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UTILISATION OF AIRBORNE LASER SCANNING FOR MONITORING OF SECONDARY IMPACTS OF UNDERGROUND MINING EXPLOITATION

Summary

The article presents possibility of utilising the measurement method using airborne laser scanning for monitoring of secondary impacts of underground mining exploitation. The issue of secondary impacts is still a current subject in underground mining, especially in terrains with long history of mining. The project presents, with the example of mining exploitation in the town of Bytom, the approach to acquiring and processing data from airborne scanning measurement in a way which obtains an image of subsidence basin created as a result of exploitation and potential secondary impacts. An interpretation of the obtained results has also been presented.

Key words: airborne laser scanning, secondary impacts, LIDAR.

INTRODUCTION

Airborne Laser Scanning (ALS) consists in measuring distance form a flying plane to a point on a terrain surface, with simultaneous constant measuring of the plane position with the use of GNSS system (Global Navigation Satellite Systems) and determining the current angular inclination of the platform where a scanning head is installed with the use of navigational system INS (Inertial Navigation System). All measuring systems have to work simultaneously and be synchronised with one another. Only then can the accuracy be obtained (0,15m for altimetric measurements and 0,10m - 0,20m for topographic surveys) [Warchoł 2014].

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Measuring with the use of airborne laser scanning has the biggest range of all the measurement methods utilising technologies of a laser scanner. Therefore it is reasonable to use this method of measuring everywhere the scale of elaboration covers large or very large area. So far the ALS method has been widely applied in fields such as:

- three-dimentional modeling of towns (virtual walks),
- road planning and road monitoring,
- management of natural resources [Wężyk & Solecki 2008],
- flood risks analyses [Warchoł 2014],
- monitoring of architectural objects.

In mining and related fields of expertise, the ALS method can be used for determining the range of impacts of underground mining exploitation [Kuźnicki 2011] and indirectly also for identifying old mine workings [Gontaszewska-Piekarz & Mrówczyńska 2018] and possible detection of their activation, which is presented in more detail in the article below.

CHARACTERISTICS OF THE RESEARCH REGION

The region of research is located in the eastern part of Bytom. The town has a rich history of mining. In the 19th century the town experienced its golden years and became one of the industrial centres in Germany. In the 50s of the 20th century under the town extraction of coal from hitherto untouched so called protective pillar started [Dzieje miasta Bytom 2018]. In the analysed region exploitation was run by the mining company Bobrek-Centrum, later known as Centrum, which is currently under decommissioning.

Since 1945 in the mentioned region 18 beds were exploited, including approximately 600 plots, of which 77% were conducted with roof rock fall. Figure no.1 shows maps of beds layered upon each other, generated in the programme EDNOPN [Białek 2003]. It presents how advanced exploitation was conducted in the region of the research. Exploited walls were formed into diverse shapes, they were also differently located in relation to one another. The largest accumulation of walls could be observed in the middle part of the researched region.

The research is focused on the period: April 2010 – May 2012. During that time the exploitation was run through four walls in three beds: bed 510 lower layer, wall 6; bed 615, wall 1; bed 620, wall 2 and 3. Shape of the exploited walls, and their position in relation to one another is presented in figure no.2. On the figure the wall fragments which were exploited in the analysed period are in colour.

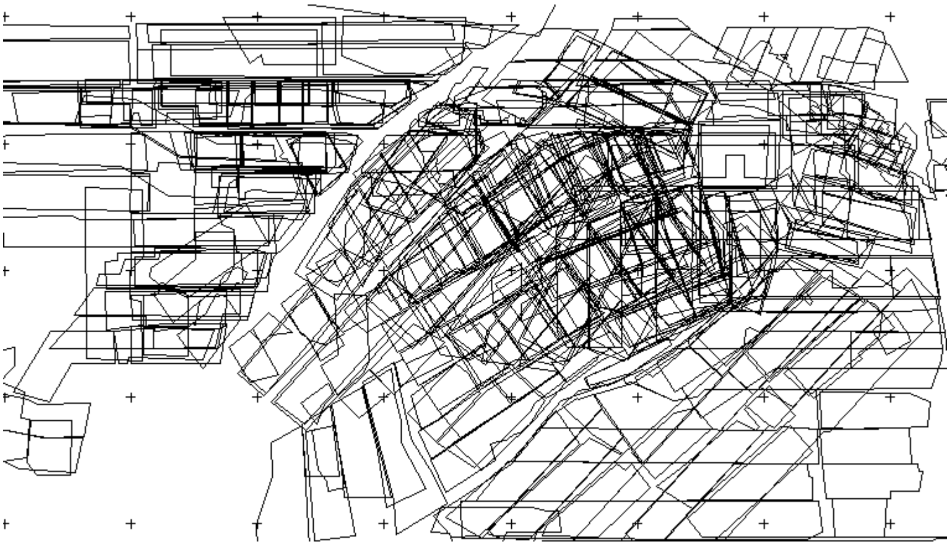

Fig. 1. Exploitation of hard coal mine Centrum between 1945 and 2012 [developed by the author]

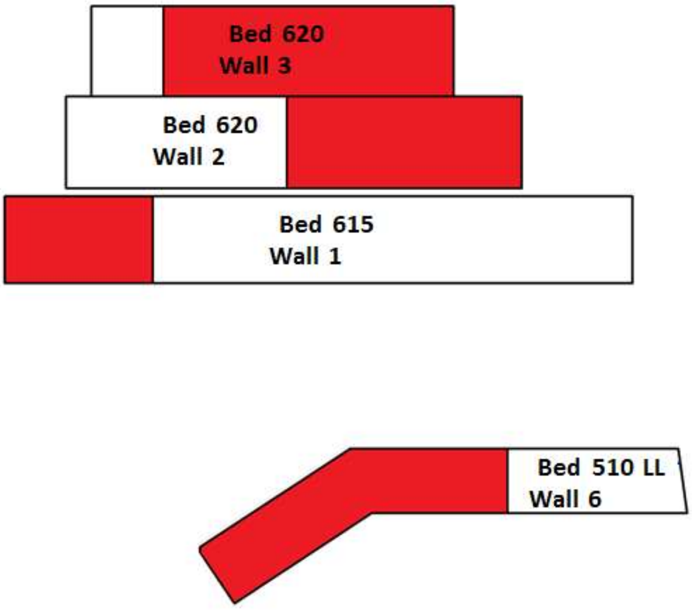

Fig. 2. Exploitation of hard coal mine Centrum between 2010 and 2012 [developed by the author]

METHODOLOGY OF RESEARCH – WAY OF OBTAINING LIDAR DATA AND ITS PROCESSING

In order to obtain an image of a subsidence basin from LIDAR data (Light Detection And Ranking) it is crucial to complete a few stages of work, which can be divided into field work and intimate work. Field work includes [Wężyk 2014]:
- calibration of parameters of a laser instrument, GNSS and INS,
- determining optimum parameters of flight,
- preparation of flight plan,
- completing the flight.

Intimate work includes [Kurczyński 2014]:
- smoothing of results,
- processing and filtering of LIDAR data,
- presentation of results.

The presented algorithm of measuring in order to obtain an image of a subsidence basin does not differ significantly from the algorithm of measuring with the ALS method for other purposes. However, in case when airborne laser scanning is intended for monitoring of terrain deformations caused by mining exploitation the time of conducting the flight is important. The first measurement should be made before commencing designed exploitation in a given region in order to register the terrain layout, distribution of buildings and surface infrastructure. Following flights should be conducted after commencing the exploitation. If measurements are aimed at determining the final range and shape of a subsidence basin, the second measurement should be made after finishing the exploitation and ceasing of the rock mass movement. However in a case when the purpose is registering falls in ground level which occurred in a given period of time or as a result of exploitation of specific plots, the second measurement is made in time appropriate for established purposes of the project.

As a result of measurement a so called cloud of dots is obtained. It is a collection of dots with well known coordinates X, Y, Z. Obtaining of a cloud of dots is automated process, however it is not the final product. The cloud of dots needs to be properly aligned (within two stages), categorised and filtered. Those processes are executed by computer programmes, yet because of the fact that the algorithms of work in those programmes are not perfect, accuracy of the obtained results has to be manually checked. The end result is obtaining of DTM (Digital Terrain Model) or DSM (Digital Surface Model).

The last step is presentation of the obtained data. Having now two clouds of dots obtained from ALS measurements in different periods of time it can be observed how falls in the ground level created by mining exploitation are formed. For this purpose volume between surfaces from the first and the second measuring period has to be calculated. In the first stage a grid of dots marking levels for each measuring period has to be generated. It is done in a specialized programme, based on terrain dots. Subsequently, the secondary surface grid has to be overlaid with the base surface grid (i.e. scanned during the first flight) and create the third volume grid (made as the result of subtraction of the second level grid from the first one), which presents distribution of gaps between levels from the first and second (or next) flight. On the basis of the obtained grid, isolines are generated. They represent falls in ground levels with desired isohypse cut.

RESEARCH RESULTS AND THEIR INTERPRETATION

As a result of subtraction of level grids generated on the basis of DTMs obtained from flights in years 2010 and 2012 a map of isolines of falls in ground levels was created (Figure no. 3). Isolines (marked with brown colour) were generated in the programme Global Mapper. The assumed isohypse cut is 0,2m. The applied limitation of isohypse projection is -0,40m, thanks to which a clearer image of isolines of falls in the formed subsidence basin was created. In the central part of the sketch an ovally shaped subsidence basin was formed. Quality analysis revealed a causal link between the formed basin and exploitation conducted at that time (marked with red colour). Isolines are shaped irregularly and „jagged". It is caused by the fact that, they were not smoothed and they reflect actual changes in orography that occurred in the researched period of time.

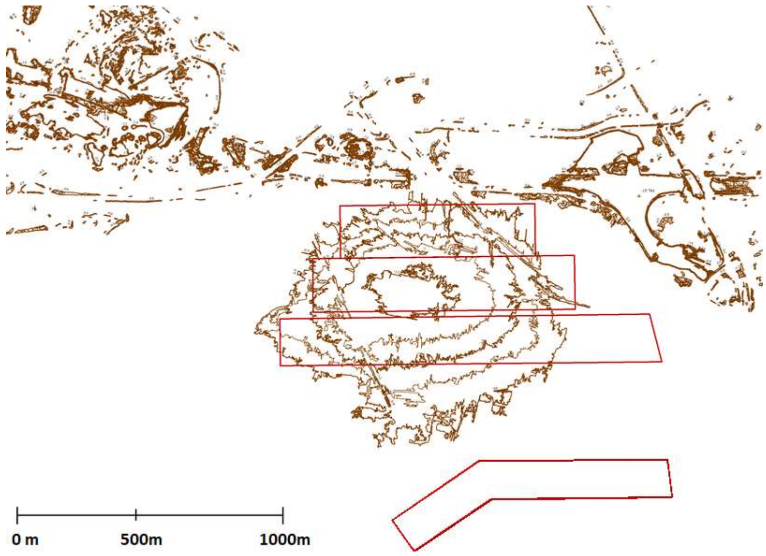

Fig. 3. Map of isolines of falls in the ground level (subsidence basin) generated in the programme Global Mapper [developed by the author]

It should also be noted that apart from the distinct subsidence basin in the central part of the sketch there are also falls of various shapes formed around the conducted exploitation. Isolines in the north-east and in the northern part of the area have taken longitudinal shapes. They present the changes in orography which formed as a result of conducted at that time earth works and road works, related to construction of a segment in Bursztynowa Highway.

However, the cause of creation of other smaller closed isolines can not be explained with earth works. They also cannot be a result of exploitation conducted at the time. In order to clarify this situation another way of presenting data was attempted. In the programme Global Mapper another map of falls in the ground level was generated (Figure no. 4), utilising shading module NDVI (Normalized Difference Vegetation Index), with marked falls deeper than 0,2m. In other words, a surface of virtual water table at the level of -0,2m was generated. The obtained benefit of this was a colourful presentation of zones which had been „flooded", as they were beneath the established level of water. As a result of utilising this method in the central part of the researched area a homogeneous blue colour can be observed. It marks the places where the biggest falls occured. On the other hand there are more than ten blue zones with longitudinal shapes formed around (especially in the western and in the south-eastern part of the analysed area – marked with arrows) which overlap with the shapes of some exploitation plots where extraction was conducted in the preceding years. In those locations fall in the ground level within 0,10 to 0,30cm occurred. Taking into consideration the fact that the given region experienced intensive exploitation in the past years, it can be concluded that the recorded falls belong to secondary impacts, i.e. they were caused as a result of so called activation of old headings.

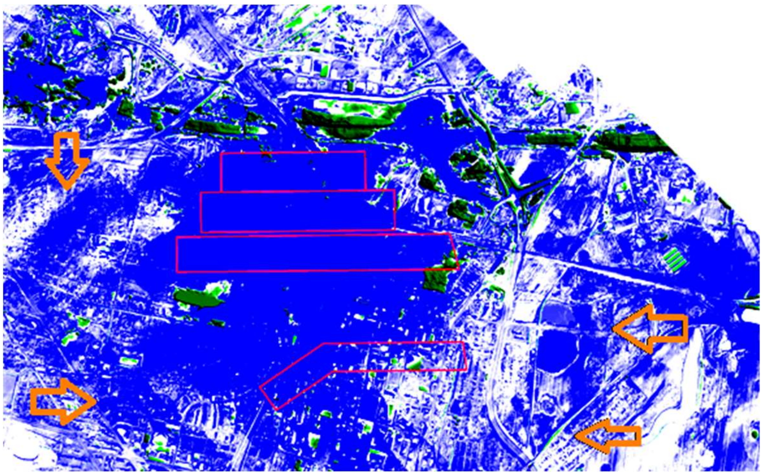

Fig. 4. Map of falls in the ground level with shading module NDVI, with marked falls deeper than 0,2m in the territory of hard coal mine Centrum between 2010 and 2012, generated in Global Mapper [developed by the author]

CONCLUSIONS

Due to the usage of ALS method for the purpose of monitoring terrain subsidence caused by underground mining exploitation it is possible to present the shape and range of the created subsidence basin in a surface manner and a comprehensive manner. The recorded falls in the ground level show close relation to activities conducted by humans (underground – mining exploitation, and surface – earth works and road works).

In cases where secondary impacts are revealed (activation of old headings) it is possible to determine the location of the occurring falls, and also their value and range.

As it was mentioned in the article, airborne laser scanning is widely implemented and possibilities of utilising this method are still not exhausted. Additionlly programmes used for data processing allow for presenting results in diverse and clear manner.

LITERATURE

1. BIAŁEK J.: *Algorytmy i programy komputerowe do prognozowania deformacji terenu górniczego.* Wyd. Politechniki Śląskiej, ss. 149-166, 2003.
2. GONTASZEWSKA-PIEKARZ A., MRÓWCZYŃSKA M.: *The application of Airborne Laser Scaning for identifying old lignite workings – case study: the mine "Borussia" near Ośno Lubuskie (Western Poland).* E3S Web of Conferences, Nr 36, 1-8, 2018.
3. KURCZYŃSKI Z.: *Fotogrametria.* PWN, 241-266, 2010.
4. KUŹNICKI W.: *Z góry lepiej widać.* Geodeta, Nr 8, 18-21, 2011.
5. WARCHOŁ A.: *Integracja danych z naziemnego, lotniczego i mobilnego skaningu laserowego do budowy numerycznego modelu terenu dla potrzeb tworzenia map zagrożenia powodziowego*. Rozprawa doktorska, Akademia Górniczo-Hutnicza im. Stanisława Staszica, 2014.
6. WĘŻYK P.: *Podręcznik dla uczestników szkoleń z wykorzystaniem produktów LIDAR.* Wyd. ISOK, 59-132, 2014.
7. WĘŻYK P., SOLCKI K.: *Określenie wysokości drzewostanów Nadleśnictwa Chojna w oparciu i lotniczy skaning laserowy (ALS)*. Archiwum Fotogrametrii, Kartografii i Teledetekcji, Nr 18b, 663–672, 2008.
8. http://www.bytom.pl/dzieje-miasta, dostęp – 07.05.2018.