

CREATING 3D MODEL OF AN OPEN PIT QUARRY BY UAV IMAGING AND ANALYSIS IN GIS

Silviya Filipova¹, Dobromir Filipov², Paulina Raeva³

¹ PhD, Eng. Silviya Katsarska-Filipova, Department of Photogrammetry and Cartography, Faculty of Geodesy, University of Architecture, Civil Engineering and Geodesy, Sofia, email: sillwy@abv.bg

² Eng. Dobromir Filipov, Department of Photogrammetry and Cartography, Faculty of Geodesy, University of Architecture, Civil Engineering and Geodesy, Sofia, email: dobrigf@abv.bg

³ Eng. Paulina Raeva, tel. +359 883 519 162, email: paulina.raeva@gmail.com

Abstract

The following article outlines the technology of creating a 3D model of an open pit quarry based on UAV digital images. Furthermore, it deals with UAV data integration into GIS and conducting spatial analysis. The main technical processes and prospects of UAV mapping and automatization are presented and described. Digital images as well as contemporary photogrammetric techniques help generate accurate geometric 3D models. Through GIS analysis a more precise information for the current processes and events in the quarry could be gathered, leading to a future managerial decisions. The characteristics of the chosen UAV are presented as well as its technical parameters. The flight plan was set as the area and environmental specifications were taken into account. The image data was processed in a specialized software for creating a digital terrain model (DSM) and orthomosaic which were later generated in GIS. By importing a DSM of the open pit quarry routinely in GIS, the processes which take part could be easily monitored and maintained. The profiles of slopes contribute to extracting a detailed geometric information about the berms, bench heights, slopes and the road infrastructure. From the presented analysis forthcoming logistics and working processes could be planned. This overall information is a base to which a vector and attribute data could be added as for a complete building of a data base.

Keywords: mine engineering, open-pit quarry, UAV photogrammetry, GIS analysis

INTRODUCTION

UAV photogrammetry in combination with geographic information systems has been popular and powerful tool in terms of many engineering spheres. Despite this, they have rarely been used for studying quarries or in particular for mine engineering. Many studies have shown that GIS is an appropriate tool for creating 3D models and post-processing of imagery data.

GIS has powerful data processing functions, according to the geological data and engineering experience. Various influence factor of the slope stability is analyzed on the slope stability problems. Based on GIS analysis, the slope stability could be established and the grading index of stability could be determined. (Shiguo Sun, 2015)

The quarry is a system which is constantly changing its location. Moreover, it is dynamic system which technological process take place relatively fast and change the environment of the surrounding area. An essential characteristic of an open-pit quarry is its integrity due to succession and implementation in time and space (expansion of new berms, preparation, extraction, transport and manufacturing). The processes which take place in a quarry are extremely tied together and connected with time. The system of the quarry could be in different states – optimal, functioning, non-functioning. In all case it is compulsory to gain, process and present different kinds of information and statistics regarding its state. The information flow could be effective provided the following conditions:

- Continual processes in time and space;
- Objective estimation of the incoming data;
- Using up-to-date state-of-the-art technology and methods;
- Duly and promising respond to the open processes

The information in the sphere of mine engineering has its own characteristics and parameters. It is gained by specialized technologies which comply with given legislations. During the mine work in an open-pit quarry, control measurements are performed in order to assess its the factual state. (Mazhdrakov, 2007)

MAPPING THE QUARRY WITH UAV PLATFORM

The quarry has been mapped with an unmanned aerial platform – eBee, the successor of Swinglet CAM, created by the Swiss company senseFly. The platform could be categorized as a fixed-wing platform. The drone is set with two softwares – eMotion for the flight planning and Postflight Terra 3D for the post processing of imagery. The drone is manually launched and then is automatically following the flight lines set previously. The eBee could be controlled at every point of the flight or be controlled in real time. After all the photos from the flight lines are taken, the drone lands to a particular place fully automatically. The landing could be linear with gradually lowering or in a circle. Thanks to the ground sensor and the ability of the motor to work backwards, the landing is fluent with an ease. The sensor is composed of a high-speed optical sensor and lens assembly, is used to detect the proximity of the ground.

FLIGHT PLAN CREATED IN EMOTION

The drone is set with a software for flight planning. eMotion is wirelessly connected with the UAV platform as the flight could be monitored and controlled from a laptop. The software interface is accessible and easy to use. A simulation of the flight could be performed as the software works with Google Earth as a map background for the flights.

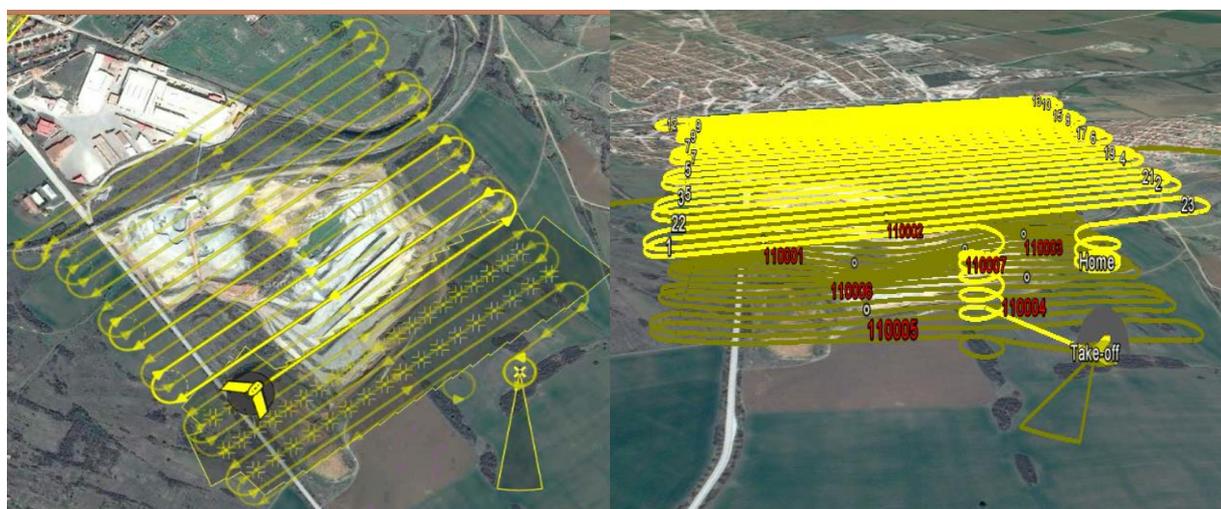


Figure 1 Google Earth imagery presenting the flight plan for mapping the quarry

The area of interest was cover by a rectangular rotated to 54°. The size of the area to be mapped is 655x644m or 42.2ha=0.42km². Figure 1 presents the geographic coordinates of the center of the rectangular - - 43° 11'48.075''N и 24° 10' 36.397''E. The resolution is 2.8cm/pixel and the longitudinal and latitude overlap – 75%. In figure 1a, the take-off position could be seen. This the place from where the drone will take-off. The take-off location is the point from which the drone is launched, automatically set to the location calculated from GPS signals. An altitude of 0m is being defined which actually means 0m above take-off (ATO). (www.sensefly.com, 2015) It was chose carefully as it is visibly higher than the object to be mapped. The surroundings are clear from natural obstacles fo the drone as trees and bushes.

CREATING A DIGITAL TERRAIN MODEL AND ORTHO MOSAIC

Creating DSM (Digital Surface Model) and ortho mosaic is the third step of the model processing. Pix4Dmapper has been used for their creating using the function – Process – Local – Processing – DSM, Orthophoto, Index. The software creates by default a DSM with the size of the ground sampling distance (GSD). The photogrammetry processing resulted in a model with GDS=3.46cm. Noise and smooth filters have been automatically applied to the model. After the point densification a mesh model has been created. Mesh is a group of triangles based on the cloud points, vertexes, polylines, etc. (Pflipsen, 2006) The mesh defines the model vertexes and its shape and structure. The process of creating a DSM is fully automatic. In order for an ortho mosaic to be created a DSM must be created first. (Pavelka, 2009)

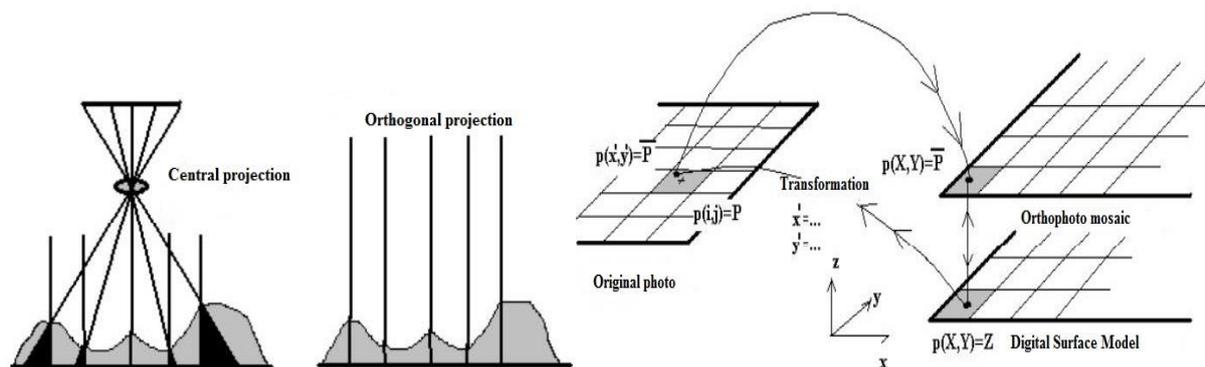


Figure 2 Basics of transformation between DSM and orthophoto mosaic

The transformation from central projection to orthogonal enables work with the model as a map which could be later studied in a GIS software.



Figure 3 Digital Surface Model with imagery

GIS ANALYSIS OF THE QUARRY

Basically the geographic information system have to be also called Spatial Information System. Geographic Information Systems and their similar, dynamic decision support systems (DSS) are aimed at processing a great amount of data, describing the environment in an extended regime. The different spatial information is being structured in thematic layers which could be organized and submitted in a various ways.

A 3D model of a particular quarry created in a photogrammetric way could be generated in ArcGIS. After every control measurement, the mine engineers accumulate information about the quarry status in a geospatial database. This database could be easily used for volumetric calculations and adhering to the concession contacts.

The date regarding the open pit quarry is of high importance in every single step from the quarry development as well as after its liquidation. The natural conditions are also a key feature in monitoring an accurate and complete model of the mine processes. The model of the quarry from different periods of time is quite different in position and shape. That is why, choosing an appropriate state-of-the-art and post processing methods is of high significance.

The DSM and orthophoto mosaic were generate in ArcGIS for a further analysis. Contours were extracted from the surface created in the photogrammetric software Pix4D. Mine engineers need a periodical information regarding the shape and extend of the berms. Given the fact that the quarry is developing through opening new berms and terraces, mapping this development is most appropriate through contour plans. Those plans show the dynamic in the mine works and serve representing the whole state of quarry. GIS softwares are an appropriate tool for the aforementioned plans. With a digital terrain model on disposal, creating profiles of the berms is fast and accurate.

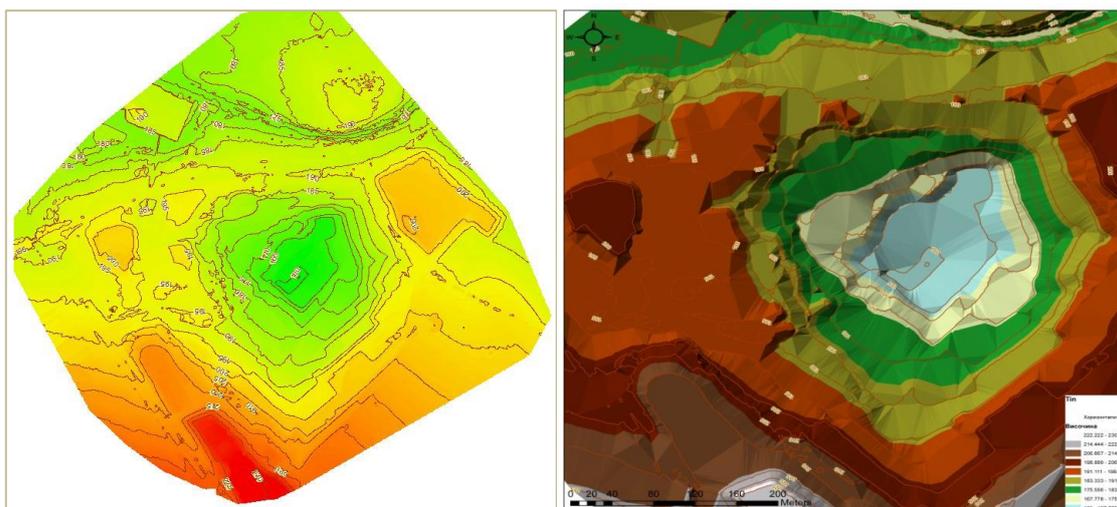


Figure 4 On the left is shown the DSM created in ArcGIS with previously created contours. On the right a TIN model of the quarry is shown.

In Figure 4 is presented the DSM and TIM model of the quarry. For further studying of the quarry, the DSM model will be used as a base for cross sections or profiles of the berms.

For the study case, three profiles have been created (see Figures 5, 6, 7, 8). As for the quarry being situated in an arc slope, only cross sections have been created. The profiles could be used for gaining information about the geometry of the pit as well as for planning the logistics and the workflow. Profiles could be made periodically at the same places for control measurements and results of the processes. Having created profiles of the quarry could be monitored several elements: over-all wall slope angle, particular berm slope, bench heights.

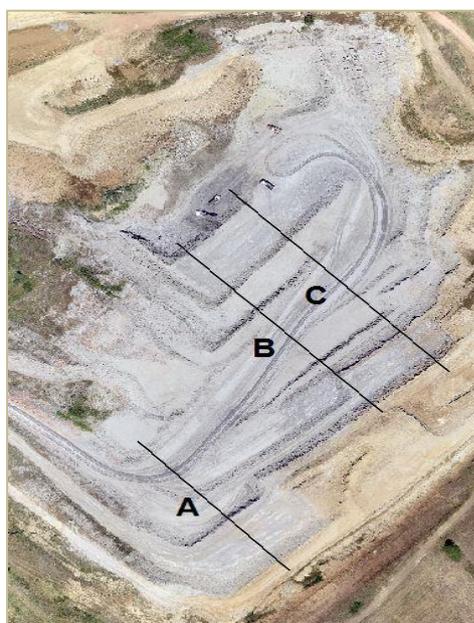


Figure 5 Sample cross sections of the quarry

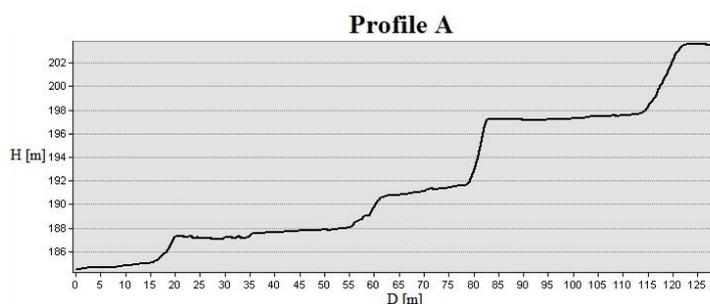


Figure 6 Section profile A

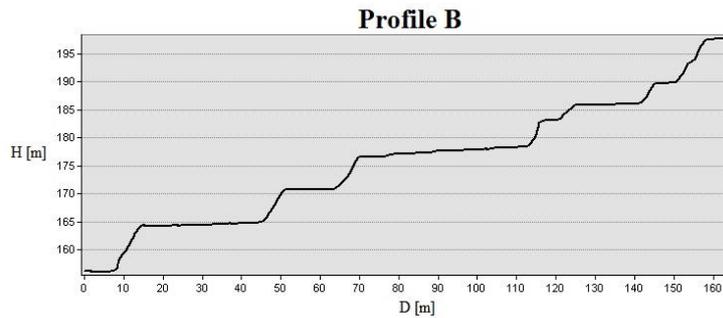


Figure 7 Section profile B

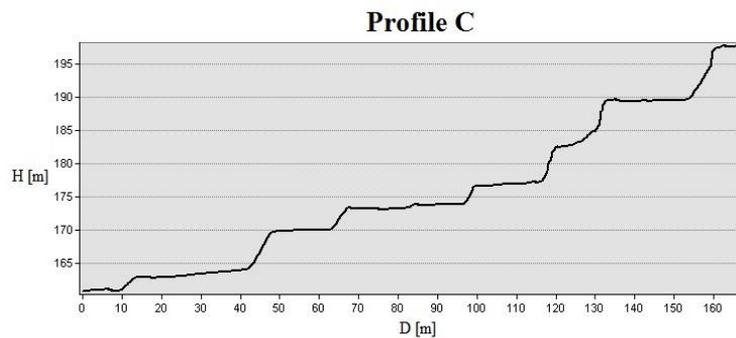


Figure 8 Section profile C

The possibility to overlap vector and raster data in GIS is of great importance. Vector data could be used for control and accuracy assessment of the orthophoto mosaics of a quarry. On the other, vector data could be used as a reference for improving the georeferencing of the raster data. Therefore, transforming a vector data into a raster data allows processing with geospatial tools. This could be the case of volumetric calculations between two neighboring berms. The toe of the berm could be vectorized with a polygon. The average height of the berm could be defined. Thereafter, a new field in the attribute table is created – Height. One of the numerous mathematical solutions for volume calculation is dividing the slope by horizontal sections. (Slavomír Labant, 2013) A volume could be achieved in this way by creating two polygons between two neighbouring toe berms (*see Figure 9*). In this particular case a reference plane was used. The created polygon with its given height has been assigned to be a reference plane. A volume is calculated, therefore, between the DSM being lower and the plane being higher.

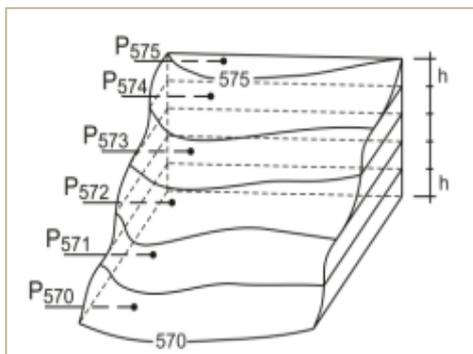


Figure 9 Horizontal sections

$$V_{570,571} = \frac{h}{6} \left(P_{570} + 4 \left(\frac{\sqrt{P_{570}} + \sqrt{P_{571}}}{2} \right)^2 + P_{571} \right), (1)$$

where P_{570} , P_{571} are the numbers of two neighbouring berms

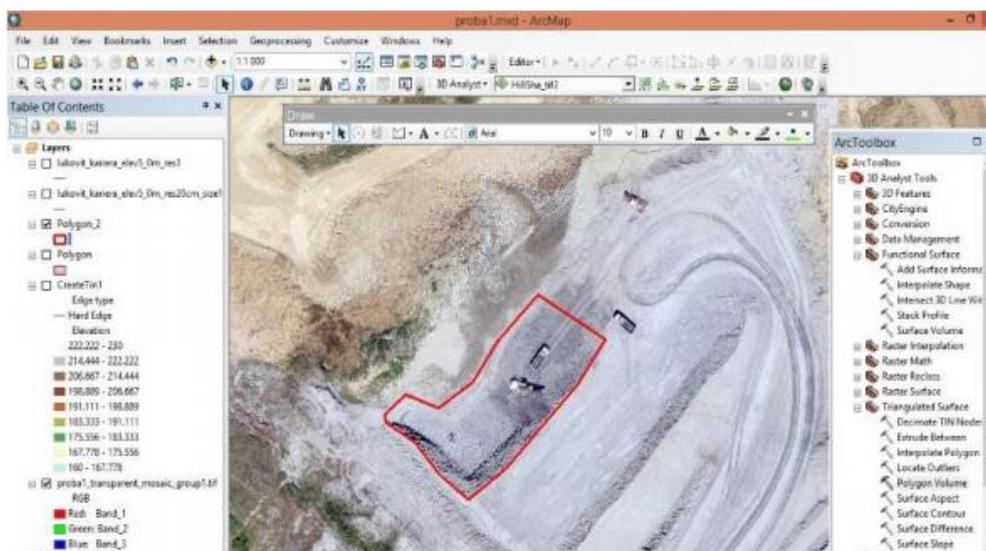


Figure 10 Creating a polygon which serves as a reference plane

Table 1 Volume of the lowest terrace of the quarry

Terrace №1	S ref.plane [m ²]	Total Volume V
	1657.53	843.22

There are many ways to present the terrain relief in ArcGIS. One of the most appropriate method for an open-pit quarry is the hillshaded model. In that representation, the berms of the quarry are emphasized on.



Figure 11 Presenting the relief in a hillshade mode

CONCLUSION

In the light of the study-case results, it could be concluded that the contemporary technologies in combination with an innovative and interactive method for processing, in particular photogrammetric and GIS methods, are completely applicable and compatible in the case of open-pit mining. The combination provides an accurate assessment of the processed in real time and helps better plan future exploitation.

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