Remote Sensing Methods for Open Pit Mine Surveying

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Abstract — In the last few years, new data acquisition technologies and related processing techniques - typically based on laser scanning or image matching- have been dominant in surveying and mine surveying. This new technology often comes into the users with only a "difficult to parametrizable" commercial product; their scientific research - from an accuracy, or economical point of view -but at the current level of development even in the search for uses - is considered.

Photogrammetry, Remote Sensing, Laser scanning

I. NEW REMEOTE SENSING METHODS IN MINE SURVEYING

Technical solutions used in the mine surveying practice in the last ten years, experienced significant changes. So far almost exclusively used the traditional row of producing discrete polar survey by these new procedures, common to the traditional territory of the professional terminology lists these remote sensing. These new procedures as well as the practice of more important, generally provide a point cloud.

Several of these techniques in "chronological" order:

- Terrestrial Laser scanning
- LIDAR
- Mobil Laser Scanning
- Digital photogrammetry (Close Range and Aerial)

The practical applicability of *Terrestrial Laser scanning* was examined in our previous article [1]. In practice, the scanners with a smaller range of reliability, but longer range, based on ToF are used. This technology has a clear economic advantage over the aerial survey, but at the operating mines (for example stocks) it is unclear even with traditional surveys.

Applying for the use of M*obile Laser Scanners* as a domestic example, we suggest Csörgits [2] presentation. Its advantage is unquestionable compared to static measurement, but the continuous provision of external orientation -in addition to the obvious economic disadvantages- may be a technical problem that significantly affects its practical applicability.

Photogrammetry -if not for digital- is of course not a novel technical solution in mine surveying. There is an example of using this close-range photogrammetry in open pit mining survey from 1979 in [3]. The practical spread of the conceptual solution was a major obstacle to the relatively high added value work, which was strongly influenced by the global matching methods.

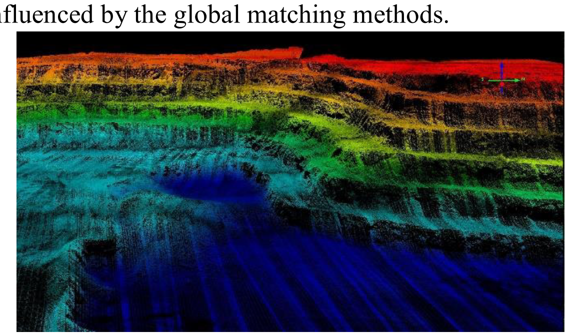

Figure 1. Lidar based Point cloud [4]

LiDAR. The appearance and spread of airborne laser scanners can be dated back to the 1990s, and their distribution is mainly related to the development of mobile telecommunications. There was a need to produce a fast surface model of large areas for the visibility test for the installation of mobile towers. For mining applications, see also international literature. Domestic relations are unlikely to allow a significant spread of the LIDAR surveys. This is primarily due to economics. On the other hand, the number of flying days is considerably limited mainly due to practical needs, weather and airspace usage. Practical approaches have not been helped by recently-based *photogrammetrical* methods.

II. LiDAR IN MINE SURVEYING

There are some practical advantages of using LiDAR in mine surveying in this cases:

- large-scale, fully homogeneous surfaces where purely photogrammetric procedures based on image-matching do not provide sufficient interface points (mining ponds)
- not entirely homogeneous, but possibly identical, repetitive texture areas are typically multi-layered faces, most of the wood-plated surface, which makes the aerial triangulation difficult
- By recording multiple reflections, it is possible to measure the vegetation-covered surface.
- This is particularly useful for abandoned mines and recultivated areas, as well as for the research surveys described in our example, where we need the DTM instead of the surface model.

An examination of the practical applicability of a pointcloud -produced by aerial laser scanning- is presented by using surface (terrain) model for mining research. For economic reasons that the technology is directly exposed under the current technical-economical conditions. But it is also a by-product of other Lidar surveys to have a practical need to deal with the subject. (e.g. abandoned mines and research surveys.)

III. LiDAR IN MINING RESEARCH

Our research is presented through a mining research example. For this purpose, almost exclusively state analogue (1:10000) topographic maps have reported geometric background content. The essence of our studies is to compare the DTM based on the topography map with the DTM based on the LiDAR survey.

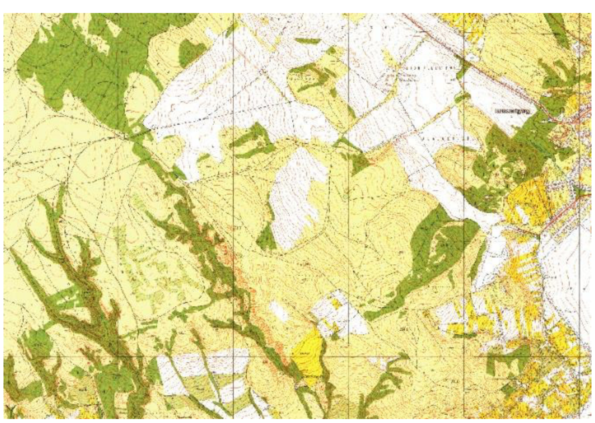

Figure 2. Test area on topographical map

For the purpose of the LiDAR survey, the DTM of the test area was produced using only the state topographic map, which was considered the base of the study. (Figure 3.)

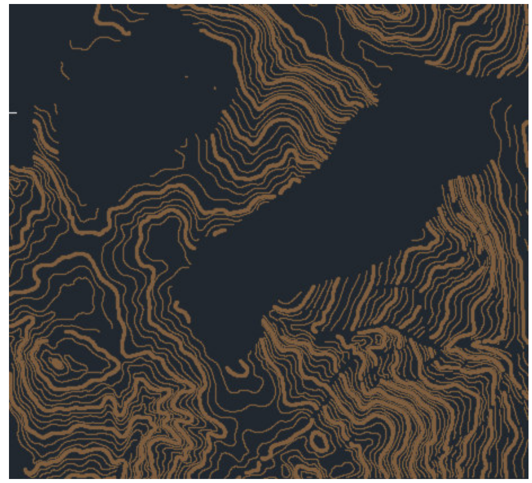

Figure 3. DTM of test area based on topography map

From our test area, our institute had a LiDAR survey from 2009. Its resolution is 1 meters*1 meters (Figure 4.) for ease of use, the test area was reduced to 500*500meters. The area has mixed vegetation, it is covered by grass, and forests. From this point of view, it is an ideal test area, since a hard-to-detachable plant cover will cause a regular error in producing DTM. Using classification algorithms, we have the possibility to separate the different plant cover, this is necessary if the multiple reflection is not counted.

Some of our investigations were carried out with commercial software (Civil 3D). For this purpose, we prepared the space indexed point cloud from LiDAR survey (Figure 5) and we built a DTM from it in CAD program.

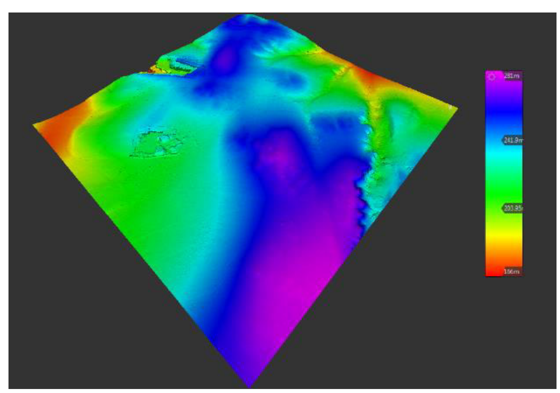

Figure 4. Indexed point cloud

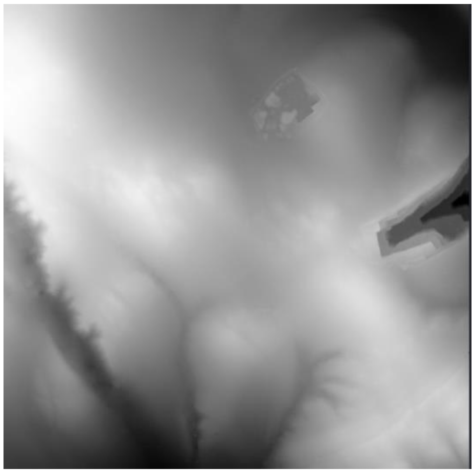

Figure 5. Text area in commercial CAD program (LiDAR-based point cloud)

Generally, three types of interpolation can be taken into consideration when building a TIN model from a point cloud in general CAD environment:

- No interpolation,
- Plane average
- Kriging interpolation

All three methods are used to construct TIN model. In order to compare the three methods we calculated the volume differences between the three TIN models.

Base surfaces	Volume differences (m3) on 250.000m2 test area		
	No interpolation	Plane average	Kriging interpolation
No interpolation	-	-27900	-18300
Plane average	+27900	-	+9700
Kriging interpolation	+18300	-9700	-

Table 1. Volume differences between interpolation methods

We also calculated other statistical measures. The biggest difference between the two surfaces (e.g. No interpolation and Plane average interpolation) is -6 meters and 0.7 meters. What seems to be excessive, however, there is an active mine and significant natural valleys in the area with high altitudes, and these differences occurred in these areas. The average deviation in the area was -11cm. Our calculations are summarized in the following two tables (Table 2, Table 3.).

Base surfaces	Min/max distances (m)		
	No interpolation	Plane average	Kriging interpolation
No interpolation	-	-5.8/+0.7	-4.9/+0.9
Plane average	-0.7/5.8	-	-1.2/3.3
Kriging interpolation	-0.9/+4.9	-3.3/1.2	-

Table 2. Min/max distances between interpolation methods

Base surfaces	Average distances (m)		
	No interpolation	Plane average	Kriging interpolation
No interpolation	-	-0.11	-0.07
Plane average	+0.11	-	0.04
Kriging interpolation	+0.07	-0.04	-

Table 3. Average distances between interpolation methods

The Table 3. shows what kind of regular error the TIN model generates in the interpolation solution. For a geological calculation, these are negligible, but are not acceptable for many civil engineering applications.

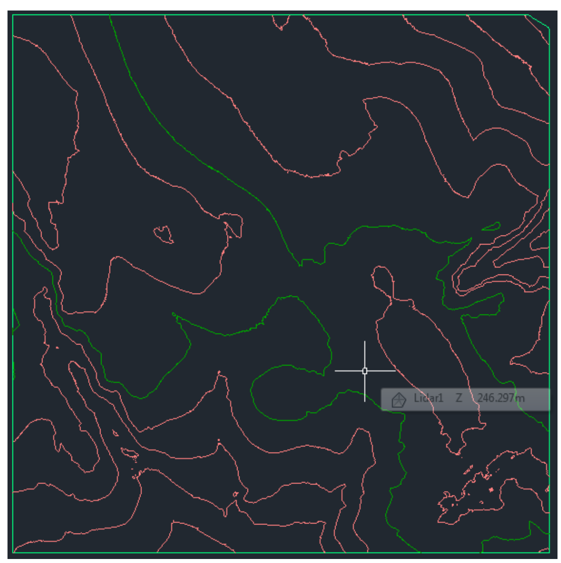

Figure 6. TIN model in commercial CAD program (LiDAR-based point cloud)

In the next step we prepared the DDM of the area based on the topographic map. We cut out those parts that have changed since the topographic map and the aerial scan (Figure 3.). These are mainly areas affected by mining. Because of the large surface and the 100 meter deep side, they would cause significant errors in the calculation.

Base surfaces	Volume differences (m3) on 150000m2 test area			
	Topographic map	No interpolation	Plane average	Kriging interpolation
Topographic map	-	+136000	+108000	+120000
No interpolation	-136000	-	-26000	-16000
Plane average	-108000	26000	-	+9000
Kriging interpolation	-12000	16000	-9000	-

Table 4. Volume differences between Topographic map and different interpolation methods

The result tables are, of course, symmetrical to the diagonal.

Base surfaces	Min/max distances (m)			
	Topographic map	No interpolation	Plane average	Kriging interpolation
Topographic map	-	-5.3/5.0	-6.8/+6.4	-6.9/+5.0

Table 5. Min/max distances between Topographic map and different interpolation methods

Base surfaces	Average distances (m)			
	Topographic map	No interpolation	Plane average	Kriging interpolation
Topographic map	-	+0.9	+0.74	+0.80

Table 6. Average distances between Topographic map and different interpolation methods

The values of the min/max distances are in dotted areas and in wooded areas. The "average distances" includes the editing errors of DDM created from the topographic map of course. The impact of vegetation on the survey is clear. The positive values of the averages distance table mean the surfaces of the Lidar based DDMs are systematic higher than the topographic based DDM. The results can be used for mining research.

IV. CONCLUSIONS

Overall, it can be stated that LiDAR surveys are perfectly suited to mining purposes. For reasons of economics, their domination is not expected, but the rapid development of UAV based LiDAR systems (cheaper, lighter sensors) is likely to contribute to the spread of technology. In addition to current economic conditions, it is possible to use it as a by-product of other LiDAR surveys in mining. This is possible in the survey of abandoned mines and research areas. In these cases, there is a great advantage in capturing multiple reflectors against image-based procedures.

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