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Application of UAV Technology in Mapping Part of University of Uyo, Akwa Ibom, Nigeria

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Abstract: ***The products of aerial photogrammetry, such as, topographic map, DTM, etc., are usually acquired from very rigorous processes, expensive equipment, highly skilled personnel, longer period. This paper explores the application of Unmanned Aerial Vehicle (UAV) technology to solve the pitfalls associated with the traditional survey methods to generate improved terrestrial information, such as digital elevation models, orthophoto maps, etc. The UAV PHANTOM-4 equipped with a small format digital camera, Global Positioning System (GPS) and Inertial Navigation System (INS) was used to acquire digital aerial spatial information of part of University of Uyo Main Campus, in Akwa Ibom State, Nigeria. While Hi- Target V30 GNSS RTK System was used to acquire ground control points (GCPs) within the area, and supported with Goggle Earth Imagery. The UAV data was processed with AGISOFT Photoscan Pro Software. The compared results from the generated ortho-rectified imagery with their corresponding RTK acquired ground control points revealed rmse of 0.00603m (6mm) and 0.00290m (3mm) for the planimetric and vertical coordinates respectively. The accuracies of the results further showed that the UAV system was reliable for cadastral surveying, mapping and the process was cost effective.***

Keywords: UAV, Ortho-rectified imagery, Digital Elevation model, Orthophoto Maps

1. Introduction

Photogrammetry as a discipline is greatly influenced by developments in computer science and electronics, and its trend of technology is fast changing. This change is evident in the shift from analogue to analytical and subsequently to digital method.

In aerial photogrammetry, normally the topographic map, DTM, orthophoto and other photogrammetric products are produced from the aerial photograph acquired using a large format aerial or small format aerial camera. Ideally, large format aerial cameras are employed in mapping large area and this is not suitable and economical for mapping smaller area. To overcome this problem, small format digital cameras are used to acquire aerial photograph [1].

The acquired aerial photograph from small format digital cameras are not used only for topographic mapping but could also be used for various applications such as for landslide, map revision, GIS and other applications which do not require high accuracy. The small format digital cameras offer several advantages compared to large format metric cameras, such as, ease of use, handy, economical, digital format of images readily available for without recourse to special aircrafts. The digital cameras could be placed on a balloon, light aircraft, such as, the micro light, and other platforms based on their applications.

Unmanned Aerial Vehicle (UAV) was developed by the United State (US) military for surveillance and reconnaissance purposes back in World War 1 and World War 2 as a prototype form. UAV was widely used in early 20th century between the year 1960s to 1980s. The Unmanned Aerial Vehicle (UAV), is a generic aircraft design to operate with no human pilot onboard [9]. This is also an aircraft which is designed or modified not carry a human pilot and is operated through electronic input initiated by the flight controller or by an on-board autonomous flight management control system that does not require flight controller intervention [11]. The simple term UAV is used commonly in the Geomatics community, but also other terms like Drone, Remotely Piloted Vehicle (RPV), Remotely Operated Aircraft (ROA), Micro Aerial Vehicles (MAV), Unmanned Combat Air Vehicle (UCAV), Small UAV (SUAV), Low Altitude Deep Penetration (LADP) UAV, Low Altitude Long Endurance (LALE) UAV, Medium Altitude Long Endurance (MALE) UAV, Remote Controlled (RC) Helicopter and Model Helicopter are often used, according to their propulsion system, altitude/endurance and the level of automation in the flight execution [9].

The term UAS (Unmanned Aerial System) comprehends the whole system composed by the aerial vehicle/platform (UAV) and the Ground Control Station (GCS). Example of the UAS is the UX5 Aerial Imaging Solution which 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]. The International Civil Aviation Organization (ICAO) classifies UAS into two types under the Circular 328 AN/190: ·

- Autonomous aircraft: These types of aircrafts are currently considered unsuitable for regulation due to legal and liability issues.
- ·Remotely piloted aircraft system(RPAS): These are a set of configurable elements, consisting of a remotely-piloted aircraft, its associated remote pilot stations, the required command and control links and any other system elements required during flight operation. RPAS are subject to civil regulation under ICAO and under the relevant national aviation authority [7].

The benefits of UAV includes and not limited to the following; speed, position and stabilisation and accuracy. So sequential aerial photographs of a site can easily be taken, and used to create 3-D point clouds, contour maps or merged into a 2-D or 3-D orthomosaic image and Digital Terrain Models. It also has the ability to quickly take interchangeable low altitude aerial shots from vertical, horizontal and oblique angles and allows high degree of precision and flexibility which simply cannot be achieved by traditional means alone, or by terrestrial surveying. While technologies such as Lidar can reveal much about the topographical features of a site, they cannot penetrate the soil. Drones can be fitted with various cameras such as Thermal infrared cameras which can reveal the presence of subsurface stone structures due to the differing heat signatures of the soil and stone, as such, reduces the need for preliminary investigative excavation. UAV can be used in mapping of high risk situations e.g. Disaster areas, mountains and volcanic zones, flood, earthquake, war zones and various accidents region etc. with minimum danger to life of the pilot, and to photograph very close objects of very small space [8]. Today, it is available in various shape, size, weight, and applications. UAV has been widely used in monitoring and mapping in many fields, like; forestry-vegetation monitoring [6], road mapping [15], cadastral mapping [5], traffic monitoring [10], landslides monitoring [14]. There are also operating UAV for remote sensing application such as photogrammetric task in recording archaeology site [3], precision agriculture, GPS remote sensing measurement, thermal and hyperspectral sensing, search and rescue, industrial and chemical plant inspection, emergency operation and production of 3D vector map [12], [13].

The study area is a fast growing campus with new engineering structures springing up. But access to up-to-date maps and plans of the campus are still not readily and easily accessible to enhance management's proactive decisions and implementation. Another related problem was the absence of database for storing of digital information, which could be caused by lack of digital spatial data itself, as well as, whether the spatial positions of the infrastructures were in their correct positions according to the designed plan of the campus? Thus, this paper assesses the use of Unmanned Aerial Vehicle (UAV) PHANTOM 4 equipped with a small format digital camera, Global Positioning System (GPS) and Inertial Navigation System (INS) as its data acquisition system to acquire digital aerial spatial information of the area so as to produce topographic map, DTM, and orthophoto of the area, as well as to explore the advantages of the new technology.

2. Study Location

The study area was the University of Uyo Main Campus at Use-Offot, Uyo Local Govt. Area in Akwa Ibom State, Nigeria. The study area was a section of university of Uyo Campus with area of 10.354 Hectares and accessed through Nwaniba Road in Uyo, Akwa Ibom State. It is located within latitudes of 05º 02' 19" N and 05º 02' 33" and longitudes 07º 58'37" E and 07º 58' 49" E. See figures 1(a), (b), (c).

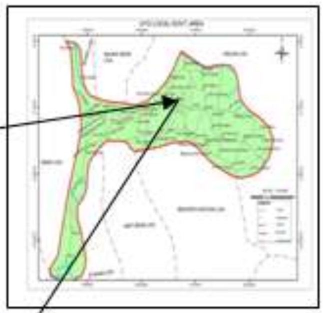


Figure 1(a): Akwa Ibom State Map **Figure 1(b):** Map of Uyo LGA

Figure 1(c): Goggle Earth Imagery of University of Uyo Main Campus

3. Methodology

The workflow for UAV photgrammetric mapping employed in this study is as shown in figure 2.

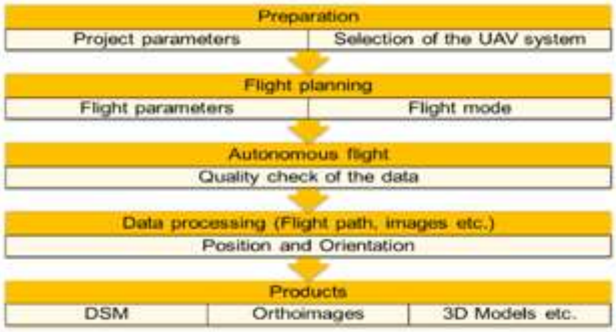


Figure 2: Workflow for UAV Photogrammetric Mapping

3.1 Reconnaissance

The reconnaissance process included among others, gathering all existing survey data about the project area, understand area outlay, planning of flight mission, establishing of targets for ground controls, redefining of the targets point in case of displacement and ensuring their visibilities, equipment selection, determining cost of execution, and to decide on the approach of execution.

This flight mission planning consisted of two items: a flight map which shows where the photographs are to be taken, which include flight lines, their location, their spacing and their orientation. While specifications outline included how to obtain aerial photographs, camera requirements, scale, flying heights, endlap, sidelap, tilt and crab tolerances etc.

The cross grid was employed in order to pick all the required points on the study area.

3.2 Equipment/Software Selection

UAVs have various shapes, sizes, endurance and performance characteristics which have emerged over the past few decades for several civil and scientific applications. The main two types of light-weight UAVs currently commercially available are the multicopters and fixed-wing aircrafts. Multicopters can often carry more payload, resulting in the possibility of installing more advanced sensing systems but their coverage area is limited, due to their relatively low flight speed and high battery drain. UAVs also can be classified according to the ranges they can travel and their endurance in the air using the following sub-classes developed by the US military:

- Very low cost close range UAVs: This class includes UAVs that have a range under 5 km, endurance time of 20 to 45 minutes, Examples of UAVs in this class are the Raven and Dragon Eye. UAVs in this class are very close to model airplanes.
- Close Range UAVs: This class includes UAVs that have a range of 50 km and endurance time of 1 to 6 hours. They are usually used for reconnaissance and surveillance tasks.
- Short range UAVs: This class includes UAVs that have a range of 150 km or longer and endurance times of 8 to 12 hours. Like the close range UAV, they are mainly utilized for reconnaissance and surveillance purposes.
- Mid-range UAVs: The mid-range class includes UAVs that have super high speed and a working radius of 650 km. They are also used for reconnaissance and surveillance purposes in addition to gathering meteorological data.

UAV Phantom 4, equipped with light-weight digital cameras was employed for this study with specification as shown below (see figure 3). On the whole, the equipment and softwares used in this study are as shown in table 1 below.

Figure 3: UAV Phantom 4

UAV Phantom 4-Specification

Aircraft Weight (battery and propellers) 1380 g
Max Ascent Speed 6 m/s (Sport mode)
Max Descent Speed 4 m/s (Sport mode)
Max Speed 20 m/s (Sport mode)
Max Service Ceiling Above Sea Level (6000 m)
Max Flight Time Approx. 28 mins
Operating Temperature 32° to 104° F (0° to 40° C)
GPS Mode GPS / GLONASS

Hover Accuracy

- Vertical: +/- 0.1 m (when Vision Positioning is active) or +/-0.5 m
- Horizontal: +/- 0.3 m (when Vision Positioning is active) or +/-1.5 m
- Diagonal Size (Excluding Propellers): 350 mm
- Obstacle Sensory Range: 2 - 49 feet (0.7 - 15 m)

Operating Environment

- Surface with clear pattern and adequate lighting: (lux> 15)
- Camera Sensor: 1/2.3" (CMOS), Effective pixels:12.4 M
- Lens: FOV 94° 20 mm (35 mm format equivalent) f/2.8

Table 1: Equipment and Software used

S/N	Equipment	Software
1.	UAV DJI Phantom 4 and its accessories	AGISOFT Photoscan
2.	Android phone	PIX 4D CAPTURE
3.	RTK (GNSS) and accessories	Google Earth
4.	Ground Targets	ArcGIS

3.3 Preflight Planning

Ten (10) ground control markers were positioned so that they were equidistantly distributed throughout the site to ensure an even distribution of errors. Flight direction was plotted at 90 degrees to the actual direction so as to maintain a constant ground speed of less than 16m/s during the photographic process. This step helped to reduce ground smear, a phenomenon which blurs the pixels due to the movement of the UAV. For this study, Pix4Dcapture was used to produce the flight map automatically on a base map (figure 4) uploaded on an android device connected to the remote controller of the UAV on site using the procedure given below:

- The project area was defined in KMZ format in Google Earth
- Double grid mission was selected
- An altitude of 50m and default overlap (both end and side laps) of 80% were selected.
- Using the above parameters and a focal length of 3.61mm, a flight map showing flight lines were automatically produced by Pix4D showing the starting and end points.

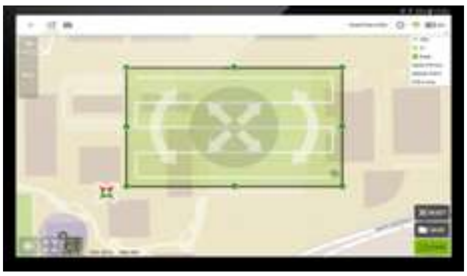


Figure 4: Snapshot of the flight map on an android phone as generated by Pix4D on site.

Figure 5 below is also a Pix4D Capture procedure to obtain flight map by keying in the basic parameters.

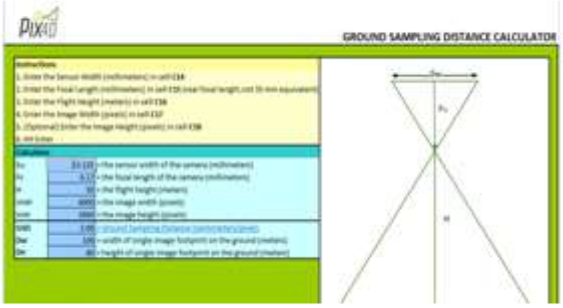


Figure 5: Pix4D Capture Procedure

3.4 Ground Control Points Establishment

With the aid of the Google map imagery of the project site, 56 targets for ground control points were established. A control points were established with photo identifiable features (white cross mark with a black centre point) to aid vision (see figure 6). Thereafter, observations to the ground control points were made using Real Time Kinematic Method with Global Navigation Satellite System (GNSS). Preflight was performed to ensure ground control points were visible on the photographs.

Figure 6: Establishment of Target for Ground Control

3.5 Flight Planning Preparation

The followings steps were taken while preparing for flight.

- Decide whether flight mission would be autonomous or manually implemented.
- The area should be walked, driven around or otherwise evaluated before the mission starts so as to identify obstacles such as power lines, large trees, sensitive areas, or other potential pitfalls.
- Finally, it is good practice to use existing satellite imagery (Google Earth) to plot out a flight plan before take-off.
- Pay attention to weather- good flights between 10 am and 2pm; relatively good scene radiometry.

Thus, Flight route design could now be done automatically especially for UAV photogrammetry;

- Carry out either with mobile apps such as Pix4D Capture and desktop tools such as Mission Planner.
- In each case, hardware (mobile phone, tablet or desktop pc) is attached to the UAV via a USB cable to upload flight plans after preparation.
- UAV mapping missions are usually flown in a specific pattern of parallel lines known as transects connected to a series of waypoints (describing camera position at each point of capture in the air).
- Typically, to create a flight plan, pilot first connects with the UAV flight controller via a USB Link.
- Pilot opens up the software and defines area to be mapped with a polygon, specifies camera model, desired flying height, and how the camera will be triggered to take photographs.

Once the above parameters are entered, the software, then generates transects with waypoints and displays the estimated ground sampling distance, required number of images, and other useful information. The user can then change the distance (airbase) between each photo, the amount that Photos will overlap, the altitude of operation, and other parameters. The software also attempts to compensate for the effects of wind. In summary, the procedural checklist before the commencement of data capture by the UAV is as shown in figure 7. Thereafter, the final mission file can be Saved to the computer or flight controller (UAV).

Figure 7: Procedural Checklist Before UAV Data Capture

3.6 UAV Data Capture

The UAV data was collected using Small format metric digital camera PIX 4D (figure 8). The images were acquired using 80% Endlap and 80% side lap and flying height of about 50m above average terrain, the total area of coverage is about 10.354 hectares. A total of 633 images collected were processed and analyzed using relevant software. The ground control points collected were used simultaneously with the images to produce the necessary photogrammetric product.

Figure 8: UAV Phantom for Deployment for Data Capturing

4. Data Processing

The general algorithm used for digital photogrammetric processing is as shown in figure 9.

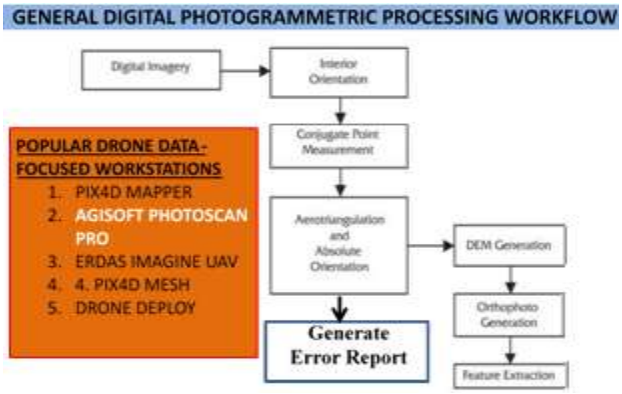


Figure 9: Digital Photogrammetric Workflow

But the steps adopted in this study for the data processing with AGISOFT Photoscan Pro is as shown in figure 10.

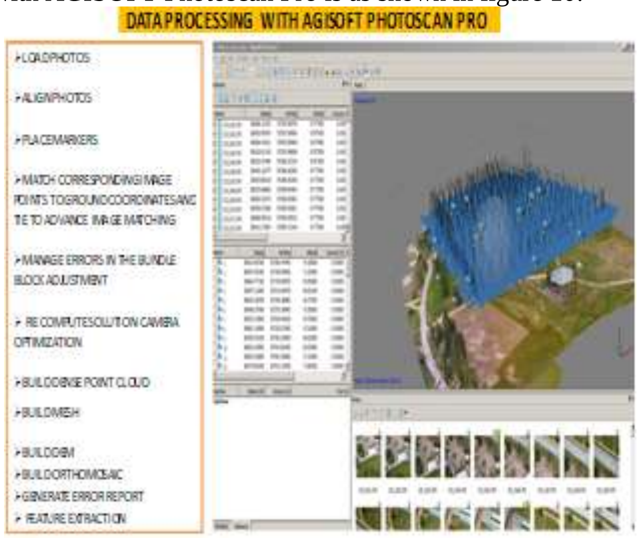


Figure 10: Data processing with AGISOFT Photoscan Pro

5. Analyses of Results

From the outcome of the process above a Dense 3D Point Cloud and Digital Elevation Model (DEM) of part of University of Uyo Permanent Main Campus was produced as shown in figures 11 and 12.

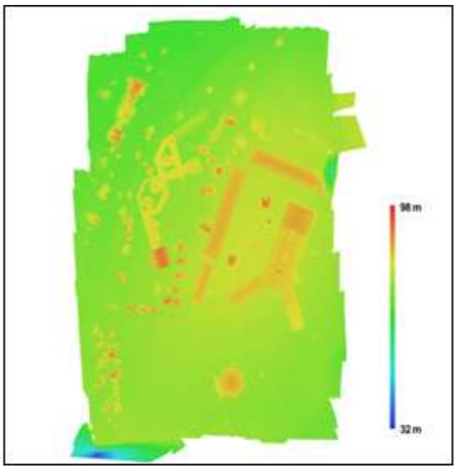


Figure 11: Dense 3D Point Cloud of Part of University of Uyo Permanent Campus
(Notice Ground Control Points with Blue Flag and Distribution)

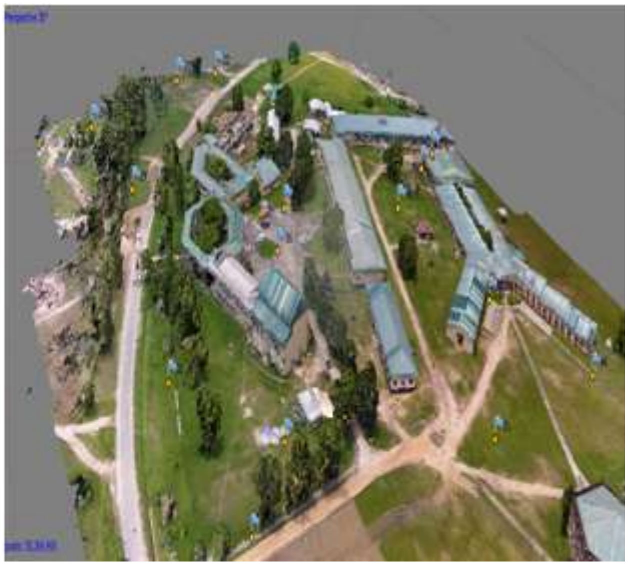


Figure 12: High Resolution Digital Surface/Elevation Model of Same Area Above

Consequently, an orthophoto map of part of the University was produced using ARCGIS (figure 13).

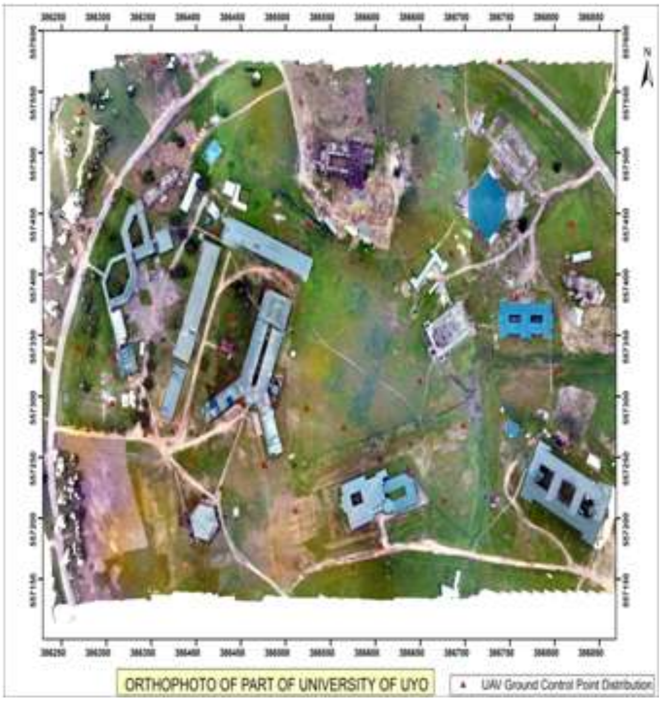
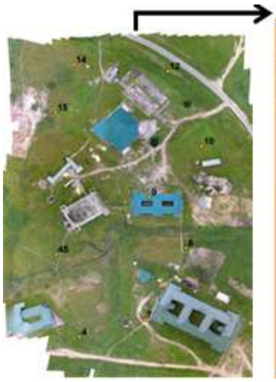


Figure 13: Orthophoto Map of part of the University of Uyo Main Campus

5.1 Analyses of Errors

The error analyses (figure 14) show that difference between ortho-rectified imagery and ground control points coordinates for a section of the university campus was good.



Number of images:	314	Camera stations:	314
Flying altitude:	61.7 m	Tie points:	225,628
Ground resolution:	2.32 cm/pix	Projections:	890,725
Coverage area:	1.26e+05 sq m	Reprojection error:	0.167 pix

Camera Model	Resolution	Focal Length	Pixel Size
FC330 (3.61 mm)	4000 x 3000	3.61 mm	1.56 x 1.56 um

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
12	0.00826893	0.00361539	-0.00901835	0.0127584	2	0.00457279
15	-0.00109612	-0.00141936	-0.00628501	0.00653586	2	0.00273183
4	0.0122987	-0.00673104	-0.0157437	0.0210815	2	0.0237185
45	0.00105341	0.00175752	0.0346066	0.0346672	2	0.00810436
7	-0.0151523	0.00929546	0.0225937	0.0287485	2	0.015521
8	-8.04492e-05	-0.00198542	0.0037977	0.00428613	2	0.0439495
Total	**0.00867509**	**0.00506341**	**0.0186691**	**0.0211998**		**0.0217144**

Figure 14: Error Difference between ortho-rectified imagery and ground control points

From the analyses, the Root Mean Square Error *(RMSE)* for the testing of the planimetric accuracy revealed that:

$$RMSE\ (xy) = \sqrt{(0.00294697 + 0.00599202)}$$

Horizontal (xy) RMSE = 0.0060278021m or 6mm

While the vertical accuracy **(z)** = *0.00289712m or 3mm.*

With the use of 633 images obtained from the UAV and 10 Ground Control Points (GCP), and four (4) of the GCPs which were used to obtain (RMSE) for the analysis shows that the 6mm and 3mm accuracies were within the standard 2cm – 4cm accuracy for horizontal coordinates, and 2cm-6cm for vertical coordinate respectively. These results were quite good and encouraging, thus, showing that UAV technology yielded accurate results and was economical, reliable in mapping topographic features. Similar result was obtained by Reference [4], showed that the map accuracy in terms of the horizontal and vertical accuracy; were 3.207m (RMSE= 1.85m) and 0.884m (RMSE= 0.45m) respectively. Thus, concluded that orthophoto generated from Trimble Aerial Imaging Solution should be employed in order to achieve accurate mapping because it was below the maximum allowable RMSE. Also, "Reference [2]" compared the results of UAV photogrammetry, (Orthomosaic, DEM) with topographic Survey - using RTK GPS Survey to capture natural and man-made surface data including topographic, cadastral, engineering and construction information with horizontal RMSE of 21mm and vertical RMSE 35mm. That the accuracy of RPAS photogrammetry was as accurate as RTK GPS, and was much faster and provides a richer representation of geography.

The tips employed to manage the errors in this study included the followings as shown in figure 16.

- A good ground targets were properly identified on the imagery.
- Good quality capture of Ground Control Points was implemented with RTK GPS.
- Ground coordinates were effectively identified and placed on imagery. Slight shifts or wrong position of ground control point will propagate error in the solution.
- A combination of east-west and north-south cross transect flight pattern was employed for aerial data capture. (Note that this will increase pressure on computing resources but increase overlap coverage helped to manage gaps between images so as to obtain better image correlation for images matching.
- Ground distances between features were measured for comparison and checks with measurements on the imagery after processing

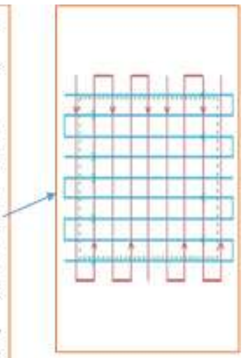


Figure 16: Tips to manage errors

6. Conclusion

Advances in airborne GPS and inertial systems have further reduced the need for aerial triangulation and ground control processes. Similarly, intermediate processes such as film processing, scanning, and photo laboratory operations will also be further eliminated as the digital camera on UAVs are being employed for terrestrial mapping purposes.

The use of UAV has proven to be the better solution to the inherent problems associated with topographic surveys of larger land areas. The cost effectiveness and time of generating a topographic map from UAV is of great advantage, as well as, offering far richer data than conventional survey vector data consisting of points, text and lines. It's versatility, accuracy and ease of usage was also a key factor to be considered. From the results of the error differences between the ortho-rectified imagery and the corresponding ground control points, in terms of the planimetric and vertical accuracies, prove that the application of UAVs technology in surveying and mapping was reliable.

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