APPLICATION OF GMT (GENERIC MAPPING TOOLS) SOFTWARE FOR VOLUME COMPUTATION IN MINING INDUSTRY

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Abstract
In a brief introductory part of this study both our former research in this theme and decree regulation of mining volume computation are overviewed. After that problems of determination of volume in home practice are discussed, and then GMT programme is introduced compactly. Finally, doing comparison analysis, application of GMT software to the task given in the title is tested in case of concrete mining depots of irregular shapes.

1. Introduction
In our former study [1] we dealt with problems of volume computation connected to mineral deposits and introduction of suitable programmes, and comparison of their results. In that article, considering carefully the setting possibilities of each software and different use among them, we performed volume calculation tests using generated point sets modelling mathematical bodies with known parameters and measured ones of real mining depots (of regular and irregular shape). After analysing the results we stated that the volume computation programmes used in home mining practice, the suitable methods and settings run with the required accuracy approaching to the real value well which is, actually, one of the key points of quality connected to measuring a depot.

Theoretically numerous points would be needed when a depot is measured so that we could obtain the volume suitable to reality, however, it is unfeasible in most cases or rather it is not justified. Moreover, it is also unsure – considering the extra work – that the large number of the measured points improves the later results at all; consequently, it is necessary to get to a compromise in the interest of the required accuracy.

Mine surveying tasks including the questions of volume computation are regulated by a separate governmental decree. As far as the registration of waste rock and mineral raw material are concerned the later is of greater significance. A mining entrepreneur, however, is obliged to survey the excavated mineral raw material, since it is the basis of determining the mining annuity which must be paid for the state. The Government Decree No. 54/2008. (III. 20) about mineral raw materials and the specific value of geothermic energy [2] deals with the declaration of mining annuity, determination of the volume of mineral raw material and the role of a chartered mine surveyor in this process. The Section 2 of this Decree regulates the payment of mining annuity with reference to solid raw materials as follows:

“Section 2, subsection 2. The licensee exploiting the mineral raw material and having an authorization is obliged to determine the quantity of the excavated mineral raw material by means of mine surveying /geodetic/ methods or other suitable ways. Documentation must be made about the applied method and its result.”
The licensee is obliged to determine the quantity change of the mineral raw material by geodetic computation (volume computation) within 60 days after finishing the production of the mineral raw material in question.”

“Section 2, subsection 3. A mining entrepreneur is obliged to determine the quantity of the exploited mineral raw material by mine surveying (geodetic) methods. In case of underground mining it can be performed by mass surveying. The change must be displayed on the exploitation map. The quantity change of mineral material related to the actual year must be determined by computation on the basis of geodetic surveying (volume computation). The result of measurement and computation must be recorded in a document.”

In surface mining practice naturally determination of waste rock mass is essential for many respects. This however is mainly important for an entrepreneur because he is not obliged to pay any annuity for the exploited waste rock.

2. Determining the quantity of mineral raw material and waste rock in home practice

The quantity of exploited waste rock and the excavated useful mineral can be determined either in an operative way or with a mine surveying method [3].

The operative registration results in only a preliminary estimation, it is not accepted officially and therefore here we do not intend to deal with it in details.

The mine surveying registration includes a comparison of monthly updated mining maps and volume computation. Examining the afore-discussed two methods mine surveying (geodetic) is more accurate and it is required from the mining authority as it was mentioned earlier.

If a depot volume is determined in a surface mine with a mine surveying method, then graphic and numerical procedures come into consideration. The graphic method is based on the comparison between the previously measured mine positions fixed on the map. When a numeric technique is used 3D surface models are established on the basis of coordinate sets related to each measured position by means of programmes known in home practice (Surfer, DigiTerra, AutoCAD Civil 3D etc.), then cutting them correctly we compute the difference between them.

3. Surface-fitting in practice

As it was already mentioned the application of some software known in home practice was tested in our former study [1]. In it we executed computations using artificial and measured coordinate sets modelling known mathematical bodies on the one hand and true regular and irregular mining depots on the other hand. In that case Kriging and Triangulation with linear interpolation algorithm produced the results which could be near the true value (that was proved on the basis of our comparison analysis of the modelled point sets as well). Considering the afore-mentioned two procedures the results of the latter one demonstrated the most consistent picture on the basis of both modelled and real measured point sets.
4. Surface-fitting and the TIN model

We consider the TIN model important because the surface of an examined body is formed as a result of linear triangulation and – considering the afore-mentioned study – the most promising results were produced on the basis of this principle when we tested point sets describing known bodies.

The TIN is an acronym which includes the initials of the English words: Triangulated Irregular Network. It means a regular triangle grid, that is to say the surface is covered by a grid (triangles) consisting of irregular grid points. In case of an irregular point set on a plane, it is possible to construct a polygon around each point the inner points of which are closer to the point in question than to all the other ones. Consequently the polygon sides are perpendicular to the lines connecting the point in question and the other points and even halve them. The parts of this polygon will consist of only those lines from whose intersections a closed convex polygon is developed. At the same time these polygon lines determine the neighbouring points considered from each point, since the formation of a polygon is influenced by only those points which bisect perpendicular lines of radius directed towards them as parts of this polygon. If we connect all the points according to the afore-mentioned conditions, in plane case we obtain an unambiguous and optimal division of triangles (from a certain point of view). This division is called Delaunay-triangulation and the polygons are termed Voronoy-ones [Figure 1].

![Figure 1: Delaunay triangulation, Voronoy-polygons](image)

In a spatial case connecting the determined points as neighbouring ones it results in an unambiguous and optimal tetrahedron division [4, 5].
5. The GMT (Generic Mapping Tools) software

In fact it is a mapping and viewing system which contains nearly 65 smaller programmes. It was originally written for Linux operation system and issued under GNU general public licence. It is not really wide-spread in practice. The GMT programme package has been developed and maintained in an updated form by now with the help of Paul Wessel, Walter H. F. Smith and many voluntary and enthusiastic specialists from all over the world. On the official website (http://gmt.soest.hawaii.edu/) 30 examples are used for introducing the possibilities of GMT software, and we can read its install; moreover the use and capability of each programme [6]. It has also become clear for the users visiting the afore-mentioned website that today this software runs in Windows or Macintosh OS X operation systems as well.

Basically there are two reasons why we are dealing with this programme package, the first one is that it is free, the second one is that it is also appropriate excellently for volume computation competing with other available software for this special purpose on the market. The grid system that we selected serves as a basis of volume determination and is computed by means of a Shewchuk-algorithm.

6. Point sets deriving from real depot surveys

The main point of our article is the following: we performed volume computation tests for four concrete mineral depots by means of Surfer and GMT (Generic Mapping Tools) software. Their results are illustrated in the following Figures 2–5. In these Figures surfaces fitted to the measured point sets of each depot and the obtained volumes with the help of GMT (upper picture) and Surfer (lower one) programmes can be seen.

![Figure 2, Depot 1](image1)

![Figure 3, Depot 2](image2)
It can also be seen in each Figure that the terrain point sets available are derived from depots of irregular shape. It is evident from the following table that the results of triangulation solution of Surfer programme were considered to be relevant values [100%], and in connection with each depot we applied them as reference values to which the results of Kriging and GMT triangulation were compared. Here it is also important to mention that in our former studies [1], [7] where we performed similar tests using point sets modelling known mathematical bodies and deriving from terrain surveys, all the compared programmes (DigiTerra, AutoCAD 3D and Surfer) showed good results, consequently we could have considered any of them listed before as a reference one. So the triangulation with linear interpolation in Surfer was selected to be reference procedure. As the results show well in Table 1 the free GMT can also be taken into account among the recommended programme lists previously mentioned since it is a potential alternative which can be used easily and well in practice and is capable of computing mining volumes.

**Table 1**

Comparing the results of volume computation connected to Surfer and GMT software

<table>
<thead>
<tr>
<th>Surfer</th>
<th>GMT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Triangulation</strong> [m³] (reference data)</td>
<td><strong>Kriging</strong> [m³] [difference]</td>
</tr>
<tr>
<td>Depot 1</td>
<td>4663</td>
</tr>
<tr>
<td>Depot 2</td>
<td>3526</td>
</tr>
<tr>
<td>Depot 3</td>
<td>2205</td>
</tr>
<tr>
<td>Depot 4</td>
<td>522</td>
</tr>
</tbody>
</table>
At the four depots the differences from each reference value were less than 3% in all cases \textit{(reference data of Surfer and GMT ones)}, that is to say they fulfilled the expected requirements connected to volume computation in practice in general.

7. Conclusions

In our study we performed surface-fitting and volume computation tests with the help of two programmes (Surfer and GMT). The Surfer – as it is known – is a grid-based, 3D surface mapping and viewing software. This programme uses a grid in all cases. To produce this grid it uses survey points with X, Y and Z coordinates located in a random way and fixed in data sets measured by a mine surveyor. The software applies various mathematical procedures to develop the afore-mentioned grid to each grid file using each coordinate set. The volume is computed on the basis of a grid. The grid with regular spacing produced in this way has the same Y grid points in certain rows and the same X coordinates in certain columns, and the programme computes their Z values by means of the mentioned mathematical methods [4].

The other software, GMT is however such a complex programme package which provides map viewing of global data, capable of treating and editing terrain models. In the circle of specialists it is known that the quality of surface fitted to a set of points is decisively influenced by the followings [7]:

- the experience in geodetic survey /identification and surveying of the most characteristic field points and lines;
- the number of survey points (it is advisable to measure as many detail points as possible, of course, in a rational manner;
- the selected and applied interpolation procedure in the programme.

We have to mention that it is advantageous if the specialist who performs data processing knows the survey site, that is to say, he could see it earlier thereby he is able to form an opinion of the surface forms after each interpolation technique.

Our present investigations however proved that the user has to consider many viewpoints when applying each programme to determine the correct volume. Among these we can mention the followings [7]:

- the geodetic survey should be detailed properly and describe the depot geometry correctly;
- it is essential what kind of software we have and the geodetic data capture must be fitted to it;
- correct selection of the necessary settings in the available programme /e.g. method, grid size/.

We would like to call the attention to the fact that volume calculation – similarly to other geodetic/mine surveying tasks – requires checking computation as well. It naturally can be performed traditionally or by means of other professional software.

Finally we can state that the favourable results of our test computations with GMT software confirmed us that we can strongly recommend this free programme to kind attention of Hungarian mining specialists/mine surveyors.
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