ISSN 2278-3091
Volume 9, No.1.1, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse5691.12020.pdf
https://doi.org/10.30534/ijatcse/2020/5691.12020

Large Scale Topographic Map Comparison Using Unmanned Aerial Vehicle (UAV) Imagers and Real Time Kinematic (RTK)

Mohd Yazid Abu Sari[1*], Asmala Ahmad[2], Yana Mazwin Mohmad Hassim[3], Shahrin Sahib[4], Nasruddin Abu Sari[5] and Abd Wahid Rasib[6]
[1,2,4]Faculty of Information and Communications Technology, Universiti Teknikal Malaysia Melaka (UTeM),76100 Durian Tunggal Melaka, Malaysia
[3]Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Batu Pahat, Johor, Malaysia
[5]Anjung Technology Sdn Bhd, 75450 Ayer Keroh, Melaka, Malaysia
[6]TropicalMap Research Group, Department of Geoinformation, Faculty of Geoinformation and Real Estate, Universiti Teknologi Ma-laysia, 81310 Skudai, Johor. Malaysia.
* mdyazid.as@gmail.com

ABSTRACT

Large scale topographical mapping is important in geospatial industries in providing high resolution 3D geospatial data sources. The field of aerial photogrammetry also plays an important role in the surveying scope and map production. Nowadays, the use of Unmanned Aerial Vehicle (UAV) platform is a quick way for low altitude aerial data acquisition for mapping. For collecting ground details data at the land-scape level, real time kinematic global positioning system (RTK GPS) is a useful tool for Ground-based topographic mapping. RTK GPS is mobile, collects data quickly at field, and measures elevation within an accuracy of 1 – 5 cm. This work aims to do a comparison of topo-graphic map generated by UAV imagers and by RTK GPS in term of accuracy. The study was conducted using UAV with high resolution non-metric digital compact camera while the ground control point were established using static observation method and ground detail survey using RTK observation method. Vertical accuracy for digital elevation model (DEM) obtained from this study was 8.015 cm at the altitude of 116 m.

Key words : Data Acquisition; Large scale topographic map; Real Time Kinematic; Unmanned Aerial Vehicle; 3D view

1. INTRODUCTION

Large scale topographical mapping is important in geospatial industries in providing high resolution 3D geospatial data sources and has been on high priority for supporting the nationwide development e.g. details spatial planning. Usually large scale topographical mapping relies on conventional aerial survey campaigns in order to provide high resolution 3D geospatial data sources. Widely growing on a leisure hobby, aero models in form of the Unmanned Aerial Vehicle (UAV) bring up alternative semi photogrammetric aerial data acquisition possibilities suitable for relatively small Area of Interest (AOI) i.e. < 5,000 hectares [1]. Topographic landscape map is a detailed and accurate graphic representation of natural features on the ground such as roads and tracks, buildings, contours, elevation, plants, marsh, pipelines, power transmission lines, forestry reserves and many others. The important attribute in generating topographic maps are information contents, geometric accuracy and contour map. There are various methods that can be used in carrying out topographic mapping applications. Among these methods are remote sensing, UAV, GPS and other conventional methods. Topographic maps are a kind of map that was marked by a large scale and detail, usually using contour lines in modern mapping.

1.1. Unmanned Aerial Vehicle (UAV)

Nowadays, Unmanned Aerial Vehicle (UAV) have attract a lot of attention from various field of study such as archaeology [2], agriculture [3] and mining [4]. 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 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 [5]. The usages of Unmanned Aerial Vehicle (UAV) are started within the military and its main purposed is for monitoring and maintaining the country border from any threat. In addition it is also used for surveillances and confirming any terrorist activities that may occurred within the country. Furthermore, due to the advancement of technology unmanned aerial vehicle (UAV) had become a multi purposed tool for collection of data. Besides that, unmanned aerial vehicle (UAV) data can be used to produce various type of product such as mapping in the close range domain [6].

Recently, the usage of UAV to generate 3D modelling had been widely used; this is because UAV provide high-resolution images with resolution in millimetre. Furthermore, the images that produce from the UAV can be used to obtain a surface reconstruction of a realistic 3D model by using high overlap images and various type 3D modelling software that can be obtained in the market [7]. The usage of

UAV platform to generated 3D model is more convenient because it is affordable and easy to use. In addition, with the improvement in technology, embedded autopilot UAV have been manufacture globally, that enables user to use UAV without any prior knowledge and less interaction during the process of flight [8].The generation of 3D model using UAV is more preferable compare to conventional method which is ground survey.

Before the invention UAV, the generation of 3D model and 2D map of the environment area is mainly using ground survey. Several procedure need to follow in order to produce a 3D model of the interested area, the procedure is more complicated and take a long period of time before the 3D model can be generated. Hence, this is the mainly reason why UAV is more convenient for generated 2D and 3D maps [8], compare to ground survey method. This study is carried out, in order to establish the relationship between generated 3D models using UAV data by using 3D software and generated 3D models by using ground survey.

1.2. Real Time Kinematic (RTK)

GPS is often labour intensive, sometimes involves surveyors working in hazardous environments and the completeness of the data captured often depends on the time allotted to the survey project [9]. GPS also has it disadvantage such as no signal in certain area because of it is covered with buildings or unreliability to locate the location [10]. GPS geographic data collection methods are accurate enough to design civil engineering and architectural projects. Although GPS data is highly spatially accurate in both absolute and relative terms it completely falls down in richness of data. Each line, point and polygon must be described by textual means in order to communicate its geographic meaning. The GPS observation has many methods such as static, rapid static and real time kinematic (RTK) observation. RTK is used for geophysical and engineering tools [11]. One the factor that differentiates these methods is the observation time. The static observation requires about an hour or more, rapid static requires about fifteen minutes to half an hour while real time kinematic requires about 2 minutes observation time. The instruments for static and rapid static are more alike while real time kinematic (RTK) more like mobile device and easy to carry on the site [12]. The accuracy of static method is the most accurate which can achieve about millimetre accuracy level. Rapid static method and real time kinematics can achieve about centimetre accuracy. Static and rapid static methods usually apply for post processing where it used the data from the GPS monument network. Real time kinematic methods can be divided into two networks namely single based and network based. The single based observation only requires one known GPS station to send the correction to the rover station while network based observation requires multi network known as GPS station to send the data correction to the rover station. In this study, network RTK observations that used to survey detail in study area.

1.3. Ground Control Point (GCP)

The selection of GCP is based on the specific characteristics such as location, identification, control point distribution and types of objects selected. The location must be in proper geometry location to accurately reference at the study area. The distribution of GCP must be located well because it will affect the accuracy and precision of correction. The identification of GCP is most critical due to the resolution of the images. The GCP must be in well distributed and the absolute geometric which minimum has four points. The types of object selected can be identified as the natural or human made object and it must be clear on the image acquired. To choose the right spots, it is safe to pick the attractive spot that easily visible and immobile on that area such as road, tree, and street lights. This will avoid distortion occurs when the images are overlaid. Indeed, establishment of GCPs very important stage to be done in the photogrammetric mapping [13].

1.4. Root Mean Square Error (RMSE)

The root mean square error (RMSE) has been used as a standard statistical metric to measure model performance in meteorology, air quality, and climate research studies [14]. RMSE is used to measure difference values between observed coordinates and reference coordinates [15]. The RMSE result shows the accuracy values of the dataset and it can be calculated using equation (1).

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

Where N_i is the observed value, N_j is the reference value and n is the number of points.

2. RESEARCH APPROACH

2.1. Study Area

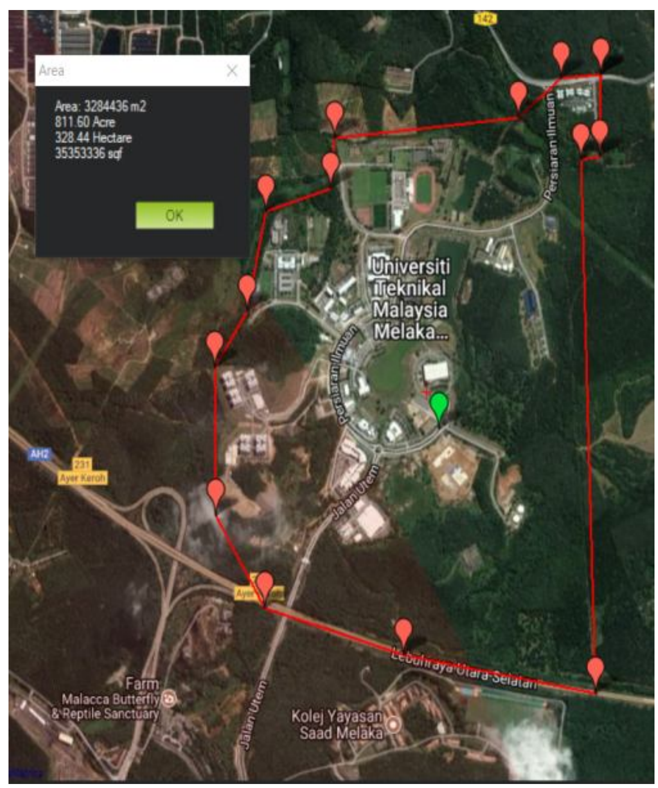

Figure 1: UTeM area

The study area is conducted in Universiti Teknikal Malaysia Melaka (UTeM) located in Durian Tunggal, Alor Gajah, Malacca, Malaysia. Set within 766 acres of lush verdant landscape boasting state-of-the art facilities in all its seven faculties.

2.2. Equipment

2.2.1. Topcon GR-5

This instrument provides accurate and precise positioning by tracking visible satellites when the power is turned on. After the receiver locks on four satellites, its absolute position in WGS-84 and the time offset between the receiver clock and GPS time are computed. Static method was done to collect the control points in the study area.

Figure 2: Topcon GR5 and Handheld

2.2.2. Quadcopter

This is a type of remote controlled flying device that has four propellers. They are arranged in a circular shape above the main body of the quadcopter. This body often carries a camera and features two legs shaped like skis. These skis allow the device to be stable when it lands. The four propellers give this craft more maneuverability and flying power. The craft can fly very steadily and reach higher altitudes.

Figure 3: Kumbang v2 UAV and remote control for the UAV

The specification of multirotor UAV is shown as in Table 1.

Table 1. Specification of Kumbang v2 UAV

Criteria	Specification
Main rotor blade length	700 mm
Length	289 mm
Width	289 mm
Height	200 mm
Brushless motor	Wk-ws-28-008a
Brushless esc	Wst-15a (g/r)
Receiver	Rx703
Main controller	Devo-m
Flight time	35 minutes

2.2.3. RGB Camera

The RGB camera which has been used in this work is Canon Powershot xs260 RGB digital camera shown as in Figure 4. This RGB camera has effective pixels of approximate 12.1 megapixels. The details specification of Canon Powershot xs260 RGB digital camera is described as in Table 2.

Figure 4: Canon Powershot XS260 Camera

Table 2. Specification of Canon Powershot XS260 Camera

Criteria	Lens
Focal Length	4.5 – 90.0 mm (35 mm equivalent: 25 – 500 mm)
Zoom	Optical 20x Zoom Plus 39x Digital Approx. 4.0x (with Digital Tele-Converter Approx. 1.5x or 2.0x and Safety Zoom[1]). Combined Approx. 80x
Maximum f/number	f/3.5 – f/6.8
Construction	12 elements in 10 groups (1 UA lens, 2 double-sided aspherical lens)
Image Stabilisation	Yes (lens shift-type), 4-stop. Intelligent IS
Effective Pixels	Approx. 12.1M

2.3. Methodology

In this study, the research methodology is divided in five (5) phases. Phase 1 involves preliminary study; it consists of literature review to get information about the research. In phase 2, the planning project design and collect data. UAV system was used to acquire aerial images of the study area. RTK-GPS technique will carried out for establish GCPs. Phase 3 is data processing, the software use are Pix4D, Trimble Total Control and AutoCAD to produce a Topographic Mapping. All the process data do the analysis in phase 4. And the last phase is conclusion.

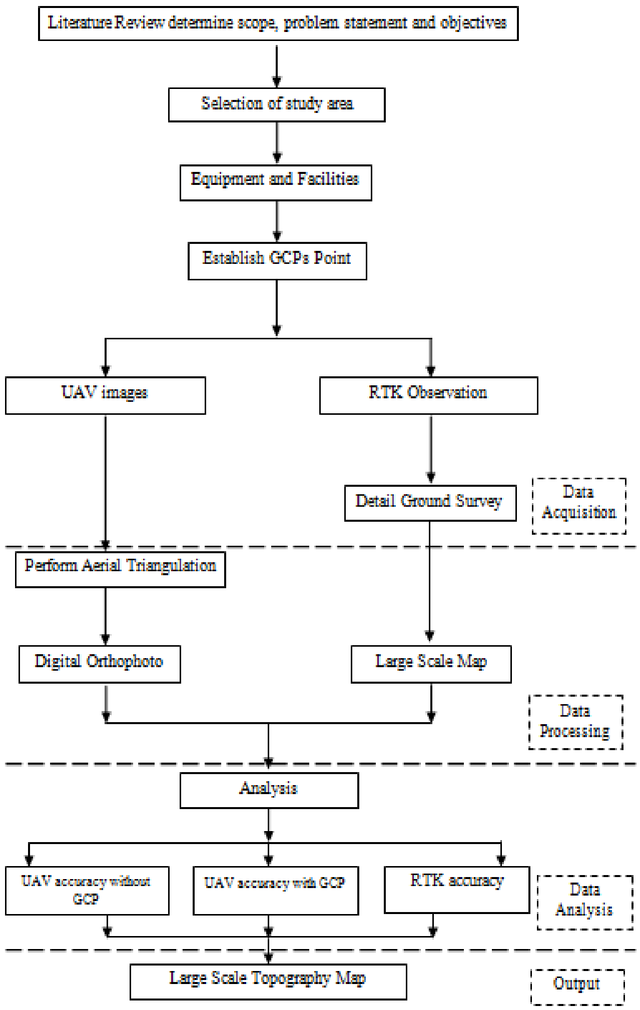

Figure 5: Research Methodology Framework

2.3. Data Acquisition

Project design is a process of framework planning that provides a clear overview of the things that need to be done in ensuring the success of this study. Process data collection is performed based on framework project planning to ensure the data obtained meet the scope study.

Data collection involved two parts which are collecting of details survey using RTK GPS and collection of RGB images from UAV. Data acquisition began with the establishment of the GCP point for the purpose of UAV aerial images geo-correction. The flight planning was design before the data acquisition by using Mission Planner software [16]. Total of 6 flight plans were carried out using Mission Planner software to cover the 328.44 Hectare of the study area with total distance flying of 74.1391 km. The altitude for data acquisition of RGB images using UAV was 116 m which equivalent to 3.64 cm spatial resolution. Figure 6 until figure 11 describe the waypoints for each single flight planned carried out in this work. Whereas, the combination of all waypoints for the total of 6 flight plans can be viewed as in figure 12.

Figure 6: Waypoints for the first flight plan covering 49.10 Hectare of the study area

Figure 7: Waypoints for the Second flight plan covering 53.83 Hectare of the study area

Figure 8: Waypoints or the third flight plan covering 53.93 Hectare of the study area

Figure 9: Waypoints for the fourth flight plan covering 51.59 Hectare of the study area

Figure 10: Waypoints for the fifth flight plan covering 49.15 Hectare of the study area

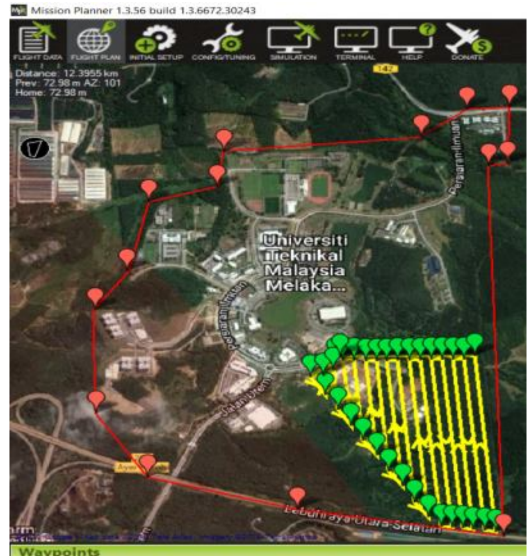

Figure 11: Waypoints for sixth flight plan covering 53.64 Hectare of the study area

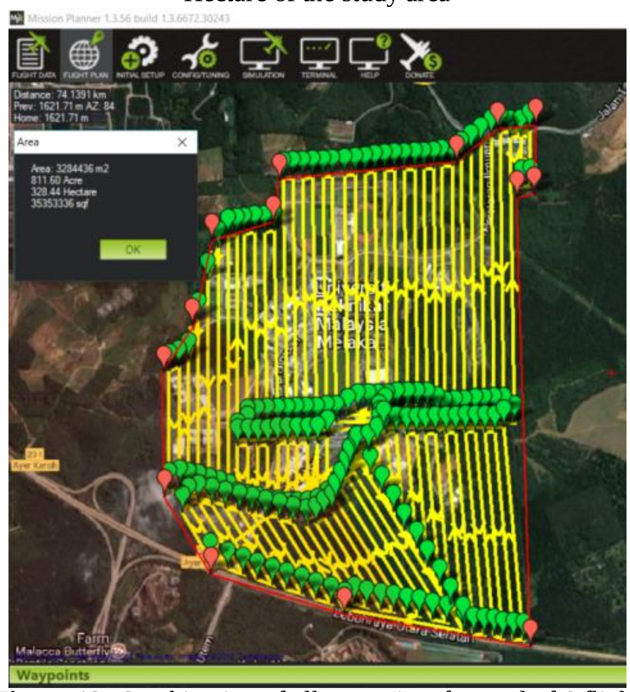

Figure 12: Combination of all waypoints for total of 6 flight plans covering 328.44 Hectare of the study area

2.4. Data Processing

All the data obtained from UAV observation were processed using Agisoft Photoscan Pro [17] while the details survey data by RTK were processed by using Trimble Total Center software and AutoCAD software. These data then were analysed using Global Mapper.

2.4.1. Image Processing

Agisoft Photoscan software was used to mosaic the imagery and align it with georeferenced points using Structure from Motion (SfM) algorithms. For each set of images, Agisoft PhotoScan software automatically aligns the images and builds point cloud models of the surface. Agisoft allows generating and visualising a dense point cloud model based on the estimated camera positions to combine into a single dense point cloud [18]. The software provides a user friendly process for mosaicking the imagery. The imagery was added and aligned by using Align Photo function. Then, the imagery generates and visualized a dense point cloud model based on the estimated camera position using Build Dense Cloud function. It calculates the depth information for each camera to be combined into a single dense point cloud. The geometrics of the map are reconstructed due to the poor texture of some elements of the scene and noisy or poorly focused images (Known as outliers among the points) by using the Build Mesh function. The images were used to build the texture exported as a mosaiced orthophoto image. Finally, the mosaicked orthophoto generate a Digital Surface Model (DSM) and import the DSM and orthoimage to build the 2.5 digital models. The whole process flow of mosaicking RGB imagery is summarized as in figure 13 and the result of the mosaicking process from Agisoft Photoscan software is presented as in figure 14, figure 15 and figure 16.

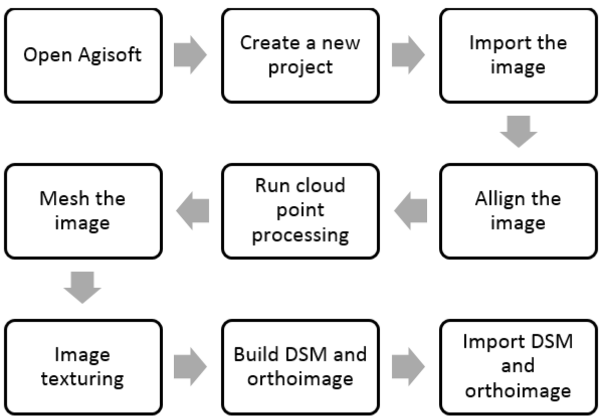

Figure 13: Flow chart for mosaicking RGB imagery

Figure 14 shows the orthophoto image produced by the mosaicking process. The orthophoto is an aerial photograph or image geometrically corrected ("orthorectified") so that the scale of the map is uniform for the whole study area. The orthophoto image provides the information about the ground resolution of 3.64 cm per pixel for the study area.

Figure 15 shows the digital elevation model obtained from the mosaicking process. The digital elevation model provides information about the terrain surface of the study area with vertical resolution of 14.5 cm per pixel and point density of 47.3 points per square meters.

Number of images:	4,063	Camera stations:	3,971
Flying altitude:	116 m	Tie points:	3,770,508
Ground resolution:	3.64 cm/pix	Projections:	12,577,250
Coverage area:	3.76 km²	Reprojection error:	1.59 pix

Figure 14: Orthophoto result from mosaicking process

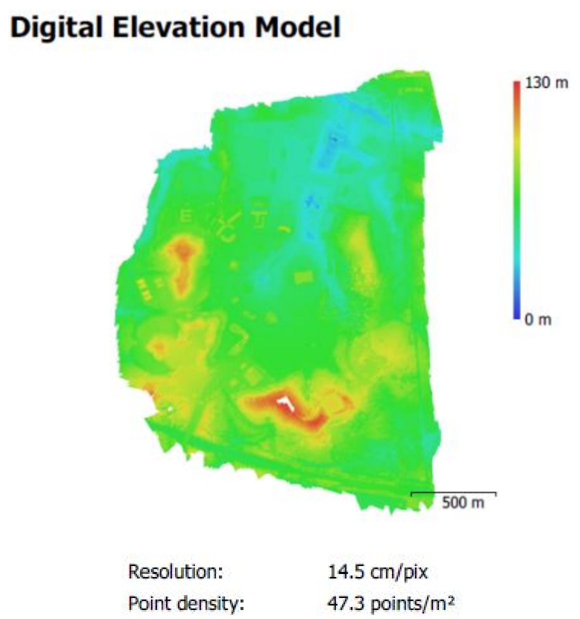

Figure 15: Digital Elevation model

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
4	2.3971	1.47013	5.55741	2.812	6.22834

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
GCP01	-3.59136	-1.10236	3.62004	5.21706	0.952 (22)
GCP02	3.14228	0.376944	2.60097	4.09647	1.534 (15)
GCP03	0.405855	-1.6851	-9.20346	9.36526	2.362 (18)
GCP04	-0.218648	2.10911	4.35498	4.84376	0.849 (20)
Total	**2.3971**	**1.47013**	**5.55741**	**6.22834**	**1.506**

Figure 16: Ground Control Points

2.4.2. RTK Data Processing

In RTK GPS surveying technique, one of the software used are AutoCAD to join the details data using RTK observations.

Figure 17: AutoCAD Processing

3. ANALYSIS AND RESULTS

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.

3.1. Quantitative analysis

Quantitative analysis is about the numerical quantity that can be done by calculating or computation of the data. Quantitative assessment was carried out by calculating root mean square error (RMSE).

Table 3: Comparison of coordinates obtained from UAV and RTK-GPS.

POINT	Longitude	Latitude	UAV (meter) height	RTK-GPS (meter) height
1	102.322459	2.309579	52.213	52.212
2	102.326950	2.317740	41.555	41.481
3	102.326690	2.317222	40.458	40.401
4	102.318538	2.312510	52.790	52.698
5	102.320782	2.311695	37.272	37.206
6	102.320419	2.312004	37.450	37.357
7	102.321973	2.312972	37.278	37.179
8	102.324082	2.316283	36.096	36.029
9	102.324370	2.316359	35.717	35.622
10	102.321886	2.313063	36.364	36.402
11	102.324089	2.318992	21.351	21.264
12	102.323298	2.317111	22.303	22.214
13	102.322484	2.309397	53.069	53.001
14	102.322814	2.309623	53.576	53.483
15	102.322509	2.309572	53.067	52.995
16	102.319292	2.311442	46.907	46.813
17	102.319547	2.211388	40.034	39.967
18	102.320064	2.309616	47.768	47.674
19	102.320890	2.310124	48.887	48.778
20	102.315931	2.310350	40.494	40.472
21	102.320638	2.310680	39.735	39.636
22	102.322942	2.311239	47.383	47.282
23	102.321774	2.311518	69.914	69.836
24	102.320321	2.313568	51.559	51.476
25	102.323337	2.316387	29.624	29.667
26	102.320338	2.313759	51.210	51.128
27	102.321354	2.313480	51.831	51.737
28	102.321517	2.313465	47.551	47.482
29	102.321774	2.313340	38.837	38.758
30	102.325052	2.317913	22.934	22.845

The RMSE value determined the accuracy of coordinates of each point using different observation methods. The table 3 shows the comparison of check points between UAV and RTK-GPS Survey. Here, we also show the exact location with elevation information for both UAV and RTK of check point 1, 10 and 20 highlighted in yellow, red and green in figure 18, 19 and 20 respectively. 30 points of UAV and RTK in the same longitude ans latitude coodinate were taken within the open space area of the study area. From table 3, the difference of error between UAV coordinates and RTK-GPS coordinates is calculated as in table 4.

Table 4: Error for each coordinate between UAV and RTK-GPS.

POINT	$(UAV_i - RTK_i)$ Z	$(UAV_i - RTK_i)^2$ Z
1	0.001	0.000001
2	0.074	0.005476
3	0.057	0.003249
4	0.092	0.008464
5	0.066	0.004356
6	0.093	0.008649
7	0.099	0.009801
8	0.067	0.004489
9	0.095	0.009025
10	-0.038	0.001414
11	0.087	0.007569
12	0.089	0.007921
13	0.068	0.004624
14	0.093	0.008649
15	0.072	0.005184
16	0.094	0.008836
17	0.067	0.004489
18	0.094	0.008836
19	0.109	0.011881
20	0.022	0.000487
21	0.099	0.009801
22	0.101	0.010201
23	0.078	0.006084
24	0.083	0.006889
25	-0.043	0.001885
26	0.082	0.006724
27	0.094	0.008836
28	0.069	0.004761
29	0.079	0.006241
30	0.089	0.007921
	Total	**0.192743**
	MSE	**0.006425**
	RMSE	**0.080155**

Equation (1) is used to determine the root means square error. From table 4 the RMSE for coordinate Z is ±0.080155. The results show that the value of RMSE is less than 1m. The smaller RMSE indicates higher accuracy.

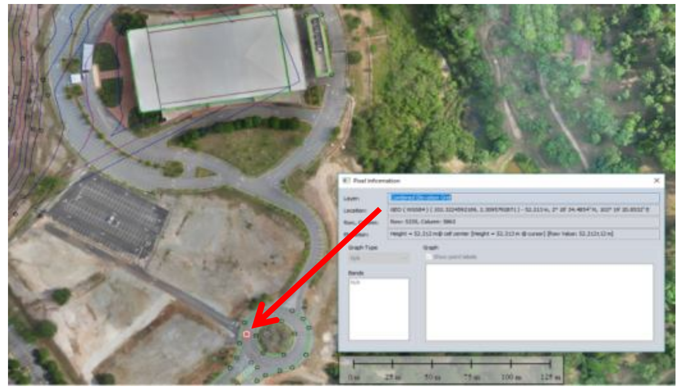

Figure 18: The location of Point 1 (highlighted in yellow in table 4) with elevation information for both UAV and RTK

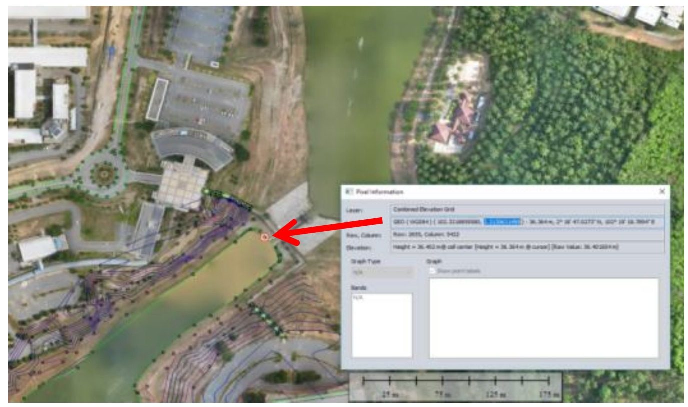

Figure 19: The location of Point 10 (highlighted in red in table 4) with elevation information for both UAV and RTK

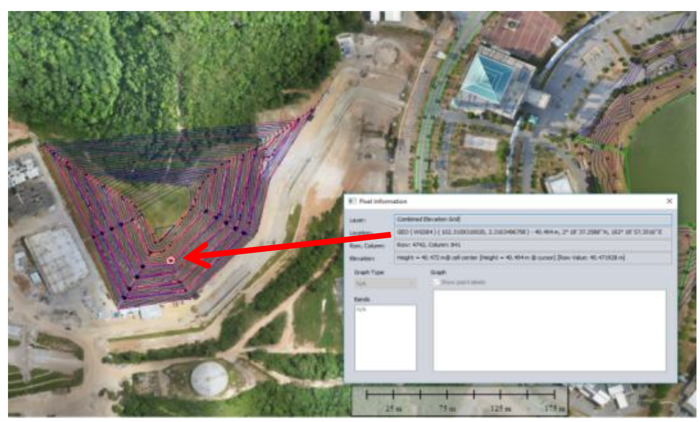

Figure 20: The location of Point 20 (highlighted in green in table 4) with elevation information for both UAV and RTK

3.2. Qualitative assessment

Qualitative assessment is about visualization of the map by digitizing features in the images. The analysis is carried out by comparing digitizing features from RTK observations using AutoCAD and UAV images using Agisoft Photoscan software. We then use the Global Mapper software to carry out qualitative assessment presented as in figure 21 until figure 26. In this assessment, we overlapped the orthomosaic image by UAV imager with the topographic map from RTK. The result shows that the orthomosaic image produced by UAV imager matched with the topographic map by RTK as presented in figure 23 until figure 26.

Figure 21: Topographic Map using RTK observation

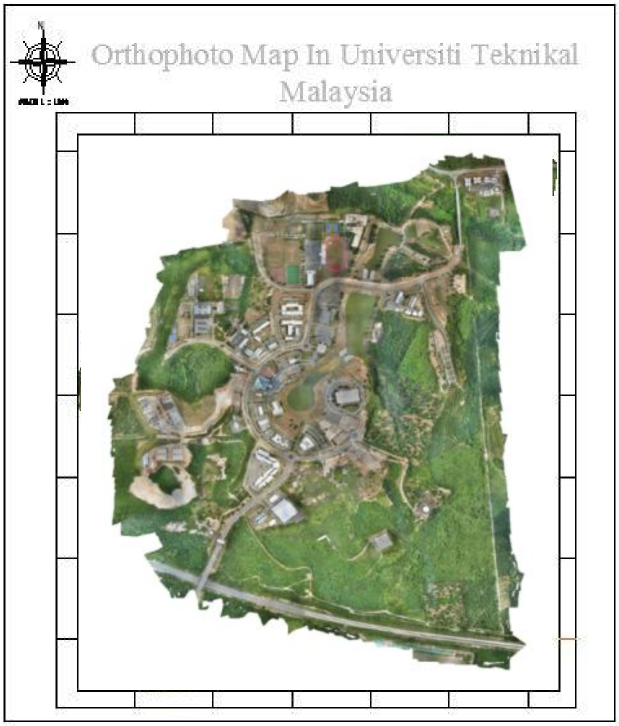

Figure 22: Orthophoto Map using UAV

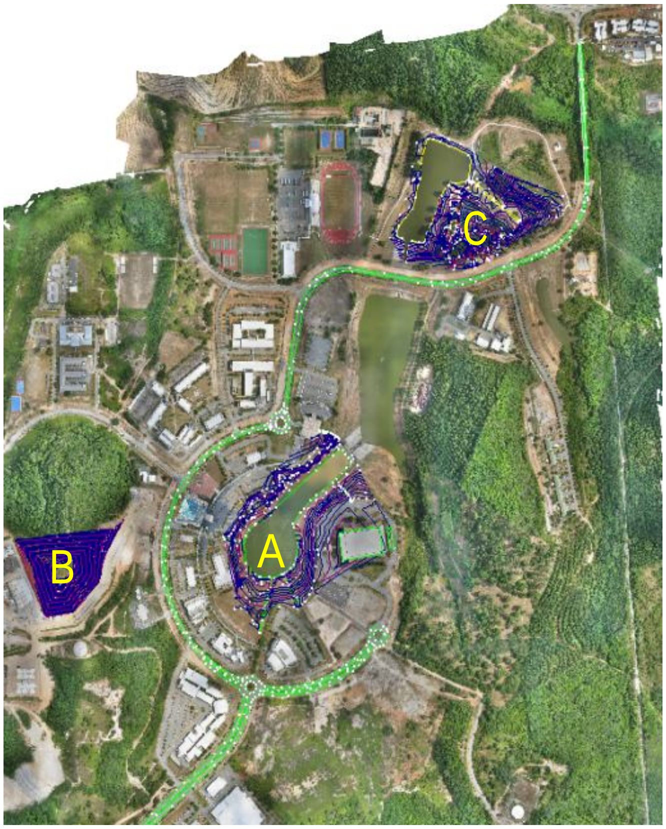

Figure 23: Results of the overlapped for entire study area

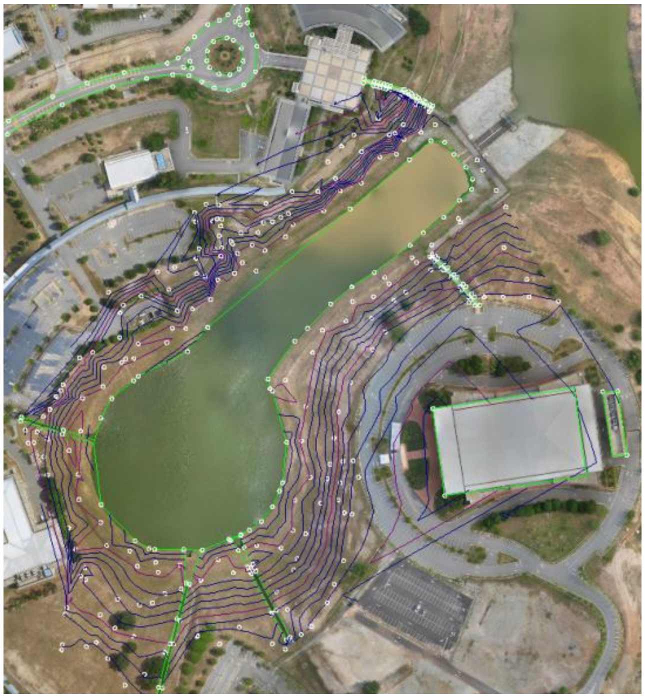

Figure 24: Zoom in of overlapped area labeled "A"

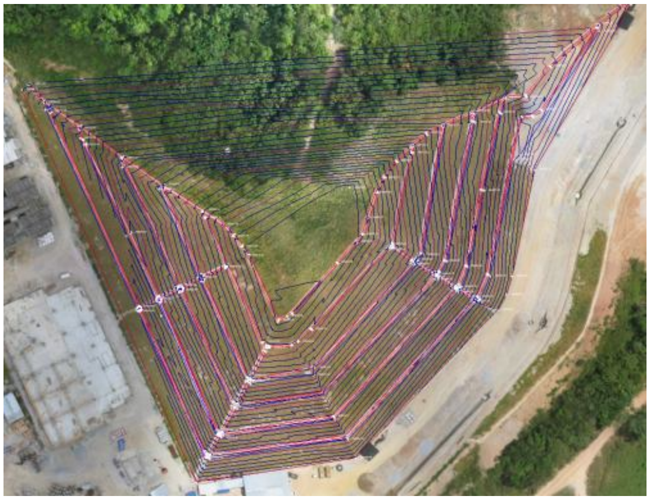

Figure 25: Zoom in of overlapped area labeled "B"

Figure 26: Zoom in of overlapped area labeled "C"

4. CONCLUSION

This paper presents an analysis of large scale topographic map using UAV Imager and RTK conducted in Universiti Teknikal Malaysia Melaka (UTeM). The accuracy of topographic map generated by Unmanned Aerial Vehicle (UAV) Imager compare to ground survey using Real Time Kinematic (RTK) indicates RMSE for Z is ±0.080155 m. From the qualitative assessment by visualization of the map from digitizing features in the images, the result shows that the orthomosaic image produced by UAV imager matched with the topographic map by RTK. Therefore, it can be concluded that the UAV imager can be considered as an alternative technique for updating topographic map. However with different type of UAV specifications, the RMSE value might get slightly different.

REFERENCES

[1] W. Tampubolon and W. Reinhardt, "UAV data processing for large scale topographical mapping," *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 40, p. 565, 2014. https://doi.org/10.5194/isprsarchives-XL-5-565-2014

[2] G. Verhoeven, "Taking computer vision aloft–archaeological three-dimensional reconstructions from aerial photographs with photoscan," *Archaeological prospection*, vol. 18, pp. 67-73, 2011. https://doi.org/10.1002/arp.399

[3] E. Honkavaara, *et al.*, "Hyperspectral reflectance signatures and point clouds for precision agriculture by light weight UAV imaging system," *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci*, vol. 7, pp. 353-358, 2012.

[4] A. Tscharf, *et al.*, "On The Use of UAVs In Mining And Archeology-geo-accurate 3D Reconstructions Using Various Platforms and Terrestrial Views," *ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences,* 2015.

[5] H. Eisenbeiss, "The potential of unmanned aerial vehicles for mapping," in *Photogrammetric Week'11*, 2011, pp. 135-145.

[6] H. Eisenbeiß, "UAV photogrammetry," ETH Zurich, 2009.

[7] K. Nakano, *et al.*, "On Fundamental Evaluation Using Uav Imagery and 3d Modeling Software," *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*, vol. 41, 2016.

[8] M. Shahbazi, *et al.*, "Development and evaluation of a UAV-photogrammetry system for precise 3D environmental modeling," *Sensors*, vol. 15, pp. 27493-27524, 2015.

[9] P. Barry and R. Coakley, "Accuracy of UAV photogrammetry compared with network RTK GPS," *Int. Arch. Photogramm. Remote Sens*, pp. 27-31, 2013.

[10] K. Djaja, *et al.*, "The Integration of Geography Information System (GIS) and Global Navigation Satelite System-Real Time Kinematic (GNSS-RTK) for Land use Monitoring," *International Journal of GEOMATE*, vol. 13, pp. 31-34, 2017. https://doi.org/10.21660/2017.36.2768

[11] C. Yu, *et al.*, "Generation of real-time mode high-resolution water vapor fields from GPS observations," *Journal of Geophysical Research: Atmospheres*, vol. 122, pp. 2008-2025, 2017.

[12] F. Zarzoura, *et al.*, "Investigating Accuracy Enhancement of Global Navigation Satellite System," *British journal of earth sciences research*, vol. 1, pp. 1-9, 2013.

[13] K. Tahar, "Height accuracy based on different RTK GPS method for ultralight aircraft images," *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 40, p. 287, 2015.

[14] T. Chai and R. R. Draxler, "Root mean square error (RMSE) or mean absolute error (MAE)?," *Geoscientific Model Development Discussions*, vol. 7, pp. 1525-1534, 2014.

[15] S. M. Azmi, *et al.*, "Accuracy assessment of topographic mapping using UAV image integrated with satellite images," in *IOP Conference Series: Earth and Environmental Science*, 2014, p. 012015.

https://doi.org/10.1088/1755-1315/18/1/012015
[16] *Mission Planner software*. Available: http://ardupilot.org/planner/index.html
[17] C. Y. N. Norasma, *et al.*, "Rice crop monitoring using multirotor UAV and RGB digital camera at early stage of growth," *IOP Conference Series: Earth and Environmental Science*, vol. 169, p. 012095, 2018. https://doi.org/10.1088/1755-1315/169/1/012095
[18] N. N. Che'Ya, "Site-Specific Weed Management Using Remote Sensing," 2016.