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High-Resolution Mapping Using Digital Imagery of Unmanned Aerial Vehicle (UAV) at Quarry Area, Machang, Kelantan

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Abstract. Traditional structural and engineering geological survey data can only be acquired at the bottom of slopes or by climbing high rock walls in most quarries; these data frequently provide an incomplete picture of the area. UAV technology enables the safe study of difficult-to-access or hazardous locations. The key to future advancements in mining efficiency is the acquisition of high-precision, high-resolution 3D-positioned data. The goal of this research is to produce a high-resolution mapping from photographs captured by UAV. A DJI Mavic Pro 2 captured an image of a 0.131 km^2 region of the Bukit Buloh Quarry Center. The final outputs in the forms of Orthomosaic and Digital Surface Model (DSM) were generated using Pix4Dmapper software. By comparing the coordinates of 6 Ground Control Points (GCPs) with coordinates determined using the RTK GPS method, the horizontal and vertical accuracies of the obtained UAV products were calculated. The vertical Root Mean Square Error (RMSE) for the geometric correctness of the data based on the 6 GCPs was 0.044 m. For large-scale maps, the resulting model met the American Society for Photogrammetry and Remote Sensing (ASPRS) accuracy standards. In a conclusion, UAV photogrammetry has evolved into a strong technology that can be used as a viable alternative to traditional mapping methods, particularly the use of expensive measurement equipment and labour. Besides its ability to analyze output data in qualitative or quantitative form, accurate mapping data is essential not only for 3D modelling but also for predicting geological risk in the quarry area.

1. Introduction

The most recent technological advancements in unmanned aerial systems (UAS), such as unmanned air vehicles (UAVs) and data processing technologies, have led to the widespread application of these methods in a variety of industries [1,2]. Various mapping applications, such as forestry [3,4], archaeology and historical sites [5], and emergency mapping [6], may be supported by the remote driving system. This is because it has a range of sensor technologies [7,8] based on the appropriateness of the mapping application in terms of parameters and GSD control [9,10]. It will also be aided by geomatic control for accuracy requirements; create Ground Control Point (GCP) so that the percentage of final turns and side turns in each flight mode side of the UAV fit the standard block configuration to prevent image distortion [11] of each needed output angle. The element is critical for producing high-resolution mapping that meets the American Society for Photogrammetry and Remote Sensing (ASPRS) criteria of no more than 0.2 metres in the standard deviation of the mean RMS error [12].

The core of the study was to produce high-resolution quarry area mapping using UAV imaging technology. Therefore, various angular flight modes and altitude UAVs were used in this study to maximize distortion and wide field of view [11]. GCP point control ensures that the alignment and accuracy of [13] are maintained. The Orthomosaic and Digital Surface Model (DSM) may be standardized, allowing for large-scale mapping in the quarry region, which covers 0.131 km^2. Quantitative analysis is supplied in the form of RMSE, Index, and other mathematical formulas to maintain data reliability while meeting criteria set in high-resolution mapping development because conversational mapping is less efficient due to the irregular surface shape of quarry area which makes it difficult for workers' access for data acquisition. The proof of the data is at a high level of reliability so that the UAV method in quarries mapping is comparable to the conventional method.

2. Methodology

According to the flow chart of overall research methodology in Figure 1, the approach is separated into four phases: a preliminary study, fieldwork, results, and analysis.

2.1. Preliminary study

Selection of study area (quarry) which free from rockfall is crucial for ensuring safety because it might interrupt excavation activities. Besides, the area of coverage and boundary of mapping the quarry wall was determined. The area must be easily accessible and should include open area for easy take-off and landing of the UAV. The quarry area is at Machang, Kelantan. The geographical position of the quarry site is at a coordinate of 5 ° 52'13.42 "N, 102 ° 14'47.65" with an average elevation of 38 meters from Mean Sea Level (MSL). The estimated area of this area is about 12.5 hectares.

The initial process also involved the process of defining UAV types and specification as well as the collection of related information, data, records, maps and imagery for pilot study. The flight map is prepared based on Google Earth and include number of aerial photograph and flight line.

2.2. Establishment of Ground Control Point (GCP)

With the aim to improve the external orientation and overall accuracy level of the photogrammetric model, Ground Control Point (GCP) need to be planned properly before aerial image acquisition and uncontrolled mosaic formation. The GCPs were established using static and real time chemical techniques (RTK) using the Global Navigation Satellite System (GNSS). The were used for data processing and analysis purpose using Root Mean Square (RMSE) mathematical equation.

2.3. UAV survey

Height of the chosen quarry wall was considered when conducting photogrammetric surveys using UAV technology to obtain high -resolution digital products. The UAV is equipped with a GPS and an inertial navigation system that can record 3D spatial coordinates and the orientation of the camera at every shot. The flight uses UAV auto pilot with the help of Map Pilot Pro software. The aerial photographs were acquired in a straight line and form a block of photograph. The overlapping area of adjacent images is approximately 60% and the same set of control points were used for photogrammetric processing.

2.4. Processing small format aerial photograph

The aerial photographs were processed using GCPs and digital photogrammetric software. Photogrammetric output (georeferenced products) such as 3D point clouds, DSMs, orthophotos and textured models were produced, and later analysis was conducted.

2.5. Accuracy assessment

The accuracy factor of the photogrammetric output generated by digital image processing was taken into consideration, as well as the accuracy evaluation of Orthophoto and DSMs images [11] utilizing a 6-point GCP control to randomly cover the whole picture. The rectification triangulation accuracy of the difference between the absolute point of GCP and the relative picture of photogrammetry data processing was calculated using the Root Mean Square (RMSE) mathematical equation [16] as shown in Equation 1. Mean errors in the three coordinate directions and localization accuracy per GCP. The number of calibrated photos where the GCP has been automatically validated vs. manually indicated is counted in the last column.

Formula:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \hat{x}_i)^2}{N}}$$

i = variable i
N = number of non-missing data points
x_i = actual observations time series
$\hat{x}_i$ = estimated time series

(Equation 1)

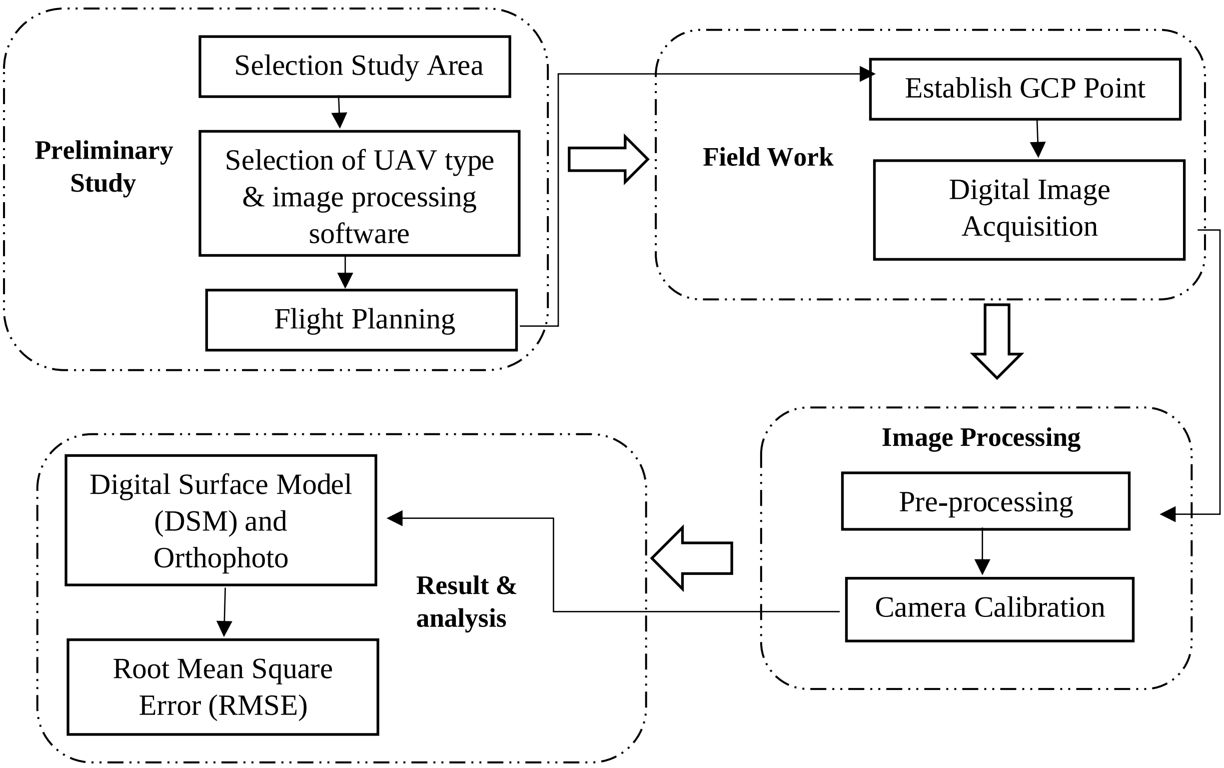

Figure 1. Flowchart of research methodology.

3. Results and Discussion

The advantages of UAV technology advancements are used in this study for the detailed mapping of quarry area specifications. The major goal of this study is to evaluate the actual capability of UAVs in delivering high-resolution mapping, as well as to validate the correctness of photogrammetric output images created using Pix4D Mapper software technology. UAVs technology is acceptable for high-resolution mapping at the quarry as indicated by RMS error in Figure 2 which shows RMS error is only 0.044 meters and meet the maximum requirement standard less than 0.2 meters. It is done by high-quality check handling conditions because of the use of appropriate pixel average Ground Sampling Distance (GSD) in the data acquisition process with the help of georeferencing from 6 GCP point [14].

Summary

Project	umk
Processed	2021-12-15 04:08:35
Camera Model Name(s)	L1D-20c_10.3_5472x3648 (RGB), FC6310_8.8_5472x3648 (RGB)
Average Ground Sampling Distance (GSD)	2.28 cm / 0.90 in
Area Covered	0.131 km^2 / 13.0750 ha / 0.05 sq. mi. / 32.3258 acres

Quality Check

Images	median of 71845 keypoints per image	✓
Dataset	661 out of 661 images calibrated (100%), all images enabled	✓
Camera Optimization	1.86% relative difference between initial and optimized internal camera parameters	✓
Matching	median of 23472.6 matches per calibrated image	✓
Georeferencing	yes, 6 GCPs (6 3D), mean RMS error = 0.044 m	✓

Figure 2. Summary report processing with quality check.

3.1 Camera Position Calibration

The results of internal orientation and offsets computed in Pix4D software are shown in this chapter in the form of three kinds of overlaps. The bundle block adjustment approach is employed in the form of a tie point location [11] controlled by GCP points in the camera settings for self-calibration. Figure 3 shows the intersection of 3 types of image overlap that have been applied in the top-view (XY plane), front-view (XZ plane), and side-view (XZ plane), the offset between initial (blue dots) and calculated (green dots) image locations, as well as the offset between the GCPs initial (blue crosses) and computed (green crosses) positions (YZ plane). The absolute location uncertainty of the bundle block adjustment result is shown by dark green ellipses. This proved the overlap approach with a variety of angles, giving extra redundancy to the intersection of position bundle block adjustment so that image objects may be shot from different perspectives.

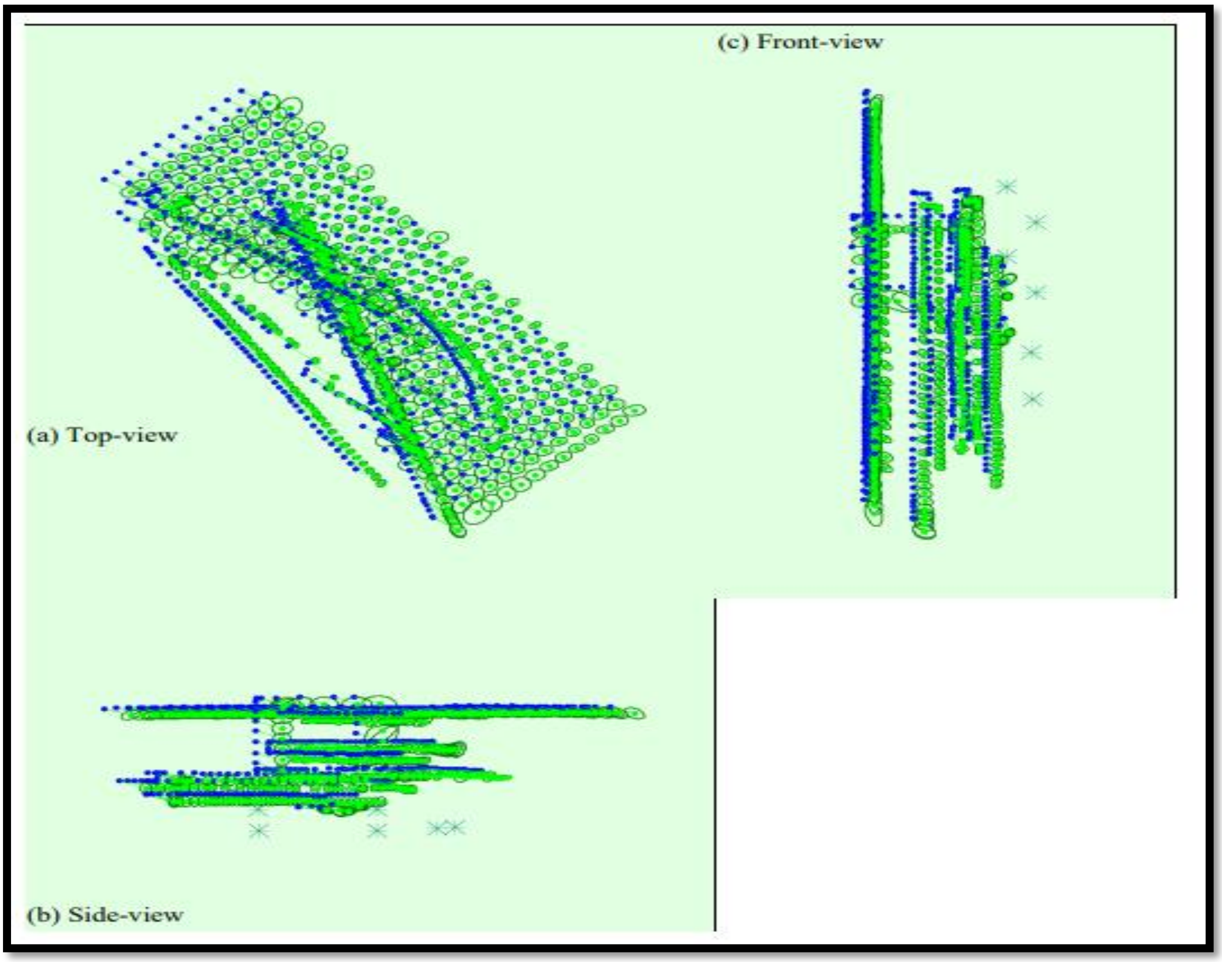

Figure 3. Flight position view of three type overlap method in the (a)top-view, (b)side-view, and (c) front-view.

3.2 Orthophoto and Digital Surface Model (DSM)

The final steps of image processing are producing orthophoto and DSM images, which are dependent on the accuracy, offset, and overlap of the image, as well as the GSD cover specification criteria. In addition, it uses the RGB colour algorithm to calculate the number of overlapping pictures for each pixel of the orthomosaic, which helps to improve the quality rate of multispectral image features [15]. Figure 4 shows final output of Orthophoto and Digital Surface Model (DSM) output before densification process in the quarry. This is the final mapping image before it is justified in the field of geology, for example, in terms of risk in the quarry area.

4. Analysis

The accuracy of geolocation details of ground control points, it is evaluated based on the observation value of UAV image coordinates with the absolute parameter coordinate value (geolocation value ground) of Pix4D software which is used as a benchmark for comparison. According to [17], the image matching method that was employed in the software during image processing could have an impact on this RMSE outcome. The inaccuracy was typically brought on by motion movement like omega, phi, and kappa as well as image matching during image processing. Based on this study, verified points (GCP) achieve 100% overlap with each other to prove the RMSE valuation method is reliable as shown in columns (Accuracy XY/Z).

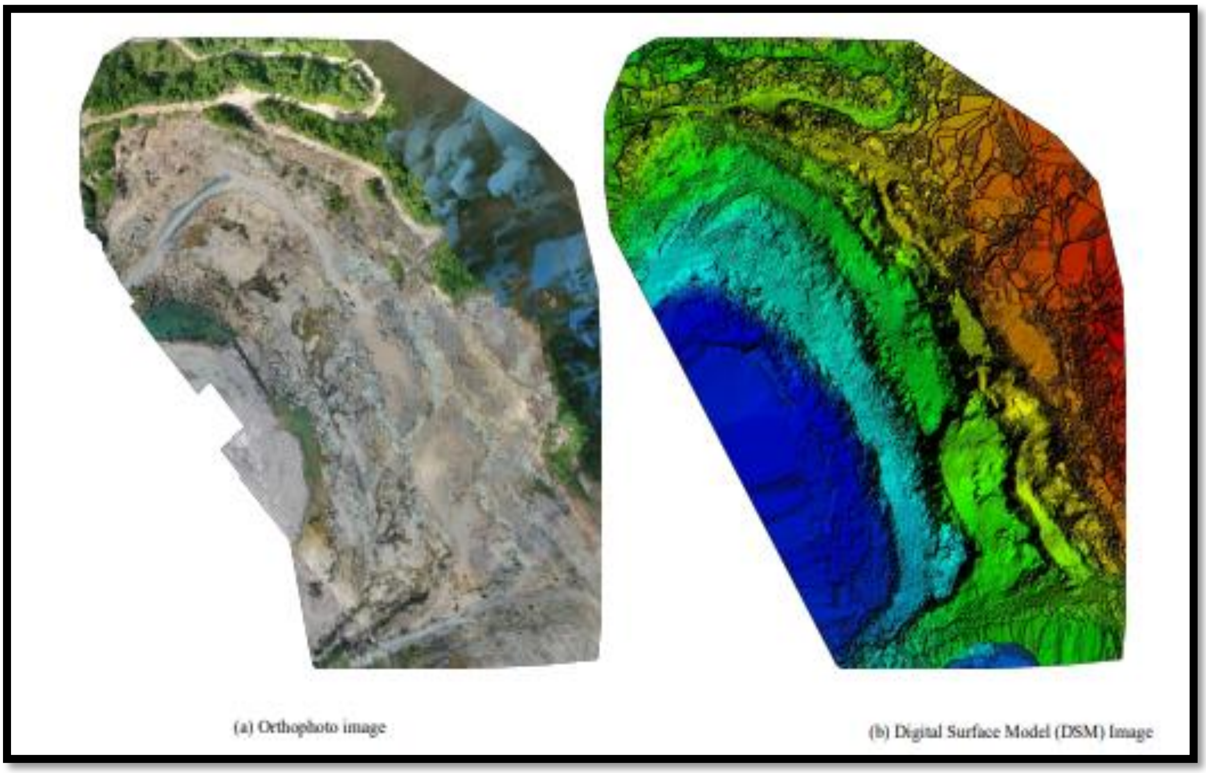

Figure 4. The output of orthophoto and DSM image processing data.

The projection error value is slightly larger because of the error generated from the UAV flight error although it does not affect the error value of the X, Y, and Z coordinates when compared to the original value. As a result, the RMSE value for 6 coordinate points (X, Y, Z) can be verified because the error of all three values does not exceed 0.2m as set by the American Society for Photogrammetry and Remote Sensing (ASPRS). The significance of this analysis is that the image output data that has been applied certificate in terms of accuracy and suitable for use in industry, especially in determining hazards in mining (Table 1).

Table 1. Accuracy geolocation details of ground control points.

GCP Number	Accuracy XY/Z[m]	Error X[m]	Error Y[m]	Error Z[m]	Projection Error [pixel]	Verified/ Marked
1	0.020/0.020	-0.032	-0.019	0.092	0.546	147/147
2	0.020/0.020	-0.074	-0.014	-0.080	0.675	91/91
3	0.020/0.020	0.006	0.005	-0.035	0.722	92/92
4	0.020/0.020	0.051	0.051	0.075	0.478	66/66
5	0.020/0.020	0.067	0.003	-0.041	0.688	118/118
6	0.020/0.020	-0.009	-0.021	0.018	0.988	118/118
Mean[m]		0.001644	0.000818	0.004921		197/197
Sigma[m]		0.047476	0.024382	0.062591		
RMS Error[m]		0.047504	0.024396	0.062784		

5. Conclusion

As a conclusion, UAV technology is generally effective for high mapping tasks in quarry sites. The mathematical analysis combined with procedures and controls used by expert operators during data collecting proves this. Image data from UAVs for mapping reasons could be utilized in engineering study control operations at quarries, which is an advantage for future studies since its accuracy is guaranteed. Accuracy is taken into consideration so that the use of UAVs in applying mapping in quarries can be certified by the authorities when compared to the conventional method. After a careful analysis, the researcher hopes that UAS fixed-wing technology, especially UAV, could be used for its advantages in all disciplines linked to the geo-study investigation.

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