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Volume Analysis of Mining Excavation Progress Using Unmanned Aerial Vehicle-Photogrammetry Method

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ABSTRACT

In recent years, the use of unmanned aerial vehicles (UAVs) has become an alternative for topographic mapping, and this is called the UAV-Photogrammetry method. Topographic mapping in mining activities is carried out to determine the progress of actual volume of material taken. However, in general, topographic mapping is carried out using terrestrial survey methods. These methods require a long data acquisition time and a lot of personnel. This paper focuses on surveying the volume of mining progress using the UAV-Photogrammetry method and compares it with truck count volume data. The results of this study showed that the deviation in volume calculations using UAV-Photogrammetry method compared with truck count volume data in week I was 233 m3 or 0.654%, week II was 214 m3 or 0.151%, week III was 496 m3 or 0.840%, and week IV was 243 m3 or 0.210%. The results of the t-test showed that there was no significant difference between the volume calculation using the UAV-Photogrammetry method and truck count data, which means both measurement types produce statistically similar results.

Keywords: *Volume; UAV-Photogrammetry; Truck count; Excavation.*

INTRODUCTION

In recent years, the use of unmanned aerial vehicles (UAVs) has increased in various sectors for various uses [1]. In the case of mapping, UAVs are considered more effective and efficient in terms of time and cost. UAVs can also be operated closer to objects to obtain object images with a resolution of several centimeters [2]. In addition, UAVs can also be used to collect data in large areas in a shorter time. UAVs can also be controlled remotely or guided through a flight plan controlled by software that works integrated with the Global Positioning System (GPS) or even when the GPS signal is lost [3] [4].

Topographic survey in mining activities is carried out to determine of the progress of actual volume of material taken compared to truck count data. However, a topographic survey is carried out using conventional methods, some techniques that are often used are Total Station, Terrestrial Laser Scanner, and GPS/GNSS [5]. The use of these methods requires a long data acquisition time and a lot of personnel and is also difficult to use in hazardous areas [6] [7]. This paper will focus on measuring the volume of mining progress using the UAV-Photogrammetry method which will then be compared with the truck count volume data results. Research on the survey of mining material volume using UAV-photogrammetry has been

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conducted by several previous researchers. [8] analyzed the differences in stockpile volume surveys between terrestrial surveys and UAV-Photogrammetry methods. The results of the analysis showed that the differences between the two methods resulted in deviations of -2.3% to +2.9%. Compared to terrestrial surveys using total stations, the UAV-Photogrammetry showed more efficient performance in terms of data collection time. However, the data has not been compared with truck count data, so the deviation from truck count data is unknown. [9] analyzed the comparison of coal stockpile volumes measured from the UAV-Photogrammetry method with the terrestrial survey method. The results of the analysis showed that the deviation between the two methods is 2.34%. However, the data has not been compared with the truck count data, so the deviation from truck count data is unknown [10] analyzed the stockpile volume using the UAV-photogrammetry method by combining the number of GCP distributions and flight height. The results of the analysis showed that the volume calculation carried out using three software, namely Pix4D, Agisoft, and SimActive, produced the best Pix4D software performance with a deviation of 3% when compared to GNSS survey results. However, the data has not been compared with the truck count data, so the deviation from the truck count data is unknown. This paper will focus on the deviation between the volume of mining excavations using UAV-Photogrammetry and truck count data and also the location of data collection is at the Pit, not in the stockpile as done by several previous researchers.

METHOD

This research was conducted through three stages: data collection, data processing, and data analysis. Figure 1 shows the flow of the research stages.

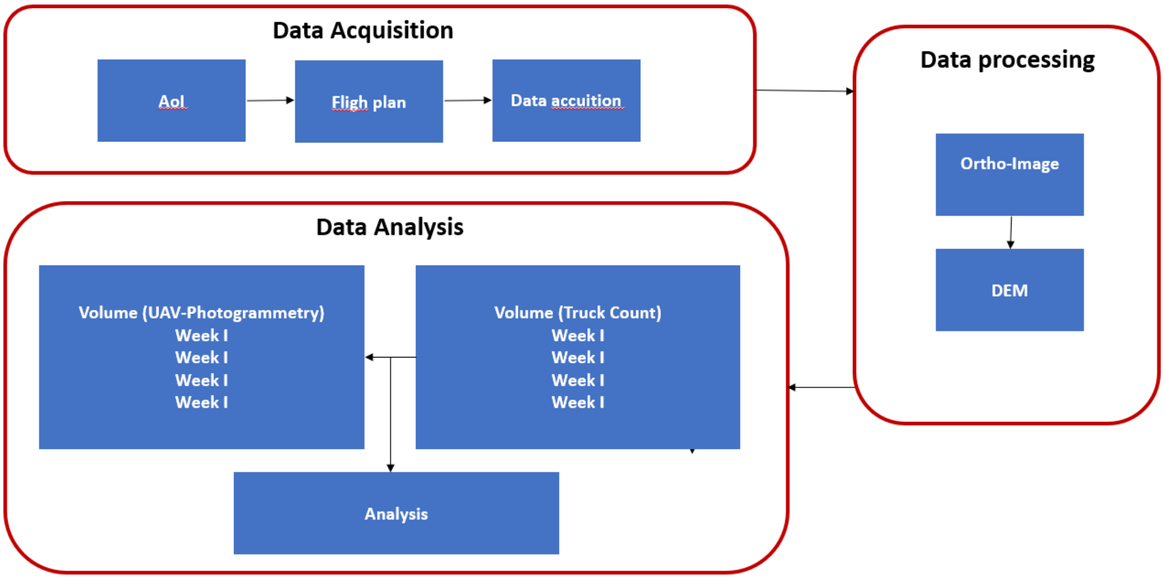

Figure 1. Research stages

The data collection process begins with flight plan planning in the area of interest. Aerial photogrammetry data collection requires flight path planning so that the resulting photos are good quality and by geometry planning. The flight path is planned based on the area of interest so that the shape and size of the shooting location can be determined.
Aerial photogrammetry is carried out in the area of interest automatically based on the flight path that has been injected into the UAV navigation software. Aerial photogrammetry produces partial photos, and the results of aerial photogrammetry from the UAV in the form of partial

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photos are then processed into a complete aerial photo map (orthophoto map) and a digital elevation model (DEM) map. Figure 2 shows the orthophoto map from the results of data processing in weeks I to IV.

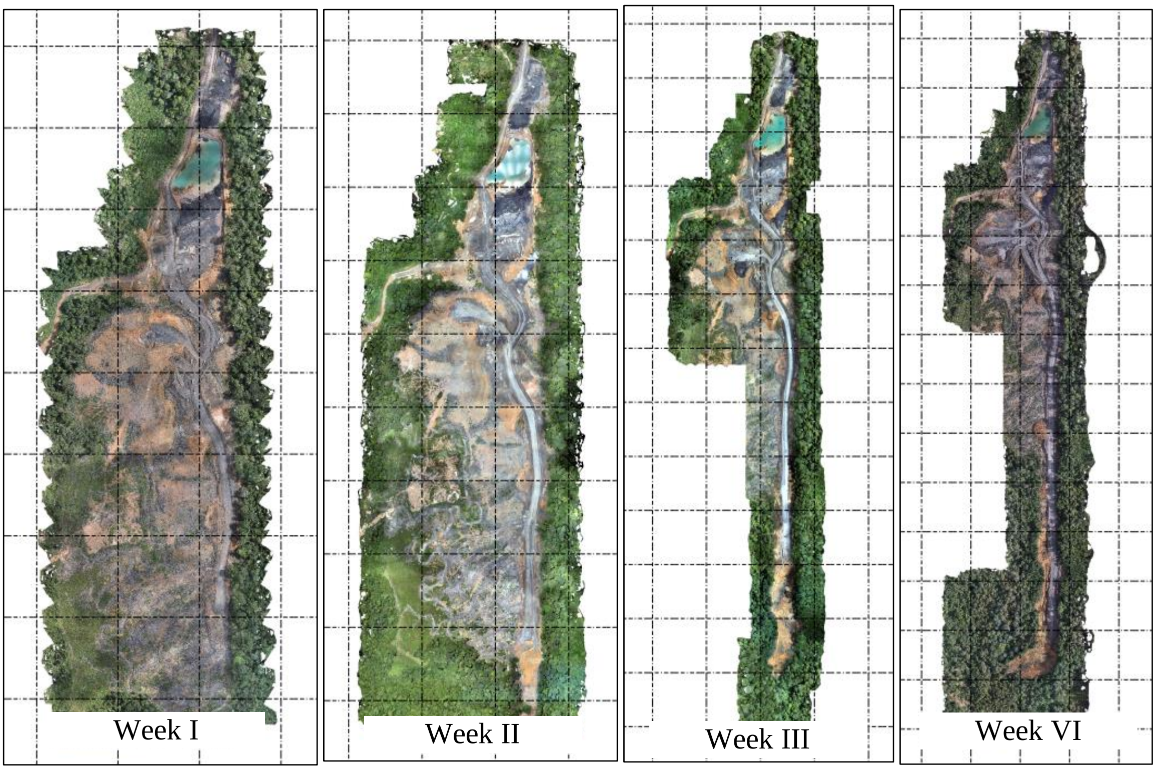

Figure 2. Orthopoto Maps

The results of the orthophoto maps in Figure 2 are converted into a DEM map. A DEM map is a representation of a digital elevation model that allows for measuring the relative height of various points on the surface in raster/grid format that can be derived into elevation or height information. Figure 3 shows the DEM map that was converted from orthophoto maps in Figure 2. The DEM map can be used to calculate the volume of mining excavation progress each week.

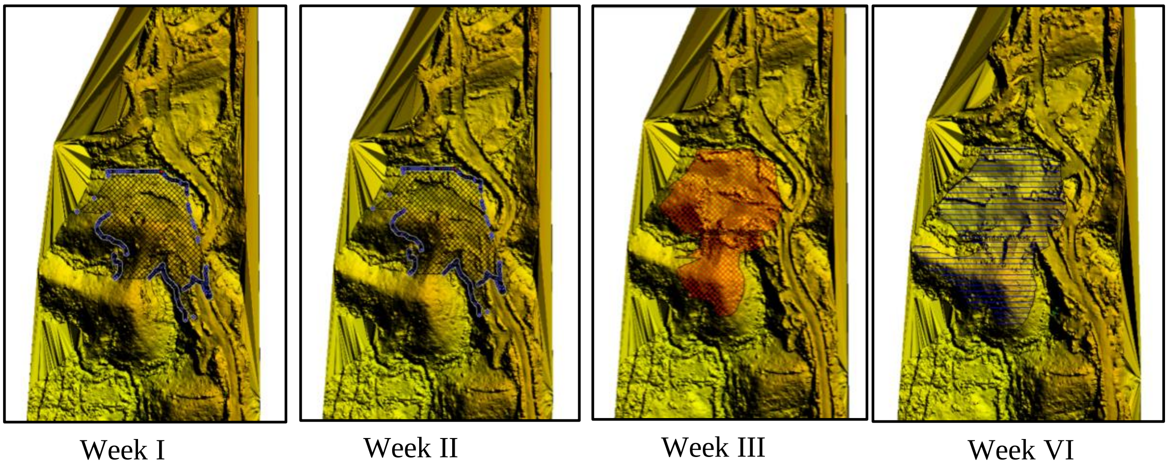

Figure 3: Digital Elevation Model Maps

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The DEM maps as a representation of the earth's surface in the form of a grid with elevation values at each point. The DEM map is used as a reference to calculate the volume of material that has been excavated each week. This process begins with the creation of an initial DEM map before work begins, which reflects the original surface conditions of the land. After that, every week, a new DEM map is created to represent the current surface conditions after excavation is carried out.

RESULTS AND DISCUSSION

Comparative Analysis of Excavation Volume in Week I

The results of the volume of mining material excavation in the week I using UAV-Photogrammetry method were compared with the volume from truck count data in week I. Truck count volume data for week I was used as comparative data that was considered correct for the volume calculation using UAV-Photogrammetry method in week I. The surface used in the calculation of the volume of the week I used the surface DEM of the initial week of mining and the surface DEM extracted from the orthophoto map from the results of UAV-Photogrammetry method in week I. Volume calculation using the surface-to-surface in week I obtained a volume of mining material excavation of 35374 m^3. While the volume obtained from truck count data was 35607 m^3. The comparison of these volumes can be seen in Table 1.

Table l. Comparison of UAV-Photogrammetry Volume and Truck Count Volume in Week I

Week I	UAV-Photogrammetry (m^3)	Truck Count (m^3)	Deviation (m^3)	Deviation %
1	35374	35607	233	0,654

Based on Table 1, the comparison of the calculation of the measurement results using the UAV-Photogrammetry method and truck count volume data shows a deviation of 233 m3 or 0.654%.

Comparative Analysis of Excavation Volume in Week II

The results of the volume of mining material excavation in week II using UAV-Photogrammetry method were compared with the volume from truck count data in week II. Truck count data was used as comparative data that was considered correct for the volume calculation using the UAV-Photogrammetry method in week II. The surface used in the calculation of the volume of week II used the DEM surface of week I mining and the DEM surface extracted from the orthophoto map of the results of image capture using the UAV-Photogrammetry method in week II. Volume calculation using the surface-to-surface method in week II obtained a volume of mining material excavation of 41791 m3, while the volume obtained from the truck count data was 41577 m3. The comparison of these volumes can be seen in Table 2.

Table 2. Comparison of UAV-Photogrammetry Volume and Truck Count Volume in Week II

Week II	UAV-Photogrammetry (m^3)	Truck Count (m^3)	Deviation (m^3)	Deviation %
2	41791	41577	214	0,515

Based on Table 2, the comparison of the calculation of the measurement results using the UAV-Photogrammetry method and truck count volume data shows a deviation of 214 m^3, or -0,515 %.

Comparative Analysis of Excavation Volume in Week III

The results of the calculation of the volume of mining material excavation in week III using the UAV-Photogrammetry method were compared with volume data from the truck count data in week III. Truck count data was used as comparative data that was considered correct for the volume calculation using the UAV-Photogrammetry method in week III. The surface used in the calculation of the volume of week II used the DEM surface of week II mining and the DEM surface extracted from the orthophoto map of the results of image capture using the UAV-Photogrammetry method in week III. Volume calculation using the surface-to-surface method in week III obtained a volume of mining material excavation of 59556 m^3, while the volume obtained from the truck count data was 59060 m^3. The comparison of these volumes can be seen in Table 3.

Table 3. Comparison of UAV-Photogrammetry Volume and Truck Count Volume in Week III

Week III	**UAV-Photogrammetry (m^3)**	**Truck Count (m^3)**	**Deviation (m^3)**	**Deviation %**
3	59556	59060	496	-0,840

Based on Table 3, the comparison of the calculation of the measurement results using the UAV-Photogrammetry method and truck count volume data shows a deviation of 496 m^3, or -0,840 %.

Comparative Analysis of Excavation Volume in Week IV

The results of the calculation of the volume of mining material excavation in week IV using the UAV-Photogrammetry method were compared with volume data from the truck count data in week IV. Truck count data was used as comparative data that was considered correct for the volume calculation using the UAV-Photogrammetry method in week IV. The surface used in the calculation of the volume of week II used the DEM surface of week III mining and the DEM surface extracted from the orthophoto map of the results of image capture using the UAV-Photogrammetry method in week IV. Volume calculation using the surface-to-surface method in week IV obtained a volume of mining material excavation of 115796 m^3, while the volume obtained from the truck count data was 115553 m^3. The comparison of these volumes can be seen in Table 4.

Table 4. Comparison of UAV-Photogrammetry Volume and Truck Volume Count in Week IV

Week III	**UAV-Photogrammetry (m^3)**	**Truck Count (m^3)**	**Deviation (m^3)**	**Deviation %**
4	115796	115553	243	0,210

Based on Table 3, the comparison of the calculation of the measurement results using the UAV-Photogrammetry method and truck count volume data shows a deviation 243 m^3, or -0.210 %.

Volume Comparison Analysis

The results of volume calculations using the UAV-photogrammetry method compared to truck count volume data are shown in Table 5. The deviation in volume from week I to week IV range from 0.210% to 0.840%.

Table 5. Comparison of UAV-Photogrammetry Volume and Truck Count Volume.

Week	UAV-Photogrammetry (m^3)	Truck Count (m^3)	Deviation (m^3)	Deviation %
1	35374	35607	233	0,654
2	41791	41577	214	0,515
3	59556	59060	496	0,840
4	115796	115553	243	0,210
Average			296	0.555

The deviation in volume calculations in week I was 233 m^3 or 0.654%, week II was 214 m^3 or 0.151%, week III was 496 m^3 or 0.840%, and week IV was 243 m^3 or 0.210%. If we look at the calculation deviation as shown in Table 5, the greater the material calculation results do not cause the greater percentage deviation in the calculation. This can be seen in the calculation results of week IV with the largest material volume of 115553 m^3, but the percentage deviation value is the smallest, 0.210%. The deviation in volume calculations is suspected to be caused by several factors, such as benchmark accuracy, horizontal and vertical position accuracy of orthophoto map results, and also material loss in trucks due to travel on the hauling road.
The difference in volume between the UAV-Photogrammetry method and the truck count data was statistically tested using the t-test. The t-test is used to determine whether there is a significant difference in volume between the UAV-Photogrammetry method and the truck count data. The statistical test was carried out simply using a one-sample t-test for volume differences, with the following hypothesis:

Ho = There is no significant difference between the volume of the UAV-Photogrammetry method and the truck count data.
H1 = There is a significant difference between the volume of the UAV-Photogrammetry method and the truck count data.

The results of the t-test statistical estimation can be seen in Table 6 below,

Table 6. t-test result

	t test		Critical t values	Decision
Volume	1,435		3,186	Accepted

From the data in Table 6. the results of the t-test, if the calculated t is smaller than the t table then the Ho value is accepted. The data in Table 6 shows that the calculated t value is smaller than the t table in volume, from these results it states that there is no significant difference between the volume of the UAV-Photogrammetry method and the truck count data. This means that both measurement types produce statistically similar results.

CONCLUSION

Measurement of excavation progress can be done using the UAV-Photogrammetry method. The results of this study showed the deviation in volume calculations using the UAV-Photogrammetry method compared to the truck count volume data in week I of 233 m^3 or 0.654%, week II of 214 m^3 or 0.151%, week III of 496 m^3 or 0.840%, and week IV of 243 m^3 or 0.210%. The results of the t-test statistical test showed no significant difference between volume calculations using the UAV-Photogrammetry method and truck count data volume, which means both measurement types produce statistically similar results.

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