

# EXPLORING THE FRONTIERS OF SURVEYING AND GEOINFORMATICS FOR NATIONAL DEVELOPMENT

EDITORS Opaluwa, Y. D Odumosu, J. O Adesina, E. A Ajayi, O. G



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# **BOOK OF PROCEEDINGS**

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for

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## **FOREWORD**

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- Education, Training and capacity Building in Surveying and Geoinformatics
- Advancement in Earth Observation and Geospatial Technologies
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- Spatial Data Infrastructure for National Security
- Surveillance and Security Monitoring
- Geo-Hazards Prediction and Mitigation
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We hope you enjoy your time at our conference, and that you have the opportunities to exchange ideas and share knowledge, as well as participate in productive discussions with the like-minded researchers and practitioners in the geospatial environment and academia.

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4<sup>th</sup> FEBRAURY, 2019

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# TABLE OF CONTENTS

| Cover Page  | iii  |
|---|------|
| Title Page  | iv   |
| Forward   | v    |
| Copyright Statement   | vi   |
| Declaration of peer review and scientific publishing policy   | vii  |
| Scientific / Review Committee   | viii |
| Local Organising Committee  | x    |
| NASGL National Executives   | xi   |
| Table of Contents   | xii  |
| SUB THEME 01: Education, Training and Capacity building in Surveying and Geoinformatics   |      |
| The Dynamics of Surveying Education Curriculum in Nigeria by Oluwadare, C. O. and Abidoye I. A.   | 2    |
| Marginalization of Female Surveying and Geoinformatics Lecturers in Tertiary Institutions <b>Opatoyinbo, Oladunni O.</b>  | 16   |
| SUB THEME 02: Advances in Earth Observation and Geospatial Technologies   |      |
| View shed Analysis of Campus Radio Fm 92.3mhz of Federal University of Technology, Minna, Niger State, Nigeria  |      |
| Gbedu, A.M., Pwasa, P. B. and Mohammed, I. K.   | 47   |
| The Establishment of an Electromagnetic Distance Measurement Calibration Baseline using the straight line configuration approach  | 62   |
| Devote, B., Hart L., Ekima, R. and Okporo, U.   | 63   |
| Realisation of Time-Dependent Geocentric Datum Transformation Parameters for Nigeria <b>Swafiudeen, B., Ojigi, L. M., Dodo, J. D. and Lawal, K. M.</b>  | 75   |
| Monitoring Atmospheric Water Vapour Variability over Nigeria from ERA-Interim and NCEP<br>Reanalysis Data<br><b>Ojigi, M. L.</b>  | 96   |
| Land Cover Mapping using Combined Soft Classification and Geographic Object Based Image<br>Analysis (SGOBIA) in the Niger Delta Region of Nigeria<br><b>Abdullahi, A. Kuta, Stephen Grebby and Doreen S. Boyd</b> | 114  |
| Proliferations of Borehole Distribution Pattern in Suleja Local Government Area of Niger State,<br>Nigeria<br><b>Areo, I.O., Arinola, F. S. and Adesina, E.A.</b>   | 130  |

| Comparison of Orthometric Heights Derived from GPS Levelling and Total Station Trigonometri<br>Heighting  | ic          |
|---|-------------|
| Uzodinma, V. N., Igwe, C. I. and Agba, B. B.  | 148         |
| Land Use Mapping of Akure Urban for Monitoring and Control of National Development <b>Ogunlade, S.O. and Tukka, A.</b>  | 163         |
| Development of an Android Application for Transformation of Nigeria Projected Coordinates fro<br>Local to Universal Transverse Mercator<br><b>Odumosu, J.O., Opaluwa, Y.D. and Alade, J.A.</b>                        | om<br>174   |
| Evaluating Improved Temperature - Vegetation Dryness Index (iTVDI) for Estimating Soil moist<br>in Enugu State Nigeria using MODIS Satellite Data<br>Ndukwu, R. I., Maduako, I. N., Chiemelu, N. E and Michael, I. J. | ture<br>190 |
| Assessment of Various Ocean Tide Models on GNSS Data over Nigerian Continuously Operating   |             |
| Reference Stations<br>Opaluwa, Y. D, Aleji G. A., Ojigi, L. M. and Adeniyi, G.  | 214         |
| 3-D Position Determination Using Close Range Photogrammetry for 3rd Order Accuracy  |             |
| Positioning<br>Odumosu, J. O, Ajayi, O. G, Nnam, V and Ajayi, S.  | 232         |
| Analysis of Telecommunication Service Mast Distribution in Minna, Niger State Using Geospatia<br>Technique  | al          |
| Adesina, E. A, Uloko, U. S., Olaniyi, A. M., Mobolaji, M. K., Animashaun, A. and<br>Abdulkareem, S.   | 251         |
| A Robust Re-Definition of the Minna Datum Origin with GPS and Gravity Data <b>Uzodinma, V. N</b> .  | 275         |
| SUB THEME04: Spatial Data Infrastructure for National Security  |             |
| Geoinformatics Based Characterization and Profiling of Solid Waste Dump Sites in Kaduna   |             |
| Metropolis<br>Lawal A. M., Sholadoye M. and Ategbe D.   | 294         |
| SUB THEME 05: Surveillance and Security Monitoring  |             |
| STE02: Applications of Surveying and Geoinformatics for National Security: The Nigerian Perspective   |             |
| Onuigbo, I. C.  | 307         |
| Surveying and Mapping: Panacea to the Challenges of Sustainable Development and National Security in Nigeria.   |             |
| Adegboyega, E. R.   | 320         |

# SUB THEME 06: Geo-Hazards Prediction and Mitigation

| Estimation and Analysis of Dams Displacement Using Geodetic Technique Olunlade O. A., Omogunloye O. and Olaleye J. B.  | 338   |
|--|-------|
| SUB THEME 07: Energy and Water Resources Inventory and Governance  |       |
| Sediment Accumulation Study in Tagwai Dam<br>Oladosu, S.O., Ojigi, L. M., Aturuocha, V. E., Anekwe, C.O and Rufai, T.<br>Geospatial Assessment of Solar Energy Potential in the South-East and Parts of South-South<br>Regions of Nigeria          | 363   |
| Ndukwe E. Chiemelu, Francis I. Okeke and Raphael I. Ndukwu   | 382   |
| Application of Geographic Information System (GIS) and Remote Sensing in Groundwater Exploration: A Case Study of Bosso Local Government Area, Minna, Nigeria <b>Ajayi, O. G., Nwadialor, I. J., Odumosu, J. O., Adekunle, O and Olabanji, I</b> . | 406   |
| Evaluating Ground Water Potential Using Dar-Zarrouk Parameters at Kaduna Millenium City N<br>Western Nigeria   | orth- |
| Ango, A, Abaleni, J. I and Danlami, A.   | 426   |
| Spatial Point Pattern Analysis: A Case Study of Electricity distribution transformers in Doka Un Kaduna State  | it of |
| Aliyu, A.A., Muhammed, T. I., Akomolafe, E.A. and Abubakar, A. Z.  | 441   |
| Single Line Diagram and GIS in Electricity Distribution Network: A Case Study of Irepo Feeder<br>Ilora Injection Station, Oyo state  | r of  |
| Jeleel A. Qaadri, Solihu O. Olaosegba  | 466   |
| Conventional Bathymetry Surveys and the use of Landsat 8 Satellite Imagery for Water Depth<br>Measurements: A case study of Ajiwa Dam  |       |
| Abdulkadir, I. F., Ahmed, B., Samaila-Ijah, H. A. and Bako, M.   | 488   |

## 3-D Position Determination Using Close Range Photogrammetry for 3rd Order Accuracy

## Positioning

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# Abstract

In close range photogrammetry, the 3D object space coordinates of points can be obtained from its 2D pixel coordinates using any of the available transformation condition equations. This paper presents the use of collinearity condition equation to obtain both the space resection (Exterior Orientation parameters) and the space intersection (determination of points coordinates from a known point), for a vertical plane close range photogrammetry operation. This was carried out by using a total station instrument to coordinate five structural control points (P1 to P5) and nine other check/analysis points (SA1-SA9), marked on one side of a building. Thereafter, two different calibrated android phones camera (Tecno W3 and Infinix X509) where used for the photogrammetry data capture to the same building side at different positions (right and left). The data obtained were processed in a multi stage process, which includes: the pixel extraction using Matlab application, pixel coordinate to camera coordinate in millimeter conversion, Space resection and intersection using collinearity condition equation with least square adjustment iterative method at 0.001 convergence condition. The 3D object space coordinate output statistically reveals that there is no significant difference between the mean and variance of the transformation coordinates output and that of the total station coordinate output, for a third order job at 99% confidence level of accuracy. And also, that there is no statistical difference between the coordinate outputs of two different phones camera (Tecno W3 and Infinix X509 with focal lengths of 543.342mm and 839.092mm respectively) output obtained, also at 99% confidence level.

**Keywords**: Collinearity Equation, Space resection, Space intersection, 3D object space coordinate, 2D Pixel coordinate.

## **1.0 Introduction**

To rigorously determine the geometric relationship that exist between image and object as at the time of image capture is the major task of photogrammetry [2]. This is so because of the transformation process from one coordinate system to the other (Image coordinates system, to Comparator coordinates system, to Camera coordinate system, then finally to object coordinate system) that photogrammetry operation is involved with. Exterior orientation thus involves the

NASGL Conference/AGM, Minna 2019:

Page 232

process of determination of the 3D spatial position and the three orientation parameters of the camera, as at the time of exposure [6]. There are three major fundamental condition equations used in photogrammetry to obtain these (Exterior orientation parameters), which includes: the collinearity, co-planarity, and co-angularity condition equations, which all uses point coordinate as their input data [3].

Several approaches have been developed over years in the field of photogrammetry for solving the problem of exterior orientation as discussed in previous researches, these includes: the Direct Linear Transformation (DLT) which is often used in photogrammetry [3]. This method gives the exterior orientation parameters without initial approximation been supplied [3]. Also [4], used matrix factorization and homogenous coordinate representation which is a cooperative strategy between the 2-D projective transformation and collinearity model linear version for linearly recovering of the exterior orientation parameters in a planar object space. In a study on the comparison of Close-Range Photogrammetry to terrestrial laser scanning for heritage documentation, [5] noted that there is no significant difference between the result outputs from two entirely independent survey processes of the photogrammetric data captured, and the laser scanner output.

The comparison between Close range Photogrammetry (CPR) using Non- Professional cameras with traditional field survey technique for volume estimation was also carried out at using the Deralok Hydropower plant site, comparing the Digital Elevation Model (DEM) for both methods [1]. The result obtained showed that the CRP method was less time consuming and more accurate for volume calculation. Mokros et al, [7] used close-range photogrammetry for estimating tree diameters, a method which was said to give as accurate result as the terrestrial laser scanning (TLS) and more hardware cost effective for forest stand survey.

This paper thus presents the use of collinearity condition equation for close range photogrammetry in vertical plane to determine both the Exterior orientation (space resection), and Pixel to Object Space Coordinates transformation (Space intersection), and the comparing of the obtained result with the total station coordinates output.

Page 233

NASGL Conference/AGM, Minna 2019:

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### 2.0 Methodology

## **Camera Calibration**

Camera Calibration is the process of acquiring the intrinsic parameters of the camera so as to use it as a measuring device [8]. Camera calibration for the two non-metric camera used for the image acquisition was thus carried out by taking ten(10) captures to a mounted checker board which has five rows and seven columns with 11.3cm dimension of each squares, as displayed in Plate 1.



Plate 1: Checker Board on a plane surface

The acquired images were then processed using Matlab 2014a programme with a camera calibration Add-In tool programme. Information from this process are displayed in Tables 1 and 2.

| Table 1: Results obtained from the camera calibration process using Tecno W3 phone |
|--|
|--|

| Parameter         | Values in pixel        |
|-------------------|------------------------|
| Focal Length      | 2053.66252             |
| Perspective point | 1334.81371, 1002.13721 |

NASGL Conference/AGM, Minna 2019:

Page 234

Table 2: Result obtained from the camera calibration process using Infinix X509 phone

| Parameter         | Values in pixel        |
|-------------------|------------------------|
| Focal Length      | 3171.38219             |
| Perspective point | 2111.01873, 1654.50768 |

A Ground control point (AST 002) was established some few meters away from the structure and coordinated using Deferential Global Positioning System (DGPS). The coordinate output is displayed in Table 3.

Table 3: AST 002 Control point Coordinate

| Station point | Easting(m) | Nothings(m) | Height(m) |
|---------------|------------|-------------|-----------|
| AS 002        | 220145.632 | 1054958.580 | 235.067   |

After a proper test of instrument has been carried out on ZTR 320 Hi-Target Total Station instrument and found reliable for use, it was then set up on control point "AST 002" in a reflectorless mode, to coordinate the marked points on the building, i.e. five structural control points (P1-P 5) used in obtaining the exterior orientation parameters, and nine other points (SA1-SA9) used for the analysis. The obtained 3D coordinate are contained in Table 4

| POINT ID | EASTINGS (m) | NORTHINGS (m) | HEIGHT(m) |
|----------|--------------|---------------|-----------|
| P1       | 220180.890   | 1054935.374   | 234.042   |
| P2       | 220180.766   | 1054935.267   | 242.362   |
| P3       | 220163662    | 1054929.622   | 238.111   |
| P4       | 220148.927   | 1054918.689   | 242.317   |
| P5       | 220149.043   | 1054918.689   | 233.924   |
| SA1      | 220177.970   | 1054934.366   | 240.216   |
| SA2      | 220170.271   | 1054930.274   | 240.255   |

| Table 4: Structural control | points and Analysis points, | coordinated using Total Station |
|-----------------------------|-----------------------------|---------------------------------|
|                             |                             |                                 |

NASGL Conference/AGM, Minna 2019:

Page 235

| SA3 | 220168.665 | 1054928.825 | 235.495 |
|-----|------------|-------------|---------|
| SA4 | 220166.562 | 1054927.807 | 236.306 |
| SA5 | 220163.087 | 1054925.937 | 234.236 |
| SA6 | 220152.406 | 1054920.313 | 234.9   |
| SA7 | 220151.289 | 1054920.381 | 240.25  |
| SA8 | 220175.894 | 1054932.695 | 237.86  |
| SA9 | 220169.454 | 1054929.400 | 237.865 |

Plate 2 describes the structural control points (P1 toP5) and the analysis marked points (SA1 to SA 9) on the building.



Plate 2: Structural control points (P1 to P5) and analysis control points (SA1 to SA9) on the building

The two calibrated non-metric android phones camera (Tecno W3 and Infinix X509) were used to capture the building part under survey from two different positions each (Left and right sides) at 100% overlap, as displayed in Plate 3. The small white stars inscribed in the black stars identifies the exact point coordinated using the total station instrument.

**Odumosu et al:** 3D Position Determination using CRP for 3<sup>rd</sup> order Accuracy Positioning.

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Plate 3: Images from Tecno W3 camera Left and right position capture, with structural control points identified

## 3.0 Data Processing

## Extraction of image pixel coordinates.

MatLab application was used as the comparator, for the extraction of the pixel coordinates of the points of interest (P1-P5 and SA1-SA9) from the acquired images. Plate 4 shows the picture of the MatLab environment during the pixel point extraction.

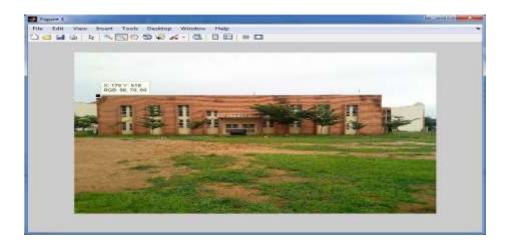


Plate 4: Matlab pixel extraction window

The pixel coordinate (x,y) of the left and right images of each of the cameras is displayed in the

Tables 5 and 6

NASGL Conference/AGM, Minna 2019:

Page 237

| Side     | Left               |                    | Ri                 | ght                |
|----------|--------------------|--------------------|--------------------|--------------------|
| Point ID | x pixel coordinate | y pixel coordinate | x pixel coordinate | y pixel coordinate |
| P1       | 175                | 984                | 159                | 967                |
| P2       | 170                | 518                | 176                | 551                |
| P3       | 1149               | 740                | 919                | 736                |
| P4       | 2159               | 515                | 2064               | 455                |
| P5       | 2154               | 983                | 2054               | 998                |
| SA1      | 322                | 633                | 263                | 652                |
| SA2      | 813                | 630                | 665                | 635                |
| SA3      | 969                | 896                | 812                | 893                |
| SA4      | 1067               | 853                | 901                | 849                |
| SA5      | 1282               | 965                | 1105               | 964                |
| SA6      | 1944               | 924                | 1805               | 928                |
| SA7      | 2010               | 626                | 1873               | 592                |
| SA8      | 482                | 767                | 397                | 773                |
| SA9      | 883                | 767                | 733                | 767                |

Table 5: Pixel coordinate (x,y) of points from Tecno W3 capture for both stations

Table 6: Pixel coordinate(x,y) of points captured from Infinix X509 at both stations.

| Side     | Left               |                    | Ri                 | ght                |
|----------|--------------------|--------------------|--------------------|--------------------|
| Point ID | x pixel coordinate | y pixel coordinate | x pixel coordinate | y pixel coordinate |
| P1       | 365                | 1499               | 496                | 1581               |
| P2       | 342                | 751                | 493                | 896                |
| P3       | 1910               | 1094               | 1842               | 1191               |
| P4       | 3566               | 1469               | 3663               | 1583               |
| P5       | 3580               | 689                | 3670               | 729                |
| SA1      | 581                | 934                | 678                | 1056               |
| SA2      | 1368               | 923                | 1374               | 1031               |
| SA3      | 1626               | 1350               | 1618               | 1445               |
| SA4      | 1780               | 1276               | 1766               | 1371               |
| SA5      | 2128               | 1453               | 2094               | 1550               |
| SA6      | 3211               | 1376               | 3250               | 1474               |
| SA7      | 3326               | 882                | 3372               | 946                |
| SA8      | 841                | 1149               | 908                | 1254               |
| SA9      | 1483               | 1140               | 1485               | 1241               |

Pixel coordinates to image coordinate in millimeter conversion

Since the Matlab environment has its origin at the top right corner, transformation to the camera coordinate which has his origin at the perspective point was carried out by subtracting the x pixel

NASGL Conference/AGM, Minna 2019:

Page 238

coordinate from the x principal point coordinate (obtained from camera calibration) and subtracting the y principal point coordinate (obtained also from camera calibration process) from y pixel coordinate. The result of each camera coordinates were then multiplied by the pixel to millimetre conversion constant "0.2645833333"

Tables 7 and 8 displays the camera coordinates in millimetres for Tecno W3 and infinix X509 cameras.

| Table 7. Techo w 5 camera coordinates |                    |                    |                    |                    |
|---------------------------------------|--------------------|--------------------|--------------------|--------------------|
| Side                                  | Left               |                    | Ri                 | ght                |
| Point ID                              | x pixel coordinate | y pixel coordinate | x pixel coordinate | y pixel coordinate |
| P1                                    | -306.867           | 4.799              | -311.101           | 9.297              |
| P2                                    | -308.190           | 128.090            | -306.603           | 119.360            |
| P3                                    | -49.163            | 69.357             | -110.017           | 70.415             |
| P4                                    | 218.066            | 128.890            | 192.931            | 144.760            |
| P5                                    | 216.743            | 5.063              | 190.285            | 1.0946             |
| SA1                                   | -267.974           | 97.668             | -283.584           | 92.640             |
| SA2                                   | -138.063           | 98.461             | -177.222           | 97.138             |
| SA3                                   | -96.788            | 28.082             | -138.328           | 28.876             |
| SA4                                   | -70.859            | 39.459             | -114.78            | 40.518             |
| SA5                                   | -13.974            | 9.826              | -60.805            | 10.090             |
| SA6                                   | 161.181            | 20.674             | 124.404            | 19.615             |
| SA7                                   | 178.643            | 99.520             | 142.395            | 108.520            |
| SA8                                   | -225.640           | 62.213             | -248.130           | 60.626             |
| SA9                                   | -119.542           | 62.213             | -159.230           | 62.213             |

Focal length =543.341905mm

NASGL Conference/AGM, Minna 2019:

Page 239

Table 8: Infinix X509 camera coordinates

| Side     | Left               |                    | Right              |                    |
|----------|--------------------|--------------------|--------------------|--------------------|
| Point ID | x pixel coordinate | y pixel coordinate | x pixel coordinate | y pixel coordinate |
| P1       | -461.967           | 41.145             | -427.307           | 19.449             |
| P2       | -468.053           | 239.053            | -428.101           | 200.689            |
| P3       | -53.1862           | 148.301            | -71.178            | 122.636            |
| P4       | 384.964            | 49.082             | 410.628            | 18.920             |
| P5       | 388.668            | 255.457            | 412.481            | 244.874            |
| SA1      | -404.817           | 190.630            | -379.153           | 158.355            |
| SA2      | -196.590           | 193.540            | -195.003           | 164.970            |
| SA3      | -128.328           | 80.568             | -130.445           | 55.432             |
| SA4      | -87.582            | 100.150            | -91.286            | 75.011             |
| SA5      | 4.4930             | 53.316             | -4.503             | 27.651             |
| SA6      | 291.037            | 73.688             | 301.356            | 47.759             |
| SA7      | 321.464            | 204.390            | 333.635            | 187.459            |
| SA8      | -336.026           | 133.750            | -318.299           | 105.968            |
| SA9      | -166.163           | 136.130            | -165.634           | 109.407            |

Focal length =839.093814mm

## Transformation from camera coordinates to object space coordinate system

The collinearity condition equation was being used for the transformation from camera coordinate system to object space coordinate system for this work

For this transformation, the two stages undergone are:

- a. Space resection stage (Determination of the Exterior Orientation Parameters)
- b. Space intersection stage (Determination of the 3D object space coordinate from the camera coordinate).

NASGL Conference/AGM, Minna 2019:

Page 240

#### **Space Resection**

The exterior orientation parameters of the camera positions were determined by writing a Matlab code for the collinearity condition equation for space resection, with least square adjustment equation iteration convergence at 0.001. Equations 3.1 and 3.2 below are the close range photogrammetry collinearity condition equations for space resection.

$$x_a = b_{11}d\omega + b_{12}d\phi + b_{13}d\kappa - b_{14}X_L - b_{15}Z_L - b_{16}Y_L + J$$
(1)

$$y_a = b_{21}d\omega + b_{22}d\phi + b_{23}d\kappa - b_{24}X_L - b_{25}Z_L - b_{26}Y_L + K$$
(2)

Were:

 $d\omega$ ,  $d\phi$  and  $d\kappa$  are the corrections to be applied to omega, Phi and Kappa respectively

 $X_L$ ,  $Y_L$  and  $Z_L$  are the 3D exposure station coordinates

 $x_a$  and  $y_a$  are the camera coordinate of the control points

$$\begin{aligned} b_{11} &= \frac{x}{q} (-m_{33}\Delta Y + m_{32}\Delta Z) + \frac{f}{q} (-m_{13}\Delta Y + m_{32}\Delta Z) \\ b_{12} &= \frac{x}{q} [\Delta X \cos \phi + \Delta Y (\sin \omega \sin \phi) + \Delta Z (-\sin \phi \cos \omega)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \cos k) + \Delta Y (\sin \omega \cos \phi \cos k) + \Delta Z (-\cos \omega \cos \phi \cos k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \cos k) + \Delta Y (\sin \omega \cos \phi \cos k) + \Delta Z (-\cos \omega \cos \phi \cos k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta Z (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta Z (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta Z (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta Z (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta Z (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k) + \Delta X (\cos \omega \cos \phi \sin k)] \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k) + \Delta X (\cos \omega \cos \phi \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos \phi \sin k) + \Delta X (\cos \omega \cos \phi \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \cos k) + \Delta X (\cos \omega \cos \phi \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \sin k) + \Delta X (\cos \omega \cos \phi \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \cos \phi \sin k) + \Delta X (\cos \omega \cos \phi \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta Y (-\sin \omega \sin k) + \Delta X (-\sin \omega \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \phi \sin k) + \Delta X (-\sin \omega \sin k) + \Delta X (-\sin \omega \sin k) \\ &+ \frac{f}{q} [\Delta X (-\sin \omega \sin k) + \Delta$$

Graph of the iterative convergence (0.001) for both orientation and camera position, for Infinix X509 left camera position is shown in Figure 1.

NASGL Conference/AGM, Minna 2019:

Page 241

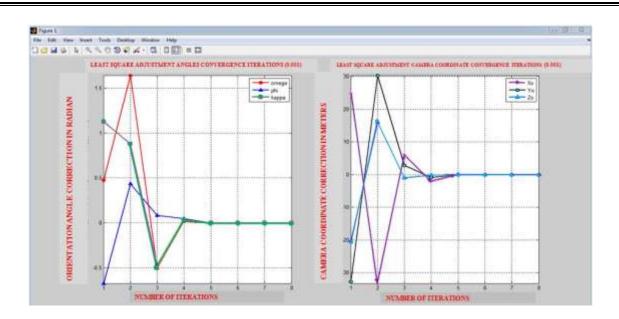


Figure 1: Iteration graphs of Infinix X509 right image

Adjusted exterior orientation parameters for each camera position acquired using a developed MatLab Program codes are displayed in Table 9.

| Phone Type               | Tecno W3     |              | Infinix X509 |              |
|--------------------------|--------------|--------------|--------------|--------------|
| Capture Position         | Left Images  | Right images | Left Images  | Right images |
| Adjusted Omega(degrees)  | 182.9322     | 183.4229     | 183.0718     | 185.2538     |
| Adjusted phi (degrees)   | -26.7967     | -41.2212     | -38.8186     | -28.4174     |
| Adjusted kappa (degrees) | 181.1068     | 182.3364     | 181.4428     | 181.6795     |
| adjusted xo(m)           | 220145.4223  | 220136.0937  | 220141.1457  | 220146.3859  |
| Adjusted yo(m)           | 1054958.9838 | 1054950.7310 | 1054953.2322 | 1054957.4581 |
| Adjusted zo(m)           | 235.3817     | 235.3238     | 234.6407     | 234.9954     |

| Table 9: Adjusted Exterior | Orientation | Parameters |
|----------------------------|-------------|------------|
|----------------------------|-------------|------------|

## **Space Intersection**

Transformation from the 3D camera coordinate to 3D object coordinate system was carried out by writing a MatLab code using the space intersection collinearity condition equation given in

NASGL Conference/AGM, Minna 2019:

Page 242

equation 3.3 and 3.4. The formula requires the exterior orientation parameters of the left and right camera stations, and the homogenous points camera coordinates (in millimetres) from two images of the same camera at different positions (left and right), in other to give the 3D object space coordinate of those points.

$$vx_a = b_{14}X_a + b_{15}Z_a - b_{16}Y_a + J$$
(3)

$$vy_a = b_{24}X_a + b_{25}Z_a - b_{26}Y_a + K$$
(4)

The coordinate output from the space intersection process for both Tecno W3 and Infinix X509 data capture are presented in Table 11

### 4.0 Result and Discussion

This involves the presentation of results from the processed data, analysis, and discussion of results.

#### **3D** Object Space Coordinates

The 3D object coordinates obtained from the analysis points (SA1 to SA9) by total station instrument and the two cameras (Tecno W3 and Infinix X509) transformation are presented in Tables 10 and 11 respectively.

| POINT ID | EASTINGS (m) | NORTHINGS (m) | HEIGHT(m) |
|----------|--------------|---------------|-----------|
| P1       | 220180.890   | 1054935.374   | 234.042   |
| P2       | 220180.766   | 1054935.267   | 242.362   |
| P3       | 220163.662   | 1054929.622   | 238.111   |
| P4       | 220148.927   | 1054918.689   | 242.317   |
| P5       | 220149.043   | 1054918.689   | 233.924   |
| SA1      | 220177.570   | 1054934.667   | 240.216   |
| SA2      | 220170.271   | 1054930.394   | 240.255   |
| SA3      | 220168.165   | 1054928.665   | 235.550   |
| SA4      | 220166.562   | 1054927.807   | 236.340   |
| SA5      | 220163.087   | 1054925.937   | 234.236   |

Table 10: Coordinates of points obtained using Total station.

NASGL Conference/AGM, Minna 2019:

Page 243

| SA6 | 220152.406 | 1054920.413 | 235.020 |
|-----|------------|-------------|---------|
| SA7 | 220151.289 | 1054920.381 | 240.330 |
| SA8 | 220175.894 | 1054932.699 | 237.890 |
| SA9 | 220169.424 | 1054929.490 | 237.865 |

Table 11: 3D Object space coordinates of points obtained from Tecno W3 and Infinix X509 capture.

| POINT | EASTINGS   | NORTHINGS   | HEIGHT(m) | EASTINGS   | NORTHINGS    | HEIGHT(m) |
|-------|------------|-------------|-----------|------------|--------------|-----------|
| ID    | (m)        | (m)         |           | (m)        | (m)          |           |
|       |            | Tecno W3    |           |            | Infinix X509 |           |
| SA1   | 220177.452 | 1054934.759 | 240.157   | 220177.716 | 1054934.506  | 240.288   |
| SA2   | 220170.256 | 1054930.551 | 240.240   | 220170.249 | 1054930.323  | 240.302   |
| SA3   | 220168.150 | 1054928.653 | 235.556   | 220168.137 | 1054928.693  | 235.619   |
| SA4   | 220166.552 | 1054927.847 | 236.339   | 220166.630 | 1054927.827  | 236.424   |
| SA5   | 220163.185 | 1054925.898 | 234.290   | 220163.140 | 1054926.061  | 234.416   |
| SA6   | 220152.412 | 1054920.426 | 234.981   | 220152.488 | 1054920.554  | 235.091   |
| SA7   | 220151.301 | 1054920.411 | 240.283   | 220151.398 | 1054920.317  | 240.402   |
| SA8   | 220175.820 | 1054933.009 | 237.867   | 220175.816 | 1054932.790  | 237.974   |
| SA9   | 220169.325 | 1054929.583 | 237.866   | 220169.468 | 1054929.439  | 237.96    |

## **Coordinates Residuals**

The residual coordinates of total station with Tecno W3, Total Station with infinix X509, and Tecno W3 with Infinix X509 are given in Tables 12, 13 and 14 respectively.

NASGL Conference/AGM, Minna 2019:

Page 244

## Table 12: Total Station and Tecno W3 Coordinates with residuals

|       | Total station |               |            |              | Residuals                    |         |                       |        |                       |
|-------|---------------|---------------|------------|--------------|------------------------------|---------|-----------------------|--------|-----------------------|
| Pt ID | Eastings (m)  | Northings (m) | Height (m) | Eastings (m) | (m) Northings (m) Height (m) |         | <b>E</b> ( <b>m</b> ) | N (m)  | <b>H</b> ( <b>m</b> ) |
| SD1   | 220177.570    | 1054934.667   | 240.216    | 220177.452   | 1054934.759                  | 240.157 | 0.118                 | -0.092 | 0.059                 |
| SD2   | 220170.271    | 1054930.394   | 240.255    | 220170.256   | 1054930.551                  | 240.240 | 0.015                 | -0.157 | 0.015                 |
| SD3   | 220168.165    | 1054928.665   | 235.550    | 220168.150   | 1054928.653                  | 235.556 | 0.015                 | 0.012  | -0.006                |
| SD4   | 220166.562    | 1054927.807   | 236.34     | 220166.552   | 1054927.847                  | 236.339 | 0.010                 | -0.040 | 0.001                 |
| SD5   | 220163.087    | 1054925.937   | 234.236    | 220163.185   | 1054925.898                  | 234.290 | -0.098                | 0.039  | -0.054                |
| SD6   | 220152.406    | 1054920.413   | 235.020    | 220152.412   | 1054920.426                  | 234.981 | -0.006                | -0.013 | 0.039                 |
| SD7   | 220151.289    | 1054920.381   | 240.330    | 220151.301   | 1054920.411                  | 240.283 | -0.012                | -0.030 | 0.047                 |
| SD8   | 220175.894    | 1054932.699   | 237.890    | 220175.820   | 1054933.009                  | 237.867 | 0.074                 | -0.310 | 0.023                 |
| SD9   | 220169.424    | 1054929.490   | 237.865    | 220169.325   | 1054929.583                  | 237.866 | 0.099                 | -0.093 | -0.001                |

### Table 13: Total Station and Infinix X509 Coordinates With Residuals

|       | Total station |               |            |              | Residuals     |            |        |        |        |
|-------|---------------|---------------|------------|--------------|---------------|------------|--------|--------|--------|
| Pt ID | Eastings (m)  | Northings (m) | Height (m) | Eastings (m) | Northings (m) | Height (m) | E (m)  | N (m)  | H (m)  |
| SA1   | 220177.570    | 1054934.667   | 240.216    | 220177.716   | 1054934.506   | 240.288    | -0.146 | 0.161  | -0.072 |
| SA2   | 220170.271    | 1054930.394   | 240.255    | 220170.249   | 1054930.323   | 240.302    | 0.022  | 0.071  | -0.047 |
| SA3   | 220168.165    | 1054928.665   | 235.550    | 220168.137   | 1054928.693   | 235.619    | 0.028  | -0.028 | -0.069 |
| SA4   | 220166.562    | 1054927.807   | 236.340    | 220166.630   | 1054927.827   | 236.424    | -0.068 | -0.020 | -0.084 |
| SA5   | 220163.087    | 1054925.937   | 234.236    | 220163.140   | 1054926.061   | 234.416    | -0.053 | -0.124 | -0.180 |
| SA6   | 220152.406    | 1054920.413   | 235.020    | 220152.488   | 1054920.554   | 235.091    | -0.082 | -0.141 | -0.071 |
| SA7   | 220151.289    | 1054920.381   | 240.330    | 220151.398   | 1054920.317   | 240.402    | -0.109 | 0.064  | -0.072 |
| SA8   | 220175.894    | 1054932.699   | 237.890    | 220175.816   | 1054932.790   | 237.974    | 0.078  | -0.091 | -0.084 |
| SA9   | 220169.424    | 1054929.490   | 237.865    | 220169.468   | 1054929.439   | 237.96     | -0.044 | 0.051  | -0.095 |

From the Table 13, it can be observed that the highest residuals are 0.118m (northings), -0.310m, (eastings), and 0.059m (height). With point SA1 having two of its dimensions falling in.

It can also be observed here that SA1 has two of it coordinates dimensions falling within the highest residuals. i.e. 0.146m for the Northings, and 0.161m for the Eastings. Point SA5 has the highest residuals for the height dimension.

NASGL Conference/AGM, Minna 2019:

Page 245

|       | Total station |               |            |              | Infinix X509  |            |                       |        | Residuals |  |  |  |
|-------|---------------|---------------|------------|--------------|---------------|------------|-----------------------|--------|-----------|--|--|--|
| Pt ID | Eastings (m)  | Northings (m) | Height (m) | Eastings (m) | Northings (m) | Height (m) | <b>E</b> ( <b>m</b> ) | N (m)  | H (m)     |  |  |  |
| SA1   | 220177.452    | 1054934.759   | 240.157    | 220177.716   | 1054934.506   | 240.288    | -0.264                | 0.253  | -0.131    |  |  |  |
| SA2   | 220170.256    | 1054930.551   | 240.240    | 220170.249   | 1054930.323   | 240.302    | 0.007                 | 0.228  | -0.062    |  |  |  |
| SA3   | 220168.150    | 1054928.653   | 235.556    | 220168.137   | 1054928.693   | 235.619    | 0.013                 | -0.04  | -0.063    |  |  |  |
| SA4   | 220166.552    | 1054927.847   | 236.339    | 220166.630   | 1054927.827   | 236.424    | -0.078                | 0.02   | -0.085    |  |  |  |
| SA5   | 220163.185    | 1054925.898   | 234.290    | 220163.140   | 1054926.061   | 234.416    | 0.045                 | -0.163 | -0.126    |  |  |  |
| SA6   | 220152.412    | 1054920.426   | 234.981    | 220152.488   | 1054920.554   | 235.091    | -0.076                | -0.128 | -0.11     |  |  |  |
| SA7   | 220151.301    | 1054920.411   | 240.283    | 220151.398   | 1054920.317   | 240.402    | -0.097                | 0.094  | -0.119    |  |  |  |
| SA8   | 220175.82     | 1054933.009   | 237.867    | 220175.816   | 1054932.790   | 237.974    | 0.004                 | 0.219  | -0.107    |  |  |  |
| SA9   | 220169.325    | 1054929.583   | 237.866    | 220169.468   | 1054929.439   | 237.96     | -0.143                | 0.144  | -0.094    |  |  |  |

Table 14: Tecno W3 and Infinix X509 3D Coordinates with Residuals

From Table 14, it can be seen that the highest residuals are -0.264m, 0.253m, and -0.13m for Northing, Easting, and Height coordinate respectively, which are all from SA1 point. It can thus be said that probably, this point (SA1) was not well defined during it pixel coordinate extraction from MatLab environment.

## **Statistical Testing**

### **Student t- Test**

Student t-test statistical test, which checks the significant difference that may exist between the mean of any two independent variables was carried out for Total Station and Tecno W3 coordinates output, and also for Total Station with Infinix X509 coordinate output. These tests results are shown in Tables 15 and 16 respectively.

NASGL Conference/AGM, Minna 2019:

Page 246

Table 15: t-test result of Total station and Tecno W3 Coordinates

|                                  | Levene's | s Test for | t-test for Equality of Means |       |        |         |            |  |
|----------------------------------|----------|------------|------------------------------|-------|--------|---------|------------|--|
|                                  | Equality | of         |                              |       |        |         |            |  |
|                                  | Variance | es         |                              |       |        |         |            |  |
|                                  | F        | sig.       | t                            | df    | Sig 2  | 99      | 9%         |  |
|                                  |          |            |                              |       | tailed | Confi   | dence      |  |
|                                  |          |            |                              |       |        | Interva | l of the   |  |
|                                  |          |            |                              |       |        | Diffe   | Difference |  |
|                                  |          |            |                              |       |        | lower   | upper      |  |
| Northing Equal variances assumed | 0.000    | 0.987      | 0.06                         | 16    | 0.996  | -12.61  | 12.65      |  |
|                                  |          |            |                              |       |        |         |            |  |
| Equal variances not assumed      |          |            | 0.06                         | 16    | 0.996  | -12.61  | 12.65      |  |
| Easting Equal variances assumed  |          | 0.967      | -0.032                       | 16    | 0.974  | -6.909  | 6.757      |  |
|                                  | 0.002    |            |                              |       |        |         |            |  |
| Equal variances not assumed      |          |            | -0.032                       | 15.99 | 0.974  | -6.909  | 6.757      |  |
| Height Equal variances assumed   | 0.001    | 0.975      | 0.012                        | 16    | 0.990  | -3.243  | 3.271      |  |
|                                  |          |            |                              |       |        |         |            |  |
| Equal variances not assumed      |          |            | 0.012                        | 15.99 | 0.990  | -3.244  | 3.271      |  |

From Table 15, the F and sig. columns are the Levene's test for equality of variance which tests the variance significant between the Tecno W3 and Total Station coordinate output. Since all the sig. Values are greater than the significant level chosen (0.01), it can then be said that there is no significant difference between the variance of the two approaches, which thus means that the null hypothesis (that there is no significance difference between the two methods) can be accepted.

Since the null hypothesis has been accepted, the upper values i.e. "equal variance assumed" will be read at the 'test for equality of means' part. t values and df (degree of freedom) was used to obtain the result of mean difference significance. The sig (2 tailed) column, with 0.996, 0.974

| NASGL Conference  | /AGM  | Minna  | 2019  |
|-------------------|-------|--------|-------|
| NASUL COMPLETENCE | /num, | Minina | 2017. |

Page 247

Exploring the Frontiers of Surveying and Geoinformatics for sustainable development. School of Environmental Technology, Federal University of Technology, Minna, Nigeria. February 4<sup>th</sup> – 7<sup>th</sup>, 2019.

and 0.990 thus means that there is also no significant difference between the two means for each coordinate dimensions since the values are greater than the chosen significant level (0.01). Therefore, it can now be concluded that there is no significant difference between the variances and the means of the 3D coordinates of each methods i.e. the Tecno W3 output, and Total station transformation coordinate output.

|                                  | Levene's | Test for | t-test for Equality of Means |       |        |         |          |  |
|----------------------------------|----------|----------|------------------------------|-------|--------|---------|----------|--|
|                                  | Equality | of       |                              |       |        |         |          |  |
|                                  | Variance | s        |                              |       |        |         |          |  |
|                                  | F        | sig.     | t                            | Df    | Sig 2  | 99% Co  | nfidence |  |
|                                  |          | -        |                              |       | tailed | Interva | l of the |  |
|                                  |          |          |                              |       |        | Diffe   | rence    |  |
|                                  |          |          |                              |       |        | Lower   | upper    |  |
| Northing Equal variances assumed | 0.000    | 0.992    | -0.010                       | 16    | 0.992  | -12.68  | 12.60    |  |
|                                  |          |          |                              |       |        |         |          |  |
| Equal variances not assumed      |          |          | -0.010                       | 15.99 | 0.992  | -12.68  | 12.60    |  |
| Easting Equal variances assumed  | 0.001    | 0.975    | -0.003                       | 16    | 0.998  | -6.767  | 6.755    |  |
|                                  |          |          |                              |       |        |         |          |  |
| Equal variances not assumed      |          |          | -0.003                       | 15.99 | 0.998  | -6.767  | 6.755    |  |
| Height Equal variances assumed   | 0.001    | 0.980    | -0.077                       | 16    | 0.940  | -3.344  | 3.172    |  |
|                                  |          |          |                              |       |        |         |          |  |
| Equal variances not assumed      |          |          | -0.077                       | 15.99 | 0.940  | -3.344  | 3.172    |  |

Table 16: t-test result of Total station and Infinix X509 Coordinates

The determination of the variances differences between the Infinix X509 and total station coordinate outcome are shown in the F and sig. column, with sig. values of 0.992 (nothings), 0.975(eastings), and 0.980(height) coordinates. Since all these values are greater than 0.001which is the significant level, it can thus be concluded that there is no significant difference between the coordinates variance of these methods.

The t and df columns determines the 2 tail significant column which gives 0.992, 0.998 and 0.940 for northings, eastings, and height coordinate respectively. It can thus be said that there is no significant difference between the total station and infinix X509 coordinate results, since all the values are greater than the chosen significant level (0.01)

NASGL Conference/AGM, Minna 2019:

Page 248

Therefore, it can be finally concluded that there is no significant difference between the mean and variances of the 3D coordinate of each of these methods at 99% confidence level.

## **5.0** Conclusions

This work which aims at ascertaining the statistical reliability of 3D space intersection for third order accuracy of position determination was achieved by using Collinearity condition equation using the least square adjustment for it iteration process. After all necessary survey measurement, data processing and result analysis has been properly done, it can thus be concluded that the transformation process using collinearity condition equation from 2D pixel coordinate to 3D object space coordinate for a close range Photogrammetry, obtained using android phone camera is as accurate as the use of Total station instrument for data acquisition, for any third order work accuracy, at 99% confidence level. Thus, survey works like: Volume Computation, Reconnaissance, less accurate demanding deformation studies and other survey work within third order job accuracy can be performed effectively using phone camera of at least 5 mega pixel.

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Page 249

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**Odumosu et al:** 3D Position Determination using CRP for 3<sup>rd</sup> order Accuracy Positioning.

NASGL Conference/AGM, Minna 2019:

Page 250