COMPARATIVE ANALYSIS OF UAV PHOTOGRAMMETRY AND TOTAL STATION TRAVERSING ON ROUTE SURVEY

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ABSTRACT

Currently the Unmanned Aerial Vehicle (UAV) have become an alternative for different engineering applications, especially in surveying. One of these applications is in route surveys, but there are questions about its accuracy and efficiency. The purpose of this research was to evaluate how the UAV photogrammetry technology can compete or replace the traditional ground surveying methods of data acquisition for route survey through data obtained with total station. In order to answer the questions of accuracy, data from the same test location were obtained. A comparison was conducted between the two datasets to evaluate the accuracy of the UAV technique and the classical method, compared to a referenced dataset. This referenced data consisted of twenty-three (23) Ground Control Points (GCPs) established with a dual frequency GNSS receiver, and evenly distributed along the 1.1km route. In other to maintain consistency in both methods of data acquisition, the same GCPs used as markers during image processing, were the ones used for orientation during the total station traversing. Results obtained indicated that with Ground Sample Distance (GSD) of 2.74cm, the UAV technology gave a better elevation result, while the classical method was better in the planimetric aspect. Moreover, other parameters were also considered such as execution time and the area covered along the route. The main problems associated with using a UAV was the level of precision and the visualization of the whole area. The results indicated that the precision was quite satisfactory with a maximum elevation error of 1.9 cm on ground control points.

Keywords: UAV, Route Survey, Surveying methods, RTK GNSS.

INTRODUCTION

Route survey is defined as a survey carried out in order to establish the horizontal and vertical alignment of a particular corridor for the development of social infrastructure such as roads, railways, transmission lines, pipelines and canals. The primary aim being to provide information about the nature of the terrain. Route survey is conducted for the planning design, and construction of any route of transportation (Wolf, 2012 and Roy, 2004). Route surveying therefore comprise all survey operations required for design and construction of engineering works such as laying of pipelines, railway construction, road construction, etc. It usually contains four separate but interrelated processes namely: Reconnaissance, Works design, Right of way acquisition and Construction of works (layout of the planed route).

Route surveying has to do with establishing the location of transportation route such as railways, rapid transit canals, pipeline, and transmission lines, etc. Surveying is required for all types of route alignment, planning, design and construction work and it ranges in complexity depending on the size and scope of the project. A route survey supplies the data necessary to determine alignment, grading, and earthwork quantities for the design and construction of various engineering projects such as roads, railroads, pipelines, and various utilities.

Route survey encompasses the principle of terrain representation which would be used by design engineers for construction. This terrain information is determined through a levelling process, which includes profile and cross section levelling along the proposed route. Levelling is the general term applied to any of the various processes by which elevations of points or differences in elevation are determined. Profile levelling is carried out to determine the heights of different points along the proposed route. To provide information about the surrounding terrain, a cross sectional levelling is taken at specific equal intervals perpendicular to the left and right of the centre line that clearly defines the direction of the route at equal intervals perpendicular to the left and right of the centre line that clearly defines the direction of the route.

The are several methods of carrying out Route survey. These include: the ground survey method, photogrammetric method, and remote sensing method. The first two methods were employed for in this study. Ground Surveying methods of data acquisition include the traditional land surveying methods and modern satellite methods of position fixing. The traditional land surveying includes traversing, trigonometrical heighting, chain surveying, etc. Among these methods of survey, traversing appears to be the most popular and widely used method. While aerial photogrammetry is measurements from aerial photographs (W. Schofield et al, 2007). Unmanned Aerial Vehicle (UAV) photogrammetry describes a photogrammetric measurement platform, which operates remotely controlled, semi-autonomously, or autonomously, without a pilot sitting in the vehicle (Eisenbeiss, 2009). The platform is equipped with a photogrammetric measurement system, including, but not limited to a small or medium size still-video or video camera, thermal or infrared camera systems, airborne LiDAR system, or a combination thereof. Current standard UAVs allow the registration and tracking of the position and orientation of the implemented sensors in a local or global coordinate system. Hence, UAV photogrammetry can be understood as a new photogrammetric measurement tool. UAV photogrammetry opens various new applications in the close range domain, combining aerial and terrestrial photogrammetry, but also introduces new (near) real-time application and low-cost alternatives to the classical manned aerial photogrammetry.

UAV platforms are primarily designed as fixed or rotary wings, and the most common launch/take-off methods are, beside the autonomous mode, air-, hand-, car/track-, canister- or bungee cord launched. The cost of a typical UAV platform for Geomatics purposes depends on the on-board instrumentation, payload, flight autonomy, type of platform and degree of automation needed for its specific applications. Low-cost solutions are not usually able to perform autonomous flights, but they always require human assistance in the take-off and landing phases. Low-cost and open-source platforms and toolkits were presented in (Bendea et al., 2008; Grenzdörffer et al., 2008; Meier et al., 2011; Neitzel et al., 2011; Stempfhuber et al., 2011). Simple and hand-launched UAVs which perform flights autonomously using MEMS-based (Micro Electro- Mechanical Systems) or C/A code GPS for the auto-pilot are the most inexpensive systems (Vallet et al., 2011) although stability in case of windy areas might be a problem.

Bigger and stable systems, generally based on an Internal Combustion Engine (ICE), have longer endurance with respect to electric engine UAVs and, thanks to the higher payload, they allow medium format (reflex) camera or LiDAR or SAR instruments on-board (Vierling et al., 2006; Wang et al., 2009; Berni et al, 2009).

In surveying, studies have been conducted on the specifics of the use of UAVs for specific survey applications. However, the studies that have been conducted do yield helpful results for the accuracy and precision required for certain survey works conducted within the field works involved in this dissertation. (Manyoky, et al., 2011) recommended that 'the UAV method with appropriate photogrammetric evaluation methods offers a great potential to gain information from the captured data that are useful for cadastral data'. It concluded that UAV's were capable of meeting similar accuracies to GNSS and tachymetry techniques for survey applications.

The photogrammetric models created from UAV flights can be utilized to create a digital elevation model (DEM). In order for the DEM to be created the photographs need to have geo-located ground control points (GPCs) with 3 dimensional coordinates in order for the model to relate to a real-world application. The result was that the ground resolution on the produced photogrammetric models of field accuracies was between 57 mm/pixel - 338 mm/pixel, by using 12 -19 ground control points on each photogrammetric model tested.

The Route survey operation handles extensive data collection to determine the best location, to prepare plans, specifications, and estimates for construction, and to prepare the legal documents and maps required. Therefore, data obtained during the survey must be precise and accurate to a permissible degree. Different instrument and methods can be employed in executing the survey. However, no matter the instrument or method being employed, the bottom line is the accuracy achieved in ascertaining the elevation of the ground surface along the route. The purpose of this research therefore was to evaluate how the UAV photogrammetry technology can effectively be employed in place of the traditional ground surveying methods of data acquisition using total station. In order to answer the questions of accuracy, data from the same location will be obtained and the results compared.

MATERIAL AND METHOD

Study Area

The study area was an untarred part of Ring Road III off Aka-Nung Udoe Road in Ibesikpo Asutan L.G.A. in Akwa Ibom State, Nigeria. It is located between lat. 4°59'20.84"N, long. 7°56'12.28"E and lat. 4°59'33.66"N, long. 7°57'27.79"E. This location in relation to Nigeria, Akwa Ibom State and the host Local Government Area is shown in Fig. 1.

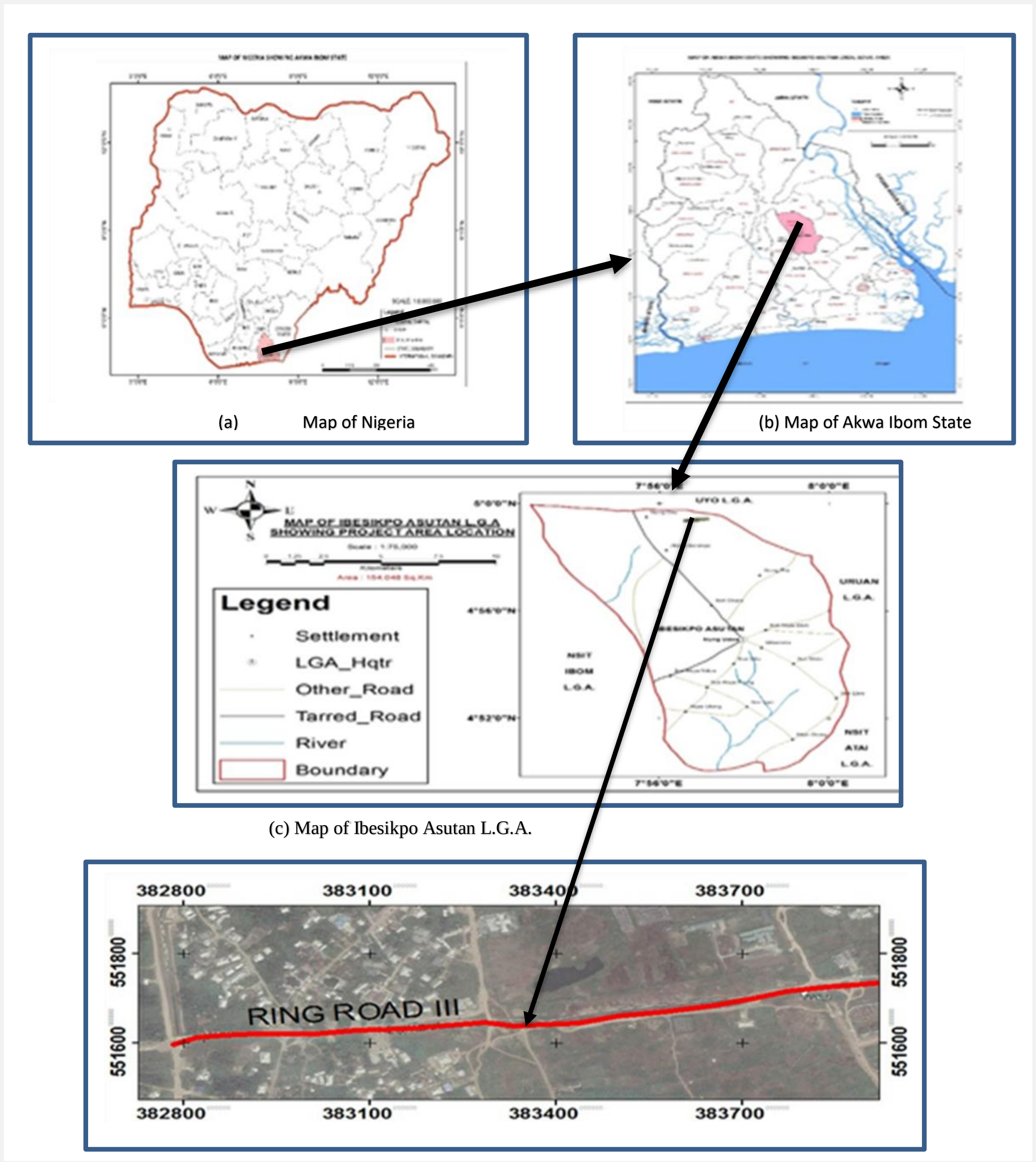

Figure 1: Study Area in relation to Nigeria and Akwa Ibom State

Establishment of Ground Control Points (GCPS)

The ground control points were constructed with PVC ceiling measuring 75cm by 75cm. The centre points were indicated by a black dot bounded by a white circle, which was also surrounded by a larger black square on each pieces of PVC ceilings. They were pre-marked on the project area at an average interval of 50m and coordinated using RTK GNSS rover before the UAV flight and Total Station traversing. The ground control points were needed in order to provide geo-referenced co-ordinates for the production of the photogrammetric model and to serve as change points during ground traversing. This was to maintain consistency in both methods of data acquisitions. The ground markers (targets) were carefully designed and geometrically patterned which allowed for easy identification on photographs and sub pixel accuracy of the centre point location when identifying ground marker positions at the post data collection and pre-processing stage.

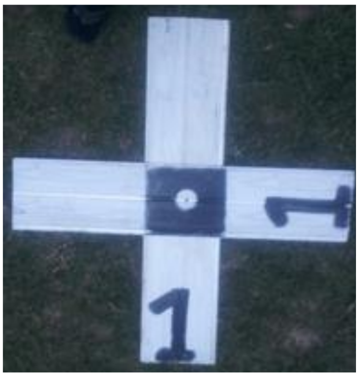

Figure 2: Ground Control Point (GCP no.1, 75cm x 75cm)

Data Acquisition

For this study, two methodologies were employed for data acquisition, first one with a multicopter UAV, and with a Total Station instrument.

Methodology for UAV Photogrammetry

In general, a photogrammetric project involves two stages:

i. Acquisition of imagery and its support data (e.g. ground-control information), and
ii. Processing the imagery to derive image and vector products.

The first stage involves several operations such as project design, mission planning, image acquisition, ground control and quality assurance. The second stage involves the use of a digital photogrammetric workstation (DPW) for processing.

The methodology employed in UAV photogrammetry for this project is summarily given in the figure 3. The input parameters are in grey, while the single workflow steps are in yellow.

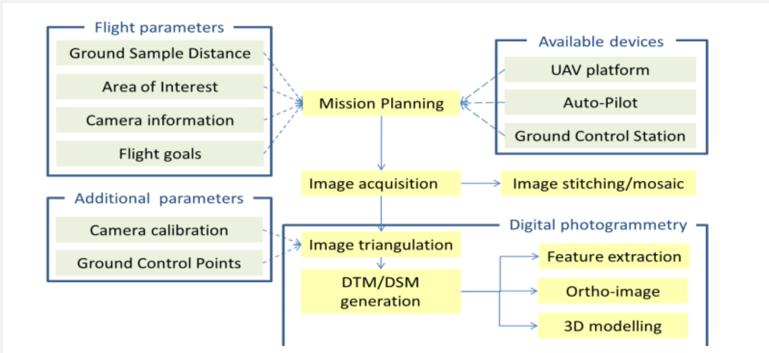

Figure 3: Project methodology with UAV photogrammetry

Mission Planning

The planning of the mission was done in the office before the flight. The area of interest was considered first, then the required Ground Sample Distance (GSD), the intrinsic parameters of the onboard camera (such as the focal length), altitude of flight, percentage of frontal and sidereal overlaps and the speed of the drone. Images were to be taken as normal, which means horizontally, but due to inaccurate stabilization systems it was never achieved and the photos were near normal. The UAV flight planning was not so complicated when it comes to computing the coordinates of the camera perspective centers (waypoints). This was important because in order for the software to be able to perform image matching, it needs to find corresponding points on several photos. Thus, a high overlap was chosen (i.e. 80% side and end) to achieve maximum stereoscopy. This was higher than in traditional aerial photogrammetry (60-30%), because UAVs are more vulnerable to wind gusts and sometimes there could be holes between the stripes. The altitude of flight was mainly dependent on the desired GSD and camera constant. The UAV was flown at 100m above mean terrain (AMT) resulting in a lower GSD of 2.74cm/pixel. After the waypoints were computed, the flight was done in autonomous mode assisted by an onboard computer and GNSS receiver. With camera focal length of 8.8mm and mean flying altitude of 100m, the scale of photography was computed manually to be 1: 11,363.

Pix4Dcapture was used to produce the flight map automatically on a base map uploaded on an android device connected to the remote controller of the UAV on site. However, before the UAV flight, a Google Earth image of the project site was downloaded and employed for physical planning (reconnaissance) on and off the site such as selection of area of interest, planning of establishment/distribution of ground control points, etc.

Image Acquisition

The DJI Phantom 4 Pro was used to record overlapping aerial images of the project area at 100m above the terrain. Using a pre-set flight pattern, the UAV covered the project area in two flights at parallel passes. Continual overlapping pictures that were tagged with their GPS location were captured. The images captured by the UAV and the flight data file were then uploaded to USB from the UAV operators tablet for post processing into a photogrammetric model.

Methodology for Ground Surveying using Total Station

The methodology employed in ground surveying is summarily given in the flowchart in figure 4.

The processes of acquiring field data are as follows:

i. Station Marking and Pegging: Stations were marked along the centre line and the cross section for terrain information acquisition
ii. Traversing: This was carried out on the GCPs to acquire the 3-Dimensional coordinates (x,y,z) of all the points.
iii. Detailing of the artificial and natural features along the route were taken, (such as buildings, access roads, etc.)

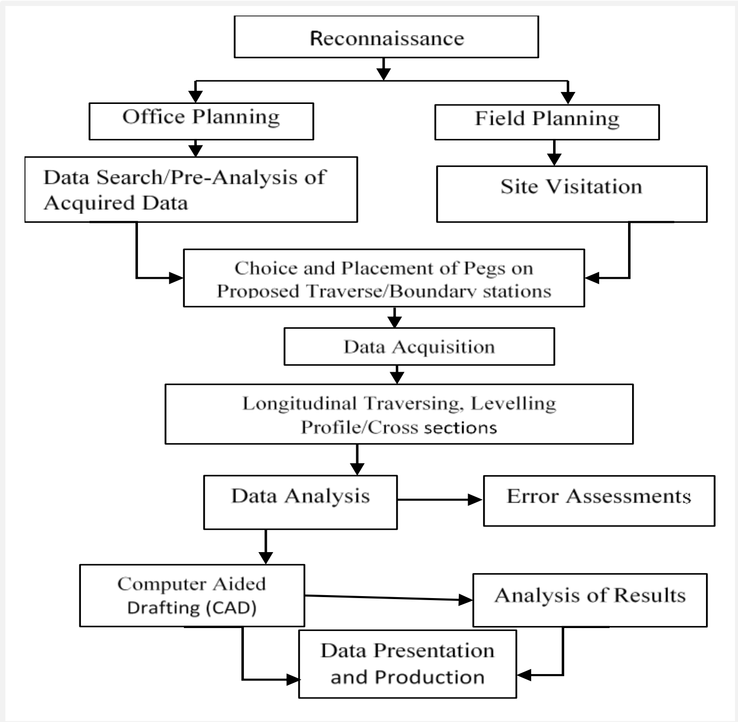

Figure 4: Project Methodology with Ground Surveying

Data Processing

Data processing was carried out in two phases;

i. For the UAV photogrammetric data, and
ii. The ground survey data.

UAV Photogrammetric Data Processing

The general algorithm used for digital photogrammetric processing is as shown in figure 5.

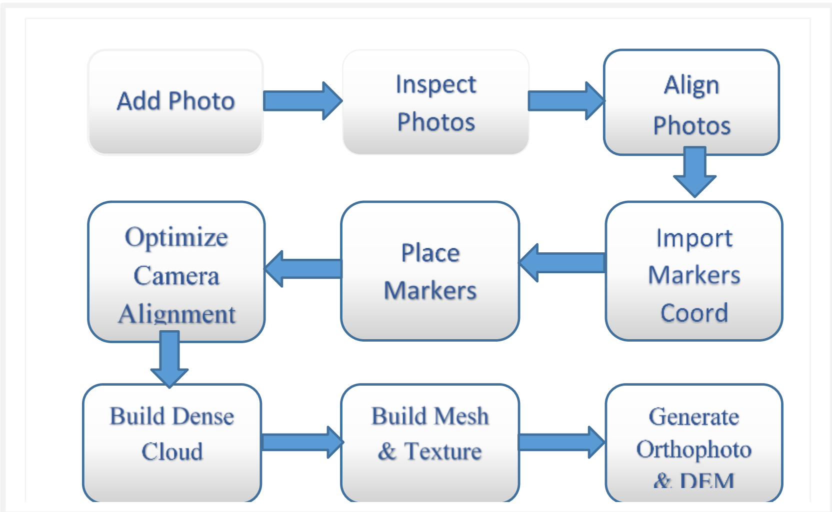

Figure 5: Digital Photogrammetric Workflow for Image Processing

A total of twenty-three ground control points were imported into Photoscan. Eleven were used as control points while ten were used as check points.

Table 1: Control Points Error

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
GCP 1	-0.023997	-0.134465	-0.043030	0.143207	7	0.261
GCP 3	0.017282	0.193007	0.049839	0.200086	8	0.444
GCP 5	0.027761	0.008478	-0.005509	0.029545	7	0.374
GCP 7	-0.018326	-0.057790	-0.005676	0.060891	7	0.262
GCP 9	0.010387	0.076233	0.014127	0.078224	13	0.297
GCP 11	-0.048695	-0.077409	-0.062816	0.110947	15	0.463
GCP 14	-0.027061	-0.056143	0.079272	0.100838	10	0.356
GCP 16	0.161294	-0.004530	-0.032791	0.164656	10	0.329
GCP 18	-0.225455	0.071132	-0.067113	0.242751	11	0.256
GCP 20	0.182445	-0.081528	0.107790	0.227050	10	0.373
GCP 22	-0.069078	0.073486	-0.082405	0.130240	8	0.323
Total Error	0.104488	0.090868	0.150677	0.130240		0.353

On completion of the process, Digital Elevation Model (DEM) and orthormosaic of the route were generated according to the user requirement. The DEM and orthomosaic built in Photoscan were exported to ArcMap for embellishment and finishing as shown in figures 6 and 7.

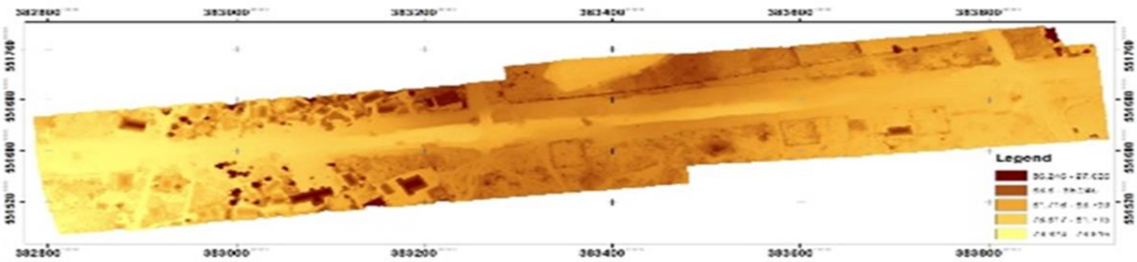

Figure 6: Digital Terrain Model of the Route

Figure 7: Orthomosaic Image of the Route

Total Station Data Processing

The following were undertaken during the processing of the Total Station data.

i. Downloading of the data from the KTS-442R4LC Total Station into the computer and edited in Microsoft Excel. After editing, the data was saved with (csv command delimited, *txt) file extension for plotting with AutoCAD Civil 3D.
ii. The imported data were used to the plot the longitudinal and cross sections of the route in AutoCAD Civil 3D
iii. Plotting of the permanent and artificial features along the route that were within 30m from the centre line were also carried out.

RESULT ANALYSIS AND DISCUSSION

The results of the data analysis are presented using tables and diagrams. A total of twenty-three (23) Ground Control Points (GCPs) were distributed along the 1.1km route. Eleven of these GCPs were used as marker to create 3-dimensional digital photogrammetric models. In order to ensure consistency in both the UAV and TST data, the same GCPs used as markers for image processing were those used as change points for orientation during ground survey. Ten (10) GCPs were used to test and compare the accuracy achieved from both instruments.

Result Analyses

The 3D model from the UAV data was computed with ground sample resolution of 24mm/pixel. This means that the point cloud data was computed at 2.74cm by 2.74cm grids. With conventional UAV GPS systems alone, a survey project can attain a 3-meter (3m) accuracy without the use of GCPs. It will, however, place the survey location in the correct area (relative accuracy), but may be off in any direction of up to 3m in the horizontal (x, y coordinate), and even more in the vertical (z coordinate) of the elevation data. With the use of RTK coordinated GCPs, absolute accuracy is improved to 0.5-2cm in the horizontal (x, y coordinates) and close to 3cm in the vertical (z coordinate). The precision of these points was dependent on the ground sampling distance (GSD) of the aerial imagery. The larger the value of the image GSD, the lower the spatial resolution of the image and subsequent visible details on the image. The GSD was directly correlated to the UAV flight height; the higher the altitude of the flight, the larger the GSD value. However, it was important to note that a number of points obtained using UAV within the project area were much higher, with the most affected areas being the heights in areas where there were tall grasses, plants and buildings. In order words, these features may have affected the UAV three-dimensional surface and measured the heights of such features instead of the actual ground level. This was not a problem in the case of the Total Station traversing as the heights of the actual ground level was capture. Table 2 gives the RTK coordinates of the test GCPs for the comparative analysis and accuracy check for both instruments. For the purpose of which these points were to serve, the GNSS observation time for each station was at an average of five minutes.

Table 2: RTK Coordinates of GCPs for Accuracy Check

Label	Eastings (mE)	Northings (mN)	Height (m)
GCP 2	383750.050	551675.004	82.165
GCP 4	383660.060	551698.586	82.483
GCP 6	383570.710	551688.225	83.356
GCP 8	383482.590	551681.894	84.106
GCP 10	383391.620	551652.304	83.449
GCP 12	383300.370	551642.641	82.564
GCP 15	383159.260	551650.938	82.448
GCP 19	382968.160	551616.749	77.576
GCP 21	382881.810	551572.900	76.069
GCP 23	382788.920	551610.043	75.958

During the ground traversing method, for the purpose of accuracy, more than one observation from different instrument stations were made to a particular test GCPs and the results averaged. On the other hand, after image processing using Agisoft Photoscan, the position of a GCP was zoomed in and the coordinates of the centre point extracted. The coordinates of these GCPs from the both Total Station traversing and the UAV Photogrammetry methods are presented in table 3. While table 4 shows the differences between the RTK coordinates and the two methods (UAV coordinates and Total Station coordinates). Their differences are also shown diagrammatically in figure 8.

Table 3: Results of TST and UAV Coordinates of GCPs

Label	UAV Photogrammetry			Total Station Traversing		
	Eastings (mE)	Northings (mN)	Height (m)	Eastings (mE)	Northings (mN)	Height (m)
GCP 2	383750.226	551675.124	81.974	383750.338	551675.213	82.074
GCP 4	383659.839	551698.558	82.227	383659.989	551698.512	82.123
GCP 6	383570.716	551688.241	83.378	383570.721	551688.23	83.384
GCP 8	383482.499	551681.857	84.428	383482.513	551681.902	84.407
GCP 10	383391.464	551652.412	83.383	383391.488	551652.266	83.384

GCP 12	383301.109	551642.468	82.663	383300.569	551642.573	82.796
GCP 15	383159.213	551650.713	82.384	383159.137	551650.821	82.275
GCP 19	382967.686	551617.416	77.682	382967.911	551617.205	77.618
GCP 21	382881.641	551572.727	75.924	382881.715	551572.809	75.894
GCP 23	382788.954	551609.842	76.129	382789.005	551609.873	76.369

Table 4: Differences in coordinate values from the referenced RTK coordinates

Label	**RTK - UAV**			**RTK - TST**		
	ΔE (m)	**ΔN (m)**	**ΔH (m)**	**ΔE (m)**	**ΔN (m)**	**ΔH (m)**
GCP 2	-0.176	-0.120	0.191	-0.288	-0.209	0.091
GCP 4	0.221	0.028	0.256	0.071	0.074	0.360
GCP 6	-0.006	-0.016	-0.022	-0.011	-0.005	-0.028
GCP 8	0.091	0.037	-0.322	0.077	-0.008	-0.301
GCP 10	0.156	-0.108	0.066	0.132	0.038	0.065
GCP 12	-0.739	0.173	-0.099	-0.199	0.068	-0.232
GCP 15	0.047	0.225	0.064	0.123	0.117	0.173
GCP 19	0.474	-0.667	-0.106	0.249	-0.456	-0.042
GCP 21	0.169	0.173	0.145	0.095	0.091	0.175
GCP 23	-0.034	0.201	-0.171	-0.085	0.17	-0.411
RSME	**0.0176**	**0.249849154**	**0.218755571**	**0.156345771**	**0.177234308**	**0.227717808**
	Horizontal Accuracy	**0.250468326**		**Horizontal Accuracy**	**0.23633874**	
	3DAccuracy (UAV)	**0.302205824**		**3D Accuracy (TST)**	**0.32819415**	

Table 5: Differences between TST and UAV Coordinates

Stations	**TST - UAV**		
	ΔEastings (m)	**ΔNorthings (m)**	**ΔHeight (m)**
GCP 2	-0.112	-0.089	-0.100
GCP 4	-0.150	0.046	0.104
GCP 6	-0.005	0.011	-0.006
GCP 8	-0.014	-0.045	0.021
GCP 10	-0.024	0.146	-0.001
GCP 12	0.540	-0.105	-0.133
GCP 15	0.076	-0.108	0.109
GCP 19	-0.225	0.211	0.064
GCP 21	-0.074	-0.082	0.030
GCP 23	-0.051	-0.031	-0.240

DISCUSSION

From the results above, table 4 gives the difference in coordinate values between the reference RTK, TST and UAV. With reference to the results in table 5, the horizontal accuracy of 0.23633874 from the total station method gives a closer planimetric result compared to 0.250468326 from the UAV. On the other hand, the UAV photogrammetric method provided a better result in elevation, with 3D accuracy of 0.302205824 compared to

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0.32819415 from the TST ground survey method. In the aspect of detailing, the photogrammetric method gives a better description of the details along the route, since the features were captured as they are at the instance of data acquisition.

The amount of details captured was dependent on the number of flight lines along the route. In this research work, there were two flight lines and the amount of details acquired spanned up to ninety-five (95) meters from the centre of the route on both sides. This was much better compared to that of the total station traversing. The amount of details acquired was dependent on the purpose of the route survey, as well as the amount of details that could be coordinated by the survey team (see figure 9.

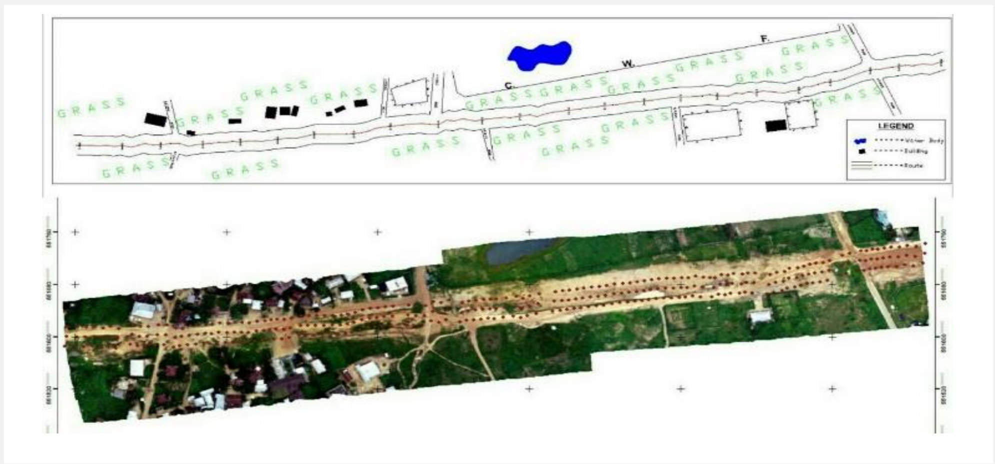

Figure 9: Description of amount of Details Captured by both Methods

CONCLUSION

From the study, the UAV field measurements were acquired in less than thirty minutes, while the ground traversing method took more than twelve hours. This was evident that the UAV photogrammetry technology are more efficient over large areas than the conventional ground surveying techniques. However, apart from an enormous time saving on data collection without an appreciable loss in accuracy, UAV aerial photogrammetry offers far richer data than conventional ground survey technique. Instead it offers the user a bird's eye view of the site without any need for text or any fear of data being omitted. In terms of representing the landscape, the orthophoto can be combined with the DEM to produce very accurate photorealistic 3D modelling in programmes such as Arc Scene and can be analyzed to yield highly accurate earthmoving volumetric calculations.

In addition, UAV based measurements are contactless which allows for highly visual representations of natural or manmade environment. They can be used to obtain information from places which cannot be easily accessible, such as, highways, rocky cliffs, remote locations, etc. As taking measurements does not interfere with traffic of work processes, low altitude photogrammetry can offer elegant control over quarries, landfills, highways or roads.
This study has validated the UAV photogrammetric data acquisition techniques in conducting route survey. The validity of the measurements was tested by comparing them to that acquired by the conventional ground survey technique using a Total Station over the same testing site. It has also demonstrated the usefulness of UAV photogrammetric technology in route surveying in terms of speed in data acquisition, the amount of high resolution data acquired, flexibility in deployment and quality of 3D outputs. The final results from this

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research work shows that the UAV photogrammetric technique for data acquisition can conveniently be used in route survey without any fear of data inadequacy.

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