3D Model By Using Oblique Images From Unmanned Aerial Vehicle (UAV)

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***Abstract*— In recent years, 3D modelling had been a major outcome for obtaining a high-level detail structure of facade and building. The role of Unmanned Aerial Vehicle (UAV) as platform had been widely used as its accessibility to the location and geometry aspects such as terrain, mount and higher building. This paper aims to obtain highly-level-detail 3D model of building acquire from oblique images of UAV. Several parameters should be considered such as flight planning, minimum time to cover whole building, inclination of camera and ground control points to achieve complete information of the building. Oblique images acquire by a very close circular flight to the building. Some nadir images will be used for further tie and strengthen block. The images obtained were processed using Agisoft Photoscan Professional. Several steps were taken for image processing such as calibration, extraction, point cloud generation and orientation. The UAV data was validated with check points observed from GPS to obtain Root Mean Square (RMSE) values. RMSE value for planimetric accuracy is ±0.026m, ±0.034m and ±0.018m for X, Y and Z respectively. The average RMSE values obtained is ±0.037m. In conclusion, the value achieved centimetre accuracy and show that the use of UAV and processing software as an effective tool for surveying, reduce cost, acquisition of data more rapid and need for high level detail.**

Keywords—Oblique Images, UAV, 3D Model

I. INTRODUCTION

UAV had been widely used due to their flexibility of use and low cost compared to traditional photogrammetric flights using expensive metric digital cameras or LiDAR sensors. According to [1], Building of 3D model by using airborne oblique images due to arisen interest of scientific community and software developers made the technique evident. In the year of 2008-2009, photogrammetric processing of oblique images with addition to nadir images were already experimented using airborne imagery. However, according to [2], common software tools with integration of computer vision algo-rithms has increased the method potentialities. A 3D model has height, width and depth which is similar to any object in the real world [3].

According to UVS international definition, UAV can be defined as generic aircraft design that operate with no human pilot onboard. The term UAV is used commonly in geomatic community but also terms like Remotely Piloted Vehicle, Remotely Operated Aircraft (ROA), Remotely Controlled (RC) Helicopter, Unmanned Vehicle System (UVS) and Model Helicopter. In the past, UAV development have been used for military purpose such as surveillance, inspection, reconnaissance and inimical areas. In geomatic application, the first pioneer which have been carry out UAV photogrammetry were done by Przybilla [4]. According to [5] and [6], UAV photogrammetry has introduced a low cost alternative to the classical manned aerial photogrammetry indeed opens various, new application in the close-range aerial domain. Modern UAV operate autonomously using GPS-driven autopilot and also an IMU sensor attached to the UAV for stability. UAV can be divided into two which is multi-rotor and fixed wing [13].

Furthermore, this method can collect the data without touching the site at all. It also permits to reach little accessible parts of the buildings (such as the higher parts, which are difficult to be recorded by means of other techniques, e.g. Terrestrial Laser Scanner, TLS). A UAV can access to narrow spaces and flight closer to the object [7]. Performing aerial photogrammetry with oblique images employ some low-cost instruments, compared to the traditionally employed ones [8]. The acquisition is performed in a little of time which make the technique suitable when it is necessary to repeat the survey many times.

Some previous researches experimented the 3D model reconstruction of a unique historical building for documentation aims from UAV [9]. In the present contribution, however, a higher number of images are used and a closer acquisition is performed, in order to reach the maximum possible detail of the building.

This study focus to obtain highly-level-detail 3D model of building from oblique images of UAV and demonstrate the use of UAV as an effective tool for surveying. Survey from UAV can use many methodology, proposed in last years. However, the traditional nadir images acquisition only are not sufficient to produce highly-level detail of 3D model as façade and vertical element surfaces were usually not modelled. Hence, with use of nadir and oblique images, complete and accurate 3D model may achieved. The results can be evaluated in terms of accuracy, completeness of the data and data density, using as ground truth a model generated by a very spread proprietary software, and a TLS point cloud for comparing the results on some façades.

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A. Highlighted of Study

The use of UAV had been increased rapidly due to the low-cost market value and acquisition of data more rapid. It also equipped with SLR (single lens reflex) and GNSS/INS system for positioning the UAV and its sensors.

UAV survey provided nadir images, which mean the images were shot in vertical direction. This type of survey was not appropriate for 3D modelling of town and cities as the model was not complete. In order to improve 3D model, integration of TLS data and nadir images have been introduced to have more completed and accurate 3D model. However, the integration required longer time and costly for staff and equipment.

In order to overcome this, there was more easy and effective way to produce 3D model without using TLS data. The procedure was by combining nadir UAV images and oblique images, that was, shot with the camera axis at an angle with respect to vertical, commonly use is 45°. The result show effectiveness in 3D model with better inclusion of façade and footprint of the buildings.

Oblique images have become an arisen interest in photogrammetry due to the capability to capture both footprints and façade of the target compared to traditional photogrammetry which enables to identify and interpret of some hard-to-see facilities from unique perspective view according to [10]. Several applications which have been verified for using oblique imaging system such as generating virtual images of city areas [10], mapping textures of 3D city model [12, 15] and verifying building [13, 16].

This study has been carried out by using UAV Photogrammetric method. Fig. 1 shows the study area which was located at T05, Faculty Science and Table 1 shows information of study area.

Fig. 1. Study Area

TABLE 1. Information of study area

No.	Information	Specification
1	Length	150 m
2	Width	165 m
3	Perimeter	630 m
4	Area	24,000 sq m

II. METHODOLOGY

In order to produce 3D model, a quadrotor which known as DJI Phantom 4 Pro (Fig. 2) is used based on specification as stated in Table 2 and Table 3 showed the flight planning information.

Fig. 2. DJI Phantom 4 Pro

TABLE II. Specification of DJI Phantom 4 Pro

No.	Items	Specification
1	Flight time (minute)	30
2	Weight (kg)	1.388
3	Battery capacity (mAh)	5870
4	Electronic shutter speed (s)	8-1/8000
5	Camera pixels (M)	20
6	ISO range (Photo)	100 – 3200
7	Operating temperature	0° to 40° C
8	Stabilization	3-axis

TABLE 3. Flight Planning Information

No.	Information	Specification
1	Number of images	307
2	Flying altitude	90.9 m
3	Ground resolution	2.25 cm
4	Coverage area	1.26e+05 sq m
5	Side lap	80 %
6	End lap	60 %

A. Flight Map

On ground control station, a software which is known as DJI Go Apps been used for flight planning. Users need to justify parameters such as end lap, side lap and waypoint. Flight map have been produced on the screen and hence, users can monitor the UAV from the ground. Flight Map produced as in Fig. 3, Fig. 4, Fig. 5 and Fig. 6. Camera calibration have been carried out before data acquisition. The parameters were used for register during interior orientation as shown in Table 4.

TABLE 4. Camera Calibration Parameter

No.	Parameter		Result
1	f (mm)	Focal length	8.8
2	f_x	Focal length in pixel	3668.47 pixel
3	f_y	Focal length in pixel	3668.47 pixel
4	c_x	Principal point	2752.19
5	c_y	Principal point	1824.12
6	skew	Skew coefficient	0.000
7	K_1	Radial distortion	0.000449353
8	K_2	Radial distortion	-0.0078063
9	K_3	Radial distortion	0.00885647
10	K_4	Radial distortion	0.000
11	P_1	Tangential distortion	-0.000334109
12	P_2	Tangential distortion	0.000625887

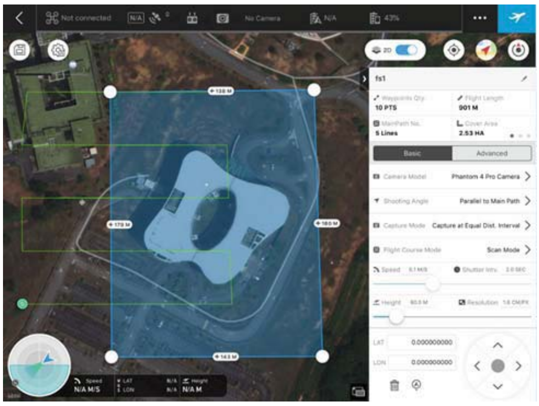

Fig. 3. Flight Map in DJI Go Application (1 set)

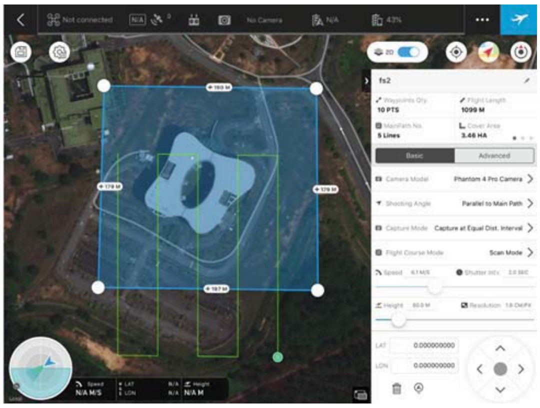

Fig. 4. Flight Map in DJI Go Application (2 set)

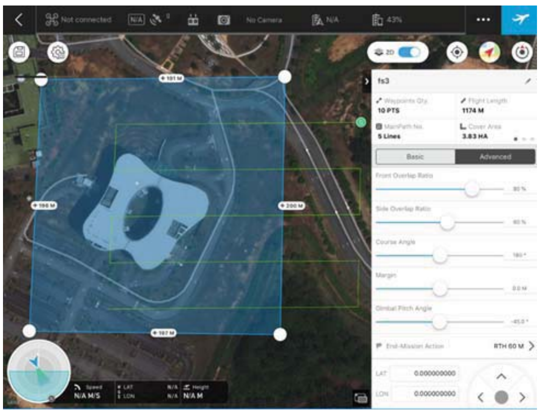

Fig. 5. Flight Map in DJI Go Application (3 set)

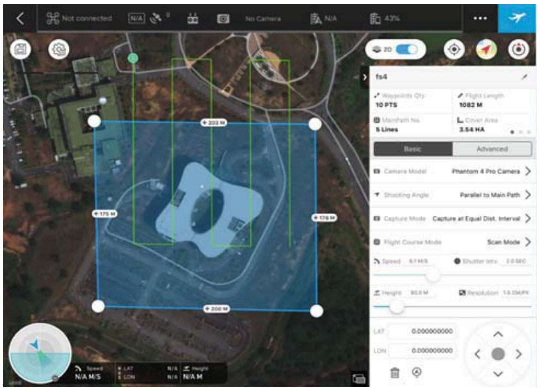

Fig. 6. Flight Map in DJI Go Application (4 set)

B. Establishment of Ground Control Points (GCPs) and Check Points (CPs)

Next, the GCPs are required for georeferenced the output. In this case, the GCPs will scale, orient and position the final results. In this study, 4 ground control points and 1 control point have been setup as shown in Fig. 7 and GCPs specification as in Table 5. Fast static observation has been used to complete observation of every ground control points and control point. Observation have been carried out for 15 minutes for every station. The known coordinate at base station has been used to compute the carrier phase correction in observation. Benchmark on helipad was used as base station. GPS equipment was set up at base station and the observation was start earlier than other GCP station. Next, GPS rover was set up at GCP 1, 2, 3,4 and CP 1. The observation was observed 15 minutes at each station. Next, GPS data have been downloaded and processed using Trimble Total Control to get the coordinate. The coordinate was converted into RSO coordinate from GDM 2000. The RSO coordinate have been used throughout this study.

▲: Ground Control Point ▲: Check Point:

Fig. 7. Distribution of GCPs and CP

TABLE 5. GCP Specification

No.	Specification	Description
1	Material	Concrete with pipe point at the middle. Laid on with white mesh vinyl (same as banner canvas)
2	Size	1.5 m x 1.5 m
3	Colour	Black - white

C. Images Acquisition

Fig. 8 shows the steps that involve in image acquisition of aerial image. DJI Go application software started in order to set up the aerial survey. Google Maps and DJI Go application have been used to obtain digital image. Polygon on covered area have been drawn on the DJI Go software and the strip lines have been drawn on the area before start flying to fully covered the project area. The survey was configured by set the default parameter, angle, altitude, take-off and landing.

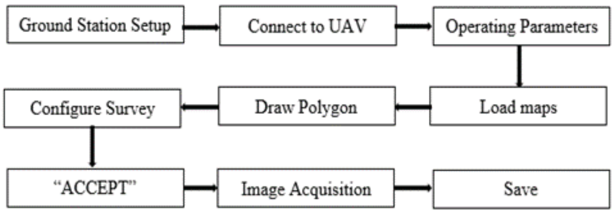

Fig. 8. Aerial Image data acquisition process

The UAV was started after configured the parameters. The flight direction was controlled towards the first waypoint after predefined altitude. The UAV was set to GPS waypoint mode and flew according to the flight strip line that have been set. After successfully flown to all the waypoints, the UAV has been returned to home automatically.

D. Aerial Images Processing

Fig. 9 described the processing of data collected by UAV. After data acquisition has been completed by DJI Phantom 4 Pro, all acquired images were processed by using Agisoft Photoscan software. This software requires camera information such as pixel size, focal length, radial lens distortion and tangential distortion to carry out interior orientation.

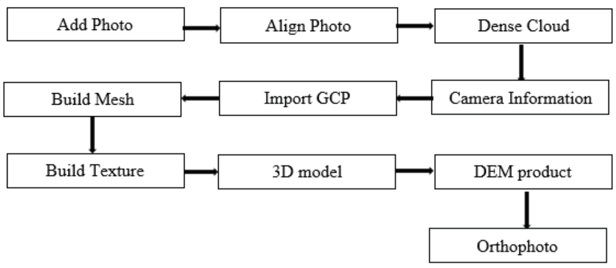

Fig. 9. Aerial Image data acquisition process

Each image has 80% end lap, 80% side lap and 307 Images were processed. All GCP were registered during exterior orientation. 4 GCP were registered as a full control (X, Y, Z), the accuracy was maintained by checking the value of RMSE. The RMSE formula is used for determining the differences value of UAV data and ground measurement data as shown in equation (1) below:

$$\sqrt{\sum \frac{((x_a - x_b)^2 + (y_a - y_b)^2)}{n}} \qquad (1)$$

x_a = UAV Coordinate (Easting)

x_b = Ground Measurement Data (Easting)

y_a = UAV Coordinate (Northing)

y_b = Ground Measurement Data (Northing)

n = Number of Observation

Fig. 10. Raw data from nadir acquisition

Fig. 10 shows the example of raw data from nadir acquisition on the field and Fig. 11 shows the example of raw data from oblique acquisition. The raw data was in Joint Photographic Expert Group (JPEG) format.

Fig. 11. Raw data from oblique acquisition

III. RESULTS AND DISCUSSION

Digital surface model or 3D model is one of the outputs after the processing. The processing was carried out using Agisoft software which medium quality been used in the processing. DSM give three-dimensional (3D) view representing x, y and z. Z values were the height from mean sea level. Orthophoto were produced by Agisoft software. Digital orthophoto only give a two-dimensional (2D) view representing x and y axis. The next product is DEM which was additional product in this study. The product was generated by Agisoft Photoscan Professional software and it was in raster form. The DEM were produced after performing aerial triangulation using GCP. Fig. 12, Fig. 13 and Fig. 14 represents the resulting of the 3D model whereas Fig. 15 represent digital orthophoto and Fig. 16 represent

digital elevation model (DEM).

Fig. 12. 3D model (Front Elevation)

Fig. 13. 3D model (Rear Elevation)

Fig. 14. 3D model (Right Elevation)

Fig. 15. Digital Orthophoto

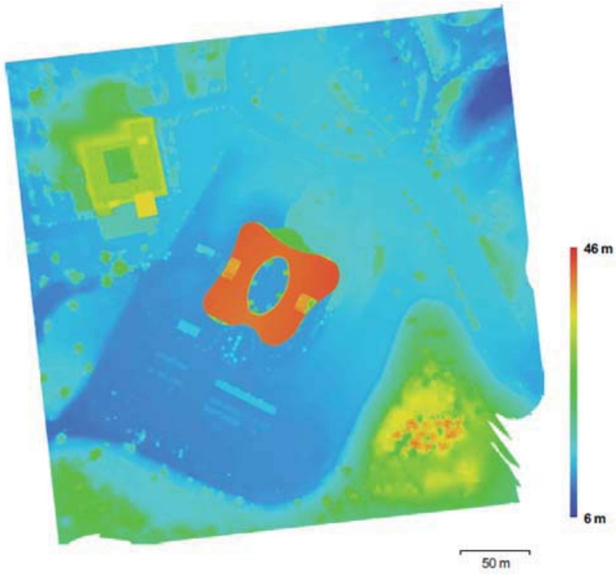

Fig. 16. Digital Elevation Model (DEM)

The accuracy from UAV can be obtained through the method of Root Mean Square (RMSE). The equation of RMSE is used to calculate the difference between coordinate from Topcon which used as benchmark with the same coordinate in stereoscopic model generated by Agisoft Photoscan Software.

Based on the Table 6, the accuracy of the RMSE is well within centimetre-level and these meets the required level of accuracy for small-scale area mapping and modelling. The smaller the RMSE value computed, the better the accuracy of orthophoto and model produced. Based on the result, if the mean approaching to zero, the observation shown is precise. More GCP is require to get better RMSE value.

TABLE 6. Comparison of Check Points between Topcon and Agisoft

LABEL	**DIFFERENCES**		
	X (m)	**Y (m)**	**Z (m)**
CP 1	-0.013197	0.003127	0.0005
CP2	0.020213	0.001034	0.002224
CP3	-0.014672	-0.03464	0.01262
CP4	0.040199	-0.02862	0.016449
CP5	-0.031384	0.0619	-0.03366
Σ(DIFFERENCES)^2	0.003399	0.005862	0.001568
MEAN	0.000232	0.00056	-0.00037
RMSE	0.026073	0.034239	0.017707

The measurement of features in term of length in Faculty of Science which is parking lot 1, parking lot 2, length 1, length 2, length 3 and length 4 were chosen. Measurement analysis consist of length measurement from architectural plan and Agisoft Photoscan as shown in Table 7 and the difference between length is shown in Table 8.

TABLE 7. Measurement in Two Type of Method

Label	Architectural plan (m)	Agisoft (m)
Parking lot 1	8.3	8.272
Parking lot 2	8	8.072
Length 1	3.7	3.673
Length 2	5.9	5.886
Length 3	8.4	8.365
Length 4	2.1	2.097

TABLE 8. Measurement in Two Type of Method

Actual (m) – Agisoft (m)	
Label	**Difference (m)**
Parking Lot 1	0.028
Parking Lot 2	-0.072
Length 1	0.027
Length 2	0.014
Length 3	0.035
Length 4	0.003
Mean	0.006
$\sum$ (Differences)^2	0.008
RMSE	0.037

Table 8 shows the difference of measurement that have been made with actual measurements and RMSE value which have been calculated. The difference shown represented the error that occurred in each of the measurement that have been made and the error accuracy achieved centimetre-level. Based on the error value, the sample standard deviation of the difference between measured values and actual values can be obtained by using RMSE formulae. The result of RMSE obtained from Agisoft measurement is ±0.037m. The accuracy achieved in this study is in centimetre accuracy and still meet the level of accuracy for 3D modelling and small-scale mapping. More number of control points to minimise the RMSE value and for better 3D model.

IV. CONCLUSION

As a conclusion, this study involved data acquisition and processing. The data acquisition was successfully executed. The establishment of GCP and CP were successfully done by using Topcon GR-5. The data was processed successfully by using Agisoft Photoscan Professional. The results were obtained and accuracy assessment of the product have been done by using RMSE formula. The accuracy achieved was in centimetre accuracy and can be used for some applications, and its new alternative to traditional techniques where low-cost UAV can generate high quality products. More number of control points to minimise the RMSE value for producing better 3D model and a larger area of study for variety research can be performed such high oblique imagery to evaluate the potential and accuracy of 3D model produces for further research.

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