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Asbuilt modeling of Nnamdi Azikiwe University, Awka

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Abstract
This project looked to address Nnamdi Azikiwe University's struggle with insufficient office buildings and lack of available as-built maps that show the current state of development within the campus. The aim of the project was achieved by employing aerial photogrammetry to produce as-built maps showing the current developments within the campus. The DJI Phantom 4 drone was used to fly a flight mission plan that was created in 41 paths and uploaded to drone deploy. A total of 2,717 images, with 75% front overlap and 65% side overlap, were taken and collected by the UAV. The accuracy of the derived products from the UAV mapping was examined using a total of 120 GCPs. An orthophoto and Digital Terrain Model (DTM) were produced using a typical photogrammetric workflow. When the results were compared to the first order controls within the school grounds, they showed a closely fitting orthographic image with a correlation value of 0.99. The derived DTM also demonstrated good geometric accuracy, with horizontal and vertical accuracies of 0.22m and 0.43m, respectively, the orthophoto produced by the UAV operations allowed for the creation of an as-built model, which in turn helped determine the size of the campus grounds, the number of buildings, and the amount of space available for development. The campus's total area was 823 hectares, with 70 buildings already built there. Ten more buildings were still under construction at the time of capture, leaving 512 hectares of the campus' total area available for future development.

Keywords: As-built, digital terrain model, drone deploy, photogrammetry, UAV

1. Introduction

As-built models document the precise location and layout of engineering works and record any design changes that may have been incorporated into the construction (Charles *et al*., 2012) [2]. These are particularly important when new facilities are being planned, so that the available locations are accurately known for planning purposes (Anil *et al*., 2011) [1]. As-Built models are important because they depict the current state of development within an area. That means that it will help the university management decide where and how to zone land for development. It will help identify finished and unfinished structures, as well as the percentage of available open spaces for planning and development.

2. Background

The Nnamdi Azikiwe University has struggled with having insufficient office buildings for the university's personnel and classrooms for students. This problem was made worse by the hiring of workers, which led to a temporary solution of turning some classrooms into offices. However, this conversion wasn't sufficient as there were three to four people still occupying each office. In actuality, this did more harm than good because the staff still lacked enough offices, while the students barely had enough classrooms. This prompted the university management to look into identifying open spaces in the campus for development purposes. However, the problem was that the available as-built maps of the school were outdated and does not show the current state of development within the campus.

3. Proposed Method

With the problem outlined, the proposed solution to this, is to employ aerial photogrammetry to produce as-built maps showing the current developments within the campus. For the personnel, there was a team on ground that undertook the task of the UAV flight operations, while the processing was done by me. The method adopted involves the following: (see figure 1 for methodology workflow):

a. Flight planning: this involves the flight parameters, placement of control markers, and picking the coordinates of the control markers.
b. Image Acquisition: the images will be captured during drone flight.
c. Image Processing: this involves image alignment and stitching, dense cloud, DTM/DSM generation and Ortho photo production.
d. As-built Modelling: this involved the production of As-Built model of the campus by feature extraction from the ortho photo.
e. Accuracy Assessment: this involves accuracy Assessment and validation of the derived ortho photo and DTM using first order controls within the campus. The validation is done using correlation coefficient, while the geometric accuracy of the DTM was determined using root mean square error (see equation 1).

$$RMSE = \sqrt{\frac{\sum (Z_i - Z_t)^2}{n}} \tag{1}$$

Where Z_i is the interpolated DEM elevation of a test point and Z_t is the true elevation of a test point and n is the number of test points.

The instruments and Software packages for the project includes

a. DJI Phantom 4 UAV.
b. Differential GPS Dual frequency receiver.
c. Drone Deploy.
d. DJI GO 4.
e. Agisoft Metashape and ArcGIS 10.7.

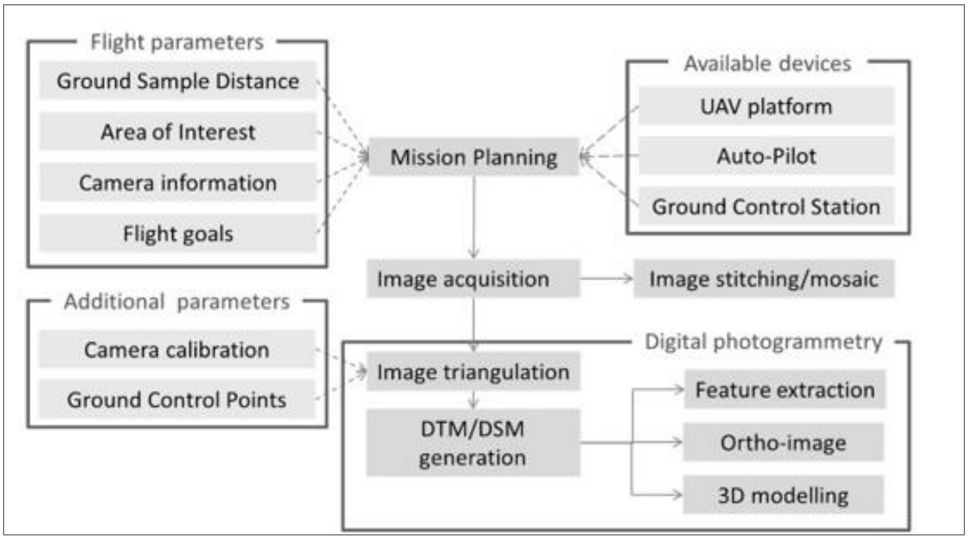


Fig 1: Methodology Flow Diagram

4. Experiments

4.1. Instrument test and calibration of UAV System

Before any instrument will be used in surveying, it is very important to test whether the instrument is in good condition for optimum accuracy. The differential global positioning system (DGPS) and Drone instrument were thoroughly checked and test run before project execution. Also, all the necessary calibrations were carried, options for system status, obstacle detection status, battery level indicator, GPS signal strength, Inertial Measurement Unit (IMU), 3D sensing system status, camera settings, intelligent flight mode, Auto take off/ Landing were all confirmed to be in working order.

Calibration is an important thing to do before flying. The workability of equipment such as UAV's, remote controller & computer (Smart Phone) needs to be checked to avoid crash and system failure due to malfunction. Subsequently, this phase was done carefully to verify that UAV is in good state and ready for take-off.

The DJI Go 4 app was used for calibration in this project. The calibration that was performed was the compass and IMU (Inertial Movement Unit) calibration. During the compass calibration, magnetic objects were ensured to be far away from the drone as it will disturb the accuracy of compass.

The Inertial Measurement Unit (IMU) which included the accelerometer of UAV was calibrated to set up the standard attitude of UAV and reduce errors caused by inaccurate sensor measurements.

4.2. Flight Planning

Flight planning help to achieve flight mission goals, keep track of flying height restrictions, to avoid restricted air spaces and battery life performance. For mapping, it can be very helpful to plan out the number of flight paths or waypoints, area to be flown, number of images taken at certain area, determine the time taken for one complete flight mission and the overlap between the images.

The flight planning was done using ArcGIS by dividing the flight area into 41 flights (see figure 2 for details). with each flight area covering a total area of 20 hectares at a flying height of 150 m, with front overlap of 75% and side overlap of 65%. After which the flight areas were converted to kml and uploaded to Drone Deploy application from which each flight area was flown autonomously.

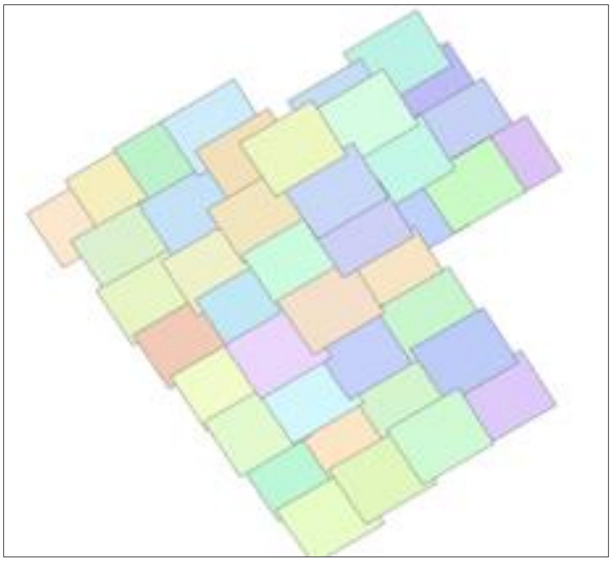


Fig 2: Flight area division

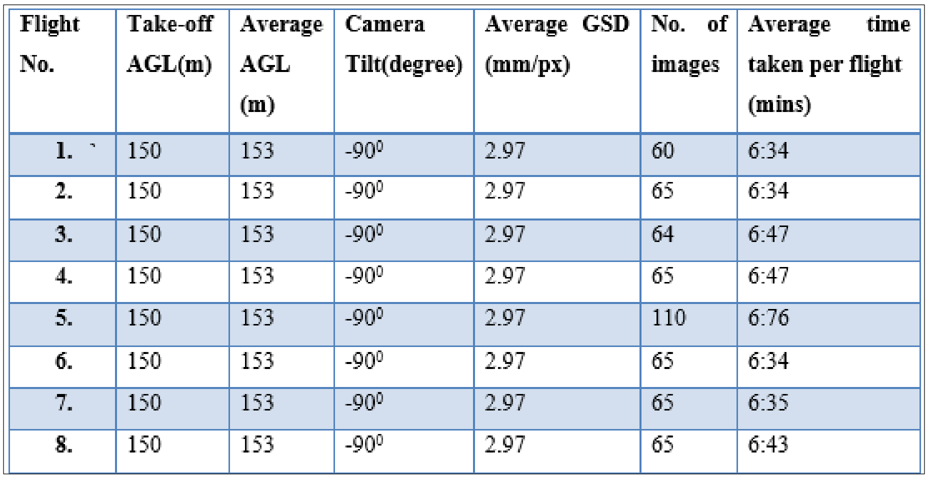
All flights were performed with DJI Phantom 4 featuring a gimbaled 1-inch 20-megapixel CMOS sensor with a mechanical shutter. The focal length of the lens was 24 mm (full-frame equivalent). The data were stored in 24-bit JPG format, and the pixel size was 2.41 µm. The camera sensitivity was set to ISO100 for all images, with the aperture ranging from 4 to 5.6 and the shutter times ranging between 1/120 and 1/500s. All images were geo-referenced with the on-board GPS. The WGS84 coordinates were stored in JPG EXIF.

5. Results and Analysis

5.1. Image Processing

The UAV flight produced approximately 2717 images with 150-meter altitude at a resolution of 6.37cm/pix, (see table 1, for flight characteristics). The Images retrieved by each flight were processed using Agisoft Metashape to derive a 3D model of the study area.

Table 1: Sample of flight characteristics



Flight No.	Take-off AGL(m)	Average AGL (m)	Camera Tilt(degree)	Average GSD (mm/px)	No. of images	Average time taken per flight (mins)
1.	150	153	-90^0	2.97	60	6:34
2.	150	153	-90^0	2.97	65	6:34
3.	150	153	-90^0	2.97	64	6:47
4.	150	153	-90^0	2.97	65	6:47
5.	150	153	-90^0	2.97	110	6:76
6.	150	153	-90^0	2.97	65	6:34
7.	150	153	-90^0	2.97	65	6:35
8.	150	153	-90^0	2.97	65	6:43

The same workflow was repeated each time while keeping the software settings constant, and following a sequence of commands as follows:

1. Photo alignment with high accuracy.
2. Optimizing alignment
3. Dense cloud building with high quality aggressive depth filtering
4. Mesh building using a dense cloud
5. Texture building with the default blending mode
6. Tiled model building.
7. DSM building using the default settings and,
8. Orthomosaic generation.

First order GCPs were adopted as check points to validate the results. Elaboration without the GCPs allowed us to better understand the role of the flight mode and the combination of different flights on the resulting DSM. This was completed by exploring the accuracies of DSMs obtained using imagery extracted from the combination of the flights.

The resulting combinations displayed wide variability in the precision of planar coordinates and elevation. This preliminary analysis allowed the identification of the best performing flight configuration and the benefits due to the use of combined flights.

To increase the quality of the 3D model, GCPs were included in the Bundle Block Adjustment (BBA). The number and distribution of GCPs per unit area were between 4 and 5. The analysis shows that the number of GCPs necessary for the flight is influenced by the extent of the study area, its morphology, camera deployed, and internal GPS precision.

The previously identified imagery datasets were analysed in order to explore the role played by GCP density and distribution. A variable number of GCPs ranging from 5 to 10 were randomly selected from the 120 control points available, while the remaining GCPs were employed as check points.

This analysis was useful for understanding the mutual benefit of flight combinations and well-designed GCP distribution. Proper use of the two settings enhances the potential of SfM-MVS algorithms in providing good quality DSMs. The comparison between single and multiple flights combined with the use of GCPs was stimulated by the need to better understand the benefits of combining multiple flights. See figures 3 and 4 for the derived products from the UAV operation.

Fig 3: Orthophoto Generated

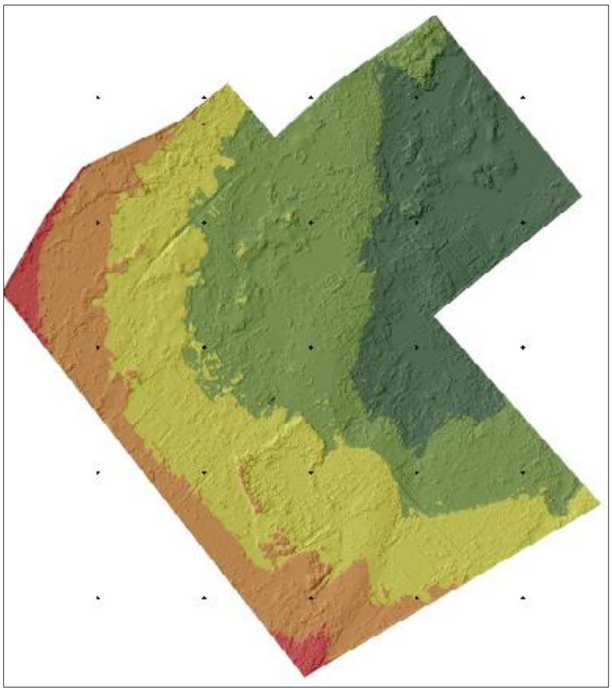


Fig 4: DTM generated

5.2. As-Built Modelling and Accuracy Assessment

As-built modelling of any property is a very important operation for the planning of developments within any property. The ortho photo generated from the UAV operations enabled an as-built model to be created (see figure 5), which in turn helped determine the area of the campus premises, the total number of buildings and available spaces for development.

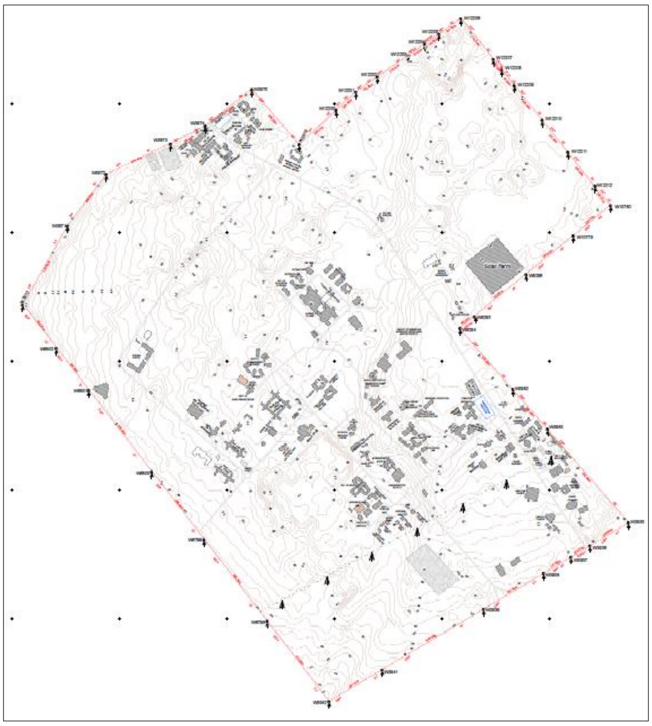


Fig 5: As-Built Model generated

The area of the school premises stood at 823 hectares, and a total number of 70 buildings stood developed within the campus, 10 buildings were still under construction at the time of capture that left a total area of 512 hectares still open for development within the school premises.

Validation of the generated orthophoto was performed by comparing the coordinates of the first order controls established within the school premises with the coordinates of the first order controls as located on the ortho photo. The comparison was done using correlation coefficient (see figure 6).

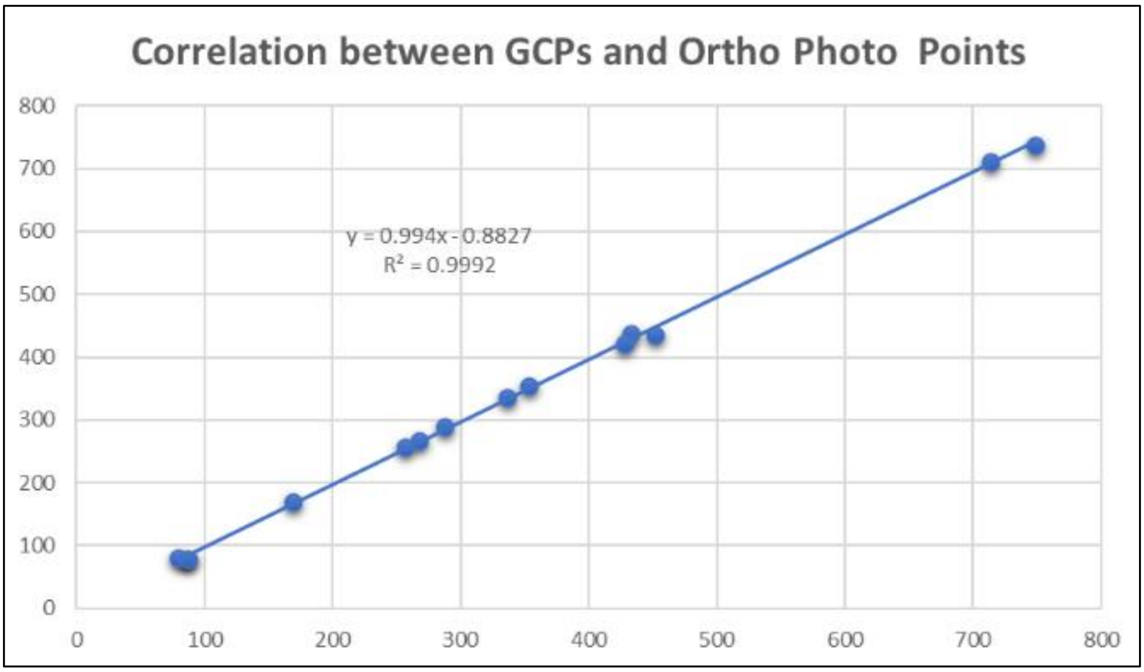


Fig 6: Correlation graph between GCPs and Ortho Photo points

From figure 6, the correlation results gave a value of 0.99 which indicates a strong positive relationship between the ground control points and the points from the ortho photo. This means that the ortho photo is a good fit and represents closely the terrain within the campus premises.

The geometric accuracy (horizontal and vertical) of the created digital terrain model from the UAV operations was determined using RMSE. To quantify the horizontal accuracy of a DEM, a linear accuracy test can be performed along a well-defined topographic feature (Gameth, 2010) [3]. To quantify the horizontal and vertical accuracy of of the generated DTM, a horizontal ridgeline accuracy assessment was used. According to Gameth, (2010) [3], when using this technique, it is important to use terrain with relief significant enough to accurately digitize ridgelines and allow for adequate detail in the test DEM delineations. The horizontal and vertical accuracies obtained were 0.22 m and 0.43 m respectively, hence the derived DTM was deemed to be accurate.

6. Conclusions

The flight path planning was developed in 41 paths using Drone Deploy software. Then, it was uploaded into the UAV in order to design path mapping. After that, all visual images from UAV during flight from different flight path were collected. All the images went through the process of scaling and levelling which also made reference to orientations such as interior, relative and exterior orientation.

It is shown that the UAV, together with the digital camera, is capable of successfully acquiring aerial photograph in a short period of time for large-scale mapping. This research study shows that UAV is also able to generate mapping of inaccessible areas. To optimize the quality of UAV image processing, different methods of camera calibration could be applied. UAV should use constant flying height to achieve better results for precise 3D model.

The examples reported in the project shows the current state-of-the-art of photogrammetric UAV technology especially in as-built modelling. Although automation is not always demanded, the reported achievements demonstrate the high level of autonomous photogrammetric processing. UAVs have recently received a lot of attention, since they are fairly inexpensive platforms, with navigation/control devices and recording sensors for quick digital data production. The great advantage of actual UAV systems is the ability to quickly deliver high temporal and spatial resolution information and to allow a rapid response in a number of critical situations where immediate access to 3D geo-information is crucial. Indeed, they feature real-time capability for fast data acquisition, transmission and, possibly, processing.

7. References

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