Application of Photogrammetry Technique for quarry stockpile estimation

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Abstract. The quarrying activities is one of the largest industries in the world which supplied aggregate primarily for construction of any buildings and structures. Continuous supply of aggregates is very important to ensure the construction activities can be carried out without delays. Hence, the quarry operators consistently monitor their stockpile volume to meet the client’s demands. In most cases, the determination of available stockpile at the quarry are done by utilizing conventional method (manual measurement of the stockpile’s dimension). This approach is time consuming and sometimes required professional surveyor to carry out the task. Hence in this work, a comparative study between conventional and photogrammetry method was done to estimate the stockpile in a quarry. Drone was flying to capture the aerial images of a stockpile in the quarry. The effect of the flying height and the percentage of overlapping on the accuracy of stockpile volume was studied. Result shows at lower percent of side overlap (50%), the accuracy of estimation is better. The difference between the photogrammetry technique and conventional method only 2.5%. It can be concluded that photogrammetry technique is very reliable to be applied by the quarry operators to estimate their stockpile volume.

1. Introduction
Drone can be defined as unmanned aircraft system or remote-controlled pilot-less aircraft. In early 1980s, drone or unmanned aerial vehicle (UAV) were used for military purposes. However, as the technology developed, drone has been used for many purposes such as management of landfill site [1], civil engineering projects [2], agriculture and food [3] and mining and quarrying activities [4].

Mining activities which include quarrying is one of the oldest industries in the world. The volume of mineral ore and aggregates stockpile in mines and quarries are constantly monitored to ensure continuous supply to the consumers. In most cases, conventional method is applied on site to estimate the stockpile which carried out by the land surveyor to measure the dimension of the stockpile. Other methods which also applied on site are eyeballing, truck load and bucket count method. However, these methods are posing problems related to the accessibility and security of the sites, survey timings cost and safety issues [5].
Photogrammetry application has been widely used for site surveying purposes thus slowly replacing the classical topography tools such as Theodolite or Total Station. Photogrammetry technique are capable to carry out fast and complex samplings of difficult area without direct access to the sites, offer greater safety and conserving operational costs and time without compromising the accuracy. In mining activities, photogrammetry technique is being used to compute the stockpile volume and backfilling [6].

In photogrammetry technique, 2D images (aerial images) were sequence into 3D modelling measurement using photo processing software such as Envi, Agisoft Metashape and Bentley Context Capture. However, one of the major challenges in photogrammetric survey is to gain the optimum image reconstruction of surveyed site. Image blur due to forward motion of the UAV, wind speed and cloud cover among factors that may influence the quality of the final orthorectified image. In addition, parameter such as flight altitude and overlap percentage play an important role in determining the minimum flight duration and computational efficiency [7]. Hence in this study, flight altitude and overlap percentage were analysed to obtain the best restoration quality while reducing flight and image processing time for stockpile estimation in quarry.

2. Methodology
2.1. Site location
This study was conducted at a limestone quarry operate by Pens Industries Sdn. Bhd. The quarry is located at Jalan Bukit Ayer, Perlis, MALAYSIA

2.2. Material
The DJI Phantom 4 Pro drone was used to capture the aerial photos of the stockpile at the quarry.

2.3. Data collection
Drone was flying at three different altitude and image overlaying percentage as shown in Table 1. Each battery was fully charged before the flight begin. This is very important because low altitudes and higher degrees of overlap produced large datasets and need longer flight times. Flight was conducted at noon to reduce shadow in captured images [8]. Five (5) ground control points (GCP) were established during all flights. Specifically, 5 red plastic carps of 1m² were randomly located within the stockpile area. GPS coordinates from each GCP manually collected with a Garmin 64 s device. The flight mission was set up using Pix4D software to get the correct sequence of the aerial photo.

| Flight (Number) | Flight Altitude (m) | Ground Sampling Distance (cm/px) | Front Overlap (%) | Side Overlap (%) |
|----------------|---------------------|---------------------------------|-------------------|-----------------|
| 1              | 40                  | 1.10                            | 80                | 70              |
| 2              | 45                  | 1.23                            | 70                | 60              |
| 3              | 50                  | 1.37                            | 70                | 65              |
2.4. Image processing and data analysis
Agisoft Photoscan software was used to process all the aerial images captured by the drone. The whole automatic process involved three major stages: image alignment, mesh and texture construction and orthoimage generation. The detail steps within the major stages can be simplified as shown in Figure 1. In all cases, image alignment required high demand of computational requirements and consequently the processing time.

![Diagram of image processing steps](image.png)

**Figure 1.** Steps for image processing using Agisoft Photoscan software.

2.5. Manual measurement of stockpile volume
The dimension of stockpile was measured using measuring tape. The shape of measure stockpile was a truncated cone. The measured dimensions were used to calculate the stockpile volume using the following equation:

\[
\text{Volume of truncated cone} = \frac{1}{3} \pi (r_1^2 + r_1 r_2 + r_2^2) h
\]

where

- \( r_1 \) = radius of base truncated cone
- \( r_2 \) = radius of top truncated cone
- \( h \) = height of truncated cone
3. Result & Discussion

Through the conventional technique, the measured and calculated dimension of the stockpile is shown in Table 2. Calculated volume of stockpile was 1607.9 m³.

| Dimension                                      | Value       |
|------------------------------------------------|-------------|
| Perimeter of base truncated cone (measured on site) | 167.1 m     |
| Radius of base truncated cone (calculated)       | 26.59 m     |
| Perimeter of top truncated cone (measured on site) | 93 m        |
| Radius of top truncated cone (calculated)        | 14.8 m      |
| Length of slant (measured on site)               | 12.6 m      |
| High of truncated cone (calculated)              | 5.38 m      |
| Volume of truncated cone (calculated)            | 6107.9 m³   |

Figure 2 and Figure 3 show the 3D image and digital elevation model (DEM) of the stockpile produced using Agisoft Photoscan software. Result using photogrammetry technique shows that the flight altitude and percent of overlapping did affect the results of calculated stockpile volume. Table 3 shows the calculated volume of the stockpile for each flight setting. Flight setting with the lowest altitude and highest overlap produced the highest estimated volume which was 6441.3 m³. The estimated volume reduced once the percentage of both overlap (front and side) reduced. Flight 2 with lowest percent overlap (60%) recorded the nearest reading compared to the conventional method. The estimated stockpile volume using images obtained from Flight 2 was 6282.5 m³ which was 2.5% different from the conventional technique. Erich Seifert et. al. [9] in his study reported that the reconstruction accuracy increased with lower side overlaps (minimum at 55%). In addition, Erich Seifert et. al. also stated that images taken at higher altitude slightly increased the error in image reconstruction precision.
Figure 3. Digital Elevation Model (DEM) of the stockpile.

Application of drone significantly reduce the time consumed for data collection from the site. It took 15 min to capture all the required aerial images of the stockpile using drone. On the other hand, 30 min was required to complete all the measurement of stockpile dimension using conventional technique. As the pilot only stay at one secure place to fly the drone, the safety is assured. In contrast, the personnel need to be on site (on the stockpile) to collect the data required to calculate the volume of the stockpile. In addition, exposure to heavy machineries also poses safety risk to the respective personnel.

| Flight | Altitude (m) | Front Overlap (%) | Side Overlap (%) | Stockpile Vol (m³) |
|--------|--------------|-------------------|-----------------|-------------------|
| 1      | 40           | 80                | 70              | 6441.3            |
| 2      | 45           | 70                | 60              | 6282.5            |
| 3      | 50           | 70                | 65              | 6426.4            |

4. Conclusion
Application of drone in photogrammetry technique in estimating the stockpile volume helps the quarry operator to save their cost and time in managing their product inventory. Estimated stockpile volume obtained using photogrammetry technique is almost the same as calculated through conventional method. In this study, the difference was only 2.5%.
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