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DETECTING ERRORS IN GNSS-PRECISE POINT POSITIONING CONTROLS USING TOTAL STATION TECHNIQUE

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Abstract

Global Navigational Satellite System-Precise Point Positioning (GNSS-PPP), is a type of GNSS technique that uses one receiver to acquire satellite signal to fix position. GNSS-PPP is not free from error just as any other measurement in surveying and the Total Station instrument could be used to detect such errors. The aim of this study was to detect errors in Precise Point Positioning (PPP) Controls using Total Station survey. Hi-Target GNSS receiver was used to acquire raw satellite data that were used to fix the selected control points at duration of 60 minutes on each point. The raw satellite data were converted to RINEX data which would be readable by the post processing software. The RINEX data were uploaded to online post-processing solution where they were processed and the results were sent back. After that, the Total Station instrument was used to run a Survey on coordinate mode on all the initially selected control point for GNSS-PPP. The Total Station survey was carried out two times on separate days to determine the average of the results. Comparison of the results of average of the Total Station and that of GNSS-PPP were made and their differences were in decimetre range except for three controls that are in meter range. Further investigation shows that the three controls that had their results in meter range were so close to power lines, communication mast and storey buildings. These contributed to interferences and obstructions to the signal of the satellites, thereby creating multipath errors on those control points. It was therefore recommended that the Total Station be used wherever there are perceived interference to clear sky satellite in order to achieve high accuracies with GNSS-PPP measurements.

Keywords: Astronomical observation, GNSS, Precise Point Positioning, Total Station survey

INTRODUCTION

Prior to the use of GNSS for survey, astronomical observations were the order of the day, where unknown quantities were determined from rigorous mathematical computations. The Surveyors measure angles and lengths of lines between points directly and use these measurements to compute station coordinates. From these coordinate values, other distances and angles that were not measured directly may be derived indirectly by computation (Buonocore & Vassallo, 1991). The idea behind Global Navigational Satellite System (GNSS) was to use signals of artificial satellites that were launched in the space to determine positions, velocity and time. These quantities are obtained via receivers (Vincent *et al.,* 2005). GNSS survey was introduced into the surveying and mapping world in order to establish controls and carry out surveys in places where controls for surveying and mapping, are not available (Larsen, 2001).

In surveying and mapping, no measurement is void of error. Measurements such as determining distances between points either by using a graduated tape, or measuring an angle by making a direct observation from the graduated circle of a theodolite or total station instrument or by satellite observations are all prone to errors (Ghilani & Wolf, 2010). GNSS measurements to compute station coordinates, distances, and angles contain errors too (Ghilani & Wolf, 2010). These errors could be multipath related, atmospheric (ionospheric or tropospheric), clock biased and other relativity (Karaim, Elsheikh & Noureldin, 2018; Gaglione & Petovello, 2015). The advent of GNSS-PPP technique has not only made GNSS observation easier but, less expensive also. This PPP technique is also prone to errors (Gaglione & Petovello 2015).

The aim of this study is to detect errors in PPP coordinates using Total Station survey. Hussain, Ahmed, Magsi, and Tiwari (2020) observed that the benefits of PPP technique in the surveying field has eliminated lots of physical constraints such as line-of-sight visibility and the rigours of extending controls from known points to unknown points of interests. It can be performed anywhere so far it is an open view space. PPP technique is preferable where there are less land-based control stations especially in coastal areas, waterways and sonar depth sounding to generate charts. It is also helpful in executing surveys for offshore oil rigs, seismic surveys, and bridge constructions in coastal environments.

LITERATURE REVIEW

Review of Concepts

The concept of Precise Point Positioning and its accuracy

Bisnath and Gao (2009) affirmed that PPP technique uses single receiver to obtain position on both static and kinematic mode for the purpose of mapping. It makes use of precise orbit and clock offsets to process satellite data that were acquired. PPP technique produces centimeter level results when used in static mode and decimeter level results when used in kinematic mode.

Researchers (Deo & El-Mowafy, 2020; Shevchuk *et al*., 2020) agreed also that, PPP technique measures in both pseudo range and carrier phase measurements using single GNSS receiver. PPP technique offers an accuracy of decimetres with at least triple frequency GNSS data observed that, PPP technique is based on the determination of high-precision coordinates using one GNSS receiver and data such as precise orbital parameters and corrections. They stated that PPP method provides root mean square of centimetre level in static, and decimetre in kinematic mode.

Kalinnikov *et al.,* (2018) observed that, PPP technique could be used for environmental monitoring and meteorological services. It could be used for estimation of vapour and water density in the atmosphere. They observed that the technique gives the position of a point anywhere on the globe, with high accuracy. It can measure base lines for high accuracy and also controls points without any line-of-sight requirement. PPP provides very accurate positioning by using only a single receiver's data in combination with precise satellite orbit and clock data products provided by different sources like IGS and NRCan. The usage of the PPP technique has several advantages apart from high-accuracy, it is cost-effective since it uses just single receiver. The PPP technique is commonly used in surveying, agricultural sector and in crustal deformation monitoring. With PPP technique, geodetic positions could be obtained within the range of centimetres accuracy in static mode and decimetre accuracy in kinematic mode (Trigubovich, Shevchuk, Kosarev & Nikitin, 2017).

The concept of Total Station (TS) and PPP surveying

Zeiske (2004), as well as Beshr, and Elnaga (2011) explained that Total Stations (TS), an electronic theodolite interfaced with electronic distance meter (EDM), works on the principle of signal-reflection line-of-sight and there must a Total Station and Prism reflector in TS observations. The Total station measures slope distances, horizontal and vertical angles in topographic and geodetic tasks. In TS surveys, results are recorded into an inbuilt memory and transferred to a computer through USB cable interface. Singh (2013) described, also, that the TS measures angles and distances and even coordinates whenever the TS is used in coordinate mode. The coordinates are in the form of northing, easting, and heights of surveyed points relative to the total station position.

TS can be used by archaeologists to record excavations as well as by police, crime scene investigators, private accident investigators and insurance companies to take measurements of scenes for analysis (Singh, 2013). The TS provides the highest possible degree of accuracy for site positioning, stakeout, grade checking and measurement. However, TS has limited range than a GNSS-based system that is why it is better suited for projects where accuracy is a fundamental factor. TS are ideal for sites where the accuracy requirements are very tight: $\pm$ 3 millimetres. However, GPS cannot be used in area with lot of trees, High rise buildings because of satellite signal interference (Ghilani & Wolf, 2010).

Singh, (2013) inferred that, despite the limitations that the TS has, it can still be used in the detecting of errors among GNSS-PPP observations. TS is best used indoors, around buildings and locations with limited or zero satellite signal visibility. The TS does not make use of GPS signals but rather of EDM technology for coordinates, angles, distances, and height measurements (Singh, 2013).

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METHODOLOGY

The Study area

The research was carried out in Kogi State Polytechnic, Lokoja Campus, which is located in Lokoja Local Government Area of Kogi State (See Figure 1). The campus lies between latitudes 7° 50' 44.8377" N to 7° 50' 2.6881" N and longitudes 6° 44' 11.2608" E to 6° 44' 21.4511" E. Lokoja town is situated in the tropical wet and dry savannah climate zone of Nigeria, and temperature remains hot all year round. The topography within 2 miles of Lokoja contains very significant variations in elevation, with a maximum elevation change of 1,266 feet and an average elevation above sea level of 277 feet. The windier part of the year lasts for 6-7 months, from February 15 to September 6, with average wind speeds of more than 5.8 miles per hour. The windiest day of the year is April 9, with an average hourly wind speed of 7.3 miles per hour. The calmer time of year lasts for 5.3 months, from September 6 to February 15. The calmest day of the year is November 8, with an average hourly wind speed of 4.2 miles per hour. The predominant average hourly wind direction in Lokoja varies throughout the year. The wet season is oppressive and overcast, the dry season is muggy and partly cloudy and it is hot all year round. The temperature typically varies from 66°F to 96°F and is rarely below 60°F or above 101°F. The hot season lasts for 2.7 months, from January 28 to April 19, with an average daily high temperature above 93°F. The hottest day of the year is March 1, with an average high of 96°F and low of 74°F (Guma, 2022).

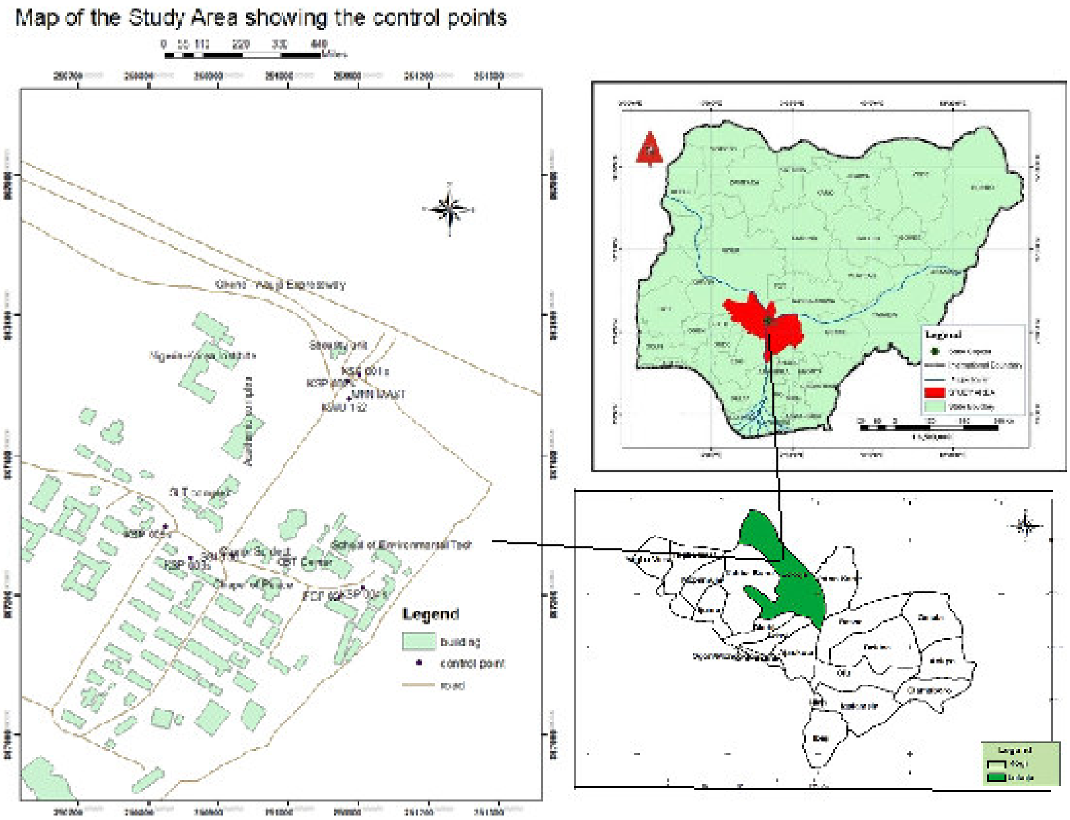

Figure 1: Maps: Nigeria showing Kogi State (top right); Kogi State Showing Lokoja (bottom right); and the study area (left)

Source: Fieldwork, 2022

The Primary data source for this research work was the direct outcomes of observations. Secondary data/sources are obtained from information provided by the GNSS-PPP observations, and not directly observed from the field.

The Primary data that are required for this research include;

i. Raw GNSS-PPP observational results which were converted to RINEX format.

The secondary data that will be required to execute the job are;

i. The converted RINEX files.
ii. Canadian Spatial Reference System (CSRS) PPP online results of the GNSS-PPP observations.

The instruments that were used can be classified into Hardware and software. For Hardware, the following were used;

a. Hi-Target Single receiver and its accessories
b. Garmin 72 Handheld GPS.

c. Data logger (iHandy)
d. A laptop
e. Internet facility

For Software, the following were used;

a. Microsoft word
b. ArcGIS 10.2
c. Hi-Target Geomatics Office
d. CSRS-PPP website (webapp.geod.nrcan.gc.ca)
e. Coordinates-converter.com
f. Geoid Eval calculator

The instruments were inspected and all its components were intact and the batteries were also checked to ensure they were fully charged before and during the observations. The instruments were tested and adjusted in two ways;

i. Permanent adjustment
ii. Temporary adjustment

The Hi-Target V30 GNSS receivers were checked for calibration status before use. An integrity test was carried out on the Hi-Target GNSS receiver and they include; setting up, centring, and levelling up on a station with all necessary connection. Checks were made on the satellite tracking and observations.

Data acquisition

Primary data acquisition with GNSS-PPP

The observations for data acquisition were carried out on Static mode with Hi-Target single receiver in which the duration of station occupation was one (1) hour for each point. Before observation at each observation station, a temporary adjustment was usually carried out. The data logger would be put on and the connection between the receiver and data logger would be made through their inbuilt Bluetooth system.

The acquisition of satellite data was carried out and at exactly 60 minutes observation, the data logger is stopped and automatically the received data from satellite are stored in the memory of the receiver. This procedure was repeated at all the observation points such that, total of 8 stations were observed in this campaign. The raw data were downloaded and converted to RINEX file and were uploaded to online post-processing solution, the Canadian Spatial Reference System (CSRS). There the processing was performed and the result was returned.

Secondary data acquisition with Total Station observation

The observation was set on coordinate mode such that, the TS was set on KGY 021 as the occupied station and the reflector is held vertically on KSP 004s another intervisible station. The coordinates of the occupied station were inputted and that of the back sight station which is the KSP 004s was inputted also. The telescope was focused at the reflector and the 'measure' button was pressed. This particular procedure can be termed as in-situ check, and it is necessary for onward position fixing. After this procedure, and the coordinate was confirmed to be in order, other points of interest such as SGI 100 and KSP 003s that were intervisible were sighted and measured. The results were displayed on the LCD of the Total Station. The same procedure was continued until all the points were observed the first and the second day of the observation.

RESULTS AND DISCUSSIONS

Result of GNSS-PPP Observations

The results of GNSS-PPP are presented on Table 1.

Table 1: GNSS-PPP results

STN ID	WGS 84			MINNA DATUM		
	Easting (m)	Northing (m)	Ellip. Height (m)	Easting (m)	Northing (m)	Orth. Height (m) Geoid=25.865
SGI 110						
KSP 004s	251025.296	867330.871	88.532	251102.025	867210.669	62.667
SGI100	250850.202	867374.709	94.151	250926.931	867255.537	68.286
FGP021	250997.845	867316.845	89.367	251074.573	867196.589	63.502
KSP003S	250802.827	867373.705	95,134	250879.555	867253.533	69.269
KWU162	250982.748	867571.404	84.274	251059.476	867451.232	58.409
KSP001S	251028.070	867636.008	80.656	251104.798	8671515.829	54.791
KSP002S	250984.348	867603.958	83.440	251061.076	867483.787	57.575
KSP005S	250738.546	867411.911	96.166	250815.274	867291.739	70.301

Source: Fieldwork, 2022

Results of Total Station survey

The results of the TS survey that were carried out are displayed on Table 2. The observation was conducted to close back after including the starting control points.

Table 2: The Results of the two Total Station survey

STN ID	1ST TOTAL STATION OBSERVATION			2ND TOTAL STATION OBSERVATION		
	Easting (m)	Northing (m)	Height (m)	Easting (m)	Northing (m)	Height (m)
KSP 004s	251102.545	867210.141	63.083	251102.028	867210.671	62.649
SGI100	250926.829	867254.568	68.568	250926.915	867254.996	62.141
FGP021	251074.573	867196.589	63.502	251075.084	867196.128	63.839
KSP003S	250879.370	867254.134	69.453	250879.801	867253.767	69.613
KWU162	251060.388	867450.927	58.498	251060.431	867450.116	58.440
KSP001S	251106.146	867515.451	54.759	251106.049	867515.381	54.556
KSP002S	251062.161	867483.752	57.604	251062.144	867483.439	57.531
KSP005S	250815.856	867292.071	69.483	250815.286	867292.546	69.311

Source: Fieldwork, 2022

The first TS readings and the second TS readings were averaged to come up with a mean TS reading as presented in Table 3.

Table 3: The mean of the TS observations

STN ID	1ST TOTAL STATION OBSERVATION			2ND TOTAL STATION OBSERVATION			TOTAL STATION MEAN		
	Easting (m)	Northing (m)	Height (m)	Easting (m)	Northing (m)	Height (m)	Easting (m)	Northing (m)	H (m)
KSP 004s	251102.545	867210.141	63.083	251102.028	867210.671	62.649	251102.287	867210.406	62.866
SGI100	250926.829	867254.568	68.568	250926.915	867254.996	68.542	250926.872	867254.782	68.555
FGP021	251074.573	867196.589	63.502	251075.084	867196.128	63.839	251074.829	867196.359	63.671
KSP003S	250879.370	867254.134	69.453	250879.801	867253.767	69.613	250879.58	867253.951	69.533
KWU162	251060.388	867450.927	58.498	251060.431	867450.116	58.440	251060.410	867450.522	58.469
KSP001S	251106.146	867515.451	54.759	251106.049	867515.381	54.556	251106.098	867515.416	54.658
KSP002S	251062.161	867483.752	57.604	251062.144	867483.439	57.531	251062.153	867483.596	57.568
KSP005S	250815.856	867292.071	69.483	250815.286	867292.546	69.311	251062.153	867483.595	57.567

Source: Fieldwork, 2022

The mean TS readings were placed side by side for possible comparisons and displayed in Table 4.

Table 4: The GNSS-PPP readings and the TS readings

STN ID	MEAN TOTAL STATION			GNSS-PPP RESULTS		
	Easting (m)	Northing (m)	Height (m)	Easting (m)	Northing (m)	Height (m)
KSP 004s	251102.287	867210.406	62.866	251102.025	867210.669	62.667
SGI100	250926.872	867254.782	68.555	250926.931	867255.537	68.286
FGP021	251074.829	867196.359	63.671	251074.573	867196.589	63.502
KSP003S	250879.586	867253.951	69.533	250879.555	867253.533	69.269
KWU162	251060.410	867450.522	58.469	251059.476	867451.232	58.409
KSP001S	251106.098	867515.416	54.658	251104.798	8671515.829	54.791
KSP002S	251062.153	867483.596	57.568	251061.076	867483.787	57.575
KSP005S	250815.571	867292.3085	69.397	250815.274	867291.739	70.301

Source: Fieldwork, 2022

The differences between the TS and GNSS-PPP were computed and the result is displayed on table 4.5 for possible analysis.

Table 5: Comparison of the TS and GNSS-PPP readings and their differences

STN ID	MEAN TOTAL STATION			GNSS-PPP RESULTS			DIFFERENCES IN E, N, H		
	Easting (m)	Northing (m)	Height (m)	Easting (m)	Northing (m)	Height (m)	$\partial e(m)$	$\partial n(m)$	$\partial H(m)$
KSP 004s	251102.287	867210.406	62.866	251102.025	867210.669	62.667	0.262	-0.263	0.199
SGI100	250926.872	867254.782	68.555	250926.931	867255.537	68.286	-0.059	-0.755	0.269
FGP021	251074.829	867196.359	63.671	251074.573	867196.589	63.502	0.256	-0.23	0.169
KSP003S	250879.586	867253.951	69.533	250879.555	867253.533	69.269	0.031	0.418	0.264
KWU162	251060.410	867450.522	58.469	251059.476	867451.232	58.409	0.934	-0.71	0.06
KSP001S	251106.098	867515.416	54.658	251104.798	8671515.829	54.791	1.3	-0.404	-0.133
KSP002S	251062.153	867483.596	57.568	251061.076	867483.787	57.575	1.077	-0.191	-0.007
KSP005S	250815.571	867292.309	69.397	250815.274	867291.739	70.301	0.297	0.57	-0.904

Source: Fieldwork, 2022

Discussion

After the TS survey was carried out on the selected points, it is expected that all the observed points when compared should have decimeter range differences or less because that was the specification value for any GNSS-PPP observations made within 60 minutes of observation time (Kalinnikov *et al,* 2018; Deo & El-Mowafy, 2020; Bisnath & Gao, 2009). However, as can be seen in Table 5, the differences between the GNSS-PPP and the TS observation were all in decimetre range except for the differences in the easting coordinates of KWU 162, KSP 001s and KSP 002s. The easting differences of control points KWU 162, KSP 001s and KSP 002s were in metres level range which is unacceptable.

The meter level differences called for further investigations and some findings were made. The meter level differences were caused by multipath errors and signal interferences in the acquisition of satellites signals on those control points. There was this proximity of the GNSS receiver to power lines, communication mast and storey buildings around. These factors can of course, obstruct the receiver's clear view of the sky, as affirmed by Bidikar, Chapa, Kumar, and Rao (2020).

Other points had clear view and were never obstructed, so their differences after comparison were in decimetre level. This result agrees with Bisnath and Gao, (2009), as well Deo and El-Mowafy, (2020). There is no doubt that Satellite signals are very weak and prone to interferences from telecommunication and other radio signals like 3G, Wi-Fi and Bluetooth, 4G LTE and 5G. When these radio signals disrupt the GNSS signals, they cause positioning accuracy problems (Fernández-Prades, Arribas & Closas). Invariably, that was what happened to control points KWU 162, KSP 001s and KSP 002s. The signals that were received by the GNSS-PPP receiver mounted on them were weakened by those inferences hence the meter level results.

CONCLUSION

The aim of the study was to use Total Station instrument to determine the presence of error in GNSS-PPP observations. The GNSS receiver was used to observe satellite signals that was used to fix position for 60 minutes on each on identified monument point. The Total Station used two of the intervisible GNSS-PPP controls to observe the reflector held on all the other PPP controls. The results were in decimetre level except for three control points whose error crossed into the meter level. The reason for this has been adduced to be the obvious obstructions of communication mast, power lines, and buildings, of GNSS signals from the space segment.

This research proved that the Aided-GNSS device such as Total Station and digital theodolite are still necessary in surveying in urban settlement where multipath errors are likely to affect GNSS observation results. Once the base stations of at least two or three intervisible fixed positions have been established, the Total Station can then be used to extend coordinated points from one place to the other. The total Station signals can be used to squash GPS errors thereby maintaining consistency in the accuracy from one points of interest to another.

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