UNIVERSITY OF PETROSANI

Faculty of Mining

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PhD THESIS

SUMMARY

IMPROVEMENT OF 3D MODELLING AND MONITORING METHODS OF MINING QUARRIES

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Key words: Geodetic methods, mining, monitoring, volumes, UAV, GNSS, 3D modelling

The goal of this PhD thesis is to present how one can use and improve the surveying and photogrammetric methods of measurement, in order to monitor up-to-date exploitation activities, in general, and the T.M.K. - ATU Resita Mining Quarry, in particular.

The monitoring and 3D modelling of an objective can be performed only on the basis of high-precision surveying measurements, but also on the basis of UAV (drone) technologies, thus obtaining an overview of a certain area studied.

The objectives proposed for this work are the following:

- Carrying out surveying measurements, using satellite technologies in order to achieve the geodetic support network for the studied area;
- Carrying out planimetric surveys of the area studied, in order to obtain the situation plan of the area studied;
- Carrying out level measurements, in view of the volumetric calculations of the material stocks;
- Using photogrammetric technologies, in order to improve geodetic measurements;
- Realizing a 3D model of the TMK Resita Quarry, based on the topo-geodetic and photogrammetric measurements made.

In order finalize the objectives established, modern geodetic technologies were used, namely:

- GNSS Systems - Global Navigation Satellite System - GPS Leica 1200 and GPS Leica GS08;

- The UAV technology: the DJI Phantom 4 Drone;
- Total High precision stations: Leica 1200 Total Station and Leica TS02 Total Station;
- Specialized software for field data processing: AutoCAD, ArcGIS, Agisoft, Pix4D.

➢ **Carrying out surveying measurements, using satellite technologies in order to achieve the geodetic support network for the studied area**

As is well known, all geodetic and topographic measurements are made on the physical topographic surface of the Earth, with which it comes into direct contact.

The processing of these measurements aimed mainly at determining, on the terrestrial surface, some **first-order geodetic support points** (order I), on which the points of order II, III, IV, V can be determined and also the detail points necessary in the elaboration of topographic plans.

The processing methods applied in determining the geodetic points are: triangulation, trilateration, and polygonometry or combinations of these.

The state triangulation network consists of chains of triangles, organized, according to the distances between them, according to different sizes and based on the accuracy of determination. Triangulation of order I-IV represents the state triangulation network, called upper triangulation, and the triangulation network of order V represents the lower order triangulation.

The points of the V-order triangulation thicken the IV order, having the sides of 1-5 km, so as to ensure a density of one point per 50 ha. For works with a special character (dams, subways, large industrial objectives), triangulation networks with special shapes appear, which are processed separately from the state triangulation, but which may have connection points with it. The accuracy of such local networks is much better than the accuracy of the state geodetic network.

For smaller areas, travel or even erasure is used, as the case may be, to determine the topographic support network.

The points that constitute the support network can be considered peaks of some triangles and from their grouping different forms of networks or canvas can result: polygons with central point, quadrilaterals, chains of triangles, quadrilaterals or combinations of these. The coordinates of the points can be determined, if in such a network all the angles of

the triangles, the length and the orientation of one side (in some cases of two sides) are measured.

- **Carrying out planimetric surveys of the area studied, in order to obtain the situation plan of the area studied**

Based on topographic surveys, the design, measurement, calculations and graphical reporting works may be realized for a piece of land.

The planimetric elevations aim at making representations of the land (plans, profiles) by topographic means, related to the specific equipment and methods.

Any topographic survey, regardless of the surface, scale, accuracy, is performed within a support network.

- **Carrying out level measurements, in view of the volumetric calculations of the material stocks**

- Volume calculations and verifications;
- Verification through topographic methods for the layers volume, with the help of the Total station;
- Measurements to determine volumes;
- Tracing the elevations as the excavations are carried out;
- 3D modelling of the current relief and the prediction of the future relief;
- Volumetric verification using topographic methods of excavations.

- **Using photogrammetric technologies, in order to improve geodetic measurements**

If classical photogrammetry deals with the determination in time and space of fixed, mobile or deformable objects and their photographic, graphic or numerical representation (by coordinates), based on special photographs called frames, UAV photogrammetry is an alternative to the methods used in the field of classical photogrammetry, which deals with the aerial recording of field data, using unmanned aerial vehicles, called drones, which fly at low and medium altitudes. Based on UAV technology, data can be obtained from large areas in a relatively short time, even in hard-to-reach or inaccessible areas with high security conditions.

In order to make an orthophotomap for the area studied, ground targets are set, which are then measured based on GNSS technology, targets that have a role in

georeferencing in the 1970 national stereographic projection system photogrammetric images, images resulting from drone flight.

Thus, coordinates of ground reference targets are determined based on GNSS technology, using the GPS system by connecting to the ROMPOS permanent station system. Data determined with GPS can be downloaded and processed with specialized software.

- **Realizing a 3D model of the TMK Resita Quarry, based on the topo-geodetic and photogrammetric measurements made**

Short distance digital photogrammetry has practical applicability in various fields, such as archaeology, medicine or heritage conservation, due to measurement methods, without direct contact with the object studied, and the results are very accurate and reliable. On the other hand, data collection is realized in a very short time and does not involve high costs, and images are taken and stored, and can be analyzed and re-measured at any time in the future.

The acquisition of data based on photogrammetric methods aims to obtain information about physical objects and the environment remotely, without having physical contact with them by recording, measuring and interpreting metric photographic images, called frames. The processing of these frames is made with the help of photogrammetric cameras, located on the ground (terrestrial photogrammetry), or placed on board some airborne platforms.

The novelty elements of the thesis are dedicated to the effective studies (modalities, software invented, softwares used, different methods and applications used) of the geodetic and topographic data, these being:

- 3D representation methods of mining works;
- Use of 3D representations in mining monitoring processes;
- Use of modern digital photogrammetry (UAV) technologies in order to make orthophotomaps, to make three-dimensional models and calculate volumes based on quarry measurements;
- Use of modern methods and specialized softwares in order to achieve the objectives proposed and compare them based on quality indicators;
- Aerial image processing and the obtaining of the point cloud useful for calculating stock volumes.

In order to achieve the goal proposed for this research, the following steps have been taken:

- Topo-geodetic, surveying measurements were performed on the terrain, based on satellite technologies, in order to obtain the geodetic support network in the area studied – the TMK Resita quarry;
- Planimetric surveys were made for the studied quarry, which led to the realization of the situation plan of the studied area;
- Classical level measurements were performed, used to calculate the volumes of material stocks;
- Compared to the classical methods for the determining of volumes, photogrammetric methods were also used, and the results obtained were much more precise, compared to the classical methods of determining volumes;
- The final result of this research consisted in the realization of the 3D model of the TMK Resita Quarry and the high precision determination of the volumes of material stocks, based on topo-geodetic and photogrammetric measurements, methods that can represent the basis of a continuous monitoring of this quarry.

The present study presented the processing of photogrammetric data, using 684 images acquired based on a DJI Phantom 4 UAV system and on 25 GCP control points located on the ground, at different altitudes, to obtain a more accurate georeferencing, and the data obtained from the processing aerial images, including textures, of the point cloud, thus obtaining a final precision of the order of millimetres.

The errors of the georeferencing process, obtained after data processing are 7.56731cm on XY and 1.87114cm on Z.

The 3D model built on the basis of the Dense Point Cloud has a resolution of 4.53cm / pixel, and the value of the digital terrain model of 72.4cm / pen.

Of the 684 images and the 25 GCP control points, 42,517,472 points were obtained. The final stage of data processing includes the generation of orthophotomaps, raster images, TIN and DEM formats, as well as the generation of point clouds.

The point cloud was initially processed with the CloudCompare software, and the treatment of the final data set contained a total of 1,534,957 points, which were further used to perform volumetric calculations.

The combination of 3D data allows the classification of the point cloud and its filtering for the interpretation and exact modelling of objects. At the end of the processing,

data exports were made in various formats, including Google Earth, LAS files, XYZ files that could later be processed with specialized softwares such as: Google Earh, AutoCAD, TopoLT, Surfer, Global Mapper, and CloudCompare.

The point cloud obtained from the processing was transcalculated from the WGS1984 System to the 1970 Stereographic System.

The topo-geodetic and photogrammetric measurements were performed on an area of 296,255 sqm, with 9 piles of slag, with the following volumes: V1 with an area of 28,930 sqm and a volume of 379559.7 m3; V2 with an area of 81327sqm and a volume of 1230304.2m3; V3 with an area of 4500sqm and a volume of 19292.3m3; V4 with an area of 19100sqm and a volume of 147758m3, V5 with an area of 9908sqm and a volume of 96779.9mc, V6 with an area of 5807sqm and a volume of 6883.2mc; V7 with an area of 2862m2 and a volume of 7712.3 m3, V8 with an area of 1980sqm and a volume of 2952.2 m2 and V9 with an area of 3484sqm and a volume of 8430.4m3. The total volume resulting from the processing of aerial photogrammetric data is 1,899,915 cubic meters spread over a total area of 15,86565 Ha.