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DETERMINING EXCAVATED VOLUMES IN SURFACE MINING OPERATIONS

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Abstract: *Recently, there has been a significant development in the use of unmanned aerial vehicles (UAVs) to obtain special information about the Earth's surface. The programs used for processing monitoring and reconstruction data aim to obtain efficient and high-quality resolutions.*
The field of use of UAVs is multiple: in military and civil applications, high-resolution surface reconstruction, for natural disaster management, topography and cartography, etc.
A main objective in mining activity is the evaluation of excavated volumes using efficient methods based on computer systems.
Keywords: *surface mining, excavations, UAVs, computer analysis, GIS systems*

1. Creating databases and realization of an information system [1]

A standard database is a logical collection of interrelated information, managed and stored as a unified whole. The objective of collecting and maintaining data stored in a database is to create and define relationships between facts and situations that are considered unrelated.

The first database systems were designed to provide a set of functions that correspond to a specific set of data. These were stored in the form of one or more files (fig. 1).

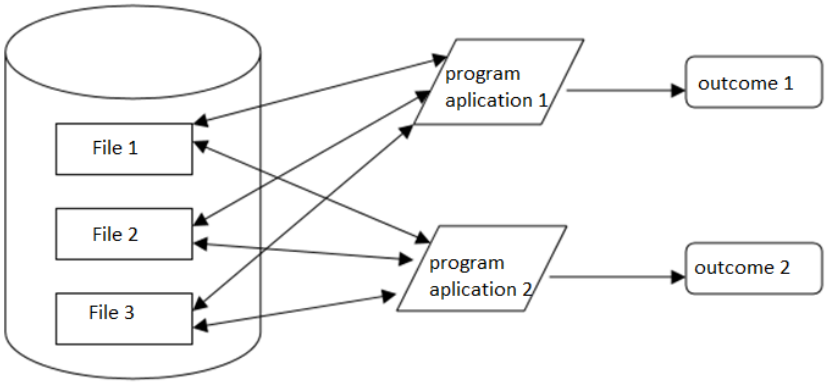

Fig. 1. File management system

File management systems represent the most common and simple approach in the field of databases. Because each program has direct access to the data in the files, these programs must "know" how the data is stored in the files.

For this reason, there is an increase in redundancy because each application must contain a set of instructions that are necessary to access the data contained in the files.

If the files are modified, then the instructions on the basis of which processing will be carried out on the data that has undergone the changes in the program applications will also be modified accordingly. To eliminate these impediments, Database Management Systems (DBMS) have been developed [2].

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A DBMS is composed of a set of programs that have the ability to process and maintain the data of a database. These programs are designed so that they are capable of managing the participation of data in a systematic manner and ensuring the integrity of the data in the database.

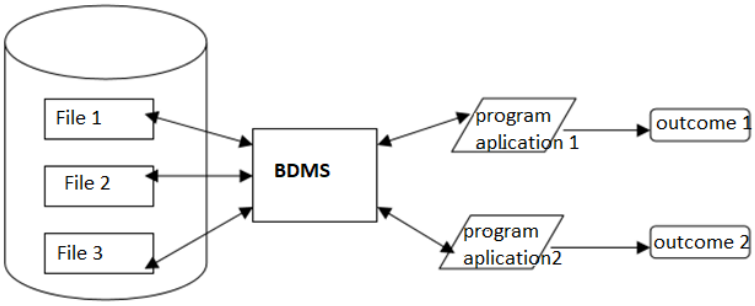

Fig. 2. Structure of a database management system

A DBMS acts as a central control unit over all interactions between the database and applications that, in turn, interact with the user (fig. 2).

A spatial database is a database that is optimized to store and query data that represents objects that are defined in a geometric space.

All databases allow a representation of objects through three graphical primitives: points, lines, polygons.

Other spatial databases have complex structures and store 3D objects, topological rules, linear networks or TINs.

In the case of complex structures there is a collection of geographic data sets of different types called Geodatabase that are stored in a common "container": Microsoft Access, Oracle.

Geodatabase databases have several dimensions, have different numbers of users and can extend from databases with a single user to databases to which multiple users have access.

Geodatabase is the data structure for the ArcGis platform and is the primary data format used for editing and managing data. ArcGis works with geographic information of the GIS system [2].

The use of IT solutions in optimizing Opencast activities [3]

Geographic Information Systems (GIS) can be defined as computer systems that are capable of holding and using geographic data that describe places on the Earth's surface.

A GIS system is a computer system that couples a database that operates with classes of geometric (spatial) objects with a spatial database that operates with attributes of the information contained in the first database (fig. 3).

The system operates according to a set of rules or procedures relating to:

- Data acquisition
- Data storage (recording)
- Data query
- Data analysis
- Data visualization

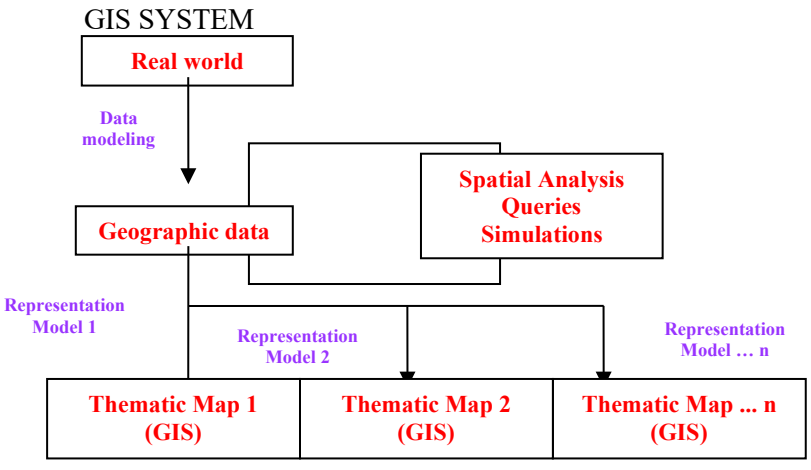

Fig.3. GIS system

2. Methods for determining excavated volumes in quarries [4]

Currently, the use of unmanned aerial vehicles (UAVs) aims to obtain spatial information related to the Earth's surface. With the help of this technology, data with resolutions ranging from 0.5 to 2 cm can be acquired. The programs used for processing monitoring and reconstruction data depend on the quality of the resolutions.

The use of unmanned vehicles has a wide field of use, from scientific and commercial studies to technical applications in the fields of topography and cartography, land management, etc.

The following presents the use of the mentioned method in calculating volumes in a Opencast.

To achieve this objective, the logical diagram of the process of calculating excavated volumes is presented (Fig. 4).

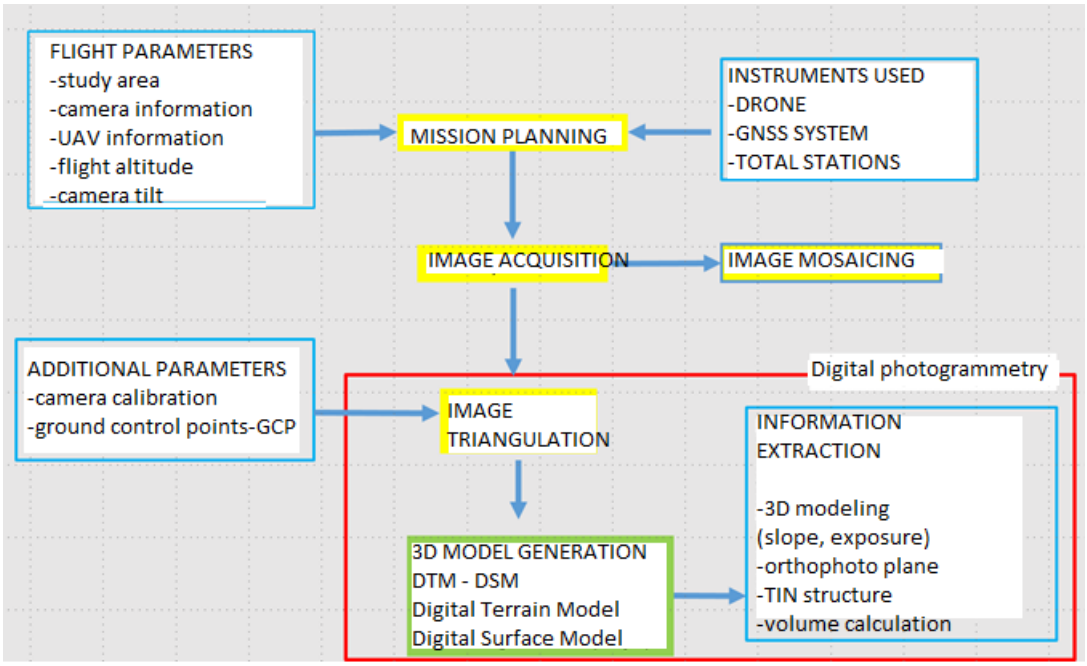

Fig. 4. Volume calculation flow chart

The research for volume calculations was carried out on a slag mountain formed in 250 years with level differences determined in the field with:

- 220.71 m minimum elevation;
- 321.76 m maximum elevation.

In plan, the contour of the slag volume is shown in Fig. 5 and 6.

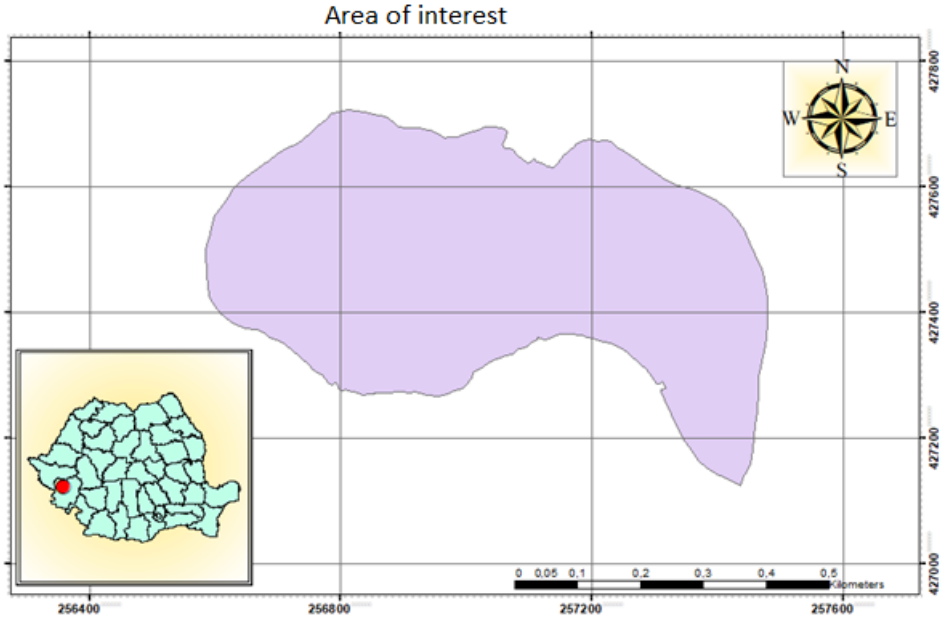

Fig.5. Opencast delimitation

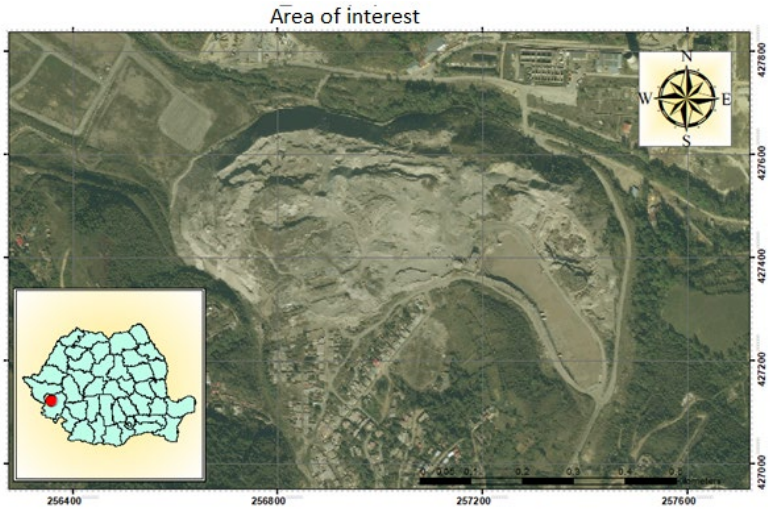

Fig.6. Google Earth image

To determine the volume, ten flights were made with a Phantom 4 Pro UAV over the slag heap.

The UAV is equipped with a camera capable of taking images at a very good resolution. The equipment includes GNSS positioning devices (GPS and GLONASS) for connecting to satellites and positioning in the air with high precision. The Phantom 4 Pro automatically records the details of each flight.

To obtain the data and perform the processing of aerial images, the Agisoft PhotoScan Professional program is used and the research itself was divided into five stages, as follows:

1. Preliminary study of the terrain relief;
2. Location and determination of ground control points (GCP);
3. Obtaining aerial data from the flights performed;
4. Processing of aerial images;
5. Performing volumetric calculations with the TopoLT program within the AutoCAD platform and the Surfer 13 program for control.

In order to obtain a high georeferencing accuracy, 25 ground control points (GCP) were used. The control points were located at different heights and determined by RTK methods with the Leica GS08 GPS equipment obtaining 3D coordinates. After performing the 10 flight rounds to obtain a point cloud necessary for determining the 3D volume, oblique and vertical images were taken with high precision.

A total of 1352 aerial images resulted from these flights, and after the image selection operation, 684 aerial images remain for the study. To determine the slag volume, the aerial images are processed and the point cloud is obtained with the AgiSoft PhotoScan Professional program. The procedure of processing the images taken from the drone involves the necessary steps from image processing to obtaining the point cloud and 3D representation of the slag volume.

To determine the volume of slag, the Surfer 13 program can be used. The Surfer 13 program is a software product specialized in computer graphics. It is a 3D surface mapping program. It is used for terrain modelling and visualization, 2D map generation, scanned image digitization, volumetric calculations, etc.

Figures 7 and 8 show volumetric calculations with the TopoLT and Surfer programs.

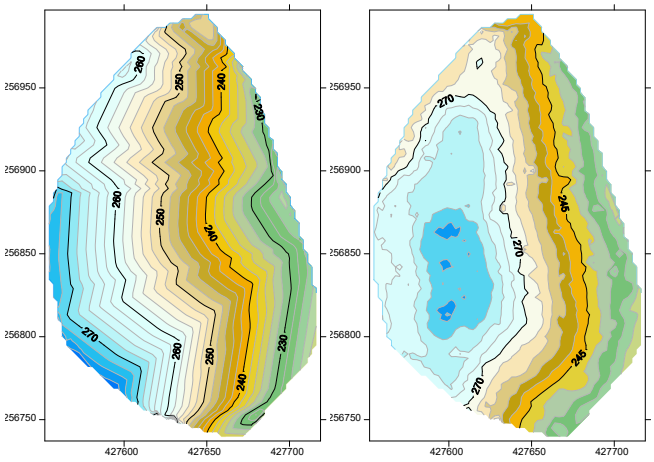

Fig.7. Calculation of excavated volumes (TopoLT)

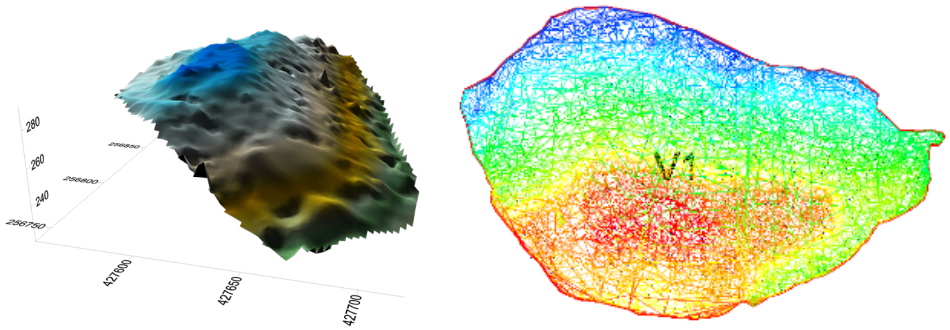

Fig.8. Calculation of excavated volumes (Surfer)

Volume calculated with TopoLT – VOLUME 1	**Grid volume calculations with Surfer 13**
Minimum land elevation = 220.619m	**Total volumes by:**
Maximum land elevation = 292.330m	Trapezoidal rule: 377.508.272m^3
Base surface area = 28930m^2	Simpson's rule: 377.435.699m^3
Volume = 379.972m^3	

The 3D model of the point cloud imported into AutoCAD can also be established, as well as the model underlying the volumetric calculations.

3. Conclusions

The theme of the work refers to the monitoring of tailings deposits (dumps) resulting from the surface exploitation of useful mineral substances.

By monitoring is meant the determination of the volume of tailings and the stability of the dumps during their existence.

To achieve the goal with superior precision and efficiency, 3D modelling of the target is required using high-precision geodetic and topographic measurements (total station and GNSS system) integrated with photogrammetric measurements - UAV.

The presented study refers to techniques and methods used in the processing of photogrammetric data using a large number of images acquired using a UAV system with GCP control points located on the ground, at different altitudes, for georeferencing and processing of aerial images.

The 3D model built based on the point cloud allowed the interpretation and modelling of the objective with great precision.

The information and training of specialists working in the field must be oriented towards modern work technologies.

It is appreciated that this paper is modern and theoretically and practically meets the requirements imposed.

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