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Accuracy assessment of topographic mapping using UAV image integrated with satellite images

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Accuracy assessment of topographic mapping using UAV image integrated with satellite images

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Abstract: Unmanned Aerial Vehicle or UAV is extensively applied in various fields such as military applications, archaeology, agriculture and scientific research. This study focuses on topographic mapping and map updating. UAV is one of the alternative ways to ease the process of acquiring data with lower operating costs, low manufacturing and operational costs, plus it is easy to operate. Furthermore, UAV images will be integrated with QuickBird images that are used as base maps. The objective of this study is to make accuracy assessment and comparison between topographic mapping using UAV images integrated with aerial photograph and satellite image. The main purpose of using UAV image is as a replacement for cloud covered area which normally exists in aerial photograph and satellite image, and for updating topographic map. Meanwhile, spatial resolution, pixel size, scale, geometric accuracy and correction, image quality and information contents are important requirements needed for the generation of topographic map using these kinds of data. In this study, ground control points (GCPs) and check points (CPs) were established using real time kinematic Global Positioning System (RTK-GPS) technique. There are two types of analysis that are carried out in this study which are quantitative and qualitative assessments. Quantitative assessment is carried out by calculating root mean square error (RMSE). The outputs of this study include topographic map and orthophoto. From this study, the accuracy of UAV image is ± 0.460m. As conclusion, UAV image has the potential to be used for updating of topographic maps.

1. Introduction

Topographic map is a detailed and accurate graphic representation of cultural and natural features on the ground such as streams lakes, dams, swamps, roads and tracks, buildings, vegetation, defense and forestry reserves. The important in generation topographic maps are information contents, geometric accuracy and contour map [1,2]. According to [3], a map shows elevations above sea level and surface features of the land by means of contour lines. Contour lines are lines drawn on a map connecting points of equal elevation. Moreover, large scales map need more details and information contents compared to small scales. In urban areas, more details can be available and information contents are necessary as a reference for user. High quality images, high resolution images, sensor types, pixel size, spectral range and the number of spectral bands are important for object identification [4].

Cloud cover is one of the hindrances for mapping when using aerial photographs and satellite images. According to [5], cloud cover is a barrier when the satellite imagery is used in the tropical region. Moreover, many valuable data and information lost due to the cloud cover. This will affect the process of updating and mapping topographic map. Therefore, the use of UAV will be able to overcome this problem by integrating UAV images on satellite images. Furthermore, this method also could be used for updating features in topographic mapping.

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1.1. Unmanned Aerial Vehicles (UAV)

Unmanned Aerial Vehicles or UAV refers to an aircraft without an on-board human pilot. UAVs can be remotely controlled aircraft which is flown by a pilot at a ground station or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems [5]. Moreover, UAV is often used in military but now UAV is also used in civil purpose such as mapping, facility management, construction and industrial applications. UAV has low manufacturing and operational cost of the systems, the flexibility of the aircraft to adjust according to user requirements and the elimination of the risk of pilots in difficult missions [6]. The continuous trend in the miniaturisation of electronics enables the production of smaller UAV while simultaneously equipping them with cameras and other sensors to support aerial geo-data collection [7].

Furthermore, the advantage of using UAV include it can fly in inaccessible area without endangering human life, such as volcanic, mountains, flood plains, lakes and the scene of an accident. The system also utilized lower operating costs, less expensive, small and easy to operate [8]. UAV employs lightweight integrated GNSS and inertial navigation systems. Accuracy of UAV can be obtained with decimeter level and the acquired orientation parameters can reduce the number of ground control points needed for post processing [9]. There are several criteria in choosing UAV systems such as size and weight of payload, stability and vibration, number of people needed for launch and control, level of piloting skills, flight time, range, minimum airspeed, minimum size of takeoff and landing area and safety [7].

1.2. High resolution satellite images

The use of high resolution satellite images becomes more useful and convenient for mapping than using aerial images. Moreover, it has opened a new field of applications and has created a competition to the use of large scale aerial images. Aerial images are important as a source of information for many years ago. According to [10], when using aerial image the acquisition cost is expensive, require more time in processing data and it is not cost-effective to map a very large area. Therefore, the use of this image is decreasing. The resolution is sufficient for the generation of orthoimages at a scale 1:8 000 up to 1: 5 000. EROS-A1, IKONOS and Quickbird are the three civilian satellites, which provide images with the highest resolution; the sensors can generate 1m, 2m and 0.6m panchromatic images, respectively [11]. Moreover, pixel size of 0.005mm up to 0.010mm in map scale is required in mapping. It is important for higher requirements of details in larger scale maps. The great resolution of IKONOS is 1m and it is appropriate for map scale of 1: 10 000, whereas 0.61m of QuickBird appropriate to map scale of 1: 6 000 [12]. Geometric potential, scale, information contents and image resolution are very important for mapping. It is important for how many details shall be included in the map based on the area. For urban area, the details will be more compact compared to rural areas.

1.3. Ground Control Point (GCP)

Ground control points are points on the ground surface of earth where the position accurately known or refer to the reference datum and easily identified and related through photo images. GCPs were established using rapid static GPS method. Time taken for observation of each GCPs point is approximately 15 minutes. It is established on permanent object on the ground surface such as street corners, drains edges, wall corners, cross roads and others. This method is used to overlapping between two or more UAV images in order to produce mosaic orthophoto and topographic map. According to [13], ground control points are used to overlapping the images with the horizontal and vertical elevation positions in (X, Y and Z). The selection of control points is very important because it will affect the overlap between the two images. At least five or more control points are needed for one image that is located in each corner and in the middle of the image. This will avoid distortion occurs when the images are overlaid. Indeed, establishment of GCPs are very important stage to be done in the photogrammetric mapping [14].

1.4. Root Mean Square Error (RMSE)

RMSE is used to measure difference values between observed coordinates and reference coordinates. The RMSE result shows the accuracy values of the dataset and it can be calculated using the following equation 1:

$$RMSE = \sqrt{\frac{\sum (N_i - N_j)^2}{n}} \qquad (1)$$

where N_i is observed values, N_j is reference values and n is number of points

2. Study Area

The study area is around Universiti Teknologi Malaysia Johor Bahru. Moreover, some of the area in QuickBird images was covered by cloud as shown in figure 1. Figure 2 shows the UAV images of the research area that will overlap with QuickBird Image.

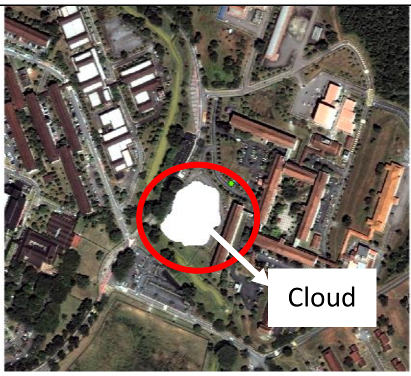

Figure 1. QuickBird Image of research area at UTM campus, Johor Bahru

Figure 2. Mosaic orthophoto UAV images of UTM

3. Methodology

In this study, the research methodology adopted is shown in figure 3. There are five (5) phases involved in this study. Phase 1 involves preliminary study. The planning stage is in phase 2. In phase 3, UAV system was used to acquire aerial images of the study area. RTK-GPS technique will carried out for establish GCPs and CPs. Phase 4 is data processing, the software use are ERDAS Imagine 8.6 and ArcGIS 9.2. Processing steps using ERDAS consist of interior orientation, exterior orientation, aerial triangulation (AT), digital terrain model (DTM), orthophoto and mosaic image. In ArcGIS, processing consist of georeference, define coordinate, overlapped image, database and others. Lastly, phase 5 is data analysis.

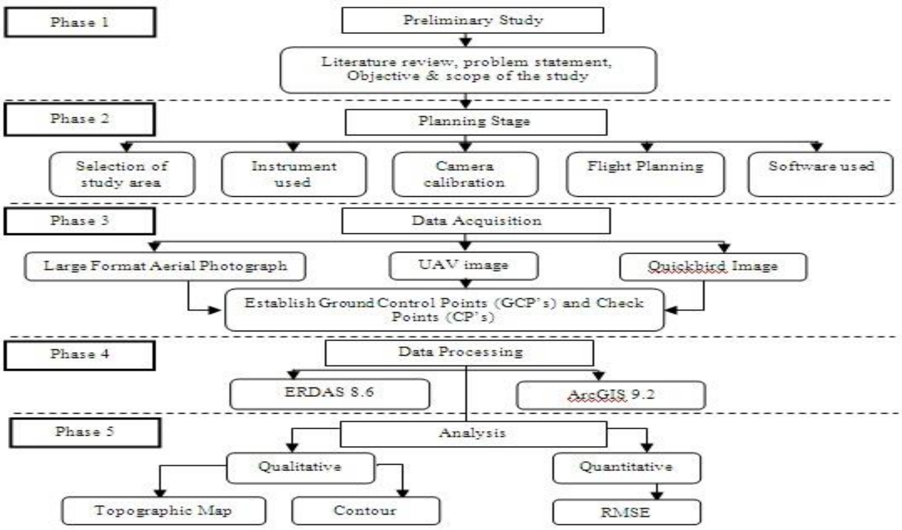

Figure 3. Flow chart of research methodology

4. Results

Figure 4 shows the footprint of UAV Images with control points, check points and tie points that are used for geometric adjustment using ERDAS software. The area covered by cloud was visible when the images are overlapped between the QuickBird and UAV images as shown in figure 5. Figure 6 shows DTM of the study area.

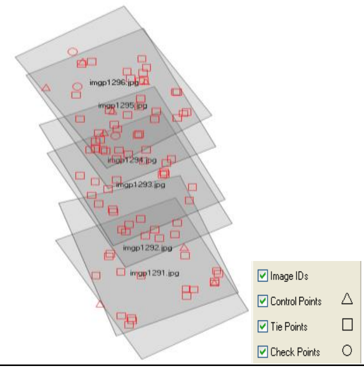

Figure 4. Footprint of UAV Images in Erdas software

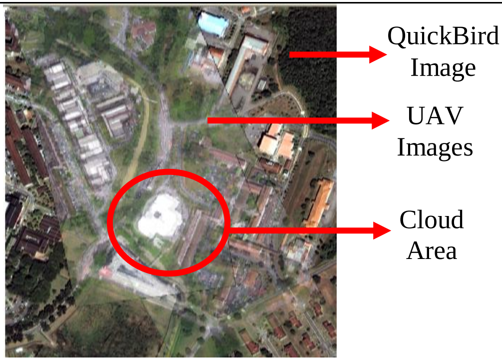

Figure 5. Overlapping between QuickBird and mosaic orthophoto UAV Images

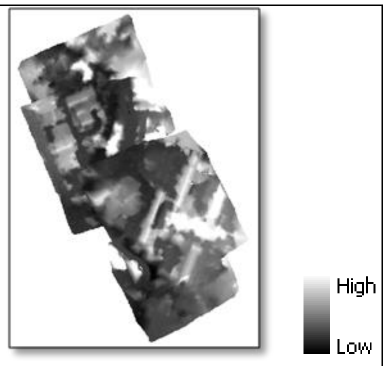

Figure 6. DTM of the study area

5. Analysis

There are two types of analysis that were carried out in this study which are quantitative and qualitative assessments. The following sections discussed about the each assessment.

5.1. Quantitative analysis

Quantitative analysis is about the numerical quantity that can be done by calculation or computation of the data. Quantitative assessment was carried out by calculating root mean square error (RMSE). In this study, quantitative analyses are carried out using two methods.

5.1.1. Comparison coordinates of check points using RTK-GPS and ERDAS. In ERDAS software, stereo analyst module was used to obtain the coordinate of check points (CPs) from UAV images and the root mean square error (RMSE) is computed for this analysis. Table 1 shows the comparison of check points and the RMSE for coordinate X and Y is ± 0.2635m and ± 0.4125m, respectively. For coordinate Z the RMSE is ± 0.7043m. The average RMSE is ± 0.460m. The results show that the value of RMSE is less than 1m. The smaller RMSE indicates higher accuracy.

Table 1. Coordinates of check points using RTK-GPS and ERDAS

Check Points	RTK-GPS			ERDAS 8.6			Difference of Coordinate		
	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	ΔX (m)	ΔY (m)	ΔZ (m)
CP11	627426.779	172512.239	19.054	627426.743	172512.825	19.206	0.0359	-0.586	-0.152
CP12	627457.496	172460.957	21.960	627457.385	172461.519	21.167	0.111	-0.563	0.793
CP13	627344.937	172650.282	16.155	627344.364	172650.759	16.424	0.573	-0.478	-0.269
CP16	627438.248	172261.483	18.854	627438.236	172262.845	17.691	0.013	-1.362	1.163
						RMSE	± 0.264	± 0.413	± 0.704
						Average	± 0.460		

5.1.2. Comparison coordinates of GCP using RTK-GPS and ArcGIS. In this method, GCPs were randomly selected as a sample for the analysis. The comparison is between GCPs of UAV images established by GPS and QuickBird image by using ArcGIS software. The two source images were overlapped in ArcGIS software. The accuracy of the overlapping between the two sources of images are shown in Table 2. The average RMSE is ± 0.906m.

Table 2. Comparison coordinates of GCP using RTK-GPS and ArcGIS

Points	RTK-GPS		QuickBird (ArcGIS)		Difference	
	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)
GCP3	627478.721	171896.670	627481.013	171898.307	-2.292	-1.637
GCP7	627575.249	172200.259	627575.309	172201.849	-0.06	-1.59
GCP6	627488.357	172209.071	627489.972	172210.155	-1.615	-1.084
GCP9	627420.617	172582.440	627422.227	172583.424	-1.61	-0.984
GCP10	627403.085	172521.045	627405.241	172522.407	-2.156	-1.362
GCP21	627319.745	172823.433	627319.784	172825.392	-0.039	-1.959
GCP24	627234.237	172927.948	627232.621	172928.908	1.616	-0.96
				RMSE	± 1.432	± 0.379
				Average	± 0.906	

5.2. Qualitative assessment

Qualitative assessment is about visualization of the map by digitizing features in the images. The analysis is carried out by comparing digitized features from QuickBird Image using ArcGIS software and UAV Images using stereo analyst module in ERDAS software as shown in figure 7. From figure 7, it is clear that there is a slight difference in term of the buildings. These differences occur due to errors in data acquisition and processing.

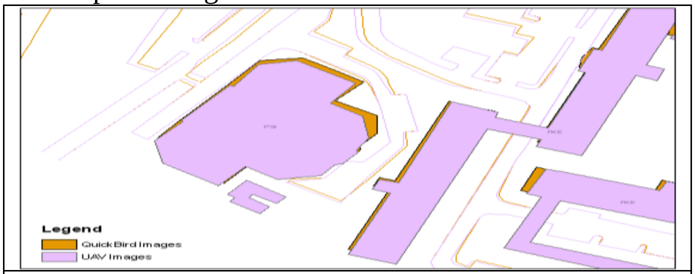

Figure 7. Results of the overlapped features

6. Conclusion

Based on the results and analyses obtained from this study, it can be concluded that the UAV images are suitable replacement for cloud covered area and for updating topographic map. UAVs are becoming increasingly popular as photogrammetric platforms for civilian use due to their relatively low cost and ease of operation. They have the ability to provide accurate data at a higher ground resolution, more economic cost, and more importantly UAV images are cloud free.

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