Comparative evaluation of the effectiveness of the laser scanning and aerial photography systems using unmanned aerial vehicles

A V Chepyzhova, E A Pravdina, O Yu Lepikhina
St. Petersburg Mining University, 2, 21st street, St. Petersburg, Russia
E-mail: anastasya_che@mail.ru, eanes@yandex.ru, olgalepikhina1984@gmail.com

Abstract. This article discusses two modern methods for making mine surveyor surveys: using ground-based laser scanning systems and aerial photography from an unmanned aerial vehicle. Methods are described in terms of time costs, the number of employees and instruments involved, the cost of the work, the necessary computer capacity, depending on weather conditions. The paper also assesses the difference in calculating the volumes of the blasted rock mass. The author made a conclusion about the possibility of using the considered methods for calculating volumes and accuracy sufficient for surveying measurements. This study is based on the experience of using these technologies in real production - Karelsky Okatysh JSC.

1. Introduction
Modern mining speed requires the surveying service to quickly solve a large number of tasks, such as: daily creation of the up-to-date digital models of the open pit, shooting the blasted rock mass camber after a massive explosion, shooting the finished goods warehouses, shooting the waste dumps, etc. The modern methods of work for solving these issues are the mine surveyors with laser scanning systems and surveys using unmanned aerial vehicles. The paper discusses the time and labor costs in the production of one type of work using two systems. The ability to quickly make a three-dimensional survey allows one to effectively solve many tasks of mining planning, keep records of mining and moving rock mass in the production of the massive explosion, to determine the loosening coefficients for calculating the remnants of the exploded rock mass brought to the pillar.

2. Materials and methods
Materials for the paper are provided by the surveying department of Karelsky Okatysh JSC. The comparison was made on the example of two surveys: carried out from the unmanned aerial vehicle of the multirotor type Geoscan 401 (the sortie was made in automatic mode) and using the Leica HDS8800 laser scanning system (shooting from 3 points), taken in one time interval and in one area career. Processing of filming materials was carried out in software: Maptek I-Site Studio, Agisoft Photo Scan. To calculate volumes, the resulting 3D models are uploaded to Surpac Geovia.

3. Results and Discussion
To compare the time and labor costs of the two methods, it is necessary to divide the work on the shooting into field and cameral work.
When using laser-scanning systems, before the field work, the surveyors study the object of shooting by choosing preliminary places for the scanner installation, thus they outline the work. The installation site should provide maximum visibility of the scanned surface, as well as minimize the presence of blind zones. The distances to the scanned object and its chromaticity are analyzed with particular care. In the field, the previously planned installation locations of the scanner can be adjusted depending on various factors. The number of scanner installation points depends on: the length of the scanned object, the distance to the scanned object, the installation location of the scanner, the presence of blind zones during scanning, weather conditions, etc.

When using a UAV, before field work, it is necessary to study the subject of shooting, create a flight contour by unloading it into kmr format, pre-select the launch site, set flight parameters and design a flight task. The flight planning process is carried out primarily with the creation of a flight map, in a specialized Ground Control Station (GCS) represented by a laptop equipped with a modem for communicating with the UAV. The basic principles of creating the flight task, as in classical aerial photometry, are the flight altitude, pivot points, longitudinal and transverse overlaps, and coverage with images of a given area.

For LSS, 1 mine surveyor, 1 miner, and Trimble R10 GNSS receiver are required. The scanner should be used under satisfactory weather conditions (air temperature not lower than -40 °C, lack of precipitation to minimize noise) from the ledges, the visibility from which allows the situation most fully. There should be at least three points of standing to fully reflect the situation. Since most often the highest visibility is observed at the very edge of the board, sometimes on the safety shaft, which is a violation of safety rules, the risk of injury is much higher. Taking into account the number of moves to the opposite sides of the pit, the operating time increases significantly, the time for one launch of the LSS is about 30-40 minutes, taking into account the installation. Cumulatively more time was spent on field work.

At the stage of field work for the UAV, 1 mine surveyor, 1 miner, Trimble R10 GNSS receiver, 5 control identifiers, coordinated in the RTK mode, are required (to improve accuracy, when using a dual-frequency GNSS module). The launch is carried out under satisfactory weather conditions (air temperature not lower than -40 °C, wind speed no more than 12 m / s, lack of precipitation), from a horizontal platform with a diameter of 5 m. The risk of injury is minimal, since work is carried out away from the pit wall. The point of standing is one. The time spent on the production of the flight is not more than 1.5 hours.

Data from the UAV Geoscan 401 is presented in the form of photographs, flight log files, as well as log files of control identifiers coordination. The processing is carried out in the Agisoft Photo Scan software, an orthophotomap, a dense cloud of points, is built using log files and shots, with further processing, filters are applied to the obtained cloud of points to discharge it to 0.5m between the points, to evenly cover the volumes of both LSS and UAV. Next, it is exported to dxf-format for further processing in Surpac.

The Agisoft Photo Scan software package is used in the process of cameraprocessing for shooting with the UAV: the images orientation, spatially reference and the model orientation in the local coordinate system, the building of the elevation model, and a cloud of points is carried out. Work production requires minimal human involvement; processing time for 577 shots and building a cloud of points of average density takes 12 hours.

In the course of cameraprocessing, the data from the tablet computer of the scanner is downloaded to a removable USB storage medium and exported to Maptek I-Site Studio projects. In this software, scans are stitched in the local coordinate system. During further processing, filters on the “topography” and “resolution” are applied to the resulting point cloud to discharge it to 0.5 m between the points. After the filtering, from the cloud of points, one cut the parts of the model with the scanned object with a margin on all sides, pre-painting the dots in a uniform color. According to the data obtained, the topographic 3D surface covered with a frame is constructed. Using Maptek I-Site Studio tools, the surface is cleaned from peaks caused by the reflected signal during scanning from large particles of dust, raindrops or snow, and exported to dxf format for further processing in Surpac [1,2,3].
Processing of the LSS data using Maptek I-Site Studio requires much more participation of the user; there is no fully automated algorithm, but processing of the scan of the plot covering the same area (as during the UAV flight) takes 1-2 hours.

To analyze the possibility of using the methods when calculating the volumes of the blasted rock mass, it is necessary to overlap the obtained clouds of points on each other, trim along one contour and calculate the volumes from the same initial surface [4,5,6].

Comparative analysis was performed in the software package Surpac Geovia. To do this, we overlap two survey data of one section of a mass explosion, performed by the LSS and the aerial survey method using the UAV.

Figure 1 in the upper part shows the dtm format model built using Agisoft Photo Scan software and loaded into Surpac. In the lower part there is a model built according to the data of laser scanning imaging. At this stage, we can say about the greatest detail of the survey made by the UAV: this is due to the difference in the number of points on which the model data is based, since the processing of LSS data allows one to specify the depression of the points through 0.5m, and when building the UAV survey model one can only choose the density of the cloud – high, medium, and low.

At the same time, the model built according to the shooting data from the UAV uses more software capacity which places high demands on the computer software of the surveying department.

One of the main tasks of the mine surveyor is counting volumes. For this type of work, it is also possible to effectively use the compared methods but it is interesting to track the difference between the calculated ones. The volume of the blasted rock mass was calculated using the Surpac software module

Figure 1. Mapping of one surface area of the DTM-model built by clouds of points. The top is built on the materials of the UAV. The bottom is built on the materials of LSS shooting.

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of one initial surface within the same contours of various sizes that capture mountain rock volumes from 30,000 to 500,000 m$^3$. There is no significant difference; it is no more than 3% of the volume in different areas of comparison; this indicates sufficient accuracy of the shooting methods. Since the number of points of models is significantly different, we can talk about the presence of excessive information that does not carry information but loads the PC system power.

4. Conclusions
On the basis of the comparison made, the indicators are summarized in Table 1 for clarity. The time and labor costs obtained in the course of work are estimated on the basis of the usability of the equipment, using the example of the work performed and the equipment used, of the software packages.

Table 1. Comparative evaluation of the ground-based LSS and UAV methods

| Parameter | LSS | UAV |
|-----------|-----|-----|
| Spent time: Field work | 40 minutes / point, more than 3 points of standing | 60 minutes, 1 flight |
| Spent time: Cameral work | 3-4 hours, manually | 12 hours, automated |
| Density if the point cloud | Customizable, can be thinned out to the desired value | Only the density levels of the cloud of points, there is no possibility to set parameters |
| Dependence on weather conditions | air temperature not lower than -40 °C, lack of precipitation | air temperature not lower than -40 °C, lack of precipitation, wind speed not exceeding 12 m/s |
| Vulnerability | Disruption of work due to failure | Disruption of work in case of falls or malfunctions, frequent repairs |
| Preparatory work | Reconnaissance, work planning | Designing of the flight task |
| Computer capacity requirements | Medium | High |

The disadvantage of the UAV system is a strong dependence on weather conditions and vulnerability (often undergoes repairs), a long time spent on post-processing. A significant advantage is the minimization of risks, the absence of the need for long movements, the speed of field work, the reduced human participation in the process of shooting and post-processing.

The disadvantage of LSS is the presence of large risks associated with the implementation of safety requirements, significant labor costs in the field stage. The advantage is quick office processing, the ability to quickly receive data, visual display of the result of shooting on the screen of a tablet computer in the field.

When calculating the volumes, the characteristic results are obtained and presented in Table 2. Where: $V_{UAV}$ is the volume of rock mass calculated by the model obtained from the UAV; $V_{LSS}$ is the volume of the rock mass calculated from the model obtained from the results of ground-based laser scanning.
Table 2. Calculation of the volumes of blasted rock mass.

|          | $V_{UAV}$, m$^3$ | $V_{LSS}$, m$^3$ | $V_{average}$, m$^3$ | $σ$, % |
|----------|-----------------|-----------------|---------------------|-------|
|          | 30287           | 31225           | 30 756              | 3.1   |
|          | 260771          | 257425          | 259 098             | 1.3   |
|          | 519097          | 514467          | 516 728             | 0.9   |

According to the results in Table 2, we can talk about the possibility of using the considered methods for calculating volumes and accuracy sufficient for surveying measurements.

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