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An Evaluation on Fixed Wing and Multi-Rotor UAV Images using Photogrammetric Image Processing

Khairul Nizam Tahar, and Anuar Ahmad

Abstract**—**This paper has introduced a slope photogrammetric mapping using unmanned aerial vehicle. There are two units of UAV has been used in this study; namely; fixed wing and multi-rotor. Both UAVs were used to capture images at the study area. A consumer digital camera was mounted vertically at the bottom of UAV and captured the images at an altitude. The objectives of this study are to obtain three dimensional coordinates of slope area and to determine the accuracy of photogrammetric product produced from both UAVs. Several control points and checkpoints were established Real Time Kinematic Global Positioning System (RTK-GPS) in the study area. All acquired images from both UAVs went through all photogrammetric processes such as interior orientation, exterior orientation, aerial triangulation and bundle adjustment using photogrammetric software. Two primary results were produced in this study; namely; digital elevation model and digital orthophoto. Based on results, UAV system can be used to mapping slope area especially for limited budget and time constraints project.

Keywords**—**Slope mapping; 3D; DEM; UAV; Photogrammetry; image processing.

I. Introduction

NOWADAYS, aerial mapping using unmanned aerial vehicle (UAV) quite popular in the mapping field aerial mapping using unmanned aerial vehicle (UAV) quite popular in the mapping field. The technology of UAV has experienced various developments over the years. Reference [8], [2] show there were hundreds of UAV operated by military and civil based organizations for numerous applications. An operator was used to control for hovering operations, landing and flying the UAV. UAVs can be operated in manual or autonomous flight according to purpose of the mission [3], [9].

A high quality fiber has been used for the model planes and complete with autonomous flight controller board [4]. Reference [10],[11] show UAV technology has been utilized in road maintenance, town planning, monitoring, natural hazard warning, environmental studies, documentation of cultural heritage and surveillance. Previous study on UAV has been explored by numerous researchers especially on sensitivity of UAV to locate point of measurement on the ground [12], [13], [14], [7], [5], [6]. Reference [15] shows studied the accuracy and precision of GPS onboard for reduction of the number of ground control points needed for photogrammetric image processing. Reference [2] shows the fixed wing UAV is suitable for large area while multi-rotor UAV suitable for small area [7]. Multi-rotor UAV is based on rotor and blade, while fixed wing UAV is similar to the model of an aircraft. Most of UAV are attached with camera or video recorder to acquire image and video of the ground from a certain altitude [10]

UAV's cost much cheaper as compared to other manned aircraft or terrestrial equipment and it also suitable and flexible in any weather condition. The advantages of UAV are in low cost, flexible maneuverings, high resolution images, flying under clouds, easy launch and landing and very safe to use as summarized [16]. The disadvantages of UAV include payload limitation, small coverage for each image, increasing number of image that need to be processed and large geometric distortion. In short, UAV promises a low cost, less time and less manpower during the data collection. An autonomous chip is installed in the UAV and it can be flown autonomously [1]. The user or operator only needs to enter the initial position and download it into the autonomous chip. This autonomous technology is used by fixed wing UAV and multi-rotor UAV in data acquisition. During autonomous flight, an operator can monitor the UAV condition via radio modem communication between UAV and laptop on the ground [17]. UAV data collection is possible under cloudless condition and the image quality is much better than satellite images which are located a hundred thousand kilometers from earth surface.

A new approach need to be carried out to obtain the ground data at the minimum cost. This study has introduced a novel method for slope photogrammetric mapping by using fixed wing and multi-rotor UAV. One study area has been selected to assess the accuracy of fixed wing and multi-rotor UAV images. The objectives of this study are to obtain three dimensional coordinates of slope area and to determine the accuracy of photogrammetric product produced from both UAVs. Low altitude UAV is the most potential equipment and very low cost budget for capturing the aerial photograph on a small area.

(a) (b)

Fig. 1 (a) Fixed wing UAV; (b) Multi-rotor UAV

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Apart from that, digital camera with high resolution images is attached at the UAV. The digital camera provides small format images. Fig. 1 shows an example of UAV and digital cameras. In this study consumer digital camera has been used in acquiring images at the selected study area. Both UAV are classified as micro UAV also known as cropcam and hexacopter (Fig. 1). These UAVs are categorized as micro UAV because it has weight below than 5 kilogram and endurance hour less than one hour. Hexacopter has six blades where three blades rotate in clockwise direction while the other three blades rotate in counter-clockwise direction. Cropcam UAV has the same designed as manned aircraft. Both UAVs have been installed with GPS onboard where it can operate autonomously.

II. The Methodology

The study was conducted at selected slope area in Skudai, Johor, Malaysia. Fig. 2 shows the location study area and the condition of slope at the landslide study areas in Skudai. The reason of these slopes has been selected for this study due to the variety of slope degrees which is suitable for this study. The selected study area located at latitude 1° 38’ 20.33” and longitude 103° 37’ 50.64”.

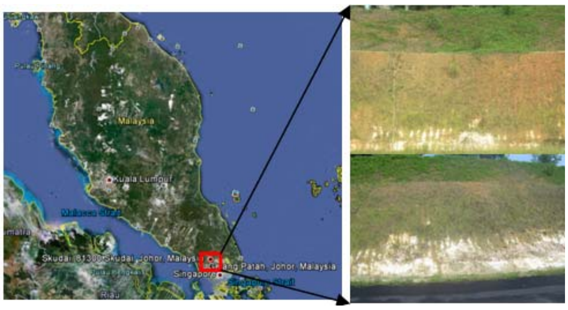


Fig. 2 Selected Study Area (Source: Google Earth)

Fixed wing UAV flight mission was used Lentsika software to design the flight path for the flight mission. In this software, an operator needs to input one initial position to be entered as the starting point of flying path. The initial stating points can be obtained from the global positioning system and we used Google Earth as the background images to view the flight path for this mission. The designed flying path were exported to different format which supported by horizon software. In horizon software, an operator can view the waypoints which covered the selected study area. Horizon software finalized the flight pattern and altitude control. The flight path file was downloaded in autonomous chipset in the fixed wing UAV. After that, the operator needs to check the motion sensor of the UAV such as elevator, rudder and throttle before start the flight mission. In this study, fixed wing UAV was launched by hand and landed using net. Fig. 3 shows the software which has been used to monitor fixed wing UAV during flight mission.

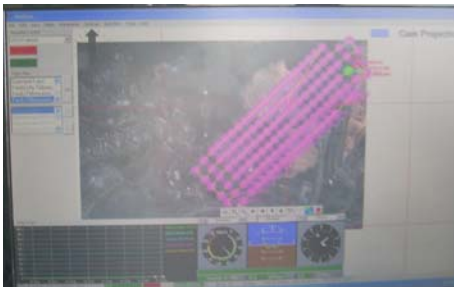


Fig. 3 Horizon software

Multi-rotor UAV flight mission was used MKToolMaps software to snap the images of the study area. The image from this software contains with coordinate system and it can be directly used for waypoints designed. The saved image was opened in the MKTool software for waypoints designed purposes. An operator can designed the waypoints according to the specific need which involves percentage of overlap images. In this software, flying height and UAV speed need to be entered to cover the whole study area. Then the designed waypoints were exported to the UAV itself for autonomous flight mission. Multi-rotor UAV is different from the fixed wing UAV because it can hover and landing at the same points. Fig. 4 shows the MKTool software for monitor multi-rotor UAV condition during flight mission.

Fig. 4 MKTool Software

A digital camera has been attached at the bottom of UAV in order to capture image vertically. Based on flight planning calculation, we can identify scale of photograph and calculate ground coverage area for each image. Pixel size can be calculated using a few elements such as number of object, length of an object in metric units, focal length and flying height during image acquisition. All acquired images were processed using photogrammetric software which involved interior orientation, exterior orientation and aerial triangulation. Interior orientation needs input from camera database and exterior orientation involves control points and tie point measurement. The ground control points and checkpoints were established evenly at the selected study area using Real Time Kinematic Global Positioning System (RTK-GPS). There were two main photogrammetric results has been produced in this study such as digital orthophoto and digital elevation model.

III. RESULTS

After completion image processing, two main results were produced; namely; digital elevation model and digital orthophoto. The footprint of the study area using fixed wing UAV and multi-rotor UAV are show in Fig. 5 and Fig. 6.

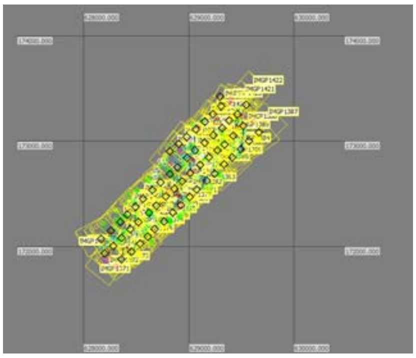


Fig. 5 Footprint from fixed wing UAV images

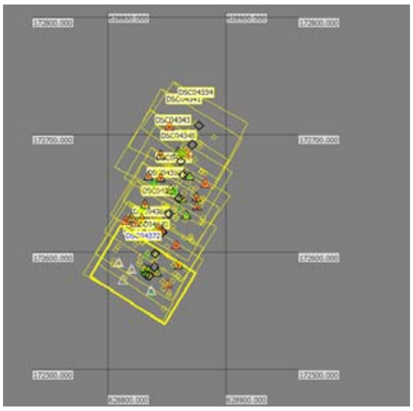


Fig. 6 Footprint from Multi-rotor UAV images

In Fig. 5 and Fig. 6, triangle symbols represent GCP and square symbols represent tie points. In this study, fixed wing UAV has covered the large area compared to the multi-rotor UAV, it is because fixed wing UAV were captured images from altitude 320m and multi-rotor captured images from altitude 80m. Therefore, the number of images from fixed wing UAV was about 60 images and 20 images from multi-rotor UAV. However, the images have been selected to fulfill the objective of this study and only the same area has been applied for the analysis purposes. The results of digital orthophoto for fixed wing UAV and multi-rotor UAV are shown in Fig. 7 and Fig. 8 respectively.

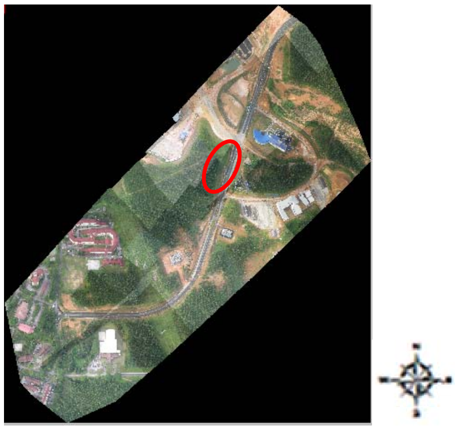


Fig. 7 Digital Orthophoto (Fixed wing UAV)

Fig. 8 Digital Orthophoto (Multi-rotor UAV)

Fig. 7 and Fig. 8 show the digital orthophoto obtained from fixed wing and multi-rotor UAV. Red circle show the area of interest of this study and all analysis only involve at the same area. Digital orthophoto product is free from any distortion and represents the whole selected slope area. The DEMs were produced using photogrammetric software and it is in raster form. In this study, DEM for fixed wing UAV and multi-rotor UAV are shown in Fig. 9 and Fig. 10 respectively.

In this study, both UAVs were successful shows the elevation mapping of the selected slope area and it means that a new approach of fixed wing and multi-rotor UAV can be used for mapping slope area.

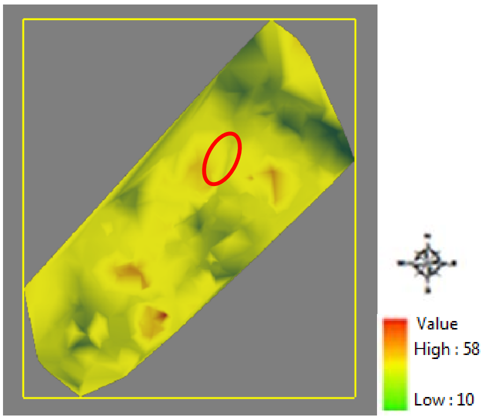


Fig. 9 Digital Elevation Model (Fixed wing UAV)

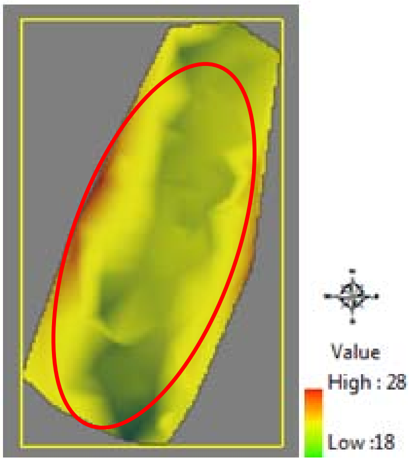


Fig. 10 Digital Elevation Model (Multi-rotor UAV)

IV. Discussions

The objectives of this study are to obtain three dimensional coordinates of slope area and to determine the accuracy of photogrammetric product produced from both UAVs. Several checkpoints were used to determine the accuracy of photogrammetric products from both UAVs. Table I and II illustrates the results of accuracy assessment of fixed wing UAV and multi-rotor UAV based on Root Mean Square Error (RMSE), and mean absolute calculation.

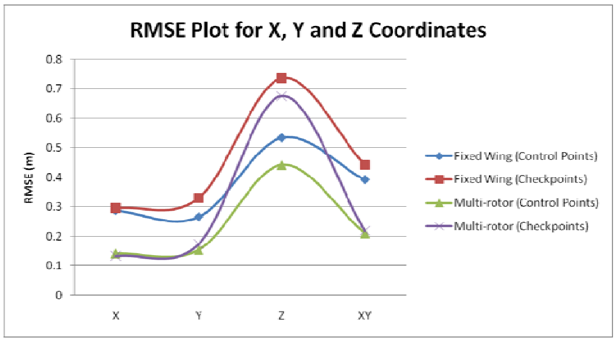
TABLE I
RESULT OF FIXED WING UAV

	GCP	RMSE(m)	Mean Absolute(m)
Control Points	X	0.288	0.200
	Y	0.266	0.203
	Z	0.534	0.476
	XY	0.392	0.346
Checkpoints	X	0.295	0.216
	Y	0.329	0.276
	Z	0.736	0.610
	XY	0.442	0.386

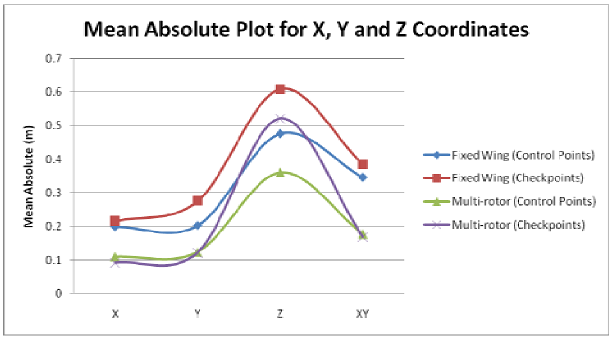
TABLE II
RESULT OF MULTI-ROTOR UAV

	GCP	RMSE(m)	Mean Absolute(m)
Control Points	X	0.143	0.110
	Y	0.155	0.124
	Z	0.442	0.360
	XY	0.211	0.177
Checkpoints	X	0.133	0.092
	Y	0.174	0.122
	Z	0.675	0.522
	XY	0.219	0.169

Refer to RMSE results, the different between fixed wing UAV and multi-rotor UAV is almost the same. The multi-rotor UAV give better results compared to the fixed wing UAV. Both UAVs results were recorded sub-meter level. Fig. 11 shows the graph of root mean square error (RMSE) for fixed wing and multi-rotor UAV with respect to x, y and z coordinates.



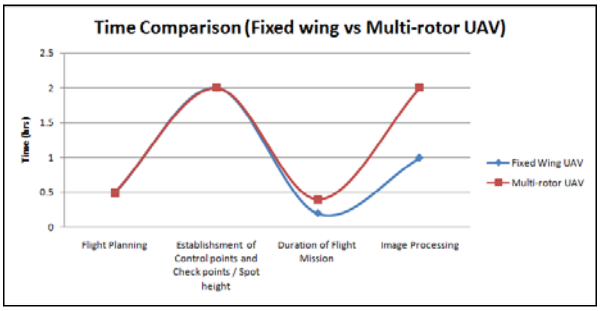
(a)



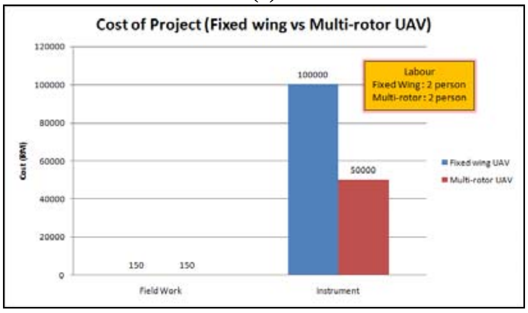
(b)

Fig. 11 (a) RMSE plot; (b) Mean Absolute Plot

Based on Fig. 11(a) and Fig. 11(b), x and y coordinates recorded good results compared to the z coordinates. The results on control points are better than checkpoints results. It is mean that the configuration control points for fixed wing and multi-rotor UAV in good configuration. In the other hand, the accuracy of checkpoints might be effect by variety of slope degree at the study area. In average, the difference between fixed wing and multi-rotor UAV is less than 10 centimeter. In future, the distribution of these errors will be explored. This study also carried out comparison between time, cost and labour needed for data acquisition until photogrammetric products obtained from fixed wing and multi-rotor UAV. Fig. 12 shows the comparison of time, cost and labour needed for fixed wing and multi-rotor UAV.



(a)



(b)

Fig. 12 (a) Time comparison graph; (b) Cost Comparison graph

Based on Fig. 12a, the time taken for fixed wing and multi-rotor UAV is almost similar except for duration of flight mission and image processing. This is because fixed wing UAV involves large area and it has many images compared to multi-rotor UAV. Fig. 12b shows fixed wing UAV is more expensive than multi-rotor UAV due to the different structure and component that include in both UAVs. The labour needed for both platforms is the same because both UAVs use the same procedure for flight mission. However, the cost, time and labour estimation only valid for the area less than two kilometers square for fixed wing and 100000 meter square for multi-rotor UAV. In other word, the cost, time and labour is subjective and it is depend on the project objectives.

V. Conclusion & Future Work

This study has been introduced a new approach in slope photogrammetric mapping using two UAVs platform; namely; fixed wing UAV and multi-rotor UAV. This study shows the results obtained from fixed wing and multi-rotor UAV. Based on these results, multi-rotor UAV has good results compared to fixed wing UAV. It is because multi-rotor UAV images were captured from low altitude, 80 meter while fixed wing UAV captured images from altitude 320 meter. However, both UAVs give accuracy achieve to sub-meter level and both UAVs were proved can be used for slope mapping. In future, the distribution of errors for both UAVs will be explored at the large area. The fixed wing and multi-rotor UAV has potential in monitoring of slope area and it is suitable for limited budget project.

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References

[1] G.S. David III, R.D. Benjamin, and R. Charles, “Development and Application Of An Autonomous Unmanned Aerial Vehicle For Precise Aerobiological Sampling Above Agricultural Fields,” J Field Robot., vol. 25, no. 3, pp. 133-147, 2008.

[2] G.J. Grenzdoffer, A. Engel, and B. Teichert, “The Photogrammetric Potential of Low Cost UAVs Forestry and Agricultural,” The International Archived of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVII, Part B1, Beijing, pp. 1207-1214, 2008.

[3] Y.C. Hai, C.C. Yong, and Q.C. Yang, “Autopilots for Small Unmanned Aerial Vehicles: A Survey,” Int. J. Control Autom., vol. 8, no. 1, pp. 36-44, 2010.

[4] Z. Lin, “UAV for Mapping – Low Altitude Photogrammetric Survey,” The International Archived of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVII, Part B1, Beijing, pp. 1183-1186, 2008.

[5] B. Mitch, and S. Salah, “Architecture for Cooperative Airborne Simulataneous Localization and Mapping,” J Intell. Robot. Syst., vol. 55, pp. 267-297, 2009.

[6] F. Remondiono, and C. Fraser, “Digital Camera Calibration Methods: Considerations and Comparisons,” ISPRS Comission V Symposium Image Engineering and Vision Metrology, IAPRS, vol.XXXVI, Part 5, pp. 266-272, 2006.

[7] K.N. Tahar, and A. Ahmad, “A simulation study on the capabilities of rotor wing unmanned aerial vehicle in aerial terrain mapping,” Int. J Phy. Sci., vol. 7, no. 8, pp. 1300 – 1306, 2012, doi: 10.5897/IJPS11.969

[8] D.G. Schmale III, B.R. Dingus, and C. Reinholtz, “Development and Application of an Autonomous Unmanned Aerial Vehicle for Precise Aerobiological Sampling above Agricultural Fields,” J. Field Robot., vol. 25, no. 3, pp. 133-147, 2008.

[9] H.Y. Chao, Y.C. Cao, and Y.Q. Chen, “Autopilots for Small Unmanned Aerial Vehicles: A Survey.” Int. J. Cont. Autom. Sys., vol. 8, no. 1, pp. 36-44, 2010.

[10] A. Hervouet, R. Dunford, H. Piegay, B. Belletti, and M.L. Tremelo, “Analysis of Post-Flood Recruitment Patterns In Braided-Channel Rivers At Multiple Scales Based On An Image Series Collected By Unmanned Aerial Vehicles, Ultra-Light Aerial Vehicles And Satellites,” GIS & Rem. Sen., vol. 48, no.1, pp. 50-73, 2011.

[11] M. Bryson, and S. Sukkarieh, “Architecture for Cooperative Airborne Simultaneous Localization and Mapping,” J. Intell. Robot Sys., vol. 55, pp. 267-297, 2009.

[12] U. Coppa, A. Guarnieri, F. Pirotti, and A. Vettore, “Accuracy Enhancement Of Unmanned Helicopter Positioning With Low-Cost System,” Appl. Geo., vol. 1, pp. 85-95, 2009.

[13] D.H. Shim, J.S. Han, and H.T. Yeo, “A Development of Unmanned Helicopters for Industrial Applications,” J. Intell. Robot Sys., vol. 54, pp. 407-421, 2009.

[14] K. Schwarz, and N. El-Sheimy, “Mobile Mapping System- State of the Art and the Future Trends. Istanbul,” Int. Arch. Photogramm. Rem. Sen., vol. XXXV, Part B1, 2004.

[15] A. Cesetti, E. Frontoni, A. Mancini, A. Ascani, P. Zingaretti, and S. Longhi, “A Visual Global Positioning System for Unmanned Aerial Vehicles Used In Photogrammetric Applications,” J. Intell. Robot Sys. vol. 61, pp. 157-168, 2011.

[16] L. Yan, Z. Gou, Y. Duan, “A UAV Remote Sensing System: Design and Tests,” Geospatial Technology for Earth Observation Data, (eds) Li Deren, Shan Jie, Gong Jianya. New York : Springer-Verlag, 2009.

[17] S.R. Herwitz, L.F. Johnson, S.E. Dunagan, R.G. Higgins, D.V. Sullivan, J. Zheng, B.M. Lobitz, J.G. Leung, B. Gallmeyer, M. Aoyagi, R.E. Slye, and J. Brass, “Demonstration of UAV-based imaging for agricultural surveillance and decision support,” Comp. Elec. in Agri., vol. 44, pp. 49-61, 2004.