Towards augmented topographic map: Integration of digital photograph captured from MAV and UAV platform

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(Keywords: topographic map updating, UAV, MAV, ortho-photograph)

1. INTRODUCTION

Photogrammetry is a process of mapping objects on the earth surface using aerial photographs as source of data, whereby object interpretation and geometrical measurement are carried out to produce line map and ortho-rectified photograph or orthophoto map. Generally it is a geospatial or geo-information technology trend of processing data captured from air using manned aerial vehicle (MAV) or unmanned aerial vehicle (UAV). The production and updating of topographical map has knowingly and largely been carried out by way of aerial photography a platform to generate true and colour photograph of the earth which then digitised smartly to create maps. Orthorectified photograph or orthophoto is an aerial photograph that has been corrected geometrically to represent uniform-scale image that is not distorted and can be intelligently used as map. Department of Survey and Mapping Malaysia, in short JUPEM, has been the sole national government mapping agency that produce maps employing orthophoto and variety of satellite images as source data.

Unmanned Aerial Vehicle (UAV) is a small unmanned aircraft that can be programmed to run the flight based on a flight instruction input that has been included in the navigation software in the aircraft. This small plane is like a remote control plane and can communicate using radio and Global Positioning System (GPS) with the ground control system. However, the rapid growth in mapping technology have caused both the military and the public to review in detail the capabilities of UAV as an alternative to commercial aircraft for aerial mapping. Many researches and developments related to UAV have been conducted concerning digital mapping. UAV orthophoto are used in this research to investigate issue of map updating. UAV images could be stitched with previously MAV captured orthophoto to produce newly updated orthophoto which can be used to digitize fresh features of a large scale map.

2. BACKGROUND AND MOTIVATION

The Department of Survey and Mapping Malaysia (JUPEM) has been the forefront of the spatial enablement in Malaysia. In the area of rapid changes, the department has planned to introduce UAV for rapid imagery acquisition. For the beginning, the department has acquired few sets of UAV system to be used in the Defence Geospatial Division in enhancing the geospatial support for the Malaysian Armed Forces (MAF). This is one of the core businesses of JUPEM since the division was formed. With this new UAV capability, the division tends to augment the current geospatial mobile system in the field. The UAV system is able to perform the function of responsiveness tasks especially in producing rapid response products.

Currently¸ topographic map updating has focussed areas in developed, urban and rural part of the nation which are becoming congested as time passes by. The changes has built up swiftly including physical man-made entities and infrastructure which has noticed the increase in number at fast rate. Map updating tasks using MAV photography is tedious, timely and costly. Furthermore, the cost of aircraft rental has rocketed due to current global economic situation. Government spending can be badly affected too. The increased cost of rental and chaotic legal requirement to install digital camera and legal right to fly has made the MAV aerial photography to become inefficient and uneconomical, and is not suitable for map updating especially when covering a small area (<1000 hectar) which has rapid changes and not localised or adjacent (Hendriatiningsih Sadikin *et al*, 2014). In addition, MAV platform with high altitude creates issue of unexpected cloudy weather which then wasted flight may take place and impractical images captured. As well, vast flight area and extensive time of flying, and massive photography leading to surplus of digital photographs has created issues of expensive storage and server maintenance cost.

Currently, the use of UAV system and technology embedding software and ground control communication has attracted researches on digital mapping process and photogrammetry. Low cost and capability of flying autonomously are the advantages of this technology in the application of photogrammetry (Colomina *et al*, 2014). The UAV system can be equipped with the software to generate orthomosaic, digital surface model (DSM) and point cloud.

This paper is proposed to solve the issues stated above, mainly to undertake the updating of detail in areas with physical features that are fast changing. The method is to integrate new orthophoto with existing orthophoto in the digital topographic database. New orthophoto is processed and generated from UAV platfrom. This method seems appropriate and practical as UAV can fly under the cloud and the cost is cheap compared to conventional method. Moreover with its small size, it is easy to carry and can be quickly assembled and operated without the use of large flight lane.

3. OBJECTIVE OF RESEARCH

The objective of this paper is to study whether orthophoto images from UAV acquisition can be appropriately used to update existing orthophoto images previously generated from MAV platform. This new updated orthophoto is then should be usable to form a background image to update topographic map, thus without having need to fly repeatedly using conventional aircraft.

A right and proper method and technique was designed to integrate both images to yield single orthophoto output. A process of overlaying both images and mosaicing them was carried out in this study. Mosaic photograph is a group of two or more overlapping photographs that has been stitched up together to create single contiguous orthophoto of an area of mapping. The process was implemented by cut and append, and cautiously assemble parts of the orthopohoto to form images that fit closely to the adjacent image view, as illustrated in Figure 1.

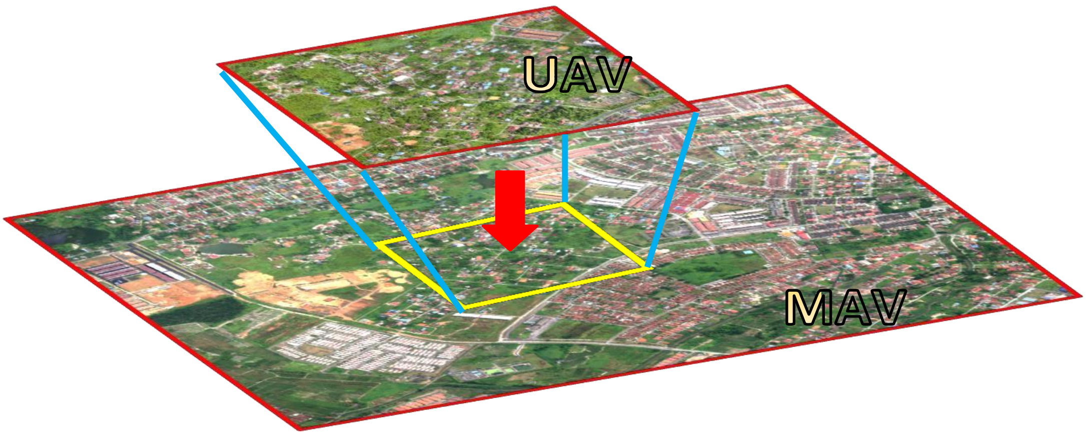

Figure 1: Illustration of the integration of new orthophoto and existing previously captured image.

4. STUDY AREA AND DATA SET

The chosen area for this study is located at Kampung Laya-Laya, in an area called Tuaran, in Sabah state, Malaysia (Figure 2), situated about 40 kilometer up north of the city of Kota Kinabalu, Sabah. The geographic coverage ranges from 6°10’22.6” N 116°08’53.0” E to 6°08’34.1” N 116 ° 10’53.2” E (4km x 4km). This area consists of few congested population near the coast and is a flat land area. Most of the built-up areas are housing scheme with one or two storey floor units, as well as some village zones.

Figure 2: Study area (in red square line) at Kampung Laya-Laya, Tuaran, Sabah, Malaysia

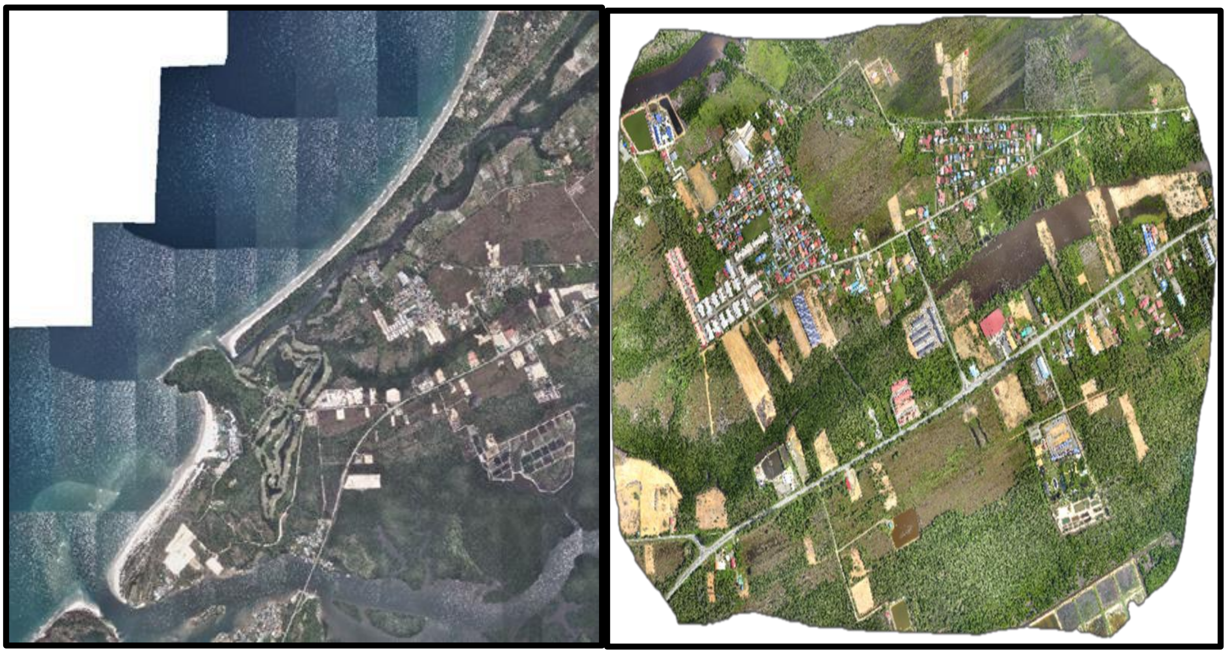

Figure 3: Orthophotos taken using MAV (left) and via UAV system (right).

Data that being utilised for the research comprise of raster images of an orthophoto of the study area taken by means of conventional aircraft and the second orthophoto was captured via aerial photography UAV of similar area. Figure 3 shows those orthophotos. Coverage of the MAV orthophoto expanded an area of 5.6km x 5.6km with the coordinates ranging from 6^{o}11’07.16”N, 116^{o}07’52.61”E to 6^{o}08’23.34”N, 116^{o}10’52.62”E. For the task, series of images were captured in Feb 2014 using digital aerial camera Vexcel UltraCam Eagle 80 with flying height of 5000 feet above means level with 60% front overlap and 50% side overlap. Ground Sample Distance (GSD) for the mission was set to 10cm. Rectified Skew Orthomorphic (RSO) East Malaysia was applied as the coordinates system and GDM2000 Malaysia was used as the reference datum.

Whilst for the UAV orthophoto, a series of aerial photography were taken on 21 September 2016 along a stretch of area 2km x 2 km using a UAV eBEE RTK model, employing compact camera Sony Cybershot DSC-WX 220 RGB 18.2 MP. GSD was set at 8.3cm with flying height of 600 feet with 80% front overlap and 60% side overlap. Coordinate system of UTM Zone 50N was applied as the spatial reference and WGS84 was used as the reference datum. A software called Pix4UAV was used in processing the UAV images to produce orthorectified photograph.

Map sheet datasets at a scale of 1:5000, namely GH33084 and GH33082 was extracted from the department’s Geospatial Data Acquisition System (GDAS). These maps will be overlaid onto the mosaicked orthophoto. Figure 4 depicts the specified dataset.

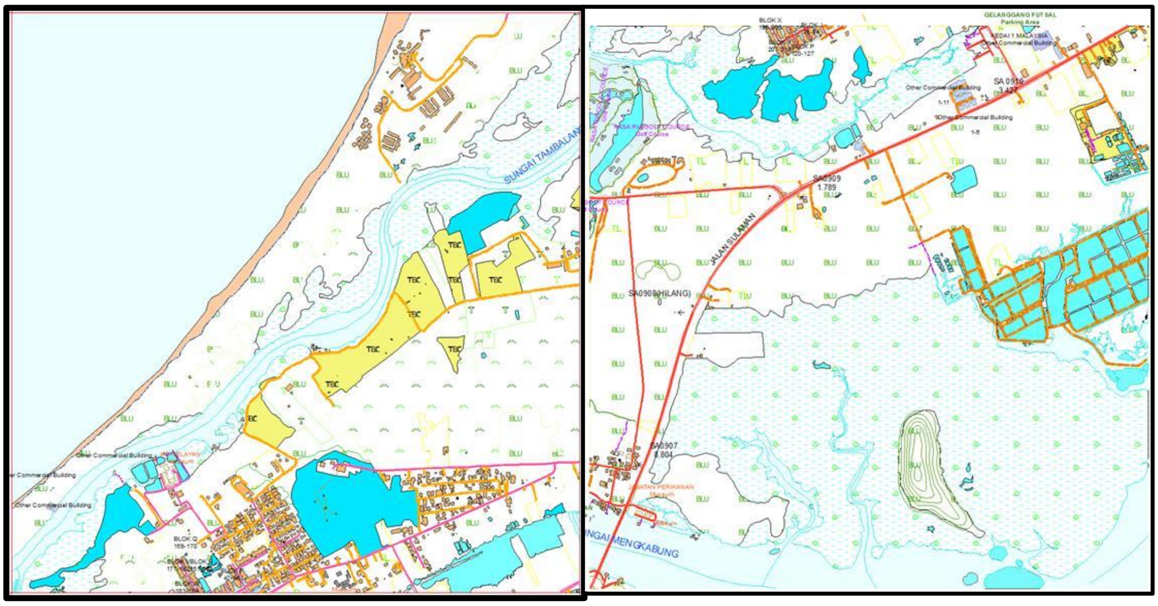

Figure 4: Dataset of the vector map sheet of the study area produced through digital mapping.

5. METHOD AND ANALYSIS

5.1 Working Flow Chart

The research working flow chart can be shown as in Figure 5. Basically the process covers the integration of two raster images, one which was taken out from the orthophoto database and the other was captured at later stage using the UAV platform. The following sub-topics explain the process taken place in the research.

5.2 Layer Stacking

UAV orthophoto that was produced consists of 4 colour bands, i.e. blue, green, red and near-infrared while the MAV orthophoto only have 3 colour bands of blue, green and red. Mosaicking process required that boths images to have similar colour bands in order to obtain a single raster image. Therefore, it is necessitated that UAV orthophoto be treated under a process called spectral subsetting. Software ENVI ver. 5.2 was employed to eliminate the fourth band, near-infrared which was managed through a module termed as layer stacking. This module is useful to create single image file that have new multiband derived from images of various pixels, colour bands and projection value.

5.3 Coordinates Transformation

Coordinate transformation was performed to the UAV orthophoto which has undergone the process of spectral subsetting. Apart from having the same colour band width, mosaicking process is compelled to the requirement that boths orthophoto should be in the same spatial reference system. The coordinates was transformed through the module of 'Project Raster' in ArcGIS ver.10.2. The coordinate system of the UAV orthophoto has therefore been converted to a new RSO East Malaysia with GDM2000 Malaysia as the reference datum.

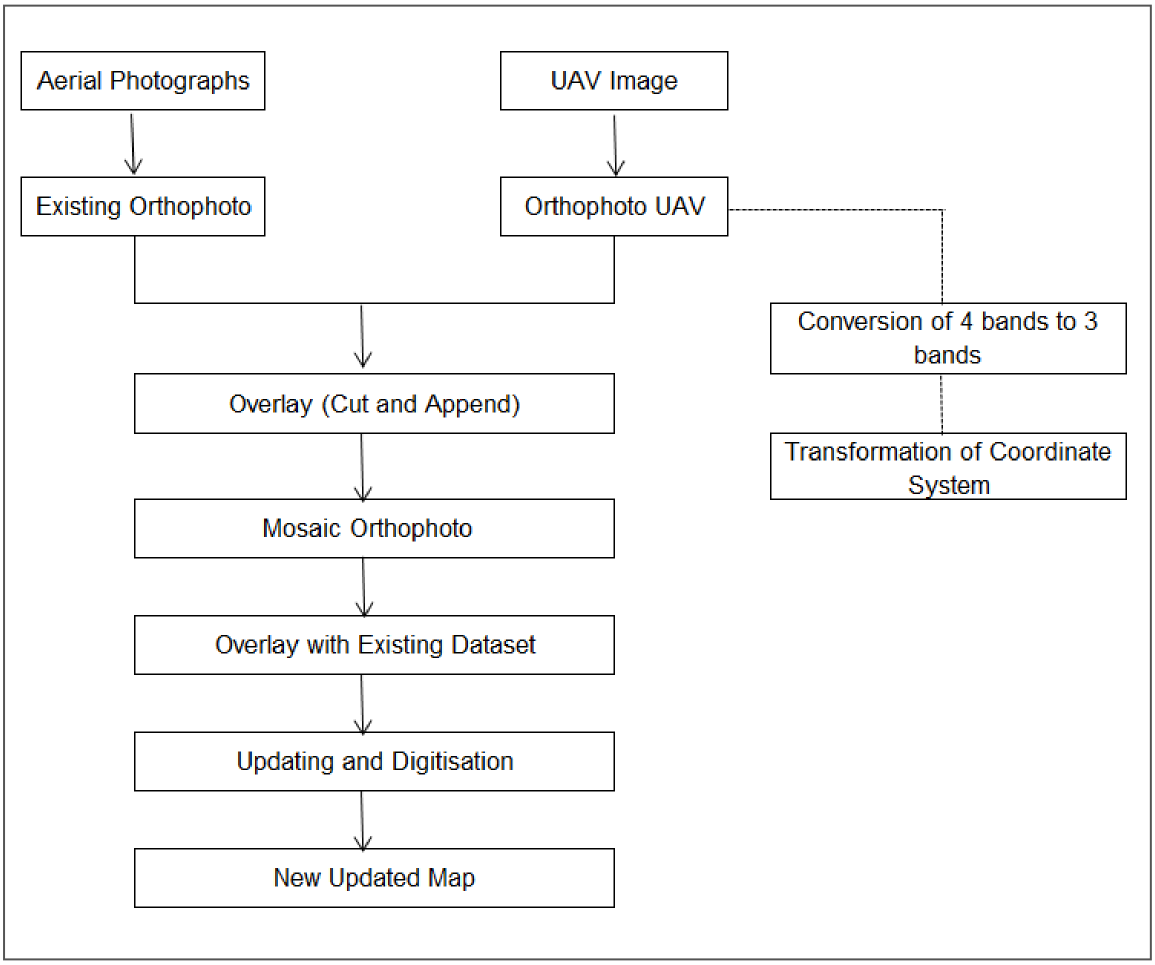

Figure 5: Flow chart of the photograph aerial acquisition and geospatial data updating process.

5.4 Mosaicking Process

Automatic mosaicking process has been utilised commonly in photogrammetry, image processing, and computer graphic. Traditionally, mosaicking is defined as the combining and building of mosaic from several aerial photographs or collection of satellite images. Basically, through the process of mosaicking an updated and new image of an area is formed and generated. Mosaicking was carried out via a module called 'seamless mosaic' in which the wizard-based information of ENVI ver.5.2 would lead user to achieve the production of single raster image. There are four (4) main interfaces utilised in this process; *Main*, *Colour Correction*, *Seamlines/Edge Feathering* and *Export*. Figure 6 indicates the interface of the module seamless mosaic in software ENVI ver.5.2.

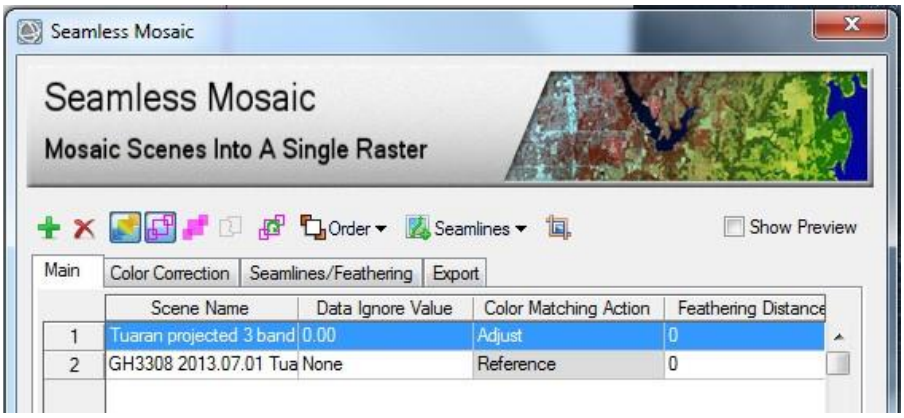

Figure 6: Seamless mosaic interface in ENVI ver.5.2

In photogrammetry, colour correction is applied out when different images with various radiometric characteristics are mosaicked. The output image is required to be consistently harmonised in colour appearance so that spatial analysis can be carried out. The technique of histogram matching was used whereby the automatic transformation resulted in output image that matches a specified histogram. The specified histogram of the known image is identified as being uniformly distributed. Figure 7 shows the interface for colour correction. Seamline is a line formed where the images overlap. Seamline feathering is a process used to streamline the overlapped part of images and eliminate seamlines, and thus image are free from unwanted features that are not theoretically useful. The process also combines pixels at the overlapped border of the images to achieve a good quality mosaicked image. Eventually, the output mosaicked image was saved in ENVI TIFF format.

Figure 7: Colour correction within seamless mosaic module

5.5 Overlay of Existing Dataset

The final ouput of the orthophoto as the result of the integration of the orthophoto from MAV aerial photography and UAV platform image acquisition by way of mosaicking is as shown in Figure 8. The mosaicked orthophoto was used as a background in the overlay process of the existing dataset (map sheet) in the ArcGIS software (Figure 9).

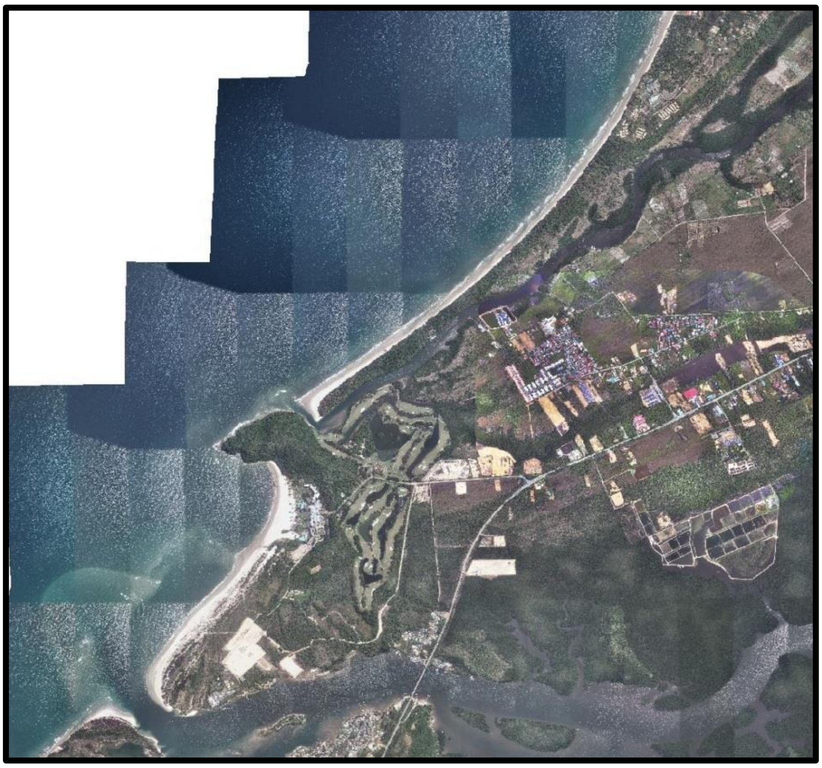

Figure 8: Overlay of the mosaicked image and existing dataset.

Figure 9: Overlay of the mosaicked image and existing vector dataset.

5.6 Digitization

The orthophoto data was then overlaid with map sheet dataset. It is found that few areas has changed due to physical development and are not yet mapped in the department's map sheet. Digitization was carried focussing on area which has revealed features that are visibly comparable when overlaying the two images. There are four major changes detected between them which reflected physical development in the area. The features identified were digitized as new spatial objects that would be used to update map sheets of the department. The table below details out the features digitized and updated.

EXISTING ORTHOPHOTO	MOSAICKED ORTHOPHOTO	DETAILS DIGITIZED
		1. Lake area amended and updated 2. Swamp area amended and updated 3. Mangrove forest amended and updated 4. Cleared land amended and updated 5. Scrub/Shrub (bushes) amended and updated 6. New residential buildings added 7. Substation & Switching Station added 8. Fence Line inserted 9. Irrigation Canal added 10. Culvert added 11. Road Line added 12. Road Edge line added 13. Road Surface polygon added 14. Footpath (Recreational) added

Table 1(a): Comparison of existing orthophoto and mosaicked orthophoto for Area 1 showing details updated.

		1. Grass area amended and updated 2. Forest area amended and updated 3. Mix Traditional Farming added 4. Mixed Annual Crops added 5. Pond area added 6. Residential Building added 7. Building polygon (Unknown) added 8. Road line (Unsealed road) inserted 9. Road Edge line added 10. Road Surface added
		1. River feature amended and updated 2. Pond amended and added 3. Grass area amended and updated 4. Mangrove forest amended and updated 5. Swamp area amended and updated 6. Track line inserted 7. Track Edge inserted 8. Track polygon added 9. Footpath added 10. Building polygon (Unknown) added 11. Tank Polygon (Unknown) added 12. Road line inserted 13. Road Surface added 14. Road Edge added 15. Institutional Building added 16. Residential Building added 17. Irrigation Canal line modified

Table 1(b): Comparison of existing orthophoto and mosaicked orthophoto for Area 2 and 3 showing details updated.

		1. Fence line added 2. Industrial building added 3. Cleared Land amended 4. Building Polygon (Unknown) added 5. Unsealed Road line added 6. Road Edge inserted 7. Road Surface inserted

Table 1(c): Comparison of existing orthophoto and mosaicked orthophoto for Area 4 showing details updated.

5.7 Quantitative Analysis

The final mosaicked orthophoto was analysed for accuracy by comparing coordinates of selected points (feature). The coordinates of matched points from MAV orthophoto and UAV orthophoto were evaluated by associating them with coordinates of Ground Control Point observed using GNSS. Ground Control Point (GCP) data is important for improving absolute accuracy of the products. GCP data was acquired by Global Positioning System (GPS) observation using MyRTK Net correction. Few GCPs have been observed at locations scattered throughout the study area. These GCPs would be used in mapping software for improving orthophoto products at the later stage.

There were 13 GCP point features utilised to evaluate the mosaicked orthophoto. GNSS observation by fast static method were carried on 13 Februari 2017 utilising Trimble 5700 GPS equipment. Observation were made for 30 minutes and correction of the observed coordinates was based to UMS CORS Station in Kota Kinabalu, Sabah. Figure 10 shows the distribution of the GCPs and features point selected for comparison.

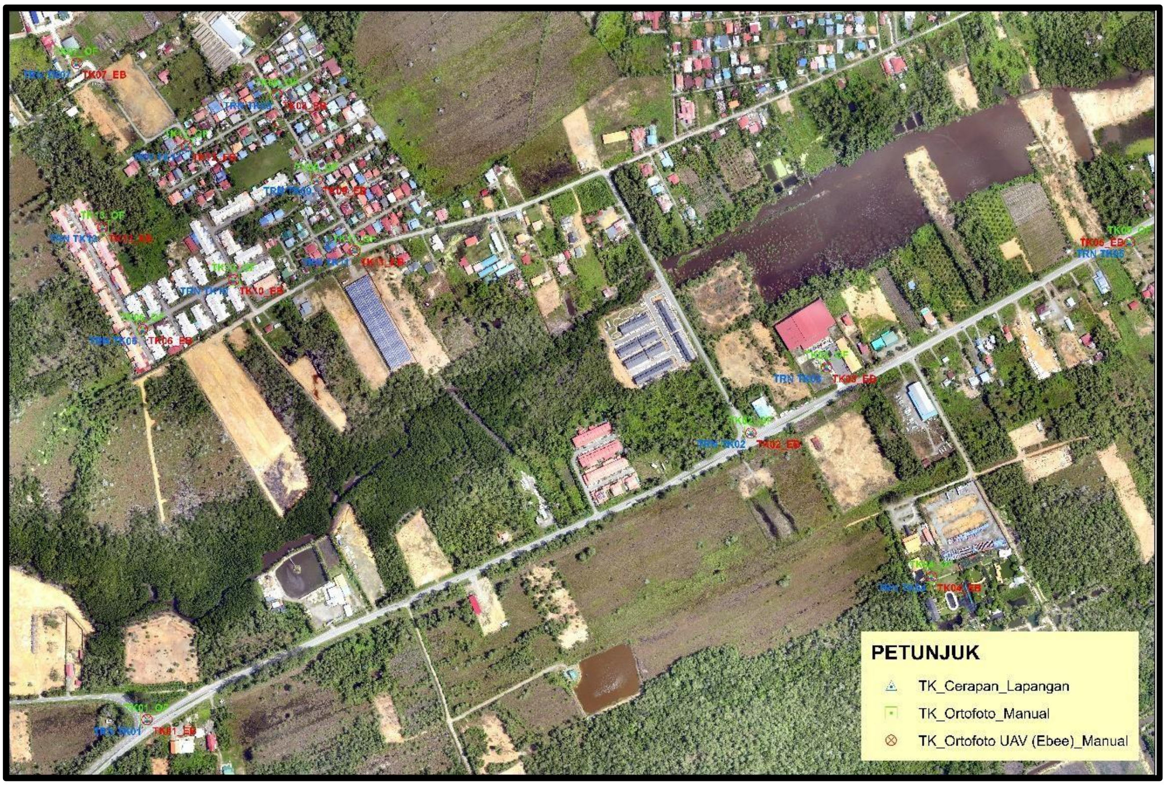

Figure 10: The distribution of the GCPs and selected features points.

The result of the analysis is illustrated in Table 2. Standard deviation of the differences between the two images coordinate are acceptable in the mapping accuracy of features to be plotted at large scale of 1: 10,000. The planimetric displacement allowable for smaller than 1: 20,000 scale map is 1/30 inches (0.85mm), in accordance to the JUPEM’s Procedure of Survey for Map Accuracy. RMSE has shown high value (1.416) when comparing coordinates of UAV versus MAV image.

Station No.	Coordinates of Orthophoto MAV		Observed Coordinates		Coordinates of Orthophoto UAV		Difference of Coordinates between Observed and Orthophoto MAV			Difference of Coordinates between Observed and Orthophoto UAV			Difference of Coordinates between Orthophoto MAV dan Orthophoto UAV		
	North	East	North	East	North	East	North	East	Magnitude	North	East	Magnitude	North	East	Magnitude
TK01	681746.128	718372.504	681745.442	718372.72	681745.943	718373.086	-0.686	0.216	0.719	-0.501	-0.366	0.620	0.185	-0.582	0.611
TK02	682247.446	719426.712	682246.882	719426.862	682246.017	719427.109	-0.564	0.150	0.583	0.865	-0.247	0.900	1.429	-0.397	1.483
TK03	682361.859	719559.253	682361.232	719559.423	682360.340	719559.493	-0.627	0.170	0.650	0.892	-0.070	0.895	1.519	-0.240	1.538
TK04	681996.365	719742.326	681995.754	719742.317	681994.989	719742.723	-0.611	-0.009	0.611	0.765	-0.406	0.866	1.376	-0.397	1.432
TK05	682579.787	720088.241	682579.076	720088.259	682578.622	720088.294	-0.711	0.018	0.711	0.454	-0.035	0.455	1.164	-0.053	1.165
TK06	682427.473	718364.931	682426.837	718364.784	682426.494	718365.566	-0.636	-0.147	0.652	0.343	-0.782	0.854	0.979	-0.635	1.167
TK07	682891.892	718249.253	682891.295	718249.394	682890.834	718250.523	-0.597	0.141	0.613	0.461	-1.129	1.220	1.058	-1.270	1.653
TK08	682837.963	718599.391	682837.22	718599.523	682836.402	718600.079	-0.743	0.132	0.754	0.818	-0.556	0.989	1.561	-0.688	1.706
TK09	682689.482	718669.372	682688.711	718669.377	682688.026	718670.060	-0.771	0.005	0.771	0.685	-0.683	0.967	1.455	-0.688	1.610
TK10	682514.375	718523.851	682513.74	718523.89	682513.184	718524.618	-0.635	0.039	0.636	0.556	-0.728	0.916	1.191	-0.767	1.416
TK11	682565.224	718735.666	682564.382	718735.634	682564.060	718736.275	-0.842	-0.032	0.843	0.322	-0.641	0.717	1.164	-0.609	1.314
TK12	682748.088	718441.527	682747.513	718441.623	682746.659	718442.321	-0.575	0.096	0.582	0.854	-0.698	1.103	1.429	-0.794	1.634
TK13	682605.678	718295.359	682605.162	718295.469	682604.646	718296.179	-0.516	0.110	0.528	0.516	-0.710	0.878	1.032	-0.820	1.318
Average							-0.213	0.022	0.216	0.176	-0.176	0.284	0.389	-0.198	0.451
Value Maximum							0.000	0.216	0.843	0.892	0.000	1.220	1.561	0.000	1.706
Value Minimum							-0.842	-0.147	0.000	-0.501	-1.129	0.000	0.000	-1.270	0.000
Std Deviation									0.316			0.424			0.670
RMSE									0.671			0.895			1.416
% Precision									100%			100%			100%

Table 2: Analysis of images accuracy captured by MAV and UAV as compared to observed true coordinates using GNSS

5.8 Ground Sample Distance (GSD)

Predominantly, it was established that GSD of the UAV orthophoto (mosaicked) resembles the GSD of the MAV orthophoto, which is 10 cm. Similarly, the result of the histogram matching has shown that colour compositions of both orthophoto are almost comparable as seen in Figure 11.

Figure 11: The sizes of GSD in the UAV and MAV orthophotos

6. CONCLUSION

The objective of this paper is to study whether orthophoto image from UAV acquisition can be appropriately used to update existing orthophoto images previously generated from MAV platform. The use of UAV was also investigated in generating an orthophoto mosaic for map updating. The deployed UAV has successfully captured imageries which in turn used to generate orthophoto over the test area. The result using Pix4UAV software showed that the UAV orthophoto production conformed the accuracy requirement for town or large scale map updating or production. In this study, the UAV orthophoto was subsequently integrated with existing MAV orthophoto previously produced from normal aircraft aerial mapping. The integration by means of mosaicking of both orthophotos was carried out very well and a new mosaicked orthophoto was evidently created. Seemingly, the final mosaicked orthophoto has provided source of data that is accurate and fitting for map updating.

Map updating process and digitization of features has seen a quick result for a large scale map of 1:5000 around apparent area of changes and physical development be mapped when compared to conventional way of digitizing the entire spatial features using the newly captured orthophoto. A traditional method of acquiring aerial photo through aircraft platform is costly and not economical for map updating of a small area. It is found that UAV platform is suitable for ‘smaller region’ map updating in JUPEM. Manned aircraft is mainly suitable for aerial mapping around vast region for the production of map at 1:25000 scale or for the initiation of base map production.

UAV platform has provided a method which is cheap and quick way to achieve aerial photographs with high resolution and quality picture. Capability to fly low below the cloud is rewarding comparing to conventional aerial mapping by normal aircraft. However, due to the smaller size of image footprint over a crowded town area, the images captured would be bigger in size (4-8 Megabytes per image) which needs a bigger storage and time consuming for processing part. Basically, about 400-500 images were being captured in a UAV aerial photography.

Weather is another factor that needs to be seriously taken into consideration while performing the mission planning. It is recommended the operation is carried out between 0900 to 1100 and 1400 to 1700 for better quality pictures. Wind speed also plays a significant role in the UAV operation and proper planning is required. Therefore it is important that the operator is always aware to the weather forecast so that the planning would be more effective.

It is not economical to conduct a conventional aerial photo mission due to the size of the Area of Interest (AOI) which is generally less than 1 km^2. Furthermore, the location of the AOI is normally far from the airport which might imply the operational cost would be high. Suitability area for taking off and landing is very crucial to the fixed wing UAV operation. It is quite challenging to find the area of at least 300 meters long and 150 meters wide that is nearer to observation areas.

7. SUMMARY

UAV is a new platform that can be used to capture imagery data and it is the alternative method to conventional aircraft platform. The UAV system contributed significantly to the rapid acquisition of imagery data to support various applications. The introduction of the UAV system would expedite the geospatial transformation program in order to meet the demand of spatially enabled forces, government and society. Few points to summarise are tabled as in the table below.

No.	**Element**	**Summary (Comparison)**	
		Manned Aircraft	**eBee RTK UAV**
1.	Installation	Very expensive; 1. Aircraft rental 2. Camera systems 3. Customs aircraft 4. Aviation law	Inexpensive; 1. Ultra-light weight radio control aircraft 2. Digital compact camera
2	Operations	Very expensive; 1. Need for pro pilot 2. Airport runway (takeoff/landing) 3. Camera system calibration	Inexpensive; 1. Mobile 2. Do not need for runway 3. Easy setup
3	Area	1. Cost effective for large mapping area bad for small area 2. Cost per km² is high 3. Processing cost per km² is cheaper **from Saip, (2016)**	1. Cost effective for small area and bad for large area 2. Cost per km² is cheaper 3. Processing cost per km² is slightly higher **from Saip, (2016**
4	Application	For mapping small scale base map (scale up to 1:50,000)	1. Updating large scale map 2. Boundary reconnaissance 3. Natural disaster monitoring

Table 3: Summary for advantages of UAV vs MAV in aerial mapping

8. FUTURE PLAN

The work will subsequently be continued to the rest of 2017 and 2018 with the evaluation on its capability on performing fast data capture and updating of place-based data. In addition JUPEM is in the process of procuring another UAV system with higher capability and more sophisticated mode of operations. It will be a vertical take-off type of UAV that will carry a bigger payload in the form of a medium format metric camera and which promises significantly longer flight duration and higher resolution image capture. Moreover, JUPEM is looking forward into the online capability of directly update 'changed area' part of the map up to the cartographic level which is normally carried out in the Division of Cartographic and GIS in JUPEM. This interoperable functionality would enhance fast mapping as the map area for updating is small and localised which only require a small scale exercise using UAV.

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Biography

Sr Dr Zainal A MAJEED **(zainal.amajeed@jupem.gov.my)** has been working in the government ever since graduated and involved in GIS, remote sensing, Spatial Data Infrastruture , engineering survey and mapping technology. Currently, he is the Director of JUPEM Selangor state with previous (2 months ago) work in the Mapping Policy and Coordination Division, JUPEM Head Quarter. He has achieved master degree in the USA and doctorate degree in United Kingdom, being Member of Institute of Chartered Surveyor UK, being registered as a Professional Licensed Surveyor under Land Survey Act Malaysia and a Fellow member of the Royal Institute of Surveyor Malaysia (RISM).

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