DTM modelling of open pit mines using unmanned aerial vehicles

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***Abstract* – In the recent year, Unmanned Aerial Vehicles (UAV) become a popular technology and is very useful for Digital Terrain Modelling and monitoring. With good UAV equipment and resources, this study is focus on the feasibility and adaptability analysis of the UAV techniques and its applications in open pit mining surveying. The first tests were developed in Belchatow open pit mine regarding the big data problem and data reduction aspect.**

Key words – UAV, UAS, open pit mines, photogrammetry, big data, DTM

I. Introduction

Digital terrain model (DTM) is the one of the most essential data set for excavation monitoring. In this study was tried to find the data and the quality that UAV and associated equipment may produce and how to achieve this goals. In the recent years, advanced approaches to mining process monitoring have been studied to replace traditional methods of collecting and managing spatial data. Classical measurement applied in open pit mining based on Total Station, GPS RTK positioning and classical photogrammetry approach was described by [1] and are used to maintenance of the DTM of open pit mines.

In the last decade, the structure form motion processing has developed. The significant improve of computer vision algorithms caused that non metric images from different sources are applied in geodetic surveying [2]. The UAV platforms are a valuable source for inspection, camera transportation up to Visual Line of Sight Rating VLOS. Moreover, the full working system are creating the Unmanned Aerial Systems and they deliver more useful images datasets with photogrammetry minimum constraints[3]. The images are overlapping and computer vision matching algorithms allow to photo alignment and point cloud generation form specified images datasets [4].

II. Motivation

In the presented paper, the small feedback on UAV platforms is presented. There are two kinds of drones, the fixed wing and the multi-rotor wings, depending of different role of classification. The multi-rotor wings are useful for inspection, frequently equipped with gimbal which allows to track of object. The higher number of rotor allows to move more heavy sensors. The various UAV platforms were presented by [5]. The area that can be covered during one flight depends on the Ground Sampling Distance. The GSD is the size of area represented by each pixel in a digital photo. Due to the low flight altitude high resolution of 5 cm GSD was achieved. The similar tests were presented by [6]. The most important advantage of this type of unmanned aerial systems (UAS) is long time of flight and relatively wide covered area compared to multi-rotor drones. The postprocessed product is full metric using ground control points. They have to be marked and measured before flight mission on the area of interested. The first tests of integration RTK into UAS were missed. The use of RTK techniques would improve the quality of positioning to a decimeter level, but the system would become too complex, expensive and heavy. But in the last few years the GPS RTK receiver and IMU accelerometer and gyroscope sensors were integrated. It was applied in UAS Sirrus Pro [7].

III. Study area

The study area was located in the eastern part of Europe, the central part of Poland. The Lignite Open Cast Mine PGE KWB Belchatow excavation consists of two adjacent excavations. The first one is named as Rogowiec Pit and signed as A at Fig.1. The geometry of open pit mine and the dumping area is clearly visible. The size of the first excavation was about 3.0 km wide by 11.0 km long and about 280.0 m deep. Opencast mining is conducted at the 12 levels of excavation. The second one is named as Szczercow Pit and signed as B. Testing field was situated in dumping area signed as C.

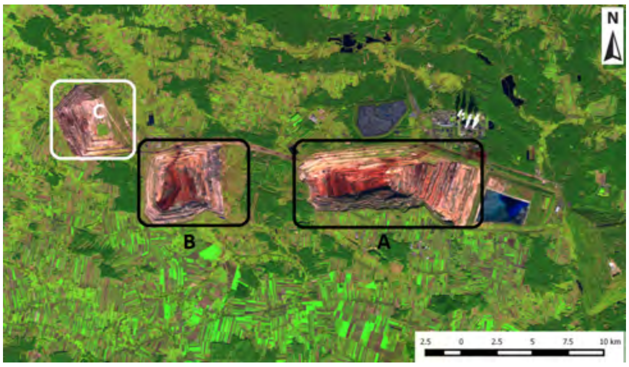

Fig. 1. Portion of the Landsat 8 composed band image of Belchatow Lignite Open Pit Mine. The combination is in false color 6-5-4 band. Acquisition time: 08.24.2014

The procedure of open pit mine modelling and monitoring in Belchatow open pit mine is making by digital photogrammetry [8] and [9]. It is carried out with full metric Rollei camera, which is used to 3D sidewall vectors measurements on postprocessed photogrammetric virtual model. The 3D vectors named as breaklines are exported directly to the Minescape software data base. However, the 3D CAD is light to compute, opposed to point cloud from UAS. Time consuming the postprocessing computation including sparse matching, motion estimation, bundle adjustment and dense matching. Moreover, the final product such as ortomozaics, digital terrain model and point cloud is high memory consuming. The data post-processing by software from raster and XYZ to 3D ridge lines may resolve the problem and the one approach was described by [10].

IV. Methodology

The applied surveying techniques in open pit mining have to provide high measurement reliability, performance, economy and easy in use regarding the extremal mining conditions. Photogrammetry has the potential to provide information about construction and mining progress more efficiently, rapidly and cost-effectively. Applied accuracy for the DTM modelling and breaklines and sidewall excavation modelling were estimated by 0.20 m. It allows to effective construction and mining progress monitoring [11].

In this study the fixed wing aircraft Trimble UX5 was used. The drone is launched by ground launcher, flies and takes photos autonomously. Then glides back down to the ground by using a preprogrammed flight plans organized by ground control system and controlled by the ground control station and remote controller. It mounted with Sony Nex5 (4912x3264pix). Moreover, the procedure off and landing of the aircraft required a safety space and looks dangerous for the aircraft. The multi-rotor UAV's is independent in this case. The testing area covered ca. 2.0 km2. Planning the fieldwork is an important part of the project. The quality of the control and check data as well as the images depends highly on this stage [12]. GSPs were signalized using triangular targets and used sharp colors to make them be distinguishable from the natural objects in the scene. Once the image acquisition was terminated, the ground marks were measured with the RTK system. During the flight mission 2003 images were taken. The row images were imported to the Agisoft Photoscan Professional software and post-proceed [13]. The software used in this analysis was treated as a black box for model creation, since in most cases the used algorithms, such as the dense matching, are proprietary and, therefore unpublished.

Figure 2 visualizes the aerial mosaic (with average ground resolution of 5 cm). The resulting file has huge capacity. Detailed data of 2.0 km2 are shown in table 1.

Fig. 2. Visualization of the preliminary orthomosaic in RGB in local terrestrial reference frame. The capacity of the finally product is 173.0 MB

TABLE 1

ACHIEVED DATASETS STATISTICS

Product	Capacity
Raw of 2003 photos	13.7 GB
Orthomosaic	173.0 MB
DTM	217.0 MB
Point Cloud	120.0 MB
PDF 3D Model	30.0 MB

Figure 3 shows the 3D point cloud colored by elevation. The red circle represents the simple which were analyzed. As seen best in figure 3, the data extraction was prepared in Global Mapper, and processed in Matlab and the selected subset which is highlighted by red circle was prepared to the next stage. The big data problem of the high resolution point cloud was estimated in Meshlab. For testing field a Poisson point cloud meshing was made. First the surface normal were estimated, and the next step was point cloud mesh generation. The processing pathway required simplifying the mesh. The results are shown in the next chapter.

V. Results

The chosen data subset was presented at Figure 4.It represents the actual pit sidewall excavation. The original size of point cloud simple was 1825 KB and represent 23,000 XYZ points. Exported data file was included in addition RGB colors of each 3D point. The first step of data reduction was saving in .PLY mesh format. The full data statistic are show in table 2.

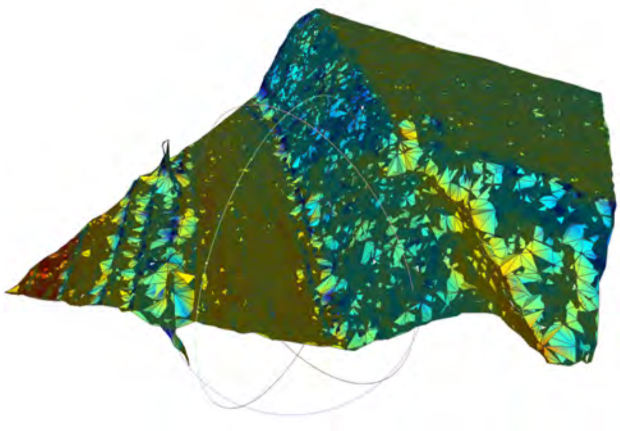

Fig. 3. Visualization of the selected simple with reconstructing mesh in the original size

TABLE 2

ADVANCED STATISTICS OF THE RESULTS

Type of file	Capacity	Reduction
Extracted sample ASCI	1825MB	-
PLY Binary	563 KB	69.2 %
PLY ASCI	813 KB	55,5 %
Simplified sample ASCI	850 KB	53,4 %
Simplified PLY ASCI	401 KB	78,0 %

Fig. 3. Visualization of the selected simple outlined by the red circle

The second step which was applied based on mesh simplified regarding accuracy DTM modeling in open pit mines. It is shown in Figure 4. The breaklines named as structure lines in DTM are clearly visible and accurate. This level of big data reduction allows to achieve the 0.20 m accuracy of DTM. It can be useful for accurate and more efficiency. In this approach a selected area was quite small which was caused by typical computer limitations. The non-metric images form UAS can be used to DTM monitoring in open pit mines. It is important to remember that UAS datasets are difficult to model and the matching algorithms has the random iteration process and they are unpublished [14]. Moreover, the processed point cloud and orthomozaics as a raster type file is difficult to use.

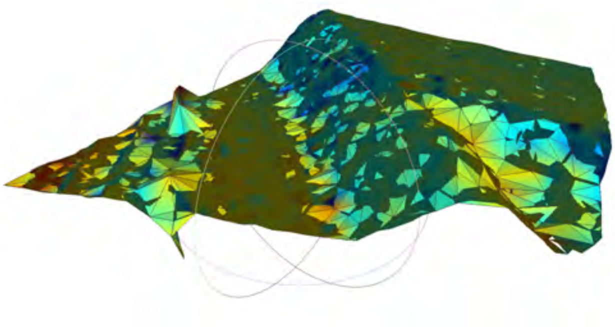

Fig. 4. Visualization of the simplified mesh

Conclusion

In this paper the procedure of DTM modeling using UAV is given. The author shown one of the approaches as well as theoretical and experimental developments of a UAV photogrammetric system in Belchatow open pit mine. Both aspects of data postprocessing and reduction were discussed. The results shown that photogrammetry image matching is grooving and the computer vision allows to using the non-metric camera to DTM modelling. Achieved accuracy is possible to apply this technology to open pit mine monitoring and volume computation. The UAV system is mobile and operative to apply in the fieldwork at open pit mine. Moreover, the computation methodology adapted for digital model reconstruction and the breaklines in 3D which represents the ridge line of floor and roof of excavation were presented. The problem with big data is visible and the presented approach allows to data reduction. The future work will focuses on UAV RTK platform and resulting data integration.

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