UTILIZATION OF UNMANNED AERIAL VEHICLE (UAV) FOR MEASUREMENT OF SURFACE COAL MINING SITUATION

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ABSTRACT

The rapid development of technology has given rise to innovations and new ways of solving problems. One of them is measuring the situation of surface coal mines. So far, measurements have been made using a Laser Scanner. However, now the Unmanned Aerial Vehicle (UAV) can replace it by considering the aspects of work safety, effectiveness, and efficiency in the field. This study analyzes the influence of the distribution of Ground Control Points (GCP). It compares the measurement method using a Laser Scanner with a UAV in a surface coal mine situation. In addition, this study aims to determine the exact parameters regarding the distribution and number of control points in using UAVs to measure surface coal mining situations. The results showed that the UAV could be used to measure the situation of surface coal with the results of the acquisition parameter research following the 1:1000 PERBIG scale tolerance map, with a tolerance value of <10 cm and the volume difference between the Laser Scanner and UAV is 0.131%. Regarding time analysis and work safety, measurements using UAVs can measure surface mining situations for ± 40 minutes. In addition, personnel do not need to approach the measurement object, so it is better than measurements using a Laser Scanner.

Keyword: Unmanned Aerial Vehicle (UAV), Laser Scanner, Surface mining situation

Introduction

Coal mining has a vital role in national development. Coal mining plays a very significant role in the national economy in the fiscal, monetary, and real sectors. One of the characteristics of the mining industry is that it is capital-intensive, technology-intensive, and has a high risk. PT. Berau Coal is one of the coal mining companies with the largest Coal Mining Concession Work Agreement (PKP2B) permit in Indonesia. PT. Berau Coal has committed to implementing a Mining Safety Management System and mining with the principles of Good Mining Practice (GMP). One of the ways to support operational activities according to the mining plan and operational activities to run safely is to make breakthroughs related to measurement methods for surveying mining situations.

Due to the current rapid technological developments, measurement of surface coal mining situations using laser scanners can be replaced using UAVs, taking into account aspects of work safety, effectiveness, and time efficiency of data collection in the field. Cross-section data from the results of the UAV situation can also be presented periodically, so that mine engineers can quickly inform supervisors in the field which areas are close to design and which areas still need to be explored. This statement means that using UAV technology can make mining operations more effective because supervisors and mine engineers can see the mining situation more broadly in actual conditions. Besides being practical, UAVs can also increase work efficiency because the time needed to capture field situations in videos to form situation data is very short compared to data collection using other methods.

Methodology

The research location was carried out in the area of the PKP2B permit holder PT. Berau Coal site Lati Mine Operation (LMO) Berau District, East Kalimantan.

Mining situation data collection was carried out at Pit SW4 LMO site with an area of 30 Ha.

Based on the problems discussed in this study, this research is classified as a quantitative study. Quantitative research is a research method used by researchers using research measuring instruments (instruments) with statistical analysis.

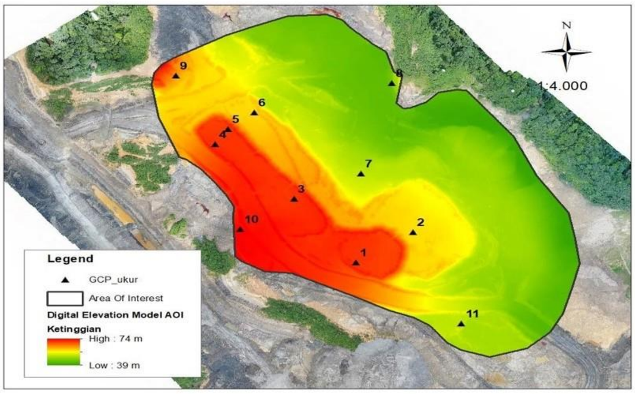


Figure 1. Research sites

Previous research has utilized UAVs for monitoring open pit mines and mining situations (Jhoni & Wildan Firdaus, 2019) to control the suitability of mine designs with actual mining activities. However, Jhoni & Wildan Firdaus have yet to discuss the effect of the distribution of Ground Control Points (GCP) on the accuracy of the results of measuring mine situations using UAVs. This research will analyze the effect of Ground Control Points (GCP) distribution on the accuracy of measurement results in mine situations and compare the measurement method using a Laser Scanner with the measurement method using a UAV in a surface coal mining situation. In addition, to find out the exact parameters regarding the distribution and number of control points in the use of UAVs for measuring surface coal mining situations.

Data Collection

Before data collection in the field, the initial stages were the planning and preparation stages. At this planning and preparation stage, Terms of Reference and determination of acquisition parameters and validation parameters are made to ensure that data collection activities in the field and the results obtained follow applicable standards and regulations. The next preparation stage is preparing equipment, personnel, and permits.

Laser Scanner Data Acquisition

Mining situation data collection was carried out using the RIEGL VZ-1000 Laser Scanner, with control points scattered around the SW4 Pit area. The principle of measurement using a laser scanner is to use light with an optical sensor. The development of computer technology and optical sensors has an impact on the use of light to measure the distance and intensity of an object in various ways. Laser scanners currently on the market are divided into two based on the type of measurement: Pulse-Based (Time-of-Flight) and Phase-Based.

After obtaining point cloud data from the Laser Scanner measurement results, point cloud registration is carried out into the same system. The system used can be a local system or a global system. This registration will make all point clouds correlate and unite in the same system. This registration step impacts the accuracy of the data to be used, as well as the next process of processing the point cloud into a 3-dimensional model.

UAV Data Acquisition

The data collection stage in this study is in the form of coordinate data and aerial photographs:

1. **Coordinate Data**
   The measurement method used is a static method with a radial net model for Ground Control Points (GCP) and Real Time Kinematics (RTK) for Independent Control Points (ICP). Prior to measurement, GCP and ICP stakes were installed. In this study, several GCP point distribution methods were used to determine the effect on the accuracy of the measurement results. After installing the stakes, a GPS Static measurement is carried out, where one GCP point is tied to a Base Station reference point in the LMO area and transmitted to other GCP points. After the static measurement, the RTK measurement is carried out to get the ICP point.
2. **Aerial Photograph Data**
   In this stage, the aerial photo shoot was carried out using the DJI Phantom 4 Pro drone with data collection techniques, namely aerial photography with an upright camera position with a shooting area of 30 ha. Before the shooting, premarks were installed on the GCP and ICP markers as markers on the photo to facilitate identifying control points during photo data processing and ICP points during the accuracy test. After all the stakes are premarked, shooting can begin.

Data Processing

1. **Laser Scanner Data Processing**
   From the results of data collection that has been obtained, namely point cloud data that has been

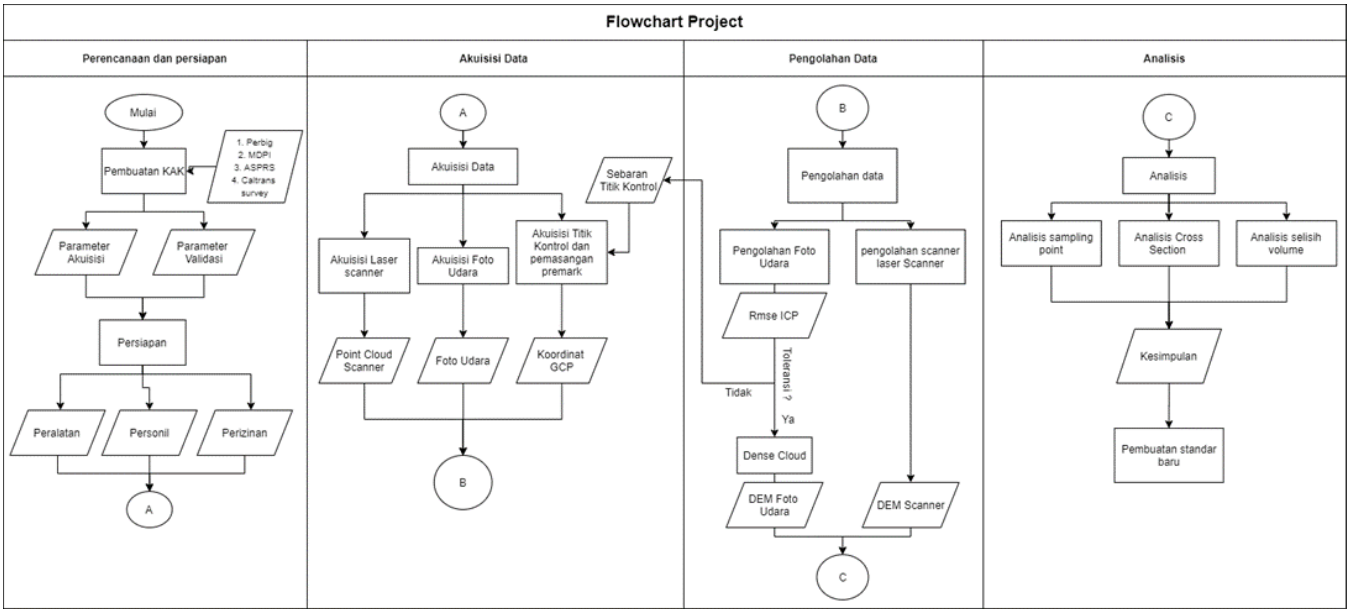


Figure 2. Research Flowchart

registered, systematically processed so that it can be used as material for analysis. Situation measurement data using a Laser Scanner were processed using Riscan Pro software to obtain Digital Elevation Model (DEM) data.

2. UAV Data Processing

At this stage, the aerial photo data is processed using the Agisoft Photoscan software, using several GCP point distribution methods for the orthorectification process. The following are several stages of processing aerial photo data using the Agisoft Photoscan software:

a. Add Photo

This stage is the earliest stage in starting processing, where the captured photos are opened in the Agisoft Photoscan software, and the general sequence of photos according to the flight path is reconstructed.

b. Align Photo

Align photo stages of the same points in the photo. This process will create matching points from 2 or more photos. This process can produce initial 3D models, camera positions, and sparse point clouds, which will be used in the next stage.

c. Import GCP Coordinates and GCP Point Identification

GCP import is performed to provide X, Y, and Z coordinate references for aligning photos to improve the geometric quality of the formed DEM and orthophotos. The use of GCP obtained from measurements using Geodetic GPS is recommended to obtain an accurate orthophoto.

d. Built Dense Clouds

Dense clouds are a collection of high points with a large amount of aerial photo processing. Dense clouds are then further processed to produce Digital Surface Models, Digital Terrain Models, and Orthophoto.

e. Build Texture

Build texture is the process of forming a 3D physical model from the features in the photo coverage area.

f. Build DEM

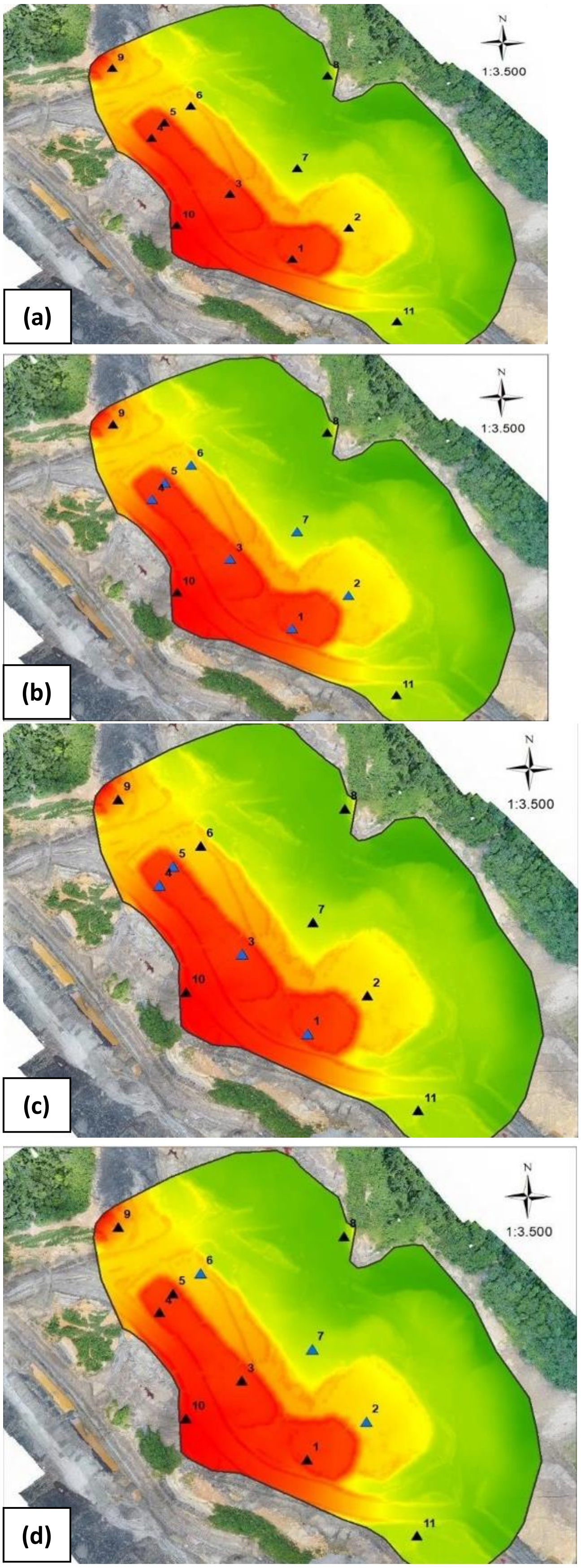
Digital Elevation Model is a digital terrain model in raster or grid format. From the DEM data, elevation information can be derived for further modeling, such as cut and fill. There are two terminologies related to DEM, namely DSM (Digital Surface Model) and DTM (Digital Terrain Model).

g. Build Orthomosaic

An orthophoto is an aerial photograph that has corrected geometric errors using DEM and GCP data to be used for mapping purposes. Orthophotos can be formed after the Dense Clouds, Mesh, and DEM manufacturing stages are completed.

Result and Discussion

This stage is the analysis stage of the horizontal accuracy of the Orthophoto, the vertical of the DEM resulting from the point digitization process, and the accuracy of objects from distance data measured in the field and distance data from interpretation results.



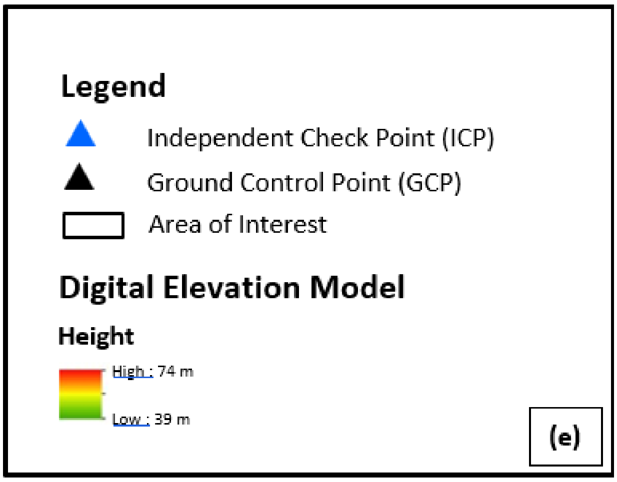


Figure 3. Distribution of GCP Points in All Areas (a), Around Boundaries (b), Around Boundary and Lowest Elevation (c), Around Boundary and Highest Elevation (d), Legend (e).

Sampling Point

Sampling point analysis is carried out by comparing the calculated position with the actual position in the field. The locations taken to compare the sampling points are flat areas, slope areas, and mine road areas.

Table 1. GCP Point Coordinates

GCP	Easting	Northing	Height
1	562332	251920.9	69.729
2	562423.6	251982.5	58.961
3	562232.9	252051.6	69.773
4	562107.3	252164.6	69.88
5	562128.2	252195.7	69.551
6	562171.2	252228.6	59.255
7	562341.1	252102.6	52.767
8	562392.1	252287.4	46.738
9	562045.4	252305.6	63.951
10	562146.5	251990.4	73
11	562500.3	251794.3	52.687

From the sampling point analysis results, the results obtained for all processing schemes and samples have an accuracy of <10 cm. From the table of accuracy values formed from the four processing schemes carried out, all processing is within the tolerance limit, which is below 10 cm.

Cross Section

In this analysis, a comparison of DEM data from the results of the Laser Scanner and drone measurements was carried out. Analysis of areas with a particular slope, such as the slope area. The difference in the DEM data was carried out through statistical analysis using linear regression to determine the effect of the difference in elevation of the DEM Laser Scanner and DEM drone data on the slope of the area in the study area.

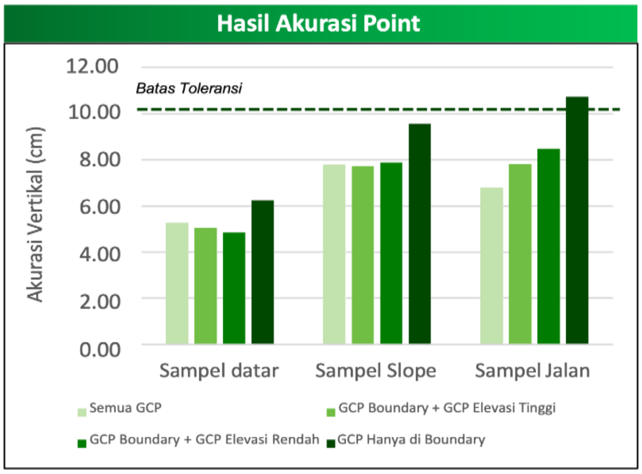


Figure 4. Point Accuracy

From the R Square value in all areas = 0.0015, it can be concluded that the elevation in the Area of Interest (AOI) has no effect on the difference in elevation from the drone data and Laser Scanner data. In the inclined area, R Square = 0.1197, so the slope of the Area of Interest (AOI) has little effect on the difference in elevation of drone data and Laser Scanner data.

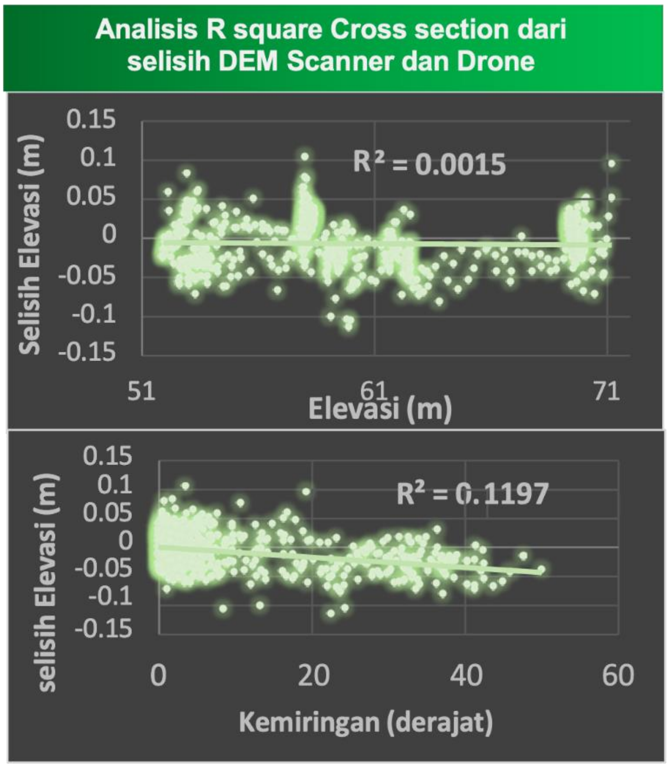


Figure 5. Cross Section Analysis

Volume Comparison

The next analysis is a volume comparison of the drone data for each GCP distribution scheme compared to the volume of the Laser Scanner data.

Table 2. Volume Comparison

Volume Scanner (m^3)	Processing Scheme	Volume	Deviation	Deviation (%)
308,088.94 **Area:** 1.3610 m^2	GCP all area	308,491.25	402.31	0.131%
	GCP in Boundary	308,609.26	520.32	0.169%
	GCP Boundary + GCP Low Elevation	308,502.59	413.65	0.134%
	GCP Boundary + GCP High Elevation	3084,94.64	405.70	0.132%

From the table of volume analysis results, the smallest deviation value is in measurements using drones using GCP, which are spread evenly in all data collection areas, namely 0.131%.

Time and Safety

Table 3. Time dan Safety Analysis

Aspects	Before (Laser Scanner)	After (Drone)
Safety Issue	• Personnel should approach the observation object area • Need to do a tool change	• Personnel need not approach the object of observation • No need to change tools
Operational	• Tool Set up (17 locations) = 136' • Move location (7' each move) = 119'	• Tool Set up = 10’ • Measurement (15" once flight) = 30'
Total Time	± 4.25 hours	± 40 minutes

Conclusion

The results of the research that has been done obtained the following conclusions:

1. The drone photogrammetry method can be implemented for measuring the situation of open pit coal mines using the acquisition parameters that have been prepared, with tolerances that enter the 1:1000 PERBIG scale map.
2. The results obtained for all drone data processing schemes are fortunate for each GCP distribution, and all samples have an accuracy of

<10 cm. From the table of accuracy values formed from the four processing schemes carried out, all processing is within tolerance limits.

3. The elevation in the Area of Interest (AOI) has no effect on the difference in elevation from drone data and Laser Scanner data, as evidenced by the value of R Square = 0.0015. The slope of the Area of Interest (AOI) has little effect on the difference in elevation of drone and Laser Scanner data, as evidenced by the value of R Square = 0.1197.
4. The best drone data processing results use GCPs spread over all measurement areas. This statement is based on the analysis of the volume deviation of the results of Laser Scanner data processing with drone processing using GCP spread over the entire measurement area of 0.131%.
5. With the application of drone technology for measuring mine situations, safety and efficiency can be increased from what previously took around 4 hours to 40 minutes to measure a mine situation with an area of 30 hectares.

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