UAV- Based Imaging – Digital Elevation Model Extraction

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Key words: Unmanned aerial vehicle, Point cloud reconstruction, Digital elevation model, accuracy.

SUMMARY

Data, whether the image, text or tabular must be manipulated using the application program to extract the required information for the decision makers. Digital elevation models (DEMs) are commonly used to solve different environmental issues due to its data structure simplicity and improved computational efficiency. Nevertheless, it must be generated with optimum accuracy. This research aims at showing the processing workflow of DEM acquired within University Putra Malaysia with a multirotor Unmanned Aerial Vehicle (UAV). The accuracy of the model assessed by utilizing the Ground Control Points (GCPs) established with a Trimble Real Time Kinematic Differential Global Positioning System (DGPS) and a sub-meter accuracy expected.

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1. BACKGROUND

A Digital Elevation Model (DEM) gives a 3D representation of the terrain. The elevation data is a continuous phenomenon. For this reason, data obtained from Global Positioning System (GPS), tacheometric, total station or contour lines considered as a Digital Terrain Model (DTM). The cost of the cartographic equipment used for DEM extraction is a significant challenge and consumes a lot of time compared with algorithmic method. It also requires adequate skill and training of the cartographers. In general, stereo images or field surveys and the equipment are not readily available to generate DEM and thus pushing the users to adopt published DEM [1]. Nowadays, the automated method is widely utilized due to the technological advancement. Although, it is time-saving and affordable, but the accuracy of the models relies on the software and DEMs sources.

Algorithmic methods can lead astray because of the appearance of noise in the data, thereby yielding erroneous pits and peaks [2]. To avoid erroneous pits and peaks required to smoothing the terrain. UAV Photogrammetry for mapping and 3D modeling [3][4] has paved way for the researchers to generate DEM with ease and a reliable accuracy. However, rapid applications of UAV to produce DEMs ruminates the platforms inexpensiveness and sensor miniaturization [4]. Previous studies investigated with the use of analytical plotter and digital photogrammetric methods of DEM extraction [5]. The analytical method provided better results over digital photogrammetric method due to the poor texture or imperfect photographic processing. PCI Geomatica offered a tutorial on how to use Geomatica OrthoEngine to extract a DEM surface from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) level 1B data [6]. The ASTER data comprises of two levels (1A and 1B); each level has strengths and drawbacks. A study in Sungai Munar Watershed conducted with Google Earth as a source of DEM extraction [7]. Accuracy of 0.19% resulted when the authors compared the DEM with 20 meter contour interval of the same study area. This research mainly focuses on an algorithmic workflow of a DEM derived from a UAV hexacopter platform Tarot 680 Ironman Red Green Blue (RGB) photos. The accuracy of the model evaluated with the existing Ground Control Points (GCPs) established by Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) within the study area.

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2. VARIOUS SOURCES OF DEMS

Fig.1.0: DEM platforms.

DEMs produced from a variety of sources [8]. Land surveying and Photogrammetry methods are the common sources of DEMs extraction. The factors required in choosing digital elevation model's platforms are the coverage area, the use of the model, required accuracy, allotted time and the available cost. Total station equipment or direct survey provides accurate elevation data, but expensive, time heating up, and not suitable for large area. Scanning and interpolation of a contour map is tedious and produce low-quality results. Hence, DEM source from a UAV. American Institute of Aeronautics and Aerospace (AIAA) committee on standards, Lexicon of UAV/ROA defines UAV to be an aircraft designed or modified, not to carry a human pilot. It operated through an electronic input initiated by a flight controller or an onboard autonomous flight management control system; that required no flight controller intervention [9]. Fig. 1.0 describes some DEM platforms, a UAV platform considered because it gives better resolution, inexpensive, operated under the cloud, and very flexible compared with traditional aircraft and space satellite. 1.0 above. A UAV platform, irrespective of their sizes could either be a fixed-wing or a multirotor. In the current studies, A UAV hexacopter platform Tarot 680 Ironman RGB photos as in Fig.1.1 below used to extract the DEM. The hexacopter is portable and foldable for easy transportation. Table 1.0 identifies the features, product specifications, and requirements of the hexacopter.
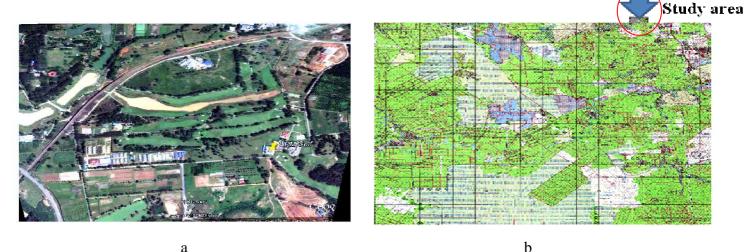
Fig.1.1: hexacopter platform Tarot 680 Ironman.

Table1.0: characteristics of hexacopter, adopted from Tarot FY680 IRON MAN 680 Hexa-Copter Carbon Kit TL68C01.

Features	Specifications	Requirements
Fold-ability for transportation and storage	Size motor to motor: 680mm	5ch Radio system
Light weight	Weight: 600g	Flight controller
15 minutes flight duration	Height from ground to lower rods: 180mm	Propeller size: 10~13 inch carbon fiber propeller
Folding landing gear	Height from ground to top: 220mm	Motor: 620~980KV 2212~4006 brushless motor
		Battery specifications: 11.1~14.8V 3000~5000mAh
		Brushless ESC: 20~30A

3. STUDY LOCATION

The study conducted at the University Putra Malaysia stadium, Selangor Darul Ehsan off Graduate school road, Malaysia. It was about 3km from the Faculty of Engineering; the location is distant and safe for taking-off and landing [4]. Fig. 1.2 a, b, and c shows the location Google map and topographic map of Selangor. The Google map overlaid on Selangor topographic map to know the exact study's location.

a

Study area

b

c

Fig. 1.2a, b, and c: Site Location Google map overlaid on Topographic map of Selangor.

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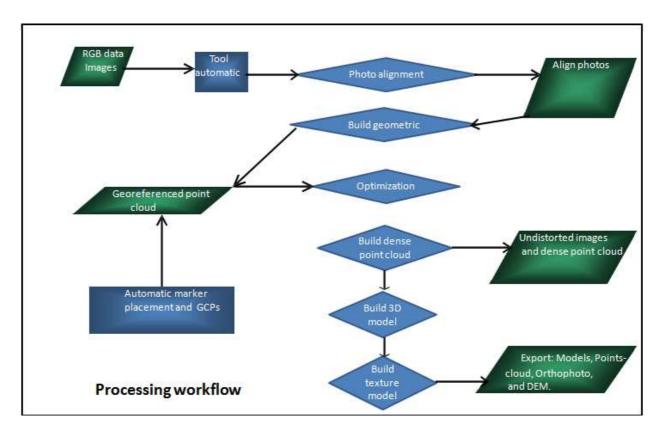
4. ALGORITHMIC DEM EXTRACTION FROM UAV

Fig.2.0: DEM extracion workflow.

In this work, PhotoScan algorithm utilized to extract digital elevation model. The UAV data are heavy and consequently command a higher computing memory and hardware configurations. The study area is approximately 0.08sqkm and encircled with structures and high-rise towers. For the optimal results, thirty five GCPs established in a safe zone used for georeferencing, optimization, and accuracy assessment. Referring to Fig.2.0 above, digital elevation model extracted by navigating to the photoScan workflow pane and selected series of processing steps such as setting the software; loading photos; performing image estimation quality, aligning photos; building geometry; georeferencing; optimizing; building dense point cloud; editing dense point cloud; building 3D model; editing mesh; generating the mesh, and then exporting the results. The intermediate results can save for further processing. PhotoScan algorithm is semi-automated, easily interactive and required human intervention to achieve accurate results. One of the human intervention tasks needed to enhance the DEM accuracy is image estimation quality. PhotoScan suggested that image estimation quality should perform to exclude poorly focussed photos from the image processing by disable any photo with quality less than 0.5 units. This study classified the DEM extracted products into two. That is, the byproducts (Fig. 3a-e) and the main products (Fig. 4a-c). The byproducts include sparse point cloud and dense point cloud. While the main products are 3D models, camera positions and image overlap, orthophoto and DEM.

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5. RESULTS

a

b

c

d

e

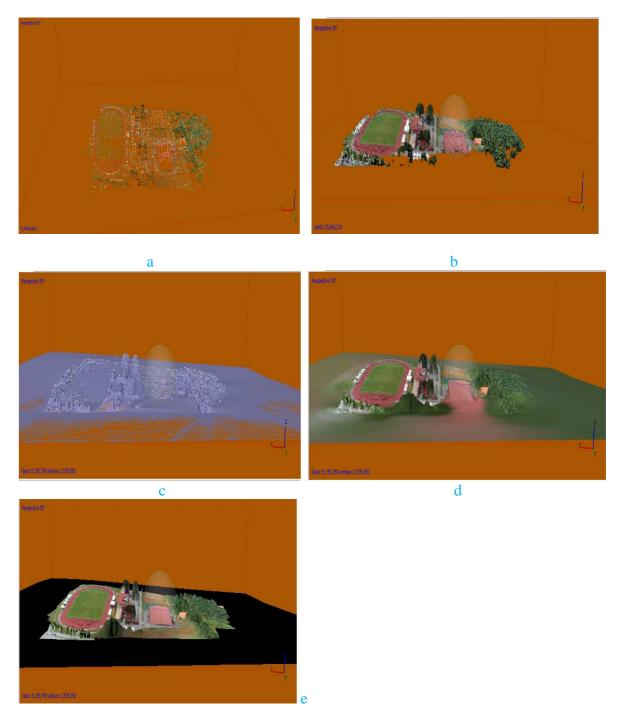Fig. 3a : Byproducts; sparse point cloud, b: dense point cloud c: 3D model in wire mode, d: 3D model in shaded mode, e: 3D model in texture mode.

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<center>a</center>

<center>b</center>

87.6809 m

45.2408 m

Fig. 4: Main products; a: ortophoto, b: camera location and image overlap, c: digital elevation model (DEM).

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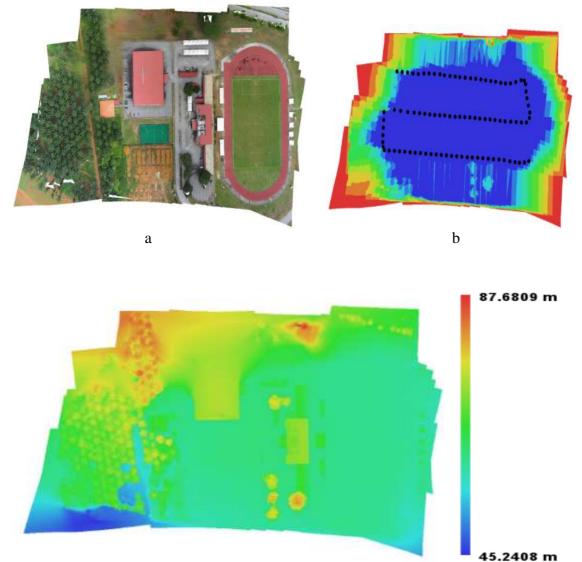Isola Ajibola, Sattri Masor, Biswajeet Pradhan and Helmi Zulhaidi (Malaysia)

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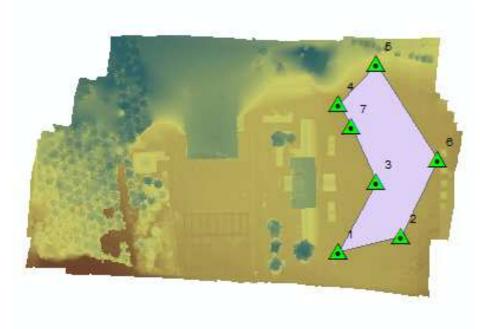
6. ACCURACY ASSESSMENT AND DISCUSSION

Fig.5a : GCPs overlaid on DEM.

Errors are of three types. These are systematic or cumulative; accidental, random or compensating; mistake or blunder. DEM is not free from erroneous ideologies. For this reason, careful attention should be devoted to processing methods and sources of data. Digital elevation model errors perceivable only in vertical direction and thus call for vertical accuracy assessment of the DEM. Nevertheless, the allowable value of a vertical component indicates the reliability of the horizontal portion. Hence, to assess the horizontal error within the DEM to a certain confidence level, the vertical component need to be clearly identified [10]. Broadly speaking, the RMSE is statistically used to assess systematic and random errors along the vertical direction within a DEM.

$$\text{RMSE} = \frac{\sqrt{\sum (D_i - D_t)^{\wedge 2}}}{n}$$

D_i is the extracted DEM height of the observed points.
D_t is the known height of the observed points.
n is number of the test points.

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Table 1.1: UAV derived DEM (Ht.), observed GCPs (Ht.), and residuals

s/n	DEM (Ht.)	GCPs (Ht.)	Residual	R^2
1	60.801	60.785	0.016	0.000256
2	60.742	60.722	0.02	0.0004
3	60.731	60.748	-0.017	0.000289
4	60.85	60.855	-0.005	2.5E-05
5	63.578	63.599	-0.021	0.000441
6	60.748	60.758	-0.01	0.0001
7	60.63	60.618	0.012	0.000144
8	66.217	66.232	-0.015	0.000225
9	58.794	58.806	-0.012	0.000144
10	60.277	60.253	0.024	0.000576
11	59.127	59.139	-0.012	0.000144
12	58.913	58.92	-0.007	4.9E-05
13	57.938	57.961	-0.023	0.000529
14	59.399	59.609	-0.21	0.0441
15	79.067	79.045	0.022	0.000484
16	70.541	70.568	-0.027	0.000729
17	66.401	66.425	-0.024	0.000576
18	61.856	61.839	0.017	0.000289
19	85.642	85.619	0.023	0.000529
20	74.02	74.002	0.018	0.000324
21	74.717	74.739	-0.022	0.000484
22	61.831	61.855	-0.024	0.000576
23	61.625	61.65	-0.025	0.000625
24	61.549	61.538	0.011	0.000121
25	73.938	73.95	-0.012	0.000144
26	75.727	75.711	0.016	0.000256
27	59.92	59.94	-0.02	0.0004
28	60.327	60.356	-0.029	0.000841
29	75.49	75.479	0.011	0.000121
30	73.85	73.835	0.015	0.000225
31	63.741	63.726	0.015	0.000225
32	62.909	62.921	-0.012	0.000144
33	73.572	73.565	0.007	4.9E-05
34	76.259	76.231	0.028	0.000784
35	71.808	71.823	-0.015	0.000225
			Mean	0.001588
			RMSE	0.039847

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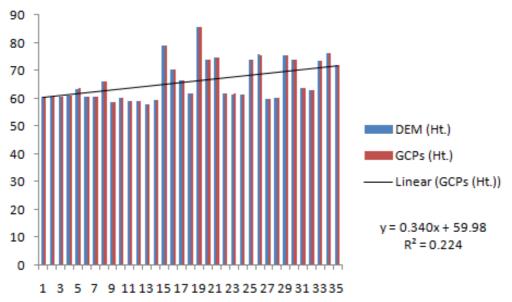Sofia, Bulgaria, 17-21 May 2015

Fig. 5b: Bar chart showing an elevation comparison between DEM and GCPs.

Fig.5a above describes the process applied to measure the accuracy of the model. The first step is to import DEM and GCPs coordinates into the ArcGIS software and thereafter constructed a polygon using the GCPs coordinates. For the easy recognition of the GCPs, the polygon overlaid on the DEM and consequently determined the model heights. The DEM and GCPs heights utilized to compute vertical accuracy, using RMSE method. The deviation between the data (DEM and GCPs), the square of the residuals, mean and root-mean-square error computed and put out in excel table as in Table 1.1 above. The table also includes mean and RMSE values. The RMSE value employed to calculate accuracy at 95% confidence level, by multiplying geospatial positioning, vertical accuracy standard constant with the RMSE and obtained 0.078m (1.9600 * 0.039847).

CONCLUSION

This research presented processing workflow and accuracy assessment of a DEM extracted from a UAV imaging. The accuracy of the model relies on the software and the DEMs sources. It became more easy, speedy, affordable, and involve no extra training when extracted DEM via algorithmic method. Algorithmic methods can lead astray because of the appearance of noise in the data, thereby yielding erroneous pits and peaks. This can be warded off by smoothing the terrain. To improve the quality of the results, photoScan suggested a process called image estimation quality so as to exclude poorly focussed images from the processing results. The extracted products basically classified into byproducts and main products. The byproducts include sparse point cloud and dense point cloud. While the main products are 3D models, camera positions and image overlap, orthophoto and DEM. The main products generated from about twenty six millions dense point clouds. The RMSE and 95% confidence level obtained are 0.04m and 0.078m respectively. Apparently, the centimeters accuracy results rely on the software and the source of the photographs used for the extraction.

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BIOGRAPHICAL NOTES

My name is Ajibola, Isola. A Nigerian and lecturer from Yaba College of Technology, Lagos Nigeria. I received the following as my training background:
Ph.D in GIS and Geomatics Engineering (in view) at Universiti Putra Malaysia (UPM);
M. Tech in Remote sensing application at Federal University of Technology FUT), Minna, Nigeria; B. Tech in Land surveying and Photogrammetry at Federal University of Technology (FUT), Minna, Nigeria; and O.N.D in Land surveying at The Polytechnic, Ibadan, Nigeria.

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