Assessment Of the Geometric Accuracy (Vertical and Horizontal) Of an Unmanned Aerial Vehicle Data

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Abstract- Today, the world and other professions face more challenges such as climate change, environmental degradation, over population, soil pollution along with the advancement in technology system and software. Roles of Surveyors also change, this does not mean that measurements are no longer relevant but processes, interpretation and management of the data gathered. Photogrammetric mapping and survey technology has evolved both in terms of data collection and processing, especially on data collection techniques using Unmanned Aerial Survey (UAS). Based on the purpose and significance of this research the project cover about Seventy-four hectares (74 hectares) of land having Seven (7) ground control points (GCPs) and Four (4) Checkpoints. The project covers a portion of Federal college of Education (Special) Oyo, after the flight which was flown according to the pre-defined and planned flight, Orthophoto and DTM were generated alongside the quality assessment report of the project after processing. The map accuracy was then assessed and defined in terms of the horizontal (position) and vertical accuracy and they are 3cm (RMSE= 7cm) and 9cm (RMSE= 7cm) respectively. However, it could be concluded that the Orthophoto and DTM generated from UAV can be employed in achieving accurate mapping because it falls within the allowable mapping error limit and RMSE according to the American Society for Photogrammetry and Remote Sensing and National Standard for Spatial Data Accuracy. This paper has been able to look into the geometric quality through geometric accuracy and resolution of its products which makes it fit for compilation of topographical map, cadastral maps, engineering survey maps etc.

Indexed Terms- Accuracy, GCP, Geometric, GPS, Mapping, Orthophoto UAS.

I. INTRODUCTION

The importance of measuring and monitoring the environment is becoming increasingly critical as the population expands, land values appreciate, natural resources dwindle and human activities continues to stress the quality of the land, water, and air, therefore there is need for topographical information system which is an improvement on topographical surveying. Surveying has been important since the beginning of civilization. Its earliest application was in measuring and marking boundaries of property ownership. Throughout the years, its importance has steadily increased with the growing demand for a variety of maps and the expanding need for establishing accurate line and grade to guide construction operations.

Today, the world and other professions faces more challenges such as climate change, environmental degradation, over population, soil pollution along with the advancement in technology system and software’s, by this the profession got its name changed to Geomatics or surveying and geo-informatics. Drastically, it is a reality that not only the name changed but roles of surveyors also change, this does not mean that measurement are no longer relevant but processes, interpretation and management of the data gathered. Photogrammetric mapping survey technology has evolved both in terms of data collection and in data processing; especially on data collection techniques using Unmanned Aerial Survey (UAS), this mapping survey uses UAS-

Photogrammetry method which is equipped with a non-metric digital camera. This UAS-Photogrammetry method is a combination of photogrammetric methods and conventional methods because in some locations there are buildings and tall trees that obstruct the object so it cannot be seen in aerial photographs.

In the past, the survey of accumulated materials was carried out using traditional topographic methods, and more recently via use of Total Stations and GNSS-RTK technology. They allow accurate and fast measures of few significant points selected by the operator, so are cost-effective for measuring simple piles or small sites. In more complex cases, a great amount of points has to be measured to reconstruct the surface and measure the volume of a stockpile, requiring a longer time and higher costs [12].

In Aerial Photogrammetry, Orthophotos, topographic maps and other map deliverables have been produced from the aerial photograph acquired using the large format metric cameras. The cost of acquiring the aerial photograph through the traditional means such as manned aircrafts is relatively high and requires critical planning. Ideally, large format aerial cameras are useful for mapping large area but the use of small format digital cameras has helped to achieve the same capacity [22].

Unmanned Aerial Vehicles (UAV) Refers to an aircraft without an on-board human pilot. UAVs can be remotely controlled aircraft which is flown by a pilot at a ground station or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems. Moreover, UAV is often used in military but now UAV is also used in civil purpose such as mapping, facility management, construction and industrial applications. UAV has low manufacturing and operational cost of the systems, the flexibility of the aircraft to adjust according to user requirements and the elimination of the risk of pilots in difficult missions [7].

The word ‘DRONE’ (Dynamic Remotely Operated Navigation Equipment) has been commonly used to mean UAV. Such act is misleading because high levels of technology were not required in drones’ operation. The existence of drone was dated back to 1800 when the Austrian army used balloons filled with bombs to attack Venice. However, these drones have no advanced piloting controls to predetermine their destination and may as well be destroyed with the missiles in the cases of decoy use unlike UAV which can be controlled to return home pilotedly/manually or autonomously. American Army also used drones in 1900s when they were used for training purposes. By 1930s, there was technological advancement in drone operation when more of UAV emerged during World War II. They were used both to train antiaircraft gunners and to fly attack missions. Nazi Germany produced and used various UAV aircraft during the war ([7]; [8]; [10]; [11]; [1]; [9]; [21]).

High resolution satellite images become more useful and convenient for mapping than using aerial images. Moreover, it has opened a new field of applications and has created a competition to the use of large scale aerial images. Aerial images are important as a source of information for many years ago. According to [7], when using aerial image, the acquisition cost is expensive, require more time in processing data and it is not cost-effective to map a very large area. Therefore, the use of this image is decreasing. The resolution is sufficient for the generation of Orthophoto at a scale 1:8 000 up to 1: 5 000. EROS-A1, IKONOS and Quickbird are the three civilian satellites, which provide images with the highest resolution; the sensors can generate 1m, 2m and 0.6m panchromatic images, respectively. Moreover, pixel size of 0.005mm up to 0.010mm in map scale is required in mapping. It is important for higher requirements of details in larger scale maps. The great resolution of IKONOS is 1m and it is appropriate for map scale of 1: 10 000, whereas 0.61m of Quick Bird appropriate to map scale of 1: 6 000. Geometric potential, scale, information contents and image resolution are very important for mapping. It is important for how many details shall be included in the map based on the area. For urban area, the details will be more compact compared to rural areas [22].

Ground Control Points (GCPs) are points on the ground surface of the earth where the position accurately known or refer to the reference datum and easily identified and related through photo images. GCPs were established using rapid static positioning method. Time taken for observation of each GCPs point is approximately 15 minutes. It is established on permanent object on the ground surface such as street corners, drains edges, wall corners, cross roads and others. This method is used to overlapping between two or more UAV images in order to produce mosaic Orthophoto and topographic map.

II. RESEARCH AIM

Ttraditional method of data management has proved to be difficult in processing. Due to advancement in surveying for carrying out land surveys through the use of unmanned area vehicles, there is need to investigate the geometric quality of an Unmanned Aerial Photograph from Aerial imaging solution for map generation and compilation as compared to the conventional method of data acquisition for map generation and compilation.

III. RESEARCH OBJECTIVES

The following objectives will be pursued for the achievement of the aim as stated below:

a. Reconnaissance survey
b. Field measurements to determine x, y, z of ground control points (GCPs).
c. Aerial image acquisition.
d. Processing and production of all deliverables from the aerial survey
e. Qualitative analysis of acquired data to determine image geometric accuracy.

IV. STUDY AREA

The project site was part of Federal College of Education (SPECIAL), Oyo, Afijio Local Govt. Area Oyo, Oyo State. It lies approximately between Latitude 07˚ 40’ 33’’N to 08˚ 30’ 20’’N and Longitude 03 40’ 51’’E to 04˚ 02’ 40’’E.

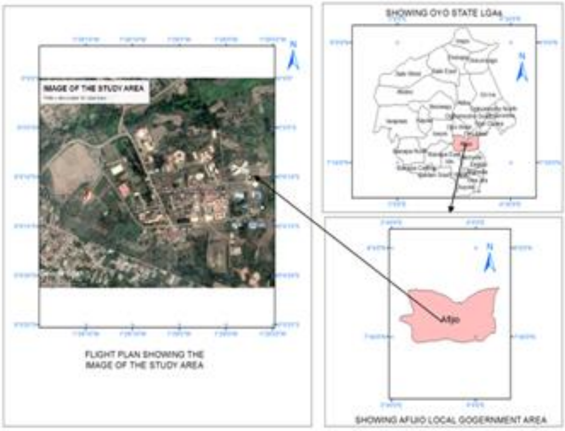


Fig. 1: Location diagram of the Study Area (Not Drawn to Scale)

V. RESEARCH REVIEW

The advent of Photogrammetry using UAV has proved a cost effective and efficient alternative to traditional remote sensing techniques [13]. The technology has been applied successfully for mining [14]. Ecological applications [15] and other constantly were changing environments such as rivers ([26]; [22]; [16]). UAV photography can provide high spatial details needed by scientists [13] and is not constrained by orbital times or flight schedules ([17]). Progress in computer vision and computing power has led to the advancement of UAV Photogrammetry. This includes key advancements such as operational solutions for 3D data acquisition based on Structure-From Motion (SFM) Photogrammetry and multi-view stereo (MVS) ([18]; [19]; [20]).

[18] Studied the straight forward reconstruction of three-dimensional (3D) surfaces and topography with a camera and achieved a general accuracy of centimeter-level precision. [19] Achieved decimeter-scale vertical accuracy. The use of computer vision software is an alternative technique to create 3D models from photographs that evolved considerably in recent years. This alternative is a cost effective and easy to use method compared to expensive laser scanners or rigorous Photogrammetry. The technique also only requires a few control measurements and the processing is automated. Computer vision software integrates state-of-the-art SfM and MVS algorithms to generate/reconstruct very dense and accurate point

clouds from a series of overlapping photographs ([18]; [19]).

UAV Photogrammetry can generate high resolution digital elevation models (DEMs) which are amongst the most important spatial information tools to investigate geomorphology and hydrology [16]. Complex wetland vegetation information at a community scale can be identified [24], delineated and classified ([25]; [17]) through high resolution orthophotos acquired using UAVs.

The importance of UAVs has grown considerably over the last years with rising application thereof in research. The number of Unmanned Aerial Systems (UAS) referenced in the 2013 annual inventory of Unmanned Vehicle Systems (UVS) International [3] indicates a gradual rise in research applications. The study by [13] indicated a considerable increase in the use of UAV imagery for research in the agricultural and the natural environment. The applications of the reviewed articles included five principal fields: precision agriculture and rangeland monitoring, natural disaster management, aquatic ecosystem management, polar remote sensing and wildlife research. However, wetlands present a different challenge to remote sensing application compared to other ecosystems that have received a great deal of attention in the remote sensing community. The interface of wetlands between terrestrial and aquatic environments makes it difficult to examine and understand these ecosystems; the paper assessed the use of UAV Photogrammetry as a tool for accurate mapping of wetland ecosystems. Such a study paves the way for comprehensive studies that ultimately support informed decision making.

The term UAS is frequently used in the Systems Engineering, Computer Science, Robotics and Artificial Intelligence, Photogrammetry and Remote Sensing World. Besides, names like Remotely Piloted Vehicle (RPV) which was first used in 1970, Remotely Operated Aircraft (ROA) or Remotely Piloted Aircraft (RPA) are used by various authors and researchers. UAVs, in contrast to manned aircraft systems have some major advantages. UAVs can be used in high-risk situations without endangering human lives and inaccessible areas, at low altitude and at flight profiles close to the objects where manned systems cannot hover [5]. These locations include natural and artificial disaster sites, e.g. mountainous and volcanic areas, mud slides, oil spillage, flood plains, earthquake and desert areas and scenes of accidents [2]. The implementation of GPS/INS systems as well as the stabilization and navigation units allow precise flights, ensuring, on the one hand, sufficient and adequate image coverage and overlap and on the other hand, enabling the robustness of flight planning process. Based on latest development by Trimble Navigation Company, a Trimble Aerial Imaging solution has been invented called UX5 Aerial Imaging Solution. This system is capable of generating three main survey deliverables namely Orthomosaic (maximum ground sampling distance of 2.4cm), digital terrain/ surface model (raster elevation) and point cloud maps [4] In their attempt has made in this research to investigate geometric quality of an Unmanned Aerial Photograph from Trimble UX5 Aerial imaging solution for map generation and compilation despite the limited number of control points used and the mode of establishment of the control points. Two important criteria are pivotal to Geometric quality assessment of an Aerial photograph; Geometric accuracy and Object-definition property but this research bothers on the geometric accuracy. In remote sensing and photogrammetric operations, the geometric quality of the imagery basically depends on the relation between pixel size and the map scale, contrast information, atmosphere and the sun elevation, the printing technology, screen resolution and the visual acuity. The Unmanned Aircraft System (UAS) deliverables which are the Orthophoto and the digital surface model (DSM) show that UAS (Trimble UX5) can be used for compilation of large-scale maps in partly accessible or inaccessible areas according to the map accuracy analysis of the National Standard for Spatial Data Accuracy [6]. The horizontal accuracy of 3.207m (RMSE: 1.85m) and vertical accuracy of 0.884m (RMSE: 0.45m) were obtained which fall within the allowable misclosure, hence, suitable for Cadastral map compilation.

VI. METHODOLOGY

This refers to the process adopted in the execution of the project. It encompasses the type of job being done, its scope, specification and the required accuracy, the type of instruments used for the execution of the job and the procedure followed, so as to obtain a reliable and accurate result. The procedure in carrying out the project follows a pattern in which one step leads to the other. For the aims and operation of the project to be realized, the operation was planned as listed below;

a. Reconnaissance.
b. Monumentation
c. Mission and Initial Flight Planning
d. Establishment of Ground Control Points
e. Image Acquisition
f. Image Processing

A. *RECONNAISSANCE*

Reconnaissance is an aspect of planning which must be done before any survey operation is carried out. It is very important in surveying since it assists the surveyor to have a good outlook of the area where the work is to be executed or to achieve a good knowledge of the land to be surveyed. The stages of reconnaissance include; Studying the project site, method to be adopted, and equipment to be used and getting necessary information such as the controls needed for orientation etc. Reconnaissance is divided into two aspects namely.

- Office Planning
- Field Reconnaissance

Office Planning

This aspect involves understanding the purpose of the project, the accuracy at which the work is to executed, the equipment to be used, number of personnel needed for the project, the amount to expended on the work, the location of the existing set of controls needed for orientation and also the existing plan of the project area. The table below shows the control station obtained from the SIWES and PRACTICALS UNIT of Federal School of Surveying Oyo with their co-ordinates of each control stations.

Table 1: Coordinates of controls used

PILLAR ID	NORTHINGS (m)	EASTINGS (m)	HEIGHT (m)
FSS2 03 CORS	859831.427	602573.392	274.779

Source: Coordinate Register; SIWES Unit, Federal School of Surveying, Oyo. Oyo state

Field Reconnaissance

This involves the actual visitation to the project site so as to have an overview of the study area and to determine the most suitable and safest way of executing the research. The field reconnaissance was done after the office planning. During the visit, the control pillars planned to be used were located on a printed-out Google satellite imagery, traverse stations which were to form the traverse framework were selected and marked using bottle cork and nails used for marking stations that would connect the site framework to the controls, the Ground Control Points (GCPs) to be used for the Drone were also established.

B. *MONUMENTATION*

Monumentation is a term used in surveying for denoting the process of demarcating boundaries or traverse stations either with the use of beacons, spikes, metals, pegs or such other method as regulation permits. For the project exercise, concrete pillar nailed at the top were used in marking the boundary stations and stout peg covered with PVCs of 80cm by 20cm was used for the GCPs. The pegs were driven into the ground and the station marks defined by the nails at the centre of the PVCs.

Fig. 2 Monumentation used for GCPs

C. *INITIAL FLIGHT PLANNING*

The initial flight planning entailed the use of Google Earth (GE) to execute an initial review and demarcation of the project area which was then saved as (kml) file format. It was also essential to do initial flight planning as the GE imagery does not show dangerous obstructions such as cell towers, power lines or other objects that could impede the flight plan. Part of the reconnaissance includes identifying an open, reasonably central location that can be used as the take-off and landing area as well as obstructions like utility poles, trees and buildings. There were no airspace laws in the study area and this sped up the planning process. On board the UAV was a Sensor

(Calibrated Camera) having a focal length of 4864 x 364mm, forward and side overlaps of 75% and 65% respectively and flown at a height of 100m above the ground. Mission and Flight planning was done with the aid of a software package, called Drone deploy. Flight plans were edited both in the graphical and the tabular sections of the screen. The Mission planning was carried out on drone deploy.

Fig. 3: Flight plan

D. ESTABLISHMENT OF GROUND CONTROL POINTS

Ground controls can be avoided or drastically minimized if the UAV has a dual frequency GNSS on board so that precise camera station coordinates are determined for each photograph but in this case, the GNSS on-board the UAV is of single frequency hence, the Ground control points were pre-marked immediately across the project area before the flight [23]. The GCPs were surveyed using Trimble R8 GNSS.

Trimble R8 differential GNSS receivers were used for the establishment of the GCPs in Rapid Static survey mode with about 15minutes occupation time, 7 GCPs were established to considerably enhance the spatial referencing quality of the Orthophoto though it's not sufficient for rough terrains. The spatial reference system used was Clarke 1880 Minna reference ellipsoid in UTM zone 31N projected coordinate system. GCP coordinates obtained are presented in Table 2.

Table 2: GCPs measured using Trimble R8 GNSS

F_ID	EASTING	NORTHING	HEIGHT
GCP1	602364.658	859302.254	270.187
GCP2	602640.978	859384.053	266.965
GCP3	603086.892	859451.854	272.404
GCP4	603575.095	859262.318	282.563
GCP5	603362.630	859055.110	298.294
GCP6	603511.307	858830.916	293.297
GCP7	602983.654	858787.329	287.356

E. IMAGE ACQUISITION

A single flight was preferably selected according to the plan which covered the study area to alleviate the stress of processing the images in batches. Wind direction, take-off and landing location were defined on the site through the UAV Ground Control Station (GCS) before flight. In preparation for the flight, the UAV, the Radio Connection (RC) transmitter and GCS were connected and the flight mission plan was uploaded to the UAV Autopilot fixed. The UAV was launched after being fully armed and covered the study area in about 30minutes before landing. The flight was ended on the GCS after which the captured data was downloaded.

F. IMAGE PROCESSING

The flight was designed with generous overlaps of 75% (forward) and 65% (side) which produced 602 overlapping image frames amounting to large set of image data of about 45MegaBytes per image frame. Consequently, the processing part of the UAS methodology is the most time-consuming image files and performs a procedure referred to as photo alignment, tie point adjustment, Mesh/Point Cloud creation and Orthophoto production. The processing was done Pix4D Mapper Pro desktop version installed on HP laptop with the following configuration properties; 64GB RAM, Intel® Core™ i7-3110M CPU @ 2.70GHz processor, 64Bits operating system and 500GB hard drive disk. The data was post-processed in UTM 31N projected coordinate system referenced to the Clarke 1880 ellipsoid. The GCPs were used for the adjustment of Tie points (Aero-triangulation) succeeded by the production of Orthophoto, Digital Surface Model (DSM), Digital Terrain Model (DTM) and Orthophoto.

Fig.4: Importing the measured or acquired GCPs/Checkpoints

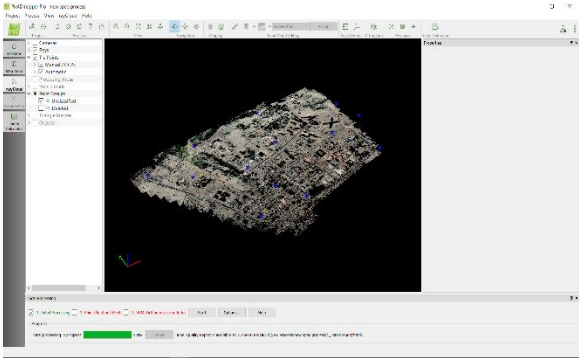


Fig. 5: Result of Initialization (Image alignment)

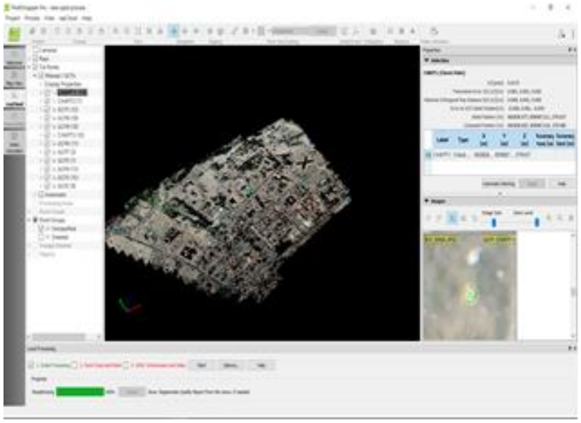
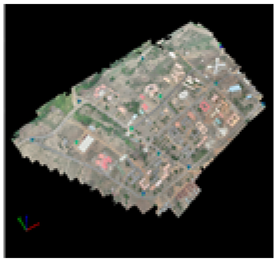


Fig. 6: Adding tie points for Geo-referencing



a

b

Fig.7a & b: Result obtained from processing the mesh viewed at a glance in 3-Dimension

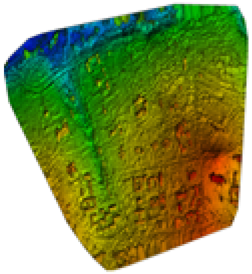
Fig. 8: Orthophoto generated from Pix4D Mapper Pro

VII. RESULTS AND ANALYSIS

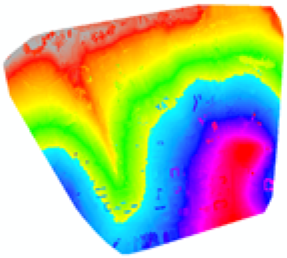
A. RESULTS

The point cloud map was used to generate Digital Surface Model, and after classifications the Digital Terrain model was generated and was later used to generate the E, N and H values of the sampled points in ArcGIS for statistical analysis.

a.



b.



c.

Fig. 9a, b & c: Orthophoto, DSM and the DTM respectively

B. ANALYSIS OF RESULTS

The analysis puts into consideration the positional accuracy of the Orthomosaic map, the linear accuracy by linear measurements on the map related to ground measurement and the spatial resolution of the Orthophoto map obtained. The details of this assessment are presented in subsequent subsections.

Quantitative Analysis

Quantitative analysis deals with assessment of the values obtained using suitable statistical tools. This aspect of the analysis was actualized by computing the root mean square error [3].

$$RMSE = \sqrt{\frac{\Sigma(N_i - N_j)^2}{n}}$$

Where, N_i = Observed values, N_j = Reference values and

n = Number of points or stations

Horizontal Accuracy=1.7308×RMSE$_r$ same for Y

$$RMSE_X = \sqrt{\Sigma\,(X_i - X_j)^2/n}$$

n = the number of Control Points

Vertical Accuracy=1.96×RMSE$_Z$

$$RMSE_Z = \sqrt{\Sigma\,(Z_i - Z_j)^2/n}$$

The Control Points used for this project were the control points within the flight area established for other purposes. In ArcMap 10.5 software, the check point coordinates were obtained from the Orthomosaic (GCPs) and the root mean square error (RMSE) was computed for this analysis. Table 3-5 shows the comparison of Control Points as observed and from the Orthophoto for the horizontal and vertical accuracies according to the National Standard for Spatial Data Accuracy [6] method for evaluating maps accuracies.

Table 3: GNSS Coordinates of GCPs and Check Points

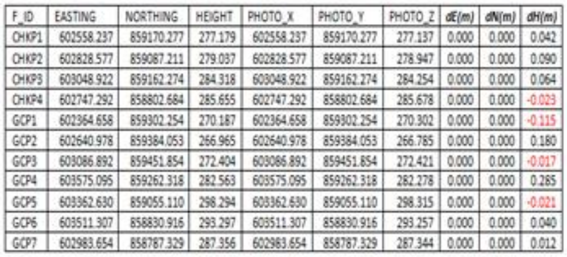
P_ID	EASTING	NORTHING	HEIGHT
CHKP1	602558.237	859170.277	277.179
CHKP2	602828.577	859087.211	279.037
CHKP3	603048.922	859162.274	284.318
CHKP4	602747.292	858802.684	285.655
GCP1	602364.658	859302.254	270.187
GCP2	602640.978	859384.053	266.965
GCP3	603086.892	859451.854	272.404
GCP4	603575.095	859262.318	282.563
GCP5	603362.630	859055.110	298.294
GCP6	603511.307	858830.916	293.297
GCP7	602983.654	858787.329	287.356

Table 4: Orthophoto Coordinates of GCPs and Check Points

F_ID	PHOTO_E	PHOTO_N	PHOTO_H
CHKP1	602558.237	859170.277	277.137
CHKP2	602828.577	859087.211	278.947
CHKP3	603048.922	859162.274	284.254
CHKP4	602747.292	858802.684	285.678
GCP1	602364.658	859302.254	270.302
GCP2	602640.978	859384.053	266.785
GCP3	603086.892	859451.854	272.421
GCP4	603575.095	859262.318	282.278

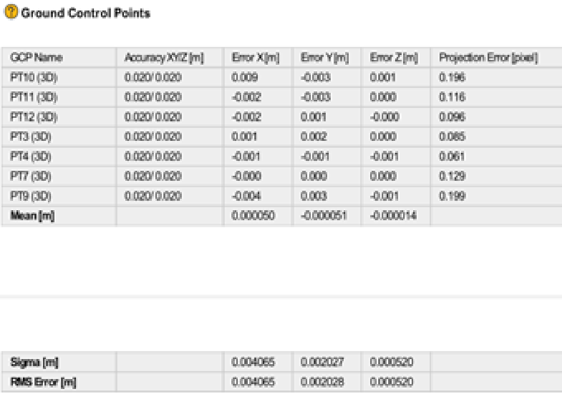
GCP5	603362.630	859055.110	298.315
GCP6	603511.307	858830.916	293.257
GCP7	602983.654	858787.329	287.344

Table 5: Comparing coordinates of Control Points using GPS post-processed and Orthomosaic



F_ID	EASTING	NORTHING	HEIGHT	PHOTO_X	PHOTO_Y	PHOTO_Z	dE(m)	dN(m)	dH(m)
CHKP1	602558.237	859170.277	277.179	602558.237	859170.277	277.137	0.000	0.000	0.042
CHKP2	602828.577	859087.211	279.037	602828.577	859087.211	278.947	0.000	0.000	0.090
CHKP3	603048.922	859162.274	284.318	603048.922	859162.274	284.254	0.000	0.000	0.064
CHKP4	602747.292	858802.684	285.655	602747.292	858802.684	285.678	0.000	0.000	-0.023
GCP1	602364.658	859302.254	270.187	602364.658	859302.254	270.302	0.000	0.000	-0.115
GCP2	602640.978	859384.053	266.965	602640.978	859384.053	266.785	0.000	0.000	0.180
GCP3	603086.892	859451.854	272.404	603086.892	859451.854	272.421	0.000	0.000	-0.017
GCP4	603575.095	859262.318	282.563	603575.095	859262.318	282.278	0.000	0.000	0.285
GCP5	603362.630	859055.110	298.294	603362.630	859055.110	298.315	0.000	0.000	-0.021
GCP6	603511.307	858830.916	293.297	603511.307	858830.916	293.257	0.000	0.000	0.040
GCP7	602983.654	858787.329	287.356	602983.654	858787.329	287.344	0.000	0.000	0.012

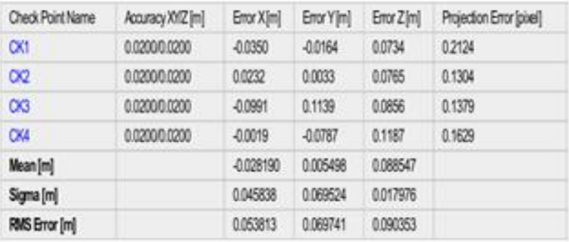
Table 6: Overall result of Georeferencing accuracy (Shown in the Root Mean Square Error)



Ground Control Points

GCP Name	Accuracy XYZ [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]
PT10 (3D)	0.020/ 0.020	0.009	-0.003	0.001	0.196
PT11 (3D)	0.020/ 0.020	-0.002	-0.003	0.000	0.116
PT12 (3D)	0.020/ 0.020	-0.002	0.001	-0.000	0.096
PT3 (3D)	0.020/ 0.020	0.001	0.002	0.000	0.085
PT4 (3D)	0.020/ 0.020	-0.001	-0.001	-0.001	0.061
PT7 (3D)	0.020/ 0.020	-0.000	0.000	0.000	0.129
PT9 (3D)	0.020/ 0.020	-0.004	0.003	-0.001	0.199
Mean [m]		0.000050	-0.000051	-0.000014	
Sigma [m]		0.004065	0.002027	0.000520	
RMS Error [m]		0.004065	0.002028	0.000520	

Table 7: Overall result of Checkpoints after Georeferencing (Shown in the Root Mean Square Error)



Check Point Name	Accuracy XYZ [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]
CK1	0.0200/0.0200	-0.0350	-0.0164	0.0734	0.2124
CK2	0.0200/0.0200	0.0232	0.0033	0.0765	0.1304
CK3	0.0200/0.0200	-0.0991	0.1139	0.0856	0.1379
CK4	0.0200/0.0200	-0.0019	-0.0787	0.1187	0.1629
Mean [m]		-0.028190	0.005498	0.088547	
Sigma [m]		0.045838	0.069524	0.017976	
RMS Error [m]		0.053813	0.069741	0.090353	

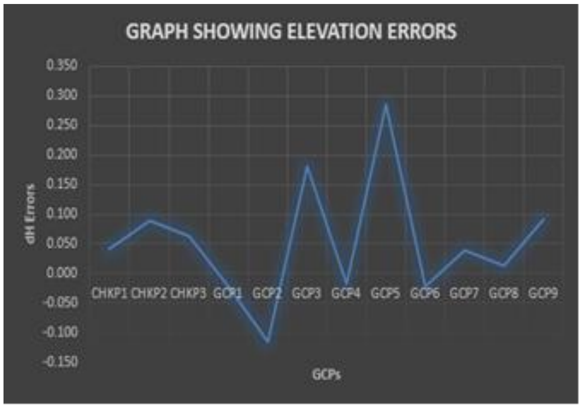


Fig.10: Elevation Errors using a graph

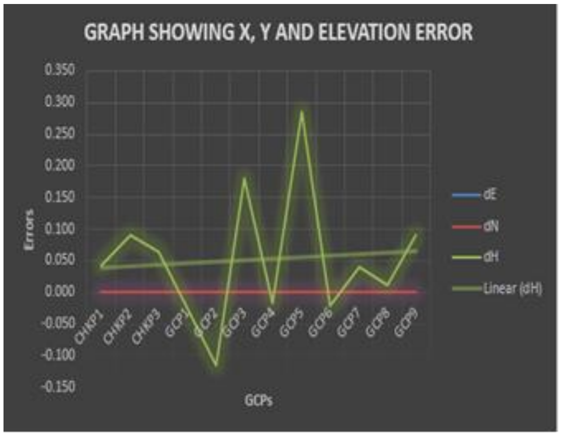


Fig.11: Easting, Northing and Elevation Errors using a graph

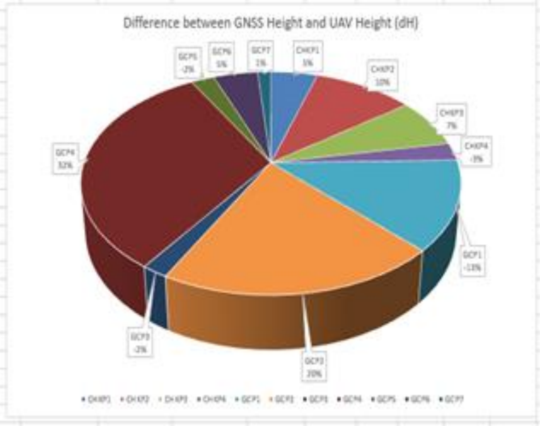


Fig. 12: Pie chart of error analysis

VIII. DISCUSSION OF RESULTS

Table 5 shows that horizontal accuracy of sub-millimeter was achieved in the horizontal position i.e. dE, dN were presented to 0.000meters accuracy while, the level of centimeter accuracy in vertical axis was achieved i.e. dH maximum negative error value of (12cm) at GCP1 and maximum positive error value of (9cm) occurred at CHCKPT2 and this shows that the errors are very much falling within the allowable limit for mapping specifications. The table also showed that the data acquired using the UAV technique has a considerable degree of accuracy in height, and as a result it is adequate for many fit for purpose applications.

For example, the acquired images can provide useful information for different applications such as engineering and environmental modeling and monitoring, and emergency assessment. In particular, the orthophotos can be used for mapping, volume computation, displacement analyses, erosion and flood management, disaster management in oil and gas and incident analysis. The DTM generated from the UAV data acquisition can allow quick multi temporal volume estimations, without the problems of occlusion that can be encountered using terrestrial techniques. The elevation data obtained can be used for cut and fill calculation and development of new structures. For example, the contour plan can be used for engineering design in Federal College of Education, Oyo (Special) to aid the sand filling of swampy areas (Land Reclamation), construction of bridges and the design of a good drainage system. Not only that, the backend database will serve as a tool enabling queries to be performed to help in making informed decision on physical developments that include rapid assessment of changes in land use/land cover and new project sites.

The ground control points were used for validation, the results obtained showed that UAV 3D mapping is applicable for the acquisition of high-resolution data at a low-cost. Accordingly, it can be deduced that this technology can be considered as a fast, safe and cost-effective method of mapping the institution landed properties

This paper has been able to look into the geometric quality through geometric accuracy and resolution of its products which makes it fit for compilation of topographical map, cadastral maps, engineering survey maps and applied in project progress monitoring, civil & heavy earthworks in mining industry, oil & gas, environmental and landfill, agriculture & forestry in the aspects of crop population, forest classification and vegetation health mapping, resource and asset mapping, as-built survey, disaster analysis and close-range Photogrammetry in the area of accident reconstruction.

CONCLUSION AND RECOMMENDATIONS

The analysis above shows that the main objective of finding out the level of geometric accuracy of UAV data was determined both in horizontal and vertical and thus encourage the use of UAV for survey jobs because of the high level of detail captured and good accuracy obtained. The overall RMS Error in both Horizontal and Vertical after georeferencing was 0.002m as against the Geolocation accuracy of the UAV; which is obtainable in 5m, 5m and 10m along the X, Y and Z axis respectively.

Thus, the study recommends further research toward the synergetic factors driving UAV mapping i.e. the use of GCPs, it is recommended to use more numbers of GCPs for jobs and make sure such points are established with minimum of rapid static mode of GNSS observation while flying at lower altitude levels below 100m at low populated areas and low vegetated area for good generation of dense cloud which will then be used to generate DTM in the case of topographic or terrain modeling.

Lastly, to save Surveyors and Geospatial data anlysts the time, energy and excess financial costs in large scale mapping requiring deliveries of products such as Perimeter Survey, Detail Survey, As-Built Survey, Topographic Survey of less vegetated areas etc. UAV should be employed.

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