8515	27 9 41.92160	-80 26 55.47404	-18.371	27 9 41.92565	-80 26 55.47431	-18.686
AJ8514	27 9 43.94567	-80 27 54.63721	-18.246	27 9 43.96080	-80 27 54.63704	-14.587
AJ8524	27 9 43.96698	-80 28 52.89519	-18.772	27 9 43.98271	-80 28 52.89921	-17.987
AJ8512	27 9 43.06358	-80 30 6.13814	-18.238	27 9 43. 04119	-80 30 6.13725	-17.060
AJ8511	27 9 43.02445	-80 31 5.44000	-18.190	27 9 43.02295	-80 31 5.45152	-20.300
AJ8510	27 9 43.23857	-80 32 2.11862	-18.823	27 9 43.23877	-80 32 2.14717	-18.557

Since 2 minutes data at seven NGS points are collected at 5 second intervals, around 24 solutions have resulted at each point. The coordinates listed in Tables 2 and 3 are the averages of all these solutions.

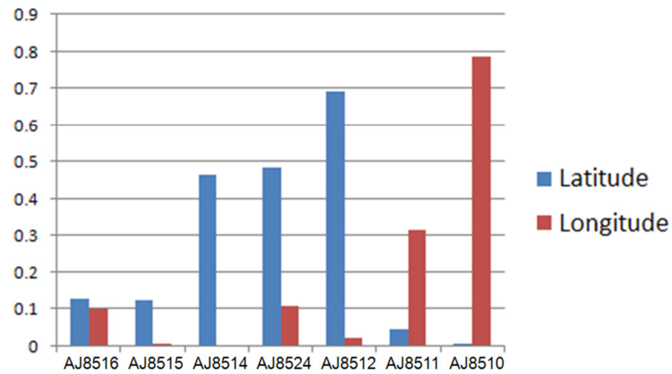

Figure 2. Discrepancies of horizontal coordinates between LGO and CSRS-PPP (m).

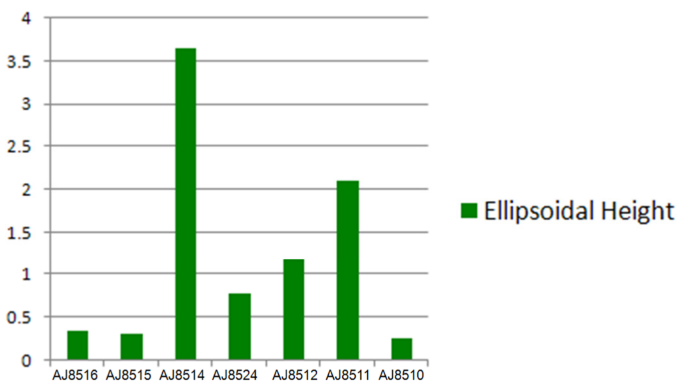

Figure 3. Discrepancies of vertical coordinates between LGO and CSRS-PPP (m).

Table 3. Comparison of LGO produced kinematic results against GAPS results.

	LGO			GAPS		
	Latitude	Longitude	Ellip. H.	Latitude	Longitude	Ellip. H.
AJ8516	27 9 43.68570	-80 25 56.70100	-18.530	27 9 43.66076	-80 25 56. 71863	-17.217
AJ8515	27 9 41.92160	-80 26 55.47404	-18.371	27 9 41. 93480	-80 26 55. 47915	-15.291
AJ8514	27 9 43.94567	-80 27 54.63721	-18.246	27 9 43. 96018	-80 27 54. 63571	-17.719
AJ8524	27 9 43.96698	-80 28 52.89519	-18.772	27 9 43. 97338	-80 28 52. 89295	-18.739
AJ8512	27 9 43.06358	-80 30 6.13814	-18.238	27 9 43. 03211	-80 30 6. 14675	-17.457
AJ8511	27 9 43.02445	-80 31 5.44000	-18.190	27 9 43. 03532	-80 31 5. 41817	-21.630
AJ8510	27 9 43.23857	-80 32 2.11862	-18.823	27 9 43. 24762	-80 32 2. 12365	-17.348

CSRS-PPP gives the option to the users that they can either determine the coordinates in ITRF or other datums. Therefore, in this study, using CSRS-PPP, the coordinates of the points are determined in NAD83 (North American Datum of 1983) datum. GAPS provides the coordinates in ITRF only. Hence, the coordinates obtained are transformed from ITRF to NAD83. Thus, all the coordinates listed in Tables 2 and 3 are in NAD83 geodetic reference system.

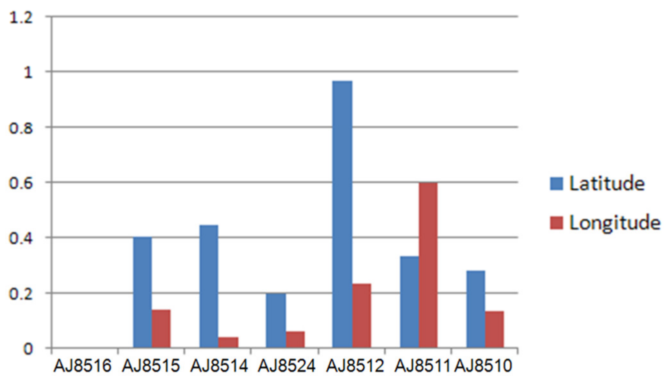

Figure 4. Discrepancies of horizontal coordinates between LGO and GAPS (m).

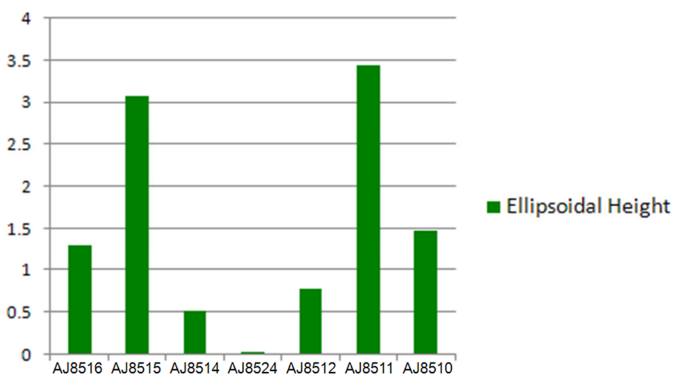

Figure 5. Discrepancies of vertical coordinates between LGO and GAPS (m).

It is hard to make sense of the results since the results do not represent any consistent pattern. In addition, it is hard to compare CSRS-PPP results against GAPS results. It turns out that the data collected for short period of time (2 min data collected in this project for each point) are not enough to resolve the integer ambiguities using the engines kinematic online data processing services use and therefore the results are in order of decimeters for horizontal coordinates and in order of meters for vertical coordinates. It is surmised that errors such as multipath, atmospheric errors, antenna types etc. cannot be the source of these large discrepancies because compared to the points' known coordinates LGO produced kinematic results are in the order of centimeters.

The purpose of the following investigations is that data sets observed with fixed or moving GNSS systems can both be processed using online kinematic GNSS data processing services. On the other hand, data collected with a fixed receiver (this is the approach used in this project) might be useful to evaluate the scatter of independent position estimates over time. Due to space limitation, however, these investigations are done at point AJ8524 only for each technique used in this study. In the following graphics, x axis represents the number of epoch processed and y axis shows the variations among the processed measurements in meters unit.

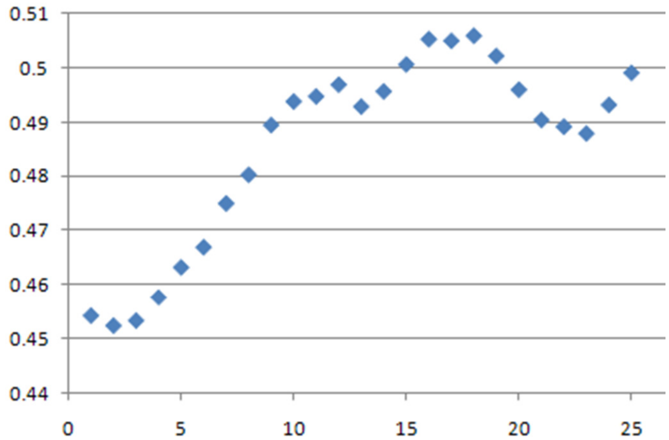

Figure 6. Residuals for latitude at AJ8524 using CSRS-PPP (m).

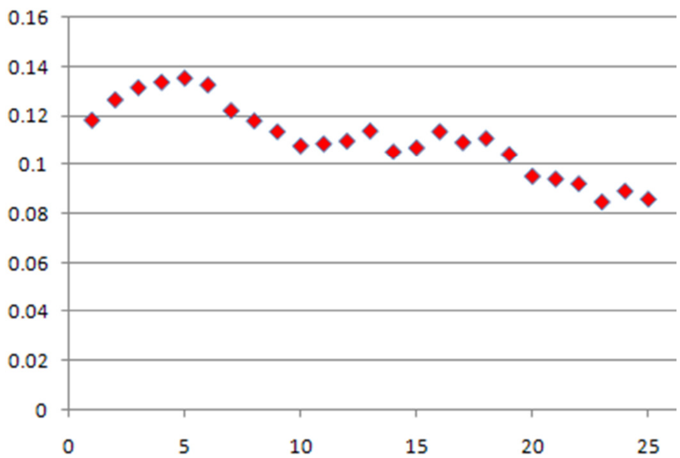

Figure 7. Residuals for longitude at AJ8524 using CSRS-PPP (m).

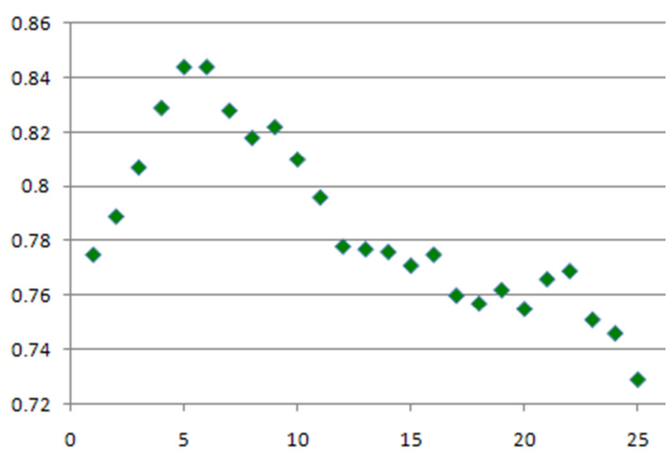

Figure 8. Residuals for ellipsoidal height at AJ8524 using CSRS-PPP (m).

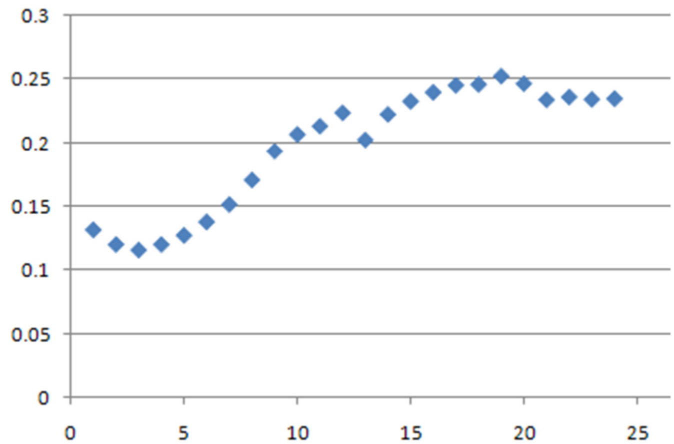

Figure 9. Residuals for latitude at AJ8524 using GAPS (m).

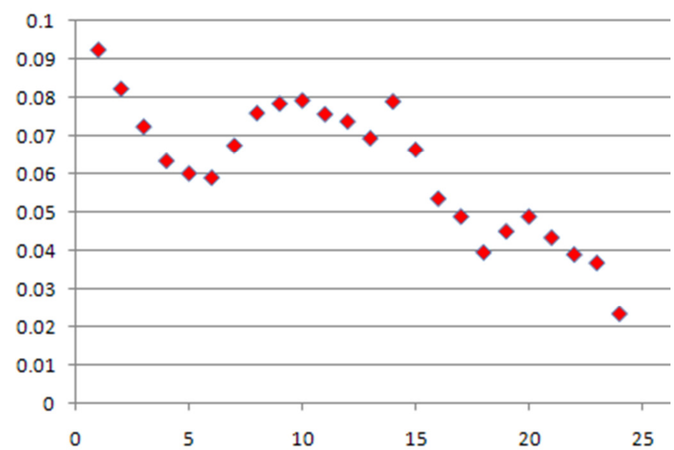

Figure 10. Residuals for longitude at AJ8524 using GAPS (m).

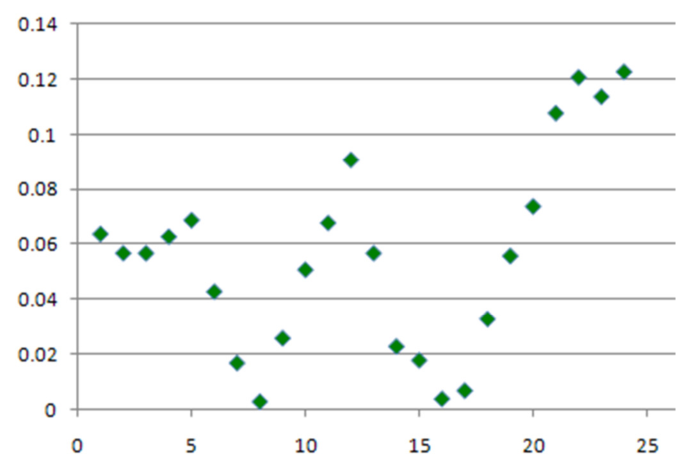

Figure 11. Residuals for ellipsoidal height at AJ8524 using GAPS (m).

As can be seen from Figures 6-11, although there are some slight variations, the processed measurements are consistent with each other. This is also evident with their RMS (Root Mean Square) values (see Table 4). While preparing the graphics, LGO produced results are considered the "truth" and the differences are computed and plotted.

Table 4. RMS values at point AJ8524 (m).

	Latitude	Longitude	Ellipsoidal Height
CSRS-PPP	0.49	0.11	0.80
GAPS	0.20	0.06	0.07

At this point we have to clarify that positions computed using online kinematic GNSS data processing will not be optimal until the carrier phase ambiguities have converged. For short data sets, positions will effectively be calculated using only the pseudo-range observations. Longer data sets make it possible to resolve the ambiguities required to recover positions using the more precise carrier phase observations. As mentioned above, in this project, only 2 min data were collected at each point. It means that for the solutions of coordinates of these points pseudo-range observations are used. As well known, use of pseudo-range observations yields meter level precision and this is what above graphs are depicting.

4 Conclusions

As with static processing, kinematic GNSS data processing using online services can be used to take advantage of precise point positioning or differential methods with one single dual frequency receiver. It appears that solution quality depends on the availability, proximity and quality of the data collected and supplied to the online services.

It seems that online kinematic data processing services can provide the results for horizontal coordinates in the order of decimeters and for vertical coordinates in the order of meters and this is attributed to not having enough time to resolve the integer ambiguities using the engines kinematic data processing services use. Thus, kinematic data processing services should be used for the projects that require less precision.

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