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INVESTIGATION OF IDEAL TIME PERIOD FOR KINEMATIC SURVEYS

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Abstract

Thanks to rapid advancements in technology, nowadays, kinematic GNSS (Global Navigation Satellite System) data processing can also be done using online services. In the not very distant past, 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. Yet, there is not a certain time frame recommended for initialization and occupation time for kinematic surveys. In this study, ideal time period for kinematic surveys are investigated on a GNSS network. The results indicate that one common initialization and occupation time is not possible for all online GNSS data processing services.

Keywords: GNSS, precise point positioning, kinematic survey, horizontal and vertical coordinates

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 been 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 (Wells et al., 1999). 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 (Wolf and Ghilani, 2006). 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 (Wolf and Ghilani, 2006). 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 of now, it has not been studied for what length of time the individual locations should be occupied and for what length of time the GNSS receiver should be initialized to achieve coordinates with sub-decimeter accuracy. Therefore, in this study, kinematic measurements are collected at five points in CSUF (California State University Fresno) campus and these measurements are processed using three online services (see section 2) to determine initialization and occupation time for kinematic surveys.

Methods

To our knowledge, among online GNSS data processing services, currently, only APPS (Automatic Precise Positioning Service), CSRS-PPP (Canadian Spatial Reference System Precise Point Positioning Service) and GAPS (GPS Analysis and Positioning Software) provide free kinematic data processing option.

APPS (http://apps.gdgps.net/) is currently using GIPSY (GNSS-Inferred Positioning System and Orbit Analysis Simulation Software) version 6.4. A PPP (Precise Point Positioning) technique (Zumberge et al., 1997) is implemented within GIPSY to process GPS phase and pseudorange measurement in RINEX (Receiver Independent Exchange Format) format. By default the most accurate orbit and clock products are used if available. APPS users may specify the elevation angle cutoff, and for kinematic positioning the output data rate. By default, the 7.5 degree elevation angle cutoff is applied, and for kinematic positioning the positions are output at the same rate as the measurement data. The reference frame for APPS is ITRF (International Terrestrial Reference Frame) 2008.

CSRS-PPP (http://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php) is an online application for GNSS data post-processing allowing users to compute high accuracy positions from raw observation data. CSRS-PPP uses the precise GNSS satellite orbit ephemerides to produce coordinates across the globe, regardless of proximity to known base stations. Users can submit RINEX observation data from single or dual-frequency receivers operating in static or kinematic mode over the Internet and receive positioning in the CSRS (Canadian Spatial Reference System) and ITRF. By default, the 10 degree elevation angle cutoff is applied by CSRS-PPP.

GAPS (http://gaps.gge.unb.ca/) provides users accurate satellite positioning using a single GNSS receiver both in static and kinematic mode. Through the use of precise orbit and clock products provided by sources such as IGS (International GNSS Service), it is possible to achieve centimeter-level positioning in static mode and decimeter-level positioning in kinematic mode given a sufficient convergence period. By default, the 10 degree elevation angle cutoff is applied by GAPS and the coordinates are provided on ITRF 2008.

Since these three services require RINEX or compressed RINEX files, all collected data files are converted to RINEX file format, and for positioning kinematic option is chosen and the files are processed.

Application and Results

Trimble R8 dual frequency receiver is used to collect the measurements. Antenna and receiver are mounted on a fixed-height 2 m range pole. CSUFNet which consists of five points in California State University Fresno campus is surveyed – see Fig. 1.

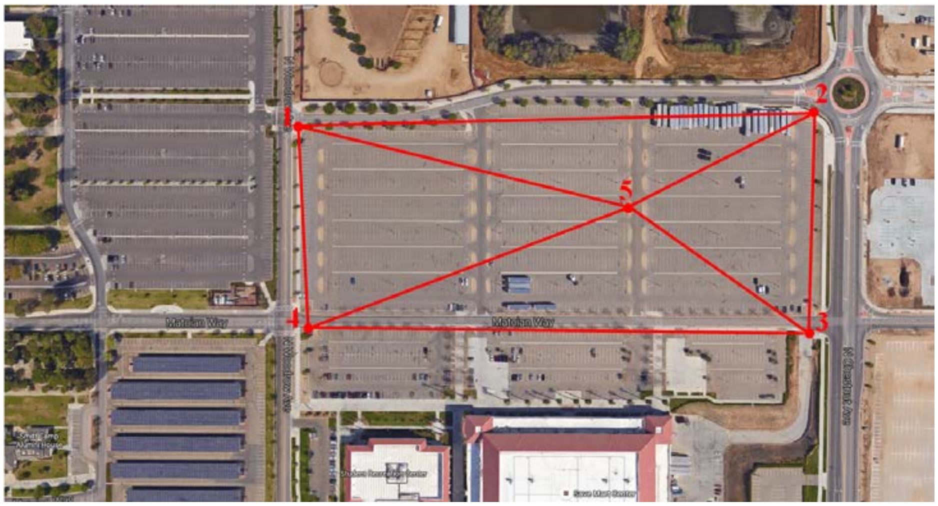

Figure 1. CSUFNet in California State University Fresno campus (image from Google).

For the survey at each point, the rover is initialized for 10, 15, 20, 30, 45 min and 1, 2 hours and then the five points of CSUFNet are surveyed for 1, 2, 3, 5, 10, 15, 20, 30, 45 sec and 1, 2, 3, 5, 10 min (see Tables 1-3 as examples). So, 7*14=98 survey files are generated for each point. Since five points are surveyed, 98*5=490 files are produced for the survey. As mentioned in section 2, three GNSS online data processing services are utilized for this study. Therefore, 490*3=1470 files are processed. In addition, for comparison purposes, eight hour data collected at these points are also processed using the three online services, 5*3=15. Thus, in total 1470+15=1485 files are processed for this project.

Three types of GPS orbit and clock information are available for processing, namely, final, rapid and ultra-rapid. Final products are available 12-18 days after data is collected. Rapid products are available around 17-41 hours after data collection. Ultra-Rapid (predicted half) products are available real-time and Ultra-rapid (observed half) products are available within 3-9 hours. As such, for precise work, final products are to be used. If other above mentioned products are used, degradation in the positional solution should be expected. This study took advantage of final products to achieve the highest precision available.

As can be seen in Fig. 1, our project area is flat. Thus, tropospheric effect on the measurements is considered the same for all the points. To examine the ionospheric conditions, Kp index values are obtained from Space Weather Center (http://www.swpc.noaa.gov/). The values range from 3 to 5.6, from 0.3 to 2.3, from 0 to 1.6 and from 0 to 1 for the GPS days of 48, 51, 52 and 53 for year 2016 respectively, which are the days GPS measurements were collected. Kp index scale ranges from 0 to 9 where 0 means there is very little geomagnetic activity and 9 means extreme geomagnetic storm is taking place. Kp index values for the days that our GPS measurements were collected do not indicate any major geomagnetic storming. The measurements were taken at these five points to take advantage of changing satellite geometry and different observation ambient such as obstructions nearby. Since the points are in an open area, multipath should not be a cause of error for the points used in this project. If there is any, multipath effect is different from point to point.

As mentioned in section 2, 495 RINEX files are submitted to APPS, CSRS-PPP and GAPS for kinematic positioning. Since RINEX files had 1 s data, these online services returned the kinematic positioning results for every second. Each of the result file returned is transferred to Excel for further processing. In Excel, after removing the initialization period data, remaining data are averaged; for instance, for 1 h and 10 s data, 1h data i.e., 3600 returns are disregarded and remaining 10 returns are averaged to determine the effect of having 1 h initialization period on 10 s occupation time.

Since by processing 1470 files in total 105 tables are created for this study, only the tables for 10 min initialization and occupation times at point 1 is shown as examples in Tables 1, 2 and 3 for APPS, CSRS-PPP and GAPS respectively. In the below tables, although negative sign is not used to indicate, listed longitudes are west longitude.

Table 1. APPS 10 min initialization results at point 1.

Occupation Time	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1 s	36 48 43.971372	119 44 26.59308	74.0298
2 s	36 48 43.971336	119 44 26.59308	74.0331
3 s	36 48 43.9713	119 44 26.59308	74.0286
5 s	36 48 43.971336	119 44 26.59308	74.02454
10 s	36 48 43.971444	119 44 26.59308	74.02753636
15 s	36 48 43.971588	119 44 26.59308	74.02044667
20 s	36 48 43.971732	119 44 26.59308	74.02197368
30 s	36 48 43.97202	119 44 26.59344	74.02019474
45 s	36 48 43.97202	119 44 26.59416	73.99401111
1 m	36 48 43.972704	119 44 26.59452	73.92197167
2 m	36 48 43.97256	119 44 26.59452	73.91378167
3 m	36 48 43.97202	119 44 26.59452	73.93134778
5 m	36 48 43.971336	119 44 26.59308	73.922552
10 m	36 48 43.973028	119 44 26.59056	73.82346617

Table 2. CSRS-PPP10 min initialization results at point 1.

Occupation Time	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1 s	36 48 43.96284	119 44 26.53918	72.775
2 s	36 48 43.962795	119 44 26.539195	72.7785
3 s	36 48 43.96275	119 44 26.53919	72.7797
5 s	36 48 43.96269	119 44 26.539174	72.7828
10 s	36 48 43.962608	119 44 26.539085	72.7814
15 s	36 48 43.96263933	119 44 26.538986	72.77393
20 s	36 48 43.962692	119 44 26.5389015	72.7683
30 s	36 48 43.96283367	119 44 26.538455	72.75607
45 s	36 48 43.96298689	119 44 26.53819489	72.74584
1 m	36 48 43.96336983	119 44 26.538466	72.72577
2 m	36 48 43.96356558	119 44 26.53793517	72.67935
3 m	36 48 43.96381394	119 44 26.53791861	72.6157
5 m	36 48 43.96422107	119 44 26.53612953	72.51127
10 m	36 48 43.96492875	119 44 26.5357155	72.45691

Table 3. GAPS10 min initialization results at point 1.

Occupation Time	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1 s	36 48 43.97821	119 44 26.58965	69.2137
2 s	36 48 43.97826	119 44 26.589775	69.21335
3 s	36 48 43.97831333	119 44 26.58989	69.21423333
5 s	36 48 43.978734	119 44 26.589646	69.20542
10 s	36 48 43.978823	119 44 26.590077	69.21726
15 s	36 48 43.9791	119 44 26.59047667	69.22348
20 s	36 48 43.97942	119 44 26.5908615	69.230915
30 s	36 48 43.980157	119 44 26.59152533	69.24703667
45 s	36 48 43.98122978	119 44 26.59259667	69.27050444
1 m	36 48 43.98232333	119 44 26.59385183	69.28149833
2 m	36 48 43.98542008	119 44 26.59694975	69.2806425
3 m	36 48 43.98588611	119 44 26.60034061	69.29256333
5 m	36 48 43.98418753	119 44 26.60300547	69.42675933
10 m	36 48 43.97962908	119 44 26.59733697	69.64932217

As can be seen in above tables, throughout this research with the results in tables, no attempt is made to round values to the appropriate significant figures until the end of the analysis. In Tables 1-3, latitude and longitude determinations vary with the third decimal meaning that variation of these coordinates is in the order of centimeters. Ellipsoidal height changes are in the order of decimeters.

If the results among these three services are compared, with horizontal coordinates variations are apparent with the second decimal meaning that variations are in the order of decimeters. Nonetheless, height variations are in the order of meters.

With GPS measurements the rule of thumb is that the longer the observation period, the more precise the results. Thus, 8 h results are considered the "truth" and the differences between 8 h static results and the results at each point are compared. Eight hour static data were collected prior to this project.

Table 4. APPS results for 8 h static solution.

Point No	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1	36 48 43.977744	119 44 26.59308	71.6707
2	36 48 43.552332	119 44 11.622012	72.0046
3	36 48 38.63106	119 44 12.628968	71.9738
4	36 48 38.600424	119 44 26.381724	71.7331
5	36 48 41.452272	119 44 16.8063	73.2527

Table 5. CSRS-PPP results for 8 h static solution.

Point No	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1	36 48 43.9666	119 44 26.5369	72.306
2	36 48 43.5411	119 44 11.5657	72.642
3	36 48 38.6199	119 44 12.5728	72.597
4	36 48 38.5892	119 44 26.3253	72.35
5	36 48 41.4412	119 44 16.7501	73.872

Table 6. GAPS results for 8 h static solution.

Point No	Latitude (º ' ")	Longitude (º ' ")	Ellipsoidal Height (m)
1	36 48 43.9787	119 44 26.5878	71.9517
2	36 48 43.5525	119 44 11.6195	72.1310
3	36 48 38.6313	119 44 12.6288	72.0439
4	36 48 38.6001	119 44 26.3809	71.8773
5	36 48 41.4502	119 44 16.8074	73.4034

If static results are compared among these three services, they portray the same pattern with horizontal coordinates i.e., with horizontal coordinates variations are in the order of decimeters. However, height variations are in the order of decimeters. It means that processing longer data (8 h as opposed to 10 min or less) brings the elevations variations from meters level down to decimeters level.

Static data processing approach estimates a single set of coordinates for the observed site. Whereas, kinematic data processing approach by default generates a time series of coordinates at a rate of equal to the measurement rate. It means that kinematic data processing estimates a trajectory based on the data submitted. Hence, some variations in kinematic results are expected. Since kinematic solutions generate a time series of coordinates, these coordinates are changing constantly. When the 1470 files are compared against the respective static results, a common pattern does not emerge, that is to say, sometimes one of the horizontal coordinates converges very rapidly and another coordinate converges after a while. Most of the time convergence of both horizontal coordinates takes some time. Even worse, these coordinates keep changing and lose convergence; therefore, even speaking of convergence is not credible. Regarding height coordinates, they vary greater than the horizontal coordinates do and sometimes they do not even come close to the 8 h results.

Conclusions

Up to now, three online GNSS data processing services provide kinematic data processing option. To this date, there is not a certain time frame for initialization and occupation time for kinematic surveys using online precise point positioning services. In this study, GNSS data collected for various initialization and occupation times are submitted to APPS, CSRS-PPP and GAPS and the results are analyzed. It is discovered that because kinematic data processing generate a time series of coordinates, coordinates change constantly. As a consequence, within the online data processing service, horizontal coordinate change is in the order of centimeters and ellipsoidal height changes are in the order of decimeters. If the three online data processing services are compared, for kinematic solutions, variations of horizontal coordinates are in the order of decimeters and height variations are in the order of meters. Since kinematic solutions keep changing it is difficult to state and ideal time period for initialization and occupation for kinematic surveys. It is our finding that one common initialization and occupation time is not possible for all online GNSS data processing services.

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