3D-Position Determination using GNSS Techniques –
A Comparative Analysis

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Abstract — This study was carried out to determine 3D-position of selected points within Obafemi Awolowo University. The points were located at Africa Regional Institute for Geospatial Information Science and Technology (AFRIGST), Central Technological and Laboratory Workshops (CTLW), main Bus Stop, Religion ground, New Environmental Design and Management (New EDM), and Spider building, China HuaCe Corporation (CHC) GPS and ProMark 3 GPS were used to carry out observation on the selected points. The data gotten were post processed using GNSS solution software for ProMark3, Compass software for CHC GPS and the result gotten were compared with the known coordinates of those points. The data was analyzed using Statistical Package for Social Sciences (SPSS) to determine the most accurate instrument between the two. The occupation time for the two instruments on each station was 45 minutes. Analysis of Variance (ANOVA) and Chi square Variance analysis were conducted, the result showed that there is no significant difference between the observations of the two instruments in comparison with the adjusted coordinate. It can be concluded that any of the two instruments can be used for 3D point positioning to obtain accurate result.

Index Terms — 3D Point Position, GNSS Techniques, Comparative Analysis, Coordinates.

I. INTRODUCTION

To determine a position, it must be referenced to a known point, such as control [2]. Many instruments have been used in the field of surveying starting from the Stone Age to this age of technological advancement, examples of such analogue and archaic instruments are Compass, Theodolite and dumpy level. During the 1970s advent of technology in the field of surveying brought about new and unique approach to surveying, different instruments which give better accuracy and save time such as Global Positioning System (GPS), Total Station, Work Station and other Global Navigation Satellite System (GNSS) instruments emerged.

These systems can be operated day or night and do not require clear line of sight between base and rovers at survey stations. This represents a revolutionary departure from conventional surveying procedures, which rely on observed angles and distances for determining point positions [5]. This constellation could allow a GPS user to access any available satellites anywhere in the world. GPS provides point position (Latitude/Longitude) and relative position (Vector).

[6] determined the quality control of GNSS- Receivers by accuracy-based analysis, using traditional statistic quality control, and the study presents a quality control method for Global Navigation Satellite System (GNSS) receivers without considering the effect of the technique used on the accuracy. [3] studied the physics of GPS working, which is of little concern to surveyors, who most of the time do not interfere with the data captured which makes many to believe that it is error prove. He further explained that there are needs for surveyors and users of GPS survey data to have a basis of accepting and rejecting a GPS survey result as these results are clearly not sacrosanct, but he did not specify the application areas and the standard for accepting or rejecting the result.

GNSS data acquired for a particular point at different time interval normally varies due to different reasons. A study carried out by [1] determined the accuracy assessment of Global Navigation Satellite System (GNSS) precise point positioning. They evaluated the accuracy and the initialization time of Precise Point Position (PPP), the accuracy of car tracks kinematic PPP solution was assessed. The study showed that observed data varied with epoch. These kinematic tracks were observed in Stuttgart, Germany using different time interval, the study needs to be carried out in Nigeria to verify the result maybe there will be variation due to different geographical locations.

[4] worked on Global Navigation Satellite System / Network Transport of Internet Protocol (GNSS/NTRIP) Service and technique accuracy Tests which aimed at the use of Real Time Kinematic and Differential Global Positioning System (RTK and DGPS) techniques, in terms of accuracy reached, to differentiate between the coordinates and others that were considered as standard, beside checking if the equipment reaches or not the accuracy stated in the manual. The study showed that the type of instrument used will determine the type of accuracy achieved, this study is limited to two techniques. This study will therefore compare different GNSS techniques in 3D position determination.

A. Overview of the Study Area

Ile-Ife is an ancient Yoruba city in south-western Nigeria. The city is located in present day Osun State. Ile is about 218 kilometers northeast of Lagos with a population of 509,813. Geographically, Ile-Ife lies within latitudes 7° 28´N and 7° 46´N, and longitude 4° 36´E and 4° 56´E; to her east lies Akure and to her west lies Ifadran. It houses the most prestigious university, Obafemi Awolowo University, where the project was carried out.

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1. Software for data processing

The software that was used for data collection, processing and spatial analysis include GNSS Solution software for ProMark 3 post processing, SPSS, Notepad, Matlab, Compass post processing software for CHC GPS, and AutoCAD.

B. Data Quality

Data are said to be of high quality if they are fit for their intended uses in operation, decision making, and planning and they correctly represent the real-world construct to which they are referred.

The under listed activities were taken to ensure the reliability and quality of data acquire:

1. All instruments used were properly tested, by carrying out repeated observation on a known point (EDM 02) and the coordinates were compared, the variation is within acceptable range.
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C. Data Processing

1. For CHC GPS data processing

Open the Compass processing software, go to file and select new project. Go to file again and select import to import data from where it was saved on the system. Select the base station, input the base station coordinates, select the coordinates system, and click on adjustment, it will bring out the adjusted coordinate.

2. For ProMark 3 data processing

The ProMark 3 GNSS solution used for processing was launched on the computer. From the first interface, new job was selected after which a dialogue box popup, the coordinate system for reference system, MINNA datum was selected, and ok button was pressed and project name was typed in, where to import the data was displayed and the data were imported from where it was saved as GNSS. The base station was selected, and the coordinate inputted, after which import, process, and adjust was selected and the adjusted coordinate was displayed on the computer screen.

III. PRESENTATION OF RESULT

The results of the observation using CHC GPS, and ProMark 3 GPS are presented in Tables II, III.

IV. ANALYSIS OF RESULTS

The obtained results using both instruments were analyzed based on the Eastings, Northings and Heights of the coordinates and compared as shown in Tables IV–VI.

![Fig. 1. Overview of the Study Area.](image-url)
A. Graphical Representation of Results

The results were also presented and analyzed using graphical representation. The standard coordinate was represented in blue while the coordinates observed using CHC and ProMark 3 were represented in black and green colors respectively. This is shown in Fig. 2-4.
B. Chi Square Test Hypothesis Analysis

Chi Square test analysis was also carried out to check the variations for the different GNSS instruments thus:

$H_0$: There is no variation between the adjusted coordinates and the coordinates gotten with other modes.

$H_1$: There is variation between the adjusted coordinates and the coordinates gotten with other modes.

1. For Easting

The Chi square test measure the discrepancy between the observed value and expected value whether they are related or not. In this case the null hypothesis is that there is no significant difference pattern or association result from the Adjusted coordinates and any of the Static or Stop-and-Go coordinates.

Since the two-sided asymptotic significance of the Chi-square value (0.375) is greater than α at 0.05, and Chi-square ($\chi^2$) calculated is 36 which is less than Chi-square critical value at degree of freedom (df) of 55.76, the null hypothesis (Ho) states that there is no significant difference between pattern of Easting resulted from the Adjusted coordinates and any of Static or Stop-and Go coordinates the result is hereby accepted. This connotes that the Easting got by using adjusted coordinates obtained by CHC GPS is the same with either of Static or Stop-and-Go mode acquired by ProMark 3.

| TABLE VII: Chi Square Test for Easting Coordinates | Chi-Square Tests | Value | Df | Asymptotic. Sig. (2-sided) |
|---------------------------------------------------|-----------------|-------|----|---------------------------|
| Pearson Chi-Square                                |                 | 36.00 | 34 | 0.375                     |
| Likelihood Ratio                                  |                 | 39.55 | 34 | 0.236                     |
| Linear-by-Linear Association                      |                 | 0.00  | 1  | 1.000                     |
| No of Valid Cases                                 |                 |       | 18 |                            |

2. For Northing

There is no significant difference between the northing taken by the Adjusted coordinates and either of the Static or Stop-and-Go mode at two-asymptotic significance value (0.375) greater than α = 0.05.

| TABLE VIII: Chi Square Test for Northing Coordinates | Chi-Square Tests | Value | Df | Asymptotic. Sig. (2-sided) |
|-----------------------------------------------------|-----------------|-------|----|---------------------------|
| Pearson Chi-Square                                  |                 | 36.00 | 34 | 0.375                     |
| Likelihood Ratio                                    |                 | 39.55 | 34 | 0.236                     |
| Linear-by-Linear Association                        |                 | 0.00  | 1  | 1.000                     |
| No of Valid Cases                                   |                 |       | 18 |                            |

From above analysis, it could be inferred that there is association between Adjusted, Static and Stop-and-Go coordinates.

3. For Height

The null hypothesis is also accepted in the case of height since the Chi-square ($\chi^2$) calculated of 36 is less than Chi-square tabulated of 55.76 at 34 df and α of 0.05. The two-sided asymptotic significance value of 0.375 is greater than 0.05. This shows that there is no significant difference between the heights of Adjusted coordinates, the one acquired by Static mode or Stop-and-Go.

| TABLE IX: Chi Square Test for Heights | Chi-Square Tests | Value | Df | Asymptotic. Sig. (2-sided) |
|--------------------------------------|-----------------|-------|----|---------------------------|
| Pearson Chi-Square                   |                 | 36.00 | 34 | 0.375                     |
| Likelihood Ratio                     |                 | 39.55 | 34 | 0.236                     |
| Linear-by-Linear Association         |                 | 0.047 | 1  | 0.828                     |
| No of Valid Cases                    |                 |       | 18 |                            |

C. ANOVA Analysis

The population variance is assumed equal, that is, $H_0$, $\sigma^2 = \sigma^2 = \sigma^2$. The null hypothesis is that there is no significant variation between the true Adjusted, Static and Stop-and-Go coordinates.

1. For Easting

Table X showed that at F – value calculated of (0.00) which is less than F – critical value at $F_{0.05,2,15}$ (3.68), and significant value of 1.0 which is greater α = 0.05, the null hypothesis is accepted. This indicates that there is no significant variation among the Easting of the three mode.

| TABLE X: ANOVA of Easting | ANOVA | Sum of Squares | Df | Mean Square | F | Sig. |
|---------------------------|-------|----------------|----|-------------|---|------|
| Between Groups            |       | 0.012          | 2  | 0.006       | 1.00 | 1.00 |
| Within Groups             |       | 5204383.93     | 15 | 346958.9    | 30 |      |
| Total                     |       | 5204383.95     | 17 | 346958.9    | 30 |      |

2. For Northing

Since F – value calculated of (0.00) is less than F – critical value at $F_{0.05,2,15}$ (3.68), and P-value of 1.0 is greater than α = 0.05 the null hypothesis is hereby accepted. This shows that there is no significant variation among the northing of the three mode at 95% confidence level.

| TABLE XI: ANOVA of Northing | ANOVA | Sum of Squares | Df | Mean Square | F | Sig. |
|------------------------------|-------|----------------|----|-------------|---|------|
| Between Groups               |       | 0.002          | 2  | 0.001       | 0.00 | 1.00 |
| Within Groups                |       | 3204124.24     | 15 | 213608.2    | 83 |      |
| Total                        |       | 3204124.24     | 17 | 213608.2    | 83 |      |

From the above, it can be deduced that, the three mode yield the same results across the six sample points.

3. For Height

At F – value calculated of (0.05) is less than F – critical value at $F_{0.05,2,15}$ (3.68), and P – value of 0.952 which is greater than α = 0.05, indicates that there is no significant variation in the heights observed with the three modes, therefore, the null hypothesis is accepted.
TABLE XII: ANOVA OF HEIGHT

| ANOVA                  | Sum of Squares | Df | Mean Square | F    | Sig. |
|------------------------|----------------|----|-------------|------|------|
| Between Groups         | 1.475          | 2  | 0.738       | 0.050| 0.952|
| Within Groups          | 222.676        | 15 | 14.845      |      |      |
| Total                  | 224.151        | 17 |             |      |      |

V. CONCLUSION

This paper has attempted to carry out a comparative analysis of 3-Dimensional point determination using different GNSS techniques and instruments. The result from the analysis of the study showed that using either of the instrument under equal time interval would not create any significant variation, the little variation would be negligible and insignificant. Also, from the hypothesis, it can be concluded that either of the instrument will give accurate results in 3-D Point positioning at 95% confidence level. Therefore, it can be concluded that any of the two instruments can be used for 3-D point position and give accurate result.

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