COMPARATIVE ANALYSIS OF DIFFERENT ONLINE GNSS PROCESSING SERVICES

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ABSTRACT

The development of online GNSS processing services for GPS data processing has become widely used because of its user-friendliness, non-requirement of license and knowledge of GPS processing software compared to the commercial software. The study aims at carrying out a comparative analysis of different online GNSS processing services (AUSPOS, CSRS-PPP, MagicGNSS/PPP, APPS, and GAPS). Field observations were carried out on seven (7) selected control points using static GNSS observation techniques and total station instruments to establish a closed traverse. The 3D coordinates of the control points were estimated using the online processing services and the coordinate differences between these services and total station coordinates were computed. The accuracy of each online processing service was determined using the root mean square error. The analysis, for each online processing services in the X, Y, and Z directions were 2.49cm, 2.33cm, and 2.41cm respectively, for AUSPOS, (3.35cm, 3.67cm and 3.19cm) for CSRS-PPP, (4.20cm, 3.60cm, and 3.43cm) for MagicGNSS/PPP, (6.91cm, 7.71cm, and 10.61cm) for APPS and (6.81cm, 7.77cm, and 9.09cm) for GAPS. It is worthy to conclude from the analysis of the result, AUSPOS has a more reliable result than other services which is most preferable and may be adopted for engineering and geodetic applications.

Keyword: Comparative Analysis, Online GNSS Processing Services

1. INTRODUCTION

The Global Navigation Satellite System (GNSS) is a standard generic term used to describe a group of satellite-based navigation systems that provide autonomous geo-spatial positioning with global coverage on or near the earth's surface. At present, GNSS consist of the American controlled Global Positioning System (GPS), the Russian controlled Global Orbiting Navigation Satellite System (GLONASS), the European Galileo, China Compass and others, which constitute the foundation for determining the positions for various applications such as agriculture, mapping, public safety, military, surveying purposes and Geographical Information System (GIS) (Tariq et al, 2017). The Galileo and the Compass are still in test mode. As of today, GPS is the most widely utilised GNSS system, used in finding many applications within the areas of surveying, navigation and recreation nationalities of each system to promote the safety and convenience of life (Feng, 2003; Yaw and Gunter, 2006). GPS is a popular utility that provides both military and civilian users with positioning, navigation, and timing services regardless of the weather conditions (Gps.Gov, 2016). To allow rapid and accurate data acquisition, land surveyors mount GPS rover on vehicles or carry it in a backpack. The rover can communicate wirelessly with reference receivers to deliver continuous, real-time, centimetre-level accuracy, and unprecedented productivity (Gps.Gov, 2016).

Not too long ago, to determine position with GPS it was necessary to use at least two receivers. It was also necessary to post-process the collected data using the GNSS data processing software whether scientific or marketable to acquire precise results. Nevertheless, the usage of such software is also quite difficult because they require knowledge of the GNSS and experience in the processing, in addition to the cost of software licensing (Adam, 2017). The users of these services need to convert the collected field data to Receiver Independent

Exchange Format RINEX and send through email or upload it to a particular website and obtained the result via the user's registered email (Alkan, 2016).

GNSS online processing or internet-based online services are now widely used as an alternative to the traditional processing method. The use of online processing services has become broadly popular because of their simplicity of use, being free of charge (or requiring a low-cost fee) and no prerequisite authorization and knowledge of a GPS processing software (Adam, 2017).
Online services present two types of solutions, which are a relative solution approach and precise point positioning (PPP) solution approach. The services that are based on a relative solution approach use national Continuously Operating Reference Stations (CORS) or IGS stations as reference control points. The services that are based on a PPP solution approach use GPS-only or GPS+GLONASS products such as orbit and clock corrections (Ocalan *et al.*, 2013).

The study of GNSS positioning and total station positioning because of its diverse accuracy is necessary to evaluate its accuracy for different applications (Adam, 2017). One or more reference stations are required in relative positioning, at least to determine the unknown positions, while the Precise Point Positioning (PPP) just needs one receiver without a base station. Some applications require metre level or centimetre level of accuracy and this depends on the required precision. The main objective of the study is to explore this problem in terms of the coordinate's disparity for each point. Therefore, the study aims at finding the extent of a coordinate discrepancy, the consistency of each available online service, and to recommend the more reliable online processing service adopted for this study based on 1hour observation data. This approach is basically divided into two sections. First, data acquisition (traversing and static observation), second is data processing (static-observation processing) and result generation. In this study, five different online GNSS processing services have been presented with their general characteristics and web addresses, and static-observation processing is done using these services (AUSPOS, CSRS-PPP, MagicGNSS/PPP, APPS, and GAPS) to generate the 3D spatial coordinates.

1.1 ONLINE GNSS PROCESSING SOFTWARE

In recent years severalorganisations have sophisticated online Global Navigation Satellite System (GNSS) for the processing services, which provide the users GNSS processing data to the user free of upload and with unlimited access. These online processing services provide results for a user that submitted data in Receiver Independent Exchange Format (RINEX) file and differential method adopted with reference stations or precise point positioning technique used by IGS Orbit Products (Ghoddousi-Fard, and Dare, 2006). The general characteristics of the services and their web addresses are discussed below:

1.1.1 Services using Relative Solution Method

Online GNSS processing services that are using the relative solution method estimates the position of a point anywhere on the earth through the double-difference technique by making use of IGS network data or CORS network data. The model for the double-difference approach for phase measurements can be given as follows

$$\blacksquare\Delta\varphi t = \blacksquare\Delta r(t, t-\tau) + \blacksquare\Delta ds(t-\tau) - \blacksquare\Delta diono + \blacksquare\Delta dtropo + \blacksquare\Delta\lambda N + \blacksquare\Delta\varepsilon(\varphi) \quad (1)$$

where;

$\blacksquare\Delta$ is the double difference operator at the time of receiving data

φ is the phase measurement

$(t)$is the time of receiving data
$(t - \tau)$ is the satellite time
(τ) is the travel time from the satellite to the receiver
$r(t, t - \tau)$ is the true geometric range
ds is the orbital prediction error
$diono$ and $dtropo$ are the ionospheric and tropospheric errors, respectively
λ is the wavelength
N is the integer phase ambiguity
ε is the noise constituent
There are three (3) online GNSS processing services that employed relative solution approach, and they are Online Positioning User Service (OPUS), Australian Online GPS Processing Service (AUSPOS) and Scripps Coordinate Update Tool (SCOUT). In this study, AUSPOS is being used and is discussed below.

1.1.2 Australian Online GPS Processing Service (AUSPOS)

AUSPOS is a free online GNSS processing service developed by Geoscience Australia and it uses the Bernese GNSS Software for processing baselines and takes advantage of both the IGS Stations Network and the IGS product range and compatible data acquired anywhere on Earth. Access is through a simple web interface; the antenna height and type are entered along with an email address for the returned report set. AUSPOS service is accessible via the Geo-science Australia website at http://www.ga.gov.au

1.1.3 Services using Precise Point Positioning (PPP) Solution Method

PPP uses un-differenced ionospheric-free both carrier-phase (Φ) and code pseudo-range (P) observations collected by a dual-frequency receiver for data processing. This technique provides precise positioning by using precise ephemeris and clock products provided by IGS and other organisations (Kouba and Héroux, 2001; Abd-Elazeem*et al.*, 2011). Kouba and Heroux (2001) stated that the ionospheric-free combinations of dual-frequency GPS pseudo-range (P) and carrier-phase observations (Φ) are related to the user position, clock, and troposphere and ambiguity parameters according to the following simplified observation equations:

$$P = \rho + C(dT - dt) + Tr + \varepsilon P \quad (2)$$

$$\Phi = \rho + C(dT - dt) + Tr + N\lambda + \varepsilon\Phi \quad (3)$$

where;
P is the ionosphere-free combination of P1 and P2 pseudo-ranges
(P3) = (2.546P1 - 1.546P2)
Φ is the ionosphere-free combination of L1 and L2 carrier-phases
(L3) = (2.546 λ1 Φ1 - 1.546 λ2 Φ2)
ρ is the geometrical range computed as a function of satellite and station coordinates
C is the vacuum speed of light
dT is the station receiver clock offset from the GPS time
dt is the satellite clock offset from the GPS time
Tr is the signal path delay due to the neutral-atmosphere (primarily the troposphere)
N is the non-integer ambiguity of the carrier-phase ionosphere-free combination
λ1, λ2, λ are the wavelengths of the carrier-phases L1, L2 and L3-combined (10.7 cm)
εP, εΦis the relevant measurement noise constituents, including multipath, observable-dependent receiver bias and observable-dependent satellite bias and other effects.

Several online services and software products are implementing a PPP processing strategy which has been developed recently by government agencies, universities, industries and individuals. They are discussed below.

1.1.4. Canadian Spatial Reference System- Precise Point Positioning (CSRS-PPP)

CSRS-PPP provides an online service for GNSS data post-processing allowing users to compute higher precision positions from their raw observed data. CSRS estimates are computed from carrier phase or code pseudo-range observations of both single and dual-frequency receivers.

Users can submit observed data in RINEX format from single or dual-frequency receivers operating in static or kinematic mode over the internet for onward processing. This service is available through GSD website at http://www.geod.nrcan.gc.ca

1.1.5. MagicGNSS Precise Point Positioning (MagicGNSS/PPP)

MagicPPP is a worldwide positioning service that allows GNSS users to determine their position or trajectory with centimetre-level accuracy. This online service implements new generation Precise Point Positioning (PPP) algorithms developed by GMV and does not require data from Continuous Operating Reference Stations (CORS) in the proximity of the user. This service is accessible via http://www.magicgnss.gmv.com/ppp

1.1.6. Automatic Precise Positioning Service (APPS)

APPS accepts GPS measurement files and uses GIPSY-OASIS software for processing the GPS measurements to estimate the position of GPS receivers, whether they are static, in motion, on the ground, or in the air. APPS uses final, rapid, ultra-rapid precise GPS orbit and clock products of JPL and supports input in RINEX 2, RINEX 2.11 input files, GIPSY TDP files. The site is accessible through http://apps.gdgps.net/

1.1.7. GPS Analysis and Positioning Software (GAPS)

The GNSS Analysis and Positioning Software (GAPS) was developed in 2007 at the University of New Brunswick and provide users with accurate satellite positioning using a single GNSS receiver both in static and kinematic mode. It makes use of precise orbit and clock products provided by the International GNSS Service (IGS) and Natural Resources Canada (NRCan). The site is accessible via http://gaps.gge.unb.ca/

2. STUDY AREA

The study area for this work lies between latitude 07^0 18’ 07.80” N, 07^0 17’ 46.92” N and Longitude 05^0 08’ 24.06” E, 05^0 08’ 45.42” E in Federal University of Technology, Akure in Akure South Local Government Area, Ondo State, Nigeria with seven unknown control points which are selected based on visibility between the previous and subsequent points, and avoidance of any effective obstructions. Figure 1 below shows the study area location.

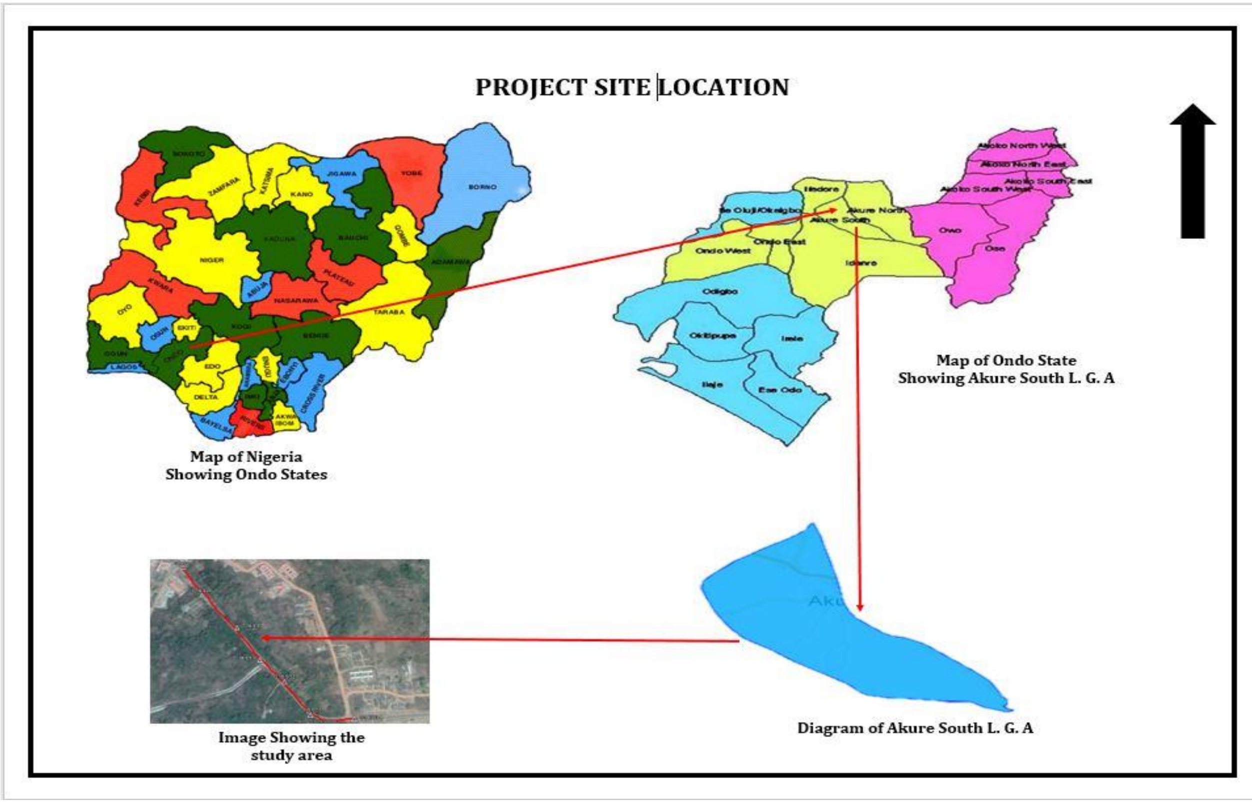

Figure 1: *Map of the Study Area*

3. METHODOLOGY

The methodology for this work is divided into three main parts. Firstly, a horizontal position for seven (7) control stations was established using static GNSS positioning techniques based on the online GNSS processing services. For this purpose, dual-frequency GNSS receiver (CHC X900) was used and the station observation time was one (1) hour. Secondly, the Total Station instrument type (Stonex R2 plus) was used to observe the control stations and closed traverse was established. Finally, an accuracy assessment of the results obtained from the online processing software with total station traverse observation is performed.

3.1. Static Observations

In this study, the dual-frequency CHC X900 GNSS receiver was used to determine the horizontal position of seven (7) selected unknown control stations. The GPS base receiver was set up on a reference station, a temporary adjustment was carried out and all precautions were taken. The GPS receiver (rover) was set up serially over the seven (7) unknown selected control points with observed time (1hr) for each point to track enough satellites in enhancing the quality of data streaming for more reliable accuracy.

3.2. Traversing

In this study, a closed connected traverse was also performed on the seven (7) selected control stations starting from a known point and end on a known point using Total Station (STONEX R2 PLUS), where the three-dimensional coordinates (X, Y, Z) of these points were obtained. This is to enable the evaluation of the accuracy of the processed results of the GNSS data obtained from the online GNSS processing services.

4. RESULTS AND DISCUSSION

The results obtained from this study are the coordinates of seven (7) selected control points determinedusing total station, which was observed through GNSS observation and post-processed using five (5) Online GNSS processing services. The differences between coordinates obtained with total station and the ones obtained by GNSS observation post-processing method, using Online GNSS processing services (AUSPOS, CSRS-PPP, MagicGNSS/PPP, APPS and GAPS) have been calculated and the accuracy of the results were estimated using the root mean square error (RMSE). In this study, n (i = 1 - 7) control points were observed with a total station and dual-frequency GPS. Thus, estimates of the root mean square spatial residual along the X, Y, and Z directions i.e., Eastings, Northings, and Heights respectively are given by the following formulae:

The X-direction:
$$rmsX = \sqrt{\frac{\sum_{i=1}^{n}(X_{Obs,i} - X_{\mathrm{Pr}oc,i})^2}{n}} \quad (4a)$$

The Y-direction:
$$rmsY = \sqrt{\frac{\sum_{i=1}^{n}(Y_{Obs,i} - Y_{\mathrm{Pr}oc,i})^2}{n}} \quad (4b)$$

The Z-direction:
$$rmsZ = \sqrt{\frac{\sum_{i=1}^{n}(Z_{Obs,i} - Z_{\mathrm{Pr}oc,i})^2}{n}} \quad (4c)$$

Where;
n is the total number of points;
X_{Obs}, Y_{Obs},and Z_{Obs}, are observed coordinates/standard coordinates of point ***i***; and
X_{Proc}, Y_{Proc}, *and* Z_{Proc}, are processed coordinates of point ***i***.
The smaller the value of the root mean square error estimate the better the accuracy attainable with the 3D coordinates obtained from the Online GNSS processing services. The comparisons between obtained results is shown in the tables below;

Table 1: RMSE in X-coordinate for AUSPOS

Point	X_{Obs}	X_{Proc}	$(X_{Obs} - X_{Proc})$	$(X_{Obs} - X_{Proc})^2$
G16/028	736364.011	736364.036	-0.025	0.000625
G16/029	736451.450	736451.438	0.012	0.000144
G16/030	736582.252	736582.270	-0.018	0.000324
G16/031	736690.773	736690.752	0.021	0.000441
G16/032	736779.842	736779.868	-0.026	0.000676
G16/033	736888.867	736888.836	0.031	0.000961
G16/034	737020.218	737020.184	0.034	0.001156
***rmsX*= 0.0249m = 2.49cm**				

Table 2: RMSE in Y-coordinate for AUSPOS

Point	Y_{Obs}	Y_{Proc}	$(Y_{Obs} - Y_{Proc})$	$(Y_{Obs} - Y_{Proc})^2$
G16/028	807597.226	807597.209	0.017	0.000289
G16/029	807469.090	807469.109	-0.019	0.000361
G16/030	807336.859	807336.839	0.020	0.000400
G16/031	807178.728	807178.758	-0.030	0.000900
G16/032	807090.978	807090.956	0.022	0.000484

G16/033	806966.644	806966.616	0.028	0.000784
G16/034	806956.678	806956.654	0.024	0.000576
***rmsY*= 0.0233m = 2.33cm**				

Table 3: RMSE in Z-coordinate for AUSPOS

Point	$\mathbf{Z_{Obs}}$	$\mathbf{Z_{Proc}}$	$\mathbf{(Z_{Obs} - Z_{Proc})}$	$\mathbf{(Z_{Obs} - Z_{Proc})^2}$
G16/028	376.441	376.474	-0.033	0.001089
G16/029	371.516	371.490	0.026	0.000676
G16/030	365.133	365.112	0.021	0.000441
G16/031	360.384	360.364	0.020	0.000400
G16/032	358.078	358.095	-0.017	0.000289
G16/033	356.821	356.846	-0.025	0.000625
G16/034	358.944	358.921	0.023	0.000529
***rmsZ*= 0.0241m = 2.41cm**				

Table 4: RMSE in X-coordinate for CSRS-PPP

Point	$\mathbf{X_{Obs}}$	$\mathbf{X_{Proc}}$	$\mathbf{(X_{Obs} - X_{Proc})}$	$\mathbf{(X_{Obs} - X_{Proc})^2}$
G16/028	736364.011	736364.036	-0.025	0.000625
G16/029	736451.450	736451.483	-0.033	0.001089
G16/030	736582.252	736582.273	-0.021	0.000441
G16/031	736690.773	736690.816	-0.043	0.001849
G16/032	736779.842	736779.815	0.027	0.000729
G16/033	736888.867	736888.830	0.037	0.001369
G16/034	737020.218	737020.176	0.042	0.001764
***rmsX*= 0.0335m = 3.35cm**				

Table 5: RMSE in Y-coordinate for CSRS-PPP

Point	$\mathbf{Y_{Obs}}$	$\mathbf{Y_{Proc}}$	$\mathbf{(Y_{Obs} - Y_{Proc})}$	$\mathbf{(Y_{Obs} - Y_{Proc})^2}$
G16/028	807597.226	807597.266	-0.040	0.001600
G16/029	807469.090	807469.041	0.049	0.002401
G16/030	807336.859	807336.833	0.026	0.000676
G16/031	807178.728	807178.760	-0.032	0.001024
G16/032	807090.978	807090.947	0.031	0.000961
G16/033	806966.644	806966.680	-0.036	0.001296
G16/034	806956.678	806956.640	0.038	0.001444
***rmsY*= 0.0367m = 3.67cm**				

Table 6: RMSE in Z-coordinate for CSRS-PPP

Point	Z_{Obs}	Z_{Proc}	$(Z_{Obs} - Z_{Proc})$	$(Z_{Obs} - Z_{Proc})^2$
G16/028	376.441	376.413	0.028	0.000784
G16/029	371.516	371.477	0.039	0.001521
G16/030	365.133	365.167	-0.034	0.001156
G16/031	360.384	360.405	-0.021	0.000441
G16/032	358.078	358.043	0.035	0.001225
G16/033	356.821	356.852	-0.031	0.000961
G16/034	358.944	358.976	-0.032	0.001024
***rmsZ*= 0.0319m = 3.19cm**				

Table 7: RMSE in X-coordinate for MagicGNSS/PPP

Point	X_{Obs}	X_{Proc}	$(X_{Obs} - X_{Proc})$	$(X_{Obs} - X_{Proc})^2$
G16/028	736364.011	736364.052	-0.041	0.001681
G16/029	736451.450	736451.475	-0.025	0.000625
G16/030	736582.252	736582.282	-0.030	0.000900
G16/031	736690.773	736690.825	-0.052	0.002704
G16/032	736779.842	736779.832	0.010	0.000100
G16/033	736888.867	736888.805	0.062	0.003844
G16/034	737020.218	737020.168	0.050	0.002500
***rmsX*= 0.0420m = 4.20cm**				

Table 8: RMSE in Y-coordinate for MagicGNSS/PPP

Point	Y_{Obs}	Y_{Proc}	$(Y_{Obs} - Y_{Proc})$	$(Y_{Obs} - Y_{Proc})^2$
G16/028	807597.226	807597.285	-0.059	0.003481
G16/029	807469.090	807469.052	0.038	0.001444
G16/030	807336.859	807336.831	0.028	0.000784
G16/031	807178.728	807178.751	-0.023	0.000529
G16/032	807090.978	807090.963	0.015	0.000225
G16/033	806966.644	806966.672	-0.028	0.000784
G16/034	806956.678	806956.635	0.043	0.001849
***rmsY*= 0.0360m = 3.60cm**				

Table 9: RMSE in Z-coordinate for MagicGNSS/PPP

Point	Z_{Obs}	Z_{Proc}	$(Z_{Obs} - Z_{Proc})$	$(Z_{Obs} - Z_{Proc})^2$
G16/028	376.441	376.422	0.019	0.000361
G16/029	371.516	371.471	0.045	0.002025
G16/030	365.133	365.182	-0.049	0.002401
G16/031	360.384	360.417	-0.033	0.001089
G16/032	358.078	358.061	0.017	0.000289
G16/033	356.821	356.86	-0.039	0.001521
G16/034	358.944	358.967	-0.023	0.000529
***rmsZ*= 0.0343m = 3.43cm**				

Table 10: RMSE in X-coordinate for APPS

Point	X_{Obs}	X_{Proc}	$(X_{Obs} - X_{Proc})$	$(X_{Obs} - X_{Proc})^2$
G16/028	736364.011	736363.949	0.062	0.003844
G16/029	736451.450	736451.496	-0.046	0.002116
G16/030	736582.252	736582.282	-0.03	0.000900
G16/031	736690.773	736690.713	0.060	0.003600
G16/032	736779.842	736779.938	-0.096	0.009216
G16/033	736888.867	736888.876	-0.009	0.000081
G16/034	737020.218	737020.335	-0.117	0.013689
***rmsX*= 0.0691m = 6.91cm**				

Table 11: RMSE in Y-coordinate for APPS

Point	Y_{Obs}	Y_{Proc}	$(Y_{Obs} - Y_{Proc})$	$(Y_{Obs} - Y_{Proc})^2$
G16/028	807597.226	807597.269	-0.043	0.001849
G16/029	807469.090	807469.023	0.067	0.004489
G16/030	807336.859	807336.824	0.035	0.001225
G16/031	807178.728	807178.858	-0.130	0.016900
G16/032	807090.978	807090.909	0.069	0.004761
G16/033	806966.644	806966.749	-0.105	0.011025
G16/034	806956.678	806956.641	0.037	0.001369
***rmsY*= 0.0771m = 7.71cm**				

Table 12: RMSE in Z-coordinate for APPS

Point	Z_{Obs}	Z_{Proc}	$(Z_{Obs} - Z_{Proc})$	$(Z_{Obs} - Z_{Proc})^2$
G16/028	376.441	376.528	-0.087	0.007569
G16/029	371.516	371.553	-0.037	0.001369
G16/030	365.133	365.225	-0.092	0.008464
G16/031	360.384	360.370	0.014	0.000196
G16/032	358.078	358.089	-0.011	0.000121
G16/033	356.821	356.939	-0.118	0.013924
G16/034	358.944	358.727	0.217	0.047089
***rmsZ*= 0.1061m = 10.61cm**				

Table 13: RMSE in X-coordinate for GAPS

Point	X_{Obs}	X_{Proc}	$(X_{Obs} - X_{Proc})$	$(X_{Obs} - X_{Proc})^2$
G16/028	736364.011	736364.083	-0.072	0.005184
G16/029	736451.450	736451.472	-0.022	0.000484
G16/030	736582.252	736582.271	-0.019	0.000361
G16/031	736690.773	736690.658	0.115	0.013225
G16/032	736779.842	736779.873	-0.031	0.000961
G16/033	736888.867	736888.829	0.038	0.001444
G16/034	737020.218	737020.322	-0.104	0.010816
***rmsX*= 0.0681m = 6.81cm**				

Table 14: RMSE in Y-coordinate for GAPS

Point	Y_{Obs}	Y_{Proc}	$(Y_{Obs} - Y_{Proc})$	$(Y_{Obs} - Y_{Proc})^2$
G16/028	807597.226	807597.259	-0.033	0.001089
G16/029	807469.090	807469.056	0.034	0.001156
G16/030	807336.859	807336.758	0.101	0.010201
G16/031	807178.728	807178.765	-0.037	0.001369
G16/032	807090.978	807090.937	0.041	0.001681
G16/033	806966.644	806966.735	-0.091	0.008281
G16/034	806956.678	806956.542	0.136	0.018496
***rmsY*= 0.0777m = 7.77cm**				

Table 15: RMSE in Z-coordinate for GAPS

Point	Z_{Obs}	Z_{Proc}	$(Z_{Obs} - Z_{Proc})$	$(Z_{Obs} - Z_{Proc})^2$
G16/028	376.441	376.512	-0.071	0.005041
G16/029	371.516	371.532	-0.016	0.000256
G16/030	365.133	365.213	-0.080	0.006400
G16/031	360.384	360.353	0.031	0.000961
G16/032	358.078	358.068	0.010	0.000100
G16/033	356.821	356.925	-0.104	0.010816
G16/034	358.944	358.759	0.185	0.034225
***rmsZ*= 0.0909m = 9.09cm**				

Table 16:Accuracy assessment (Summary of RMSEs of the Online GNSS processing service)

GNSS Processing Software	rmsX (cm)	rmsY (cm)	rmsZ (cm)
AUSPOS	±2.49	±2.33	±2.41
CSRS-PPP	±3.35	±3.67	±3.19
MagicGNSS/PPP	±4.20	±3.60	±3.43
APPS	±6.91	±7.71	±10.61
GAPS	±6.81	±7.77	±9.09

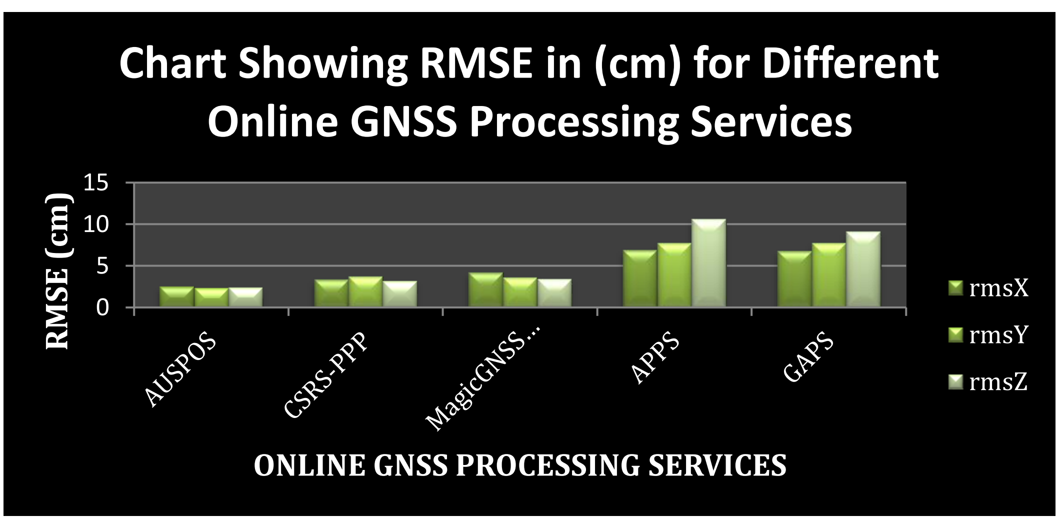

Figure 2: RMSE in (cm) for different GNSS Software based on 1hr observation period

5. DISCUSSION OF RESULT

In the X, Y, and Z direction, the best accuracy was obtained from AUSPOS online processing service which employed a relative solution approach with the calculated root mean square errors of ±2.49, ±2.33 and ±2.41 in X, Y and Z direction respectively. According to the obtained results, the root means square error provided by AUSPOS online service was less than that of other services and these can be attributed to the 14 networks of IGS reference points used in the processing of the data. Also, CSRS-PPP gives better results than other online processing services which employed a precise point positioning solution approach with the calculated root mean square error of ±3.35, ±3.67 and ±3.19 in X, Y and Z direction respectively. The maximum error was provided by APPS online service with calculated root mean square deviations of ±6.91, ±7.71 and ±10.61 in the X, Y and Z direction respectively.

6. CONCLUSION

The study has attempted to compare five (5) online GNSS processing services which are used frequently and widely in the world. For this purpose, the 3D coordinates of seven (7) selected control points were determined by using one (1) relative solution approach service and four (4) PPP solution approach services with 1-hour GPS data observation. The true station co-ordinates were obtained by running a closed traverse with a total station instrument. The accuracies provided by the services were obtained by comparing online processing service co-ordinates with total station coordinates. All the online services used in this study provide the final co-ordinates with a precision of a couple of centimetres to a few errors of decimetres which are attributed to the observation time of 1-hour. However, testing is still needed to evaluate the performance of these services in other areas and to include longer observation sessions.

REFERENCES

Abd-Elazeem, M., Farah, A., and Farrag, F. A. (2011). Assessment Study of Using Online (CSRS) GPS-PPP Service for Mapping Applications in Egypt. *Journal of Geodetic Science*, 1(3), 233-239.

Adam, M. (2017). The Use of Online and Offline Processing Tools to Improve the Precision of a GPS Passive Station. *Journal of University of Duhok*, 20(1), 335-346.

Alkan, M (2016). Precise Point Positioning (PPP) Versus Network-RTK GNSS. FIG Working Week, Christchurch, New Zealand.

Feng, Y (2003), Combined Galileo and GPS: A Technical Perspective. *Journal of Global Positioning Systems*, 2 (1): 67-72.

Ghoddousi-Fard, R., and Dare, P. (2006). Online GPS Processing Services: An Initial Study. *GPS Solutions*, 10(1): 12-20.

Gps.Gov. (2016). Welcome to GPS.gov. Retrieved December 16, 2016, from http://www.gps.gov/

Yaw and Günter's, 2006: "Framework for the establishment of a Nationwide Network Global Navigation Satellite System (GNSS)", a cost-effective tool for land Development in Ghana.

Kouba, J., Héroux, P. (2001). Precise Point Positioning using IGS orbit and clock products. *GPS Solutions*, 5(2): 12-28.

Ocalan, T., Erdogan, B., Tunalioglu, N. (2013). Analysis of Web-Based Online Services for GPS Relative and Precise Point Positioning Techniques, 19(2): 191-207.

Tariq, M., Hadi, A., and Hafedh, H. (2017). Accuracy Assessment of Different GNSS Processing Software. *Imperial Journal of Interdisciplinary Research (IJIR)*, *3*(10).

http://www.ga.gov.au/bin/gps.pl. [Accessed October, 2018].

http://www.geod.nrcan.gc.ca. [Accessed October, 2018].

http://www.magicgnss.gmv.com/ppp [Accessed October, 2018].

http://www.apps.gdgps.net/ [Accessed October, 2018].

http://www.gaps.gge.unb.ca/ [Accessed October, 2018].