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Application of Aerial 3d LiDAR Scanning Technique in Open Pit Mines

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ABSTRACT

The application of Aerial 3D LiDAR scanning techniques in open-pit mines represents a transformative advancement in the field of mining and resource extraction. This cutting-edge technology leverages Light Detection and Ranging (LiDAR) sensors mounted on aerial platforms to generate highly detailed and accurate three-dimensional representations of open-pit mining landscapes. This abstract explores the myriad ways in which Aerial 3D LiDAR scanning is revolutionizing open-pit mining operations. One significant benefit of employing Aerial 3D LiDAR scanning in open-pit mines is its unparalleled capability to provide precise topographical and geological data. The technology enables rapid and comprehensive mapping of the mining site, facilitating enhanced geological modeling and accurate volume calculations. This, in turn, contributes to optimized mine planning and improved operational efficiency. Moreover, Aerial 3D LiDAR scanning plays a pivotal role in enhancing safety measures within open-pit mines. The technology allows for real-time monitoring of pit walls, identifying potential hazards such as rockfalls or slope instabilities. By providing early warnings, it aids in preventing accidents and ensuring the well-being of on-site personnel.

In conclusion, the application of Aerial 3D LiDAR scanning in open-pit mines is a transformative force, revolutionizing the industry by offering unprecedented accuracy in mapping and monitoring. This technological innovation not only optimizes operational processes but also elevates safety standards, positioning itself as a cornerstone in the evolution of modern mining practices.

Keywords: LIDAR, mines, accuracy, scanning

INTRODUCTION

In the realm of mining operations, the quest for precision, efficiency, and safety has been a perpetual journey, marked by advancements in technology that redefine the industry's landscape. Among these transformative innovations, the application of Aerial 3D LiDAR scanning techniques in open-pit mines stands out as a groundbreaking development, revolutionizing the way mining sites are surveyed, monitored, and managed.

LiDAR, an acronym for Light Detection and Ranging, has been a stalwart in remote sensing technologies, offering unparalleled capabilities in capturing highly detailed and accurate geospatial data. When applied to open-pit mining scenarios, LiDAR takes on a new dimension, providing a three-dimensional perspective that transcends the limitations of traditional surveying methods (Abellán et al., 2008).

Open-pit mines, characterized by vast expanses and intricate topographies, pose unique challenges in terms of monitoring, planning, and safety. Aerial 3D LiDAR scanning addresses these challenges by employing laser beams emitted from airborne platforms, such as drones or aircraft, to measure distances and create detailed, high-resolution point clouds of the terrain below. This data-rich point cloud serves as a digital representation of the open-pit mine, capturing not only the surface but also the intricate details of geological formations, structures, and any changes that occur over time.

The advantages of Aerial 3D LiDAR scanning in open-pit mining are manifold. Firstly, the technology allows for swift and comprehensive surveying of vast areas, minimizing downtime and enhancing operational efficiency. Traditional survey methods often entail time-consuming ground-based measurements that may not capture the entire mine in a single operation. LiDAR, on the other hand, can cover large expanses in a fraction of the time, offering mining companies real-time insights into their operations (Bazarnik, 2018).

Moreover, the high level of detail provided by Aerial 3D LiDAR scanning allows for precise volumetric calculations, crucial for accurate stockpile assessments. This capability enables mining companies to monitor material extraction and deposition with unparalleled accuracy, facilitating optimal resource management and reducing the risk of over-extraction or inefficient stockpile utilization.

Safety, a paramount concern in mining, also receives a significant boost with the application of Aerial 3D LiDAR scanning. The technology enables the identification of potential hazards, slope instabilities, or changes in topography, empowering mining companies to proactively address safety concerns and implement preventative measures. This proactive approach not only safeguards the well-being of on-site personnel but also mitigates the risk of costly accidents and environmental damage (Deliormanli et al., 2014).

In this era of data-driven decision-making, Aerial 3D LiDAR scanning provides open-pit mining operations with a wealth of actionable insights. Advanced analytics and modeling techniques can be applied to the collected point cloud data, facilitating trend analysis, predictive maintenance, and improved long-term planning. The integration of this technology into mining workflows represents a paradigm shift towards a more sustainable, efficient, and technologically advanced industry.

As we delve deeper into the application of Aerial 3D LiDAR scanning techniques in open-pit mines, this exploration will uncover specific use cases, technological considerations, and the transformative impact this innovation holds for the mining sector. From optimizing extraction processes to enhancing safety protocols, the journey towards a more sophisticated and streamlined open-pit mining industry is underway, guided by the precision and depth offered by Aerial 3D LiDAR scanning techniques (Rengers, 1967).

METHODOLOGY

Case Study

In this study, a mine was selected in the village of Gjegjan, in the north-eastern part of Kukes, Albania. The surface of the work area is approximately 20 hectares and lies at an altitude ranging from 550-650 m. The mine is of the "Open pit" type, not underground, it is divided into two areas, the old mine, which is no longer operated, and the new mine, which has been in operation for some time. In this mine, among other things, it has been requested that there be a periodic survey to control the volume of works. In the technical requirements regarding the surveying of this area, a relatively low accuracy of ±30-40cm in plan and height is required due to the unstable and difficult nature of the terrain. Currently, there is no geodetic base in this area, and in previous works it was measured with GPS in the UTM Zone 34N coordinate system (epsg:32634) and height system based on the EGM2008 geoid.

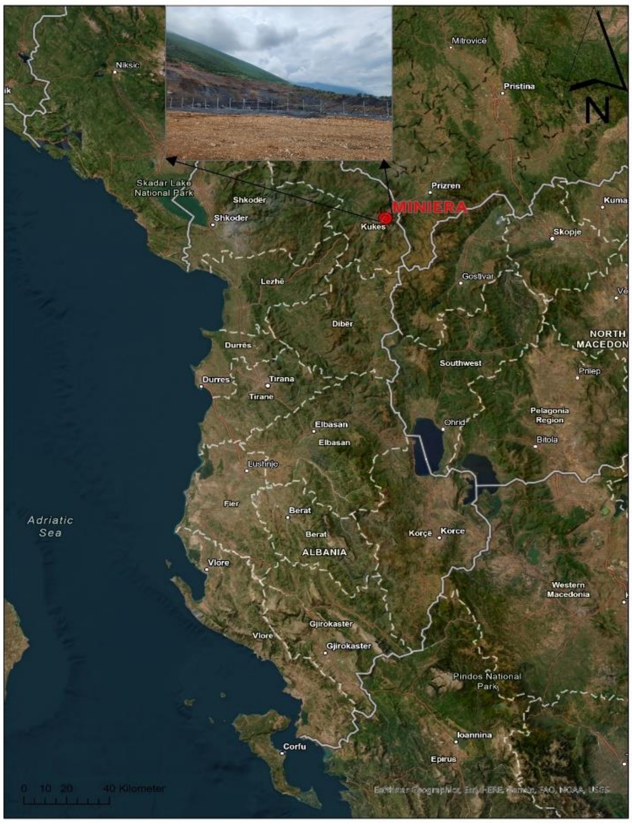

Figure 1: Location of the open-mit mine

Fieldwork for Aerial LIDAR Scanning

The workflow for the realization of fieldwork was:

a) Placing the geodetic base at a known point and securing the base-rover connection
b) Marking and measuring Ground Control Point (GCP)
b) Uploading the mission to the drone, executing the flight and scanning
c) Data download and data pre-checking for any corrupt or ungenerated files results

For this study, the DJI Matrice 300 RTK with Zenmuse L1 camera was used for the aerial survey of the open-pit mine. The DJI Matrice 300 RTK is powered by a quadcopter propulsion system. This means that it has four rotors that provide lift and propulsion. The rotors are powered by high-performance brushless motors that are designed to provide maximum power and efficiency. The motors are also designed to be quiet and reliable, which is important for professional use. The drone is equipped with a high-performance GPS system that provides accurate positioning and navigation. It also has a built-in obstacle avoidance system that uses advanced sensors and algorithms to detect and avoid obstacles in its path (Vassena et al., 2018).

The Zenmuse L1 integrates a powerful and ultra-lightweight Livox Lidar module with a 70° FOV, a high-accuracy IMU, and a 20-megapixel camera with a 1-inch CMOS sensor which can be used for photogrammetry missions.

The Zenmuse L1 can generate true-color point cloud models in real-time or acquire a vast area (up to 2km²) of point cloud data in a single flight.

With a Point Rate of 240,000 points per second and a detection range of 450 meters, the ease and speed of capturing quality Lidar data is unprecedented. Thanks to the L1's ability to support 3 returns, the point rate can be increased to 480,000 pts/sec.

The module supports both Line Scan Mode and Non-repetitive Scanning Mode, a unique technology developed by Livox. This will provide full coverage of the area of interest in a very short amount of time and allows the sensor to capture data in any direction, instead of along a defined plane.

The Zenmuse L1 Lidar solution can easily penetrate vegetation canopies and foliage.

With an IP54 rating, the L1 can be used in tricky weather conditions, providing more opportunities to collect data.

When the aircraft unexpectedly loses GNSS signal, the DJI L1 can continually use the visual assistant camera to receive orientation data and maintain system accuracy within a short period of time.

Figure 2: DJI Matrice 300 RTK drone with Zenmuse L1 camera

Marking and Measuring Ground Control Points

After studying the area to be scanned, first these points were marked on the ground, with a spray and with dimensions of approximately 2x2m. Their distribution was made to include the middle and the edges of the block in order to minimize its deformations in the case of the photogrammetric process. The measurement of the points was done with GPS connecting in base-rover mode, and measured with RTK method. The type of GPS used is AlphaGeo L8, with a declared accuracy for the RTK method, horizontal ±8mm+1ppm RMS and vertical 15mm±1ppm RMS.

Figure 3: Types of GCP used in this study

Flight Mission Planning

At this stage of flight planning for LIDAR scanning, in the selection of the specialized program, we must take into account some general criteria that are of particular importance in LIDAR scanning, such as maintaining the same flight height while the terrain below changes, and especially in large dislevels, as in our case that along the surveyed area we have a dislevel of 100 m, it is also important to correctly support the scanner parameters regarding its scanning field and the camera in order to accurately calculate the longitudinal and transverse (Decker, 2008).

We used DJI Pilot 2 to plan the mission and to set flight parameter. These parameters are easily configurable, and by contouring our area of interest and setting the flight parameters, the generation of routes is done automatically.

Before the drone is turned on, together with the LIDAR device, which performs self-calibration for a few minutes, the GPS base must be turned on and continuously take static measurements almost 5 minutes before the flight and 1 minute after the flight. The coordinates of the temporary base are determined by measuring with the RTK method through the ALBCORS system, which is the National Albanian Active GNSS Network and it offers an accuracy of 2-3 cm. These data served for the post-processing of the data through the PPK method for the accurate generation of routes and IMU data.

The flight parameters that we set in DJI Pilot 2 were:

Flight height 60m above ground (Terrain following)

Flight speed 6m/s

Longitudinal overlap 40%

Continuous scanning 720 000 points per second

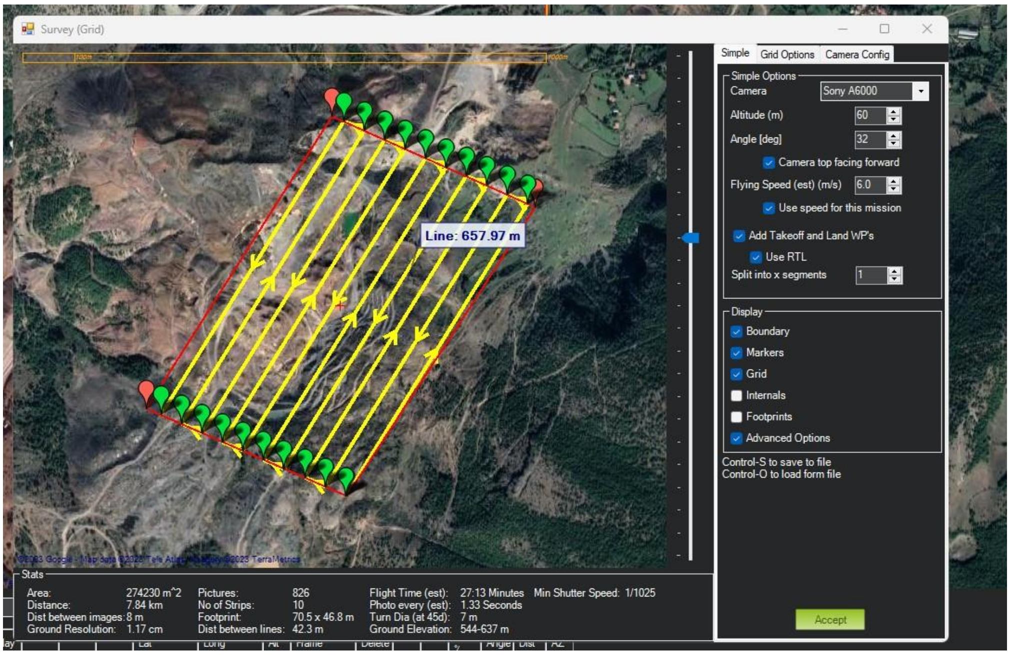

Figure 4: Flight mission planning

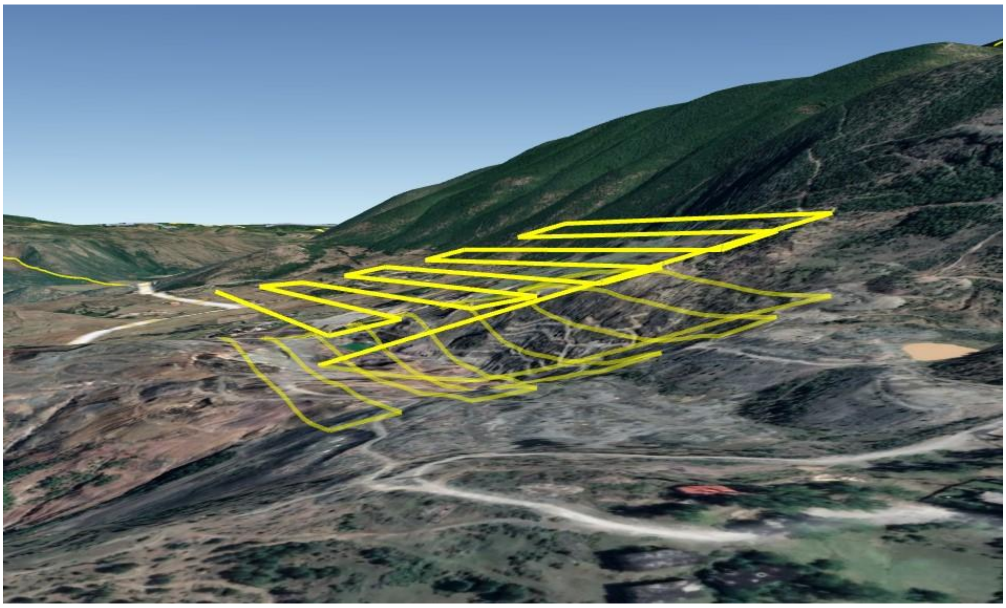

Figure 5: 3D view of planned routes as well as live monitoring of flight execution

RESULTS AND DISCUSSION

Our scanner was of the PPK type in terms of the external and internal orientation of scanning and flight, so during the entire flight at the same time we also received static readings from our base which was later used for the PPK process. Data processing in the case of LIDAR scanning takes place in two main moments.

Pre Processing

For this stage, specific programs are usually used that are connected to specific scanning devices of the same brand. These are manufactured by LIDAR scanner hardware companies along with the relevant instructions. In this case, we used DJI Terra to process lidar data.

DJI Terra is 3D model reconstruction software that has photogrammetry as its core technology. It supports a range of accurate and efficient 2D and 3D reconstruction of visible light, and data processing through DJI LiDAR. We can perform highly accurate processing of the point cloud data captured by the Zenmuse LiDAR in DJI Terra, including route calculation, precise fusion of point cloud and visible light data, optimization of point cloud accuracy, ground point extraction, DEM generation, and mission report output (Chun-Lei et al., 2019).

The processing flow at this stage is as follows:

We prepared the files as below which include the base file (observation data), IMU data (POS data), Lidar files and images.

Then we completed the parameters of our LIDAR device and chose the required coordinate system which is UTM Zone 34N (epsg:32634). We also chose the generation mode according to the routes, manually selected the routes excluding the trajectories in turns from the route to the route, chose whether or not we want to color the 3D rain through images taken from the RGB camera. The processing time of all trajectories and the generation of a 3-dimensional point cloud for our entire area was 15 minutes in the case of uncolored points and 40 minutes in the case of colored points. This is a very big advantage of LIDAR scanning compared to the classic photogrammetric process, which takes much more time to generate a 3-dimensional Point cloud.

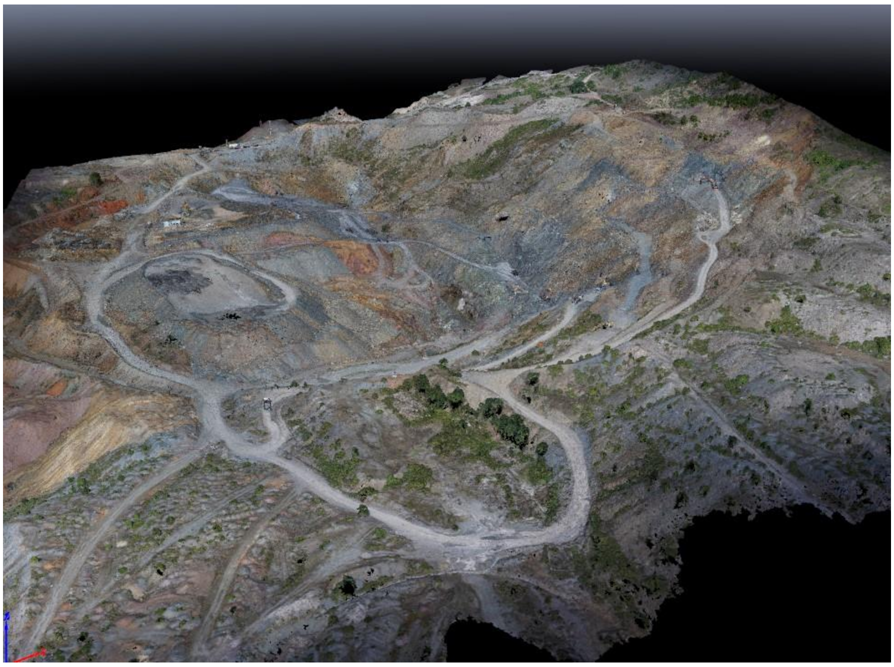

Figure 6: The generated Point Cloud according to the RGB colors of the camera

Post Processing

After obtaining a Point cloud from the pre-arrival process, the next step was the control of accuracy in plan and height, quality control and then various analyzes on this material according to the respective needs. The computer programs for this phase are diverse and independent of the physical equipment used, since the input in this process is a quantity of points in the form of a cloud, georeferenced and with data such as intensity, RGB color, number of returns...etc. in a format which is easily processed by any GIS program that supports 3D networks. In this case, we used the Global Mapper program to check accuracy, quality and perform some processing (Oparin, et al., 2007).

Checking the Accuracy and Quality of 3D Data

Through an automatic functionality in the taskbar of LIDAR commands dedicated to this program, we compared the heights of GCP points measured with GPS and those generated by 3D clouds, and specifically the 5 closest points around each GCP measured. As for the accuracy in the plan, it was done visually through the survey of each GCP point in relation to the one identified in the Point Cloud.

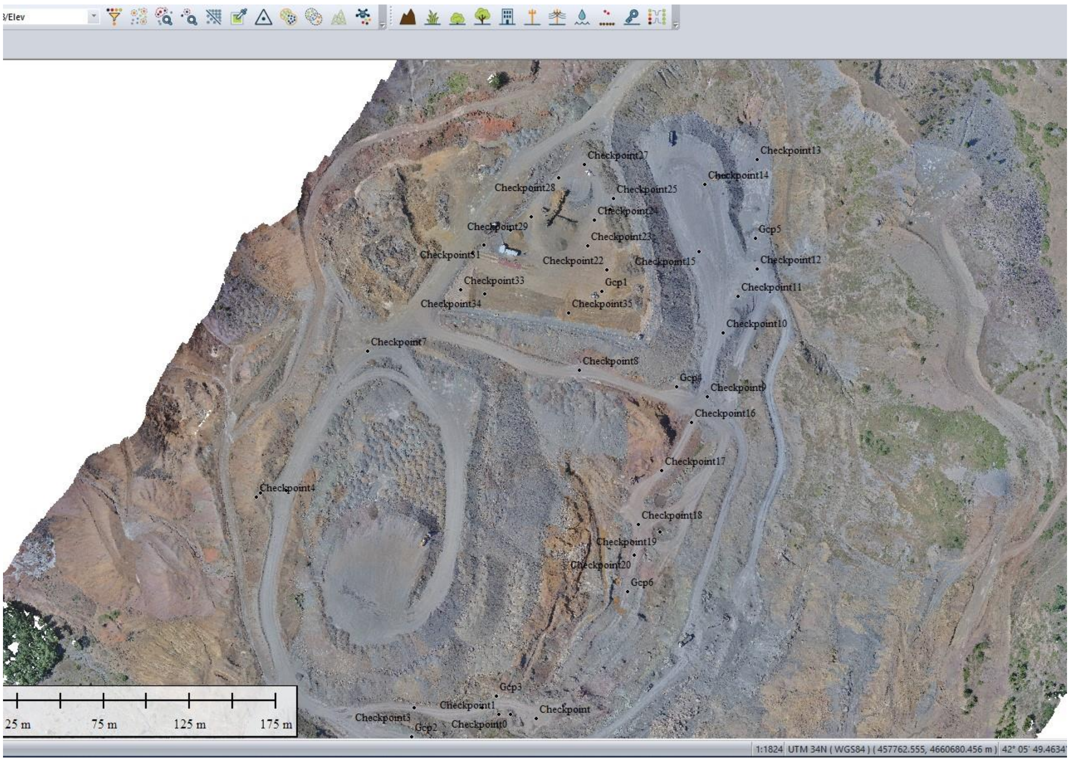

Figure 7: Distribution of GCP points and random checkpoints

We achieved a 5cm RMSE error from the quality report, taking for the same control point points from a radius of 50 cm and a maximum of 5 points.

The report of the automatic control of the accuracy in quotations with a GMK of 5 cm, taking for the same control point points from a radius of 50 cm and a maximum of 5 points.

As for checking the accuracy of the plan, it was generally done through manual surveys by comparing it visually since the density is very high, 96 points per m2, and we managed to distinguish the GCP marked on the ground from the one that we can verify the accuracy of the plan.

As can be seen from the high density of new points, it was almost practically like an orthophoto. And where from the measurements we have an accuracy in plan up to 7-8cm

Another control is the quality of the point cloud generation. This control consists in identifying the points of the point cloud that have anomalies in the heights and that are considered in the algorithm of the program as "High Noise" (Little, 2006).

Also another control is the uniformity of the point cloud in the flat areas where the heights must be within a centimeter deviation of acceptable and not abnormal. This check was carried out using the command to generate transverse profiles within a certain period, making surveys throughout the area of interest.

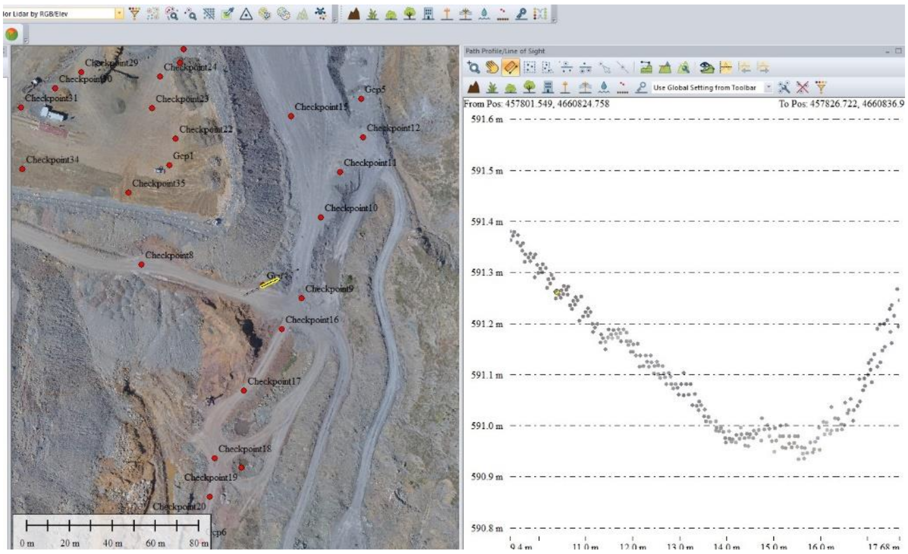
Figure 8: Visual control of the GCP position in a transverse profile

Generation of the DSM and DTM

Until now, we have generated and controlled the so-called DSM, which contains all data, including plants, objects, machinery and any other form on it. To obtain DTM we need to eliminate through the algorithms in the program used approximately and as close to reality everything on the ground, thus generating the correct DTM ground model.

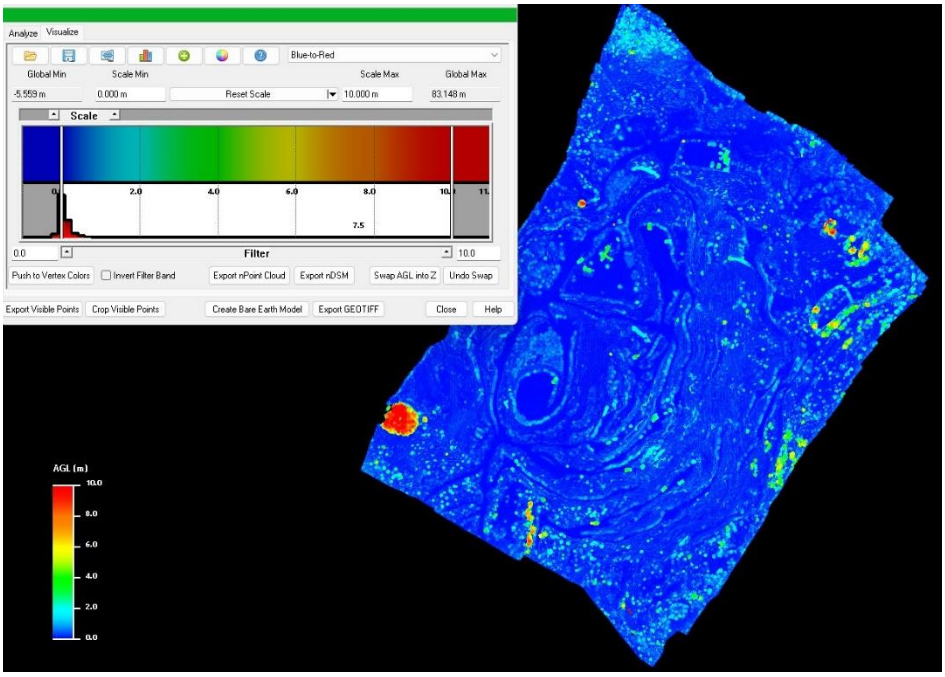
Figure 9: DSM generation

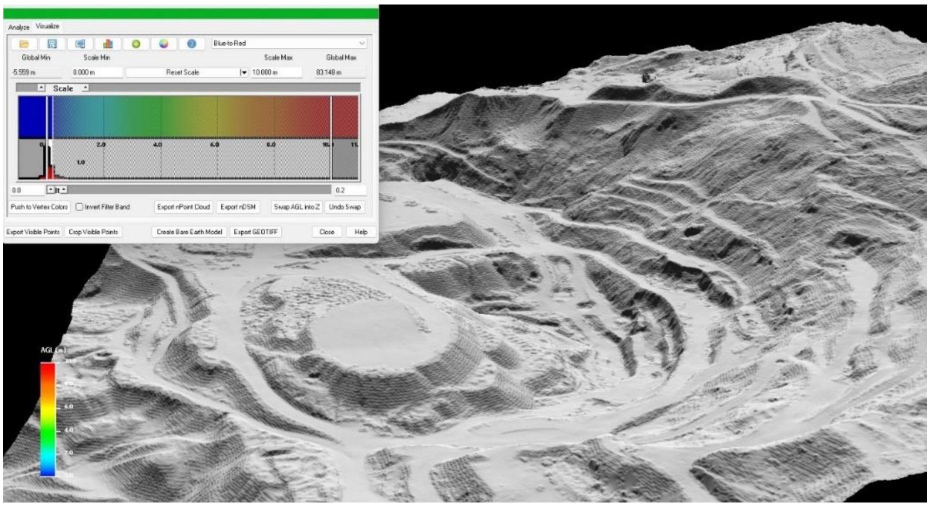

Figure 10: DTM generation in hillshade mode

Digitization of 3D Escarpments

For the digitization of the 3D escarpments, we used a special program which allows us to digitize by organizing in certain layers the entire part of the escarpments below/above and the storage areas. Then this digitization was exported in DXF format to be imported into the final project.

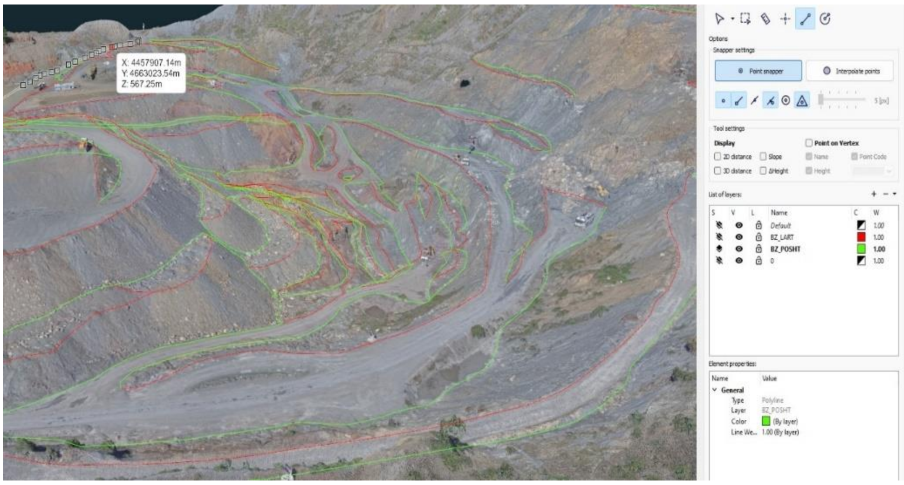

Figure 11: DTM generation in hillshade mode

Orthophoto Generation

Orthophoto was generated using Pix4dMapper software. The program automatically imports and reads in advance the parameters of the images such as geographic longitude, latitude, height, vertical and horizontal accuracy of positioning as well as rotation angles around X, Y and Z. After import, a positioning of the cameras is immediately generated in advance at the time of photography.

To increase the accuracy of the model, GCPs were imported and marked with their coordinates in the respective images in order to link the image with the control point as accurately as possible. Image processing in Pix4DMapper and orthophoto generation took 6 hours and 45 minutes.

After the generation of the orthophoto, the calculation of the volumes of excavations and fillings, and the calculation of heights based on the EGM2008 geoid for the entire area of interest was carried out.

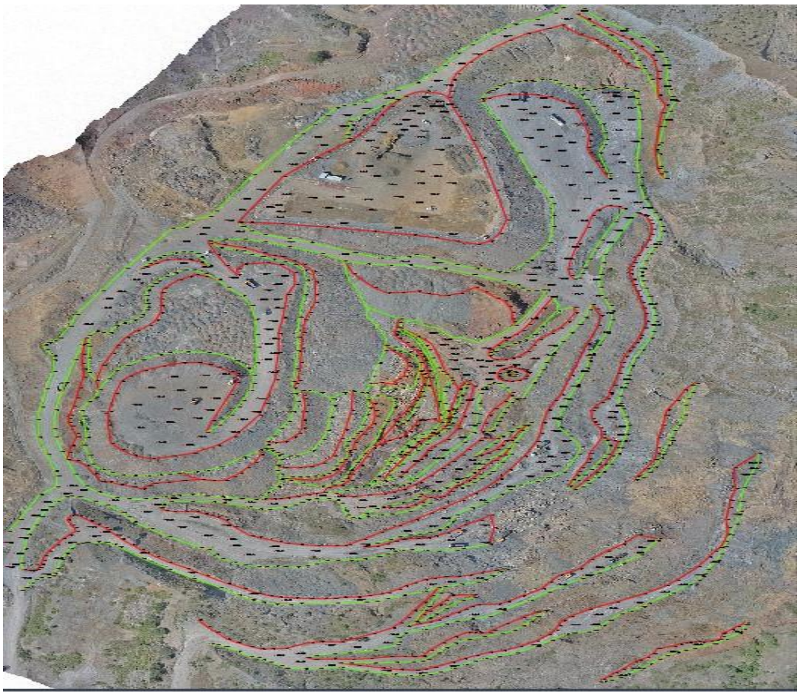

Figure 10: Orthophoto of the open-pit mine

CONCLUSION AND RECOMMENDATIONS

This study demonstrates that drone and LIDAR scanner surveys provide promising results with high resolution and accuracy, significantly increasing site safety and the efficiency of periodic surveys in open pit mines.

Through the case studied in Kukes, the process of obtaining the 3-dimensional model with LIDAR scanning is clearly shown.

A number of factors that influence the quality and accuracy of the orthophoto are mentioned in this paper, as well as the possible strategies that can be applied to eliminate some problems and to increase its accuracy.

This part of the study shows that due to the high resolution of the 3-dimensional model generated by LIDAR scanning, new elements can come to light which could not be distinguished before due to the limitations of traditional surveys.

As reported, the accuracy without control points is relatively high thanks to the PPK method applied in this set of devices. The placement and measurement of control points, which means increased time, in this approach is significantly reduced in terms of the need to generate 3-dimensional clouds, and from a primary role in the orientation of the model, they simply take on a controlling role.

While in the case of orthophoto generation, control points are necessary, but of course with a reduced number compared to the cases when we do not have a set of equipment with the possibility of the PPK/RTK system. However, the rapid development of UAV technology, improving the accuracy of the position from the GNSS integrated in the drone as well as the duration of the flight, including the development of photogrammetric programs, simplify this process and increase its efficiency and accuracy.

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