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Accuracy assessment of established control within University of Lagos, Nigeria

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ABSTRACT

This paper focuses on assessing the accuracy of established control within the University of Lagos campus. Taking full advantage of advancement and revolutions in surveying techniques, Differential Global Positioning System(DGPS) linked with Continuously Operating Reference Stations(CORS) was embraced for data acquisition to minimise the uncertainties surrounding the process. The acquired data was adjusted/reduced using Trimble Business Center and resulted in the production of a list of new coordinates. Besides, determined was Pearson correlation coefficient and t-statistics at ninety-nine per cent confidence level in Excel application for decision making between existing and newly acquired data. For the Eastings and Northings, the p-values were smaller (E = 0.002768695 and N = 0.00036642) than the 0.01 p-value specified for the computation; communicating the existence of a significant difference between the data thereby inferring the rejection of existing Eastings and Northings coordinates. For the Height, the p-value is larger (0.069657705) than the 0.01 entered value; signifying there exist no significant difference between the height data. Hence, we do not reject the existing elevation data. Finally, a map was produced in accordance with best surveying practices.

1. Introduction

Several studies have shown the existence of considerable discrepancies in data reports of all the previous attempts made to coordinate and re-coordinate Survey Control points/stations within the University of Lagos campus in Lagos, Nigeria. Iyoyojie 2014; Owodunni 2015 both re-coordinated XST347 presumed to be a first-order control and ends up producing two coordinate values (Table 1) with a significant difference. This then prompts a question of “how accurate or precisely determined are all these controls?” Survey control stations are reference monuments to which other survey works of lower accuracy are connected (John, 2020). The purpose of a control system is to prevent the accumulation of errors, by connecting detail work to a reliable geometrical network system of points that are accurate enough for projects.

Great care is taken to ensure that these controls are sufficiently accurate (Dimal et al. 2009).

Control networks consist of stable, identifiable points with published datum values derived from observations that tie the points on the Earth’s surface together; (John, 1984). Given the foregoing, this study assesses the accuracy of control points within the University of Lagos. Observations were carried out on the control points using a Differential Global Positioning System (DGPS). The DGPS was linked to a Continuously Operating Reference Station (CORS). The observed coordinates of the controls were compared with the previously documented coordinates, and the differences were statistically analysed.

Table 1. Control Points with Multiple Coordinate varying Value (WGS84 Zone 31)

Station	Eastings(X_o)	Northings(Y_o)	Height(Z_o)
CR 7	543302.330	720161.975	3.193
CR7	543308.485	720161.118	3.458
CR7	543308.350	720161.709	3.288
XST 347	543235.430	719894.220	4.701
XST 347	543245.510	719884.330	4.735

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2. Method

Figure 1 presents the methodology workflow for this study.

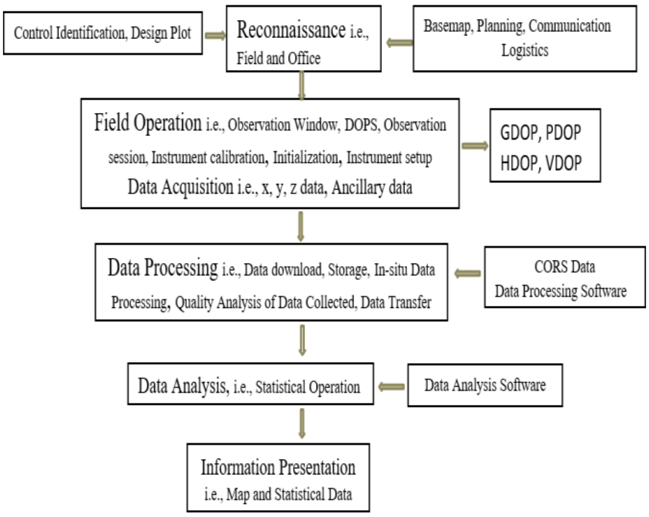

Figure 1. Methodology Workflow

2.1. Study area

The University of Lagos is within the Geographic location 06˚31' 0" N, 03˚23' 10" E. It is largely surrounded by the scenic view of the Lagos lagoon on 802 acres (324.5579 Hectares) of land in Akoka, North Eastern part of Yaba, Lagos Nigeria. Below figures 2, 3 and 4 are three out of the forty-two control monuments in the study area.

Figure 2. XST347

Figure 3. CR 7

Figure 4. GME 03

2.2. Reconnaissance

Field investigation conducted revealed the control beacons are physically present on the ground with some in bad states. The office inspections further validated the need for the research due to inconsistencies within the sourced existing data leading to a conceptual comprehensive plan devised toward instrumentation, data acquisition and processing. Furthermore, Trimble GNSS planning online software abetted the planning process, i.e. Fig. 6 below.

2.3. Instrumentation

Stonex S900A GPS Receivers and Continuous Operating Reference Station (CORS) were deployed for data acquisition. Trimble Business Center, ArcGIS, Global Mapper and Microsoft Excel were installed for data processing/statistical analysis.

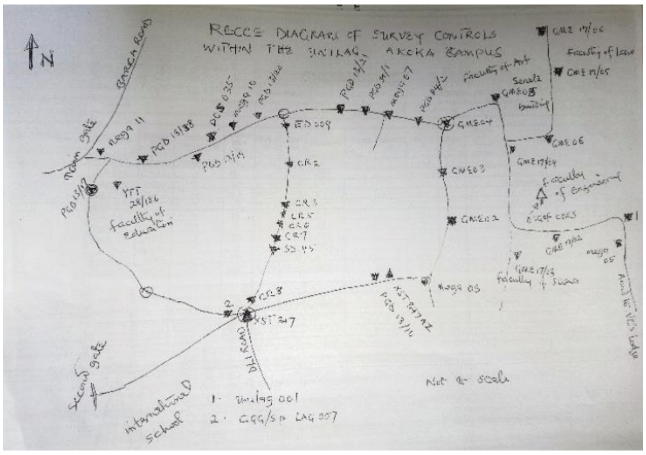

Figure 5. Recce diagram of the study area

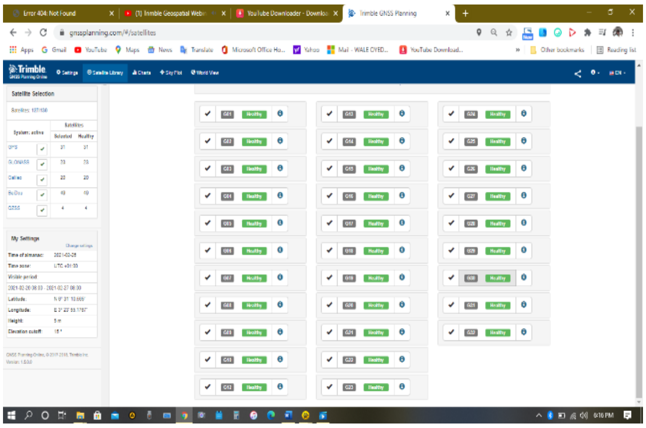

Figure 6. Satellite's Health Status for one of the Observation Days seen in Trimble GNSS Planning Online. (Source: Trimble GNSS online)

2.4. Data acquisition

Based on the expected accuracy standard (1:50,000) for second-order classification, to eliminate noisy data and unhealthy satellites, an hour Static GPS/GNSS positioning technique was applied to be the most accurate method of GPS observations.

To reduce the detrimental effects of atmospheric refraction and multipath signals, a 15° minimum elevation angle for the receiver's antenna was observed to enable a clear sky view for the satellite's microwave signal. Where power-line, metallic objects, trees and fences that could lead to imaging became inevitable, such stations were indicated in the field note. The observation window where the satellite constellation is good was critically observed. PDOP less than 4 (four) was considered. The batteries were fully powered to avoid loss of power.

Having set up and initialized the receiver, the data was acquired for each control station.

2.5. Data processing

Receiver INdependent Exchange(RINEX) Format raw data from NIGNET CORS code-named LGLA (situated in the University of Lagos), Nigerian Institution of Surveyors (NIS) CORS (Lagos branch) both corresponding to the observation epoch and the DGPS receiver were imported into the TBC. The NIS CORS coordinate values given in the geographical coordinate system was converted to their UTM equivalent using Global Mapper. The raw data were processed and adjusted using the CORS as baseline controls. The TBC uses the Chi-square test to adjust the data until the initial apriori error estimates agree with the adjusted errors for the network vectors. The CORS assigns standard estimated error values to each control point based on its quality. The TBC also determines the root mean square error which evaluates the quality of predictions.

3. Results

Table 2 shows the chi-square test performed on the data at 95% confidence level was successful and the fixed result obtained surpassed the expected second-order accuracy standard (1:50,000) for the control survey.

Table 3 gives the Root Mean Square error of XST347 and CR7 for the referenced CORS while table 4 give the final processed WGS84 zone-31 coordinates.

Table 2. Adjustment Statistics

Operation	Result
Number of Iterations for Successful Adjustment:	**3**
Network Reference Factor:	1.00
Chi-Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	368
Post Processed Vector Statistics	
Reference Factor:	1.00
Redundancy Number:	368.00
A Priori Scalar:	2.62
Fixed	0.000001(Meter)

Table 3. Processing summary for two points from two baselines

Observation	Solution Type	RMS	Distance
LGLA- CR7	Fixed	0.0150	704.43660
LGLA - X347	Fixed	0.0107	889.65660
NIS CORS-CR7	Fixed	0.0284	12054.7301
NIS CORS- XST347	Fixed	0.0288	12283.5743

Table 4. Eight of the Final processed Points WGS84 zone 31 coordinate list

Station	Eastings(X_1)	Northings(Y_1)	Height(Z_1)
CR 7	543303.42167	720160.24663	3.39415
XST347	543236.44025	719895.00637	4.79219
GME 17/04	544062.90674	720527.94721	5.97133
GME 03	543939.76545	720408.73090	7.52536
PGD 21/13	543545.36986	720566.01726	6.35497
UNILAG 001	544473.83120	720456.66867	1.51893
YTT 28/186	542622.77768	720383.12109	6.40460

4. Discussion

Ninety-one per cent of the observed controls were used for analyzing the data. The criteria are the presence of existing coordinates and stable conditions. Determining the correlation coefficient (r), equation 1 was applied between the existing variables, x (X_1, Y_1, Z_1) and the newly acquired variables, y(X_o, Y_o, Z_o). Table 5 gives a very high linear relationship between x and y.

$$r = \frac{n(\Sigma xy)-(\Sigma x)(\Sigma y)}{\sqrt{\{n\Sigma x^2-(\Sigma x)^2\}\{n\Sigma y^2-(\Sigma y)^2\}}} \quad \text{Equation 1}$$

Table 5. The Correlation coefficient between x and y

	New Easting	Existing Easting
New Easting	1	
Existing Easting	0.999985879	1
	New Northing	Existing Northing
New Northing	1	
Existing Northing	0.999993	1
	New Elevation	Existing Elevation
New Elevation	1	
Existing Elevation	0.998153	1

Determining the x horizontal points geometry vector deviation distance, S using y data as standard, equation 2 was applied. The maximum displaced point at PGD84/2 with 22.6201m(outlier) and the least displaced, PGD21/13 with 0.0825m. In the vertical point data, MEGA10 has the least difference with 0.01120m higher than the newly observed height while CR6 is with the highest difference of -0.28274m. Fig. 7 shows the corresponding difference between (X_1, Y_1, Z_1) and (X_o, Y_o, Z_o).

$$S = \sqrt{\Delta E^2 + \Delta N^2} \quad (2)$$

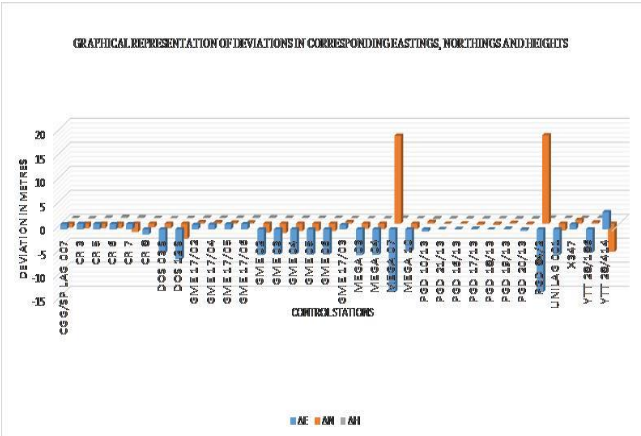

Figure 7. Chart Depicting the Difference between Two Corresponding Eastings, Northings and Heights

With a two-sample t-test for means of (X_o, X_1), (Y_o, Y_1) and (Z_o, Z_1), equation 3 was used to produce the $p - value$ based on the $t - distribution$.

$$T - Statistic = \frac{\bar{x}_i - \bar{y}_i - Hypothesized\ difference}{SE_{\bar{x}_i - \bar{y}_i}} \quad (3)$$

The mean difference between the sample means, $\bar{x}_i - \bar{y}_i$ The Standard error of the difference in the Aspin-Welch unequal-variance t-test for the unequal variance case is:

$$SE_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \quad (4)$$

n_1 *and* n_2 are the assumed sample sizes for groups x and y.

$H_0: \bar{x}_i - \bar{y}_i$ = Hypothesized Difference

Since the Hypothesized difference is zero, the t-Statistic formula reduces to:

$$T - Statistic = \frac{\bar{x}_i - \bar{y}_i}{SE_{\bar{x}_i - \bar{y}_i}} \quad (5)$$

For the unequal variance case:

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{\left(\frac{S_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{S_2^2}{n_2}\right)^2}{n_2 - 1}} \quad (6)$$

Table 6 present the result summary of the hypothesis calculations. There was a statistically significant difference at 99% confidence level in the horizontal control coordinates but no significant difference between the height data. For the Eastings and Northings, the p-values were smaller (E = 0.002768695 and N = 0.00036642) than the 0.01 p-value. For the Height, the p-value is larger (0.069657705) than the specified 0.01 p-value.

Table 6. Summary of two-sample t-test for means *x* and *y*

	mean	variance	t-stat	t-critical two-tail
X_o	543517.792	296791.317		
X_1	543516.078	296318.464	3.2606253	2.74999565
Y_o	720334.439	58484.4529		
Y_1	720333.773	58499.9592	4.0149979	2.74999565
Z_1	5.54964097	3.78898635		
Z_o	5.58976516	3.73290145	-1.8813701	2.74999565

5. Conclusion

Since there is evidence of significant difference at 99% confidence level for the Eastings and Northings and no significant difference for the height, we infer the rejection of the exiting Eastings/Northings, keep the newly acquired Eastings/Northings and fail to reject the existing height of control coordinates of the University of Lagos.

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