DIGITAL SURFACE MODELING THAT IS SUITABLE FOR THE PURPOSES OF EDUCATION IN PHOTOGRAMMETRY

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ABSTRACT. A study was conducted that presents a contemporary method for generating a digital model. The article is related to the educational process in the courses of study in the field of Photogrammetry. The aim of the article is to include this method in the curriculum, so that students could become familiar with the means and ways of creating digital surfaces, as well as to practically implement such means and ways.

Keywords: close-range photogrammetry, digital photogrammetry, education

ЦИФРОВО МОДЕЛИРАНЕ НА ПОВЪРХНИНИ, ПОДХОДЯЩО ЗА ЦЕЛИТЕ НА ОБУЧЕНИЕ ПО ФОТОГРАМЕТРИЯ
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РЕЗЮМЕ. Реализирано е изследване, което представя един съвремен метод за генериране на числен модел. Статията е свързана с учебният процес по дисциплините с направление Фотограметрия. Целта е този метод да бъде включен в учебната програма, така че студентите да се запознаят със средствата и начините за създаване на цифрови повърхнини и практически да реализират такива.

Ключови думи: близкообхватна фотограметрия, цифрова фотограметрия, обучение

Introduction

Education is the foundation on which specialists' knowledge and skills in various fields are based. The dynamic development of the ways of collecting information, along with the methods of processing, storage and exchange of information, determine the development of the process of education in photogrammetry.

Photogrammetry includes methods for image measurement and interpretation that provide information about the shape and location of objects to each other through a set of photographs. It uses the central projection as the basic mathematical design method. The shape and location of each object is determined by means of a reconstruction of beams of rays.The projection center, along with each point in the image, defines the spatial direction of the beam towards the corresponding point of the object. Provided that the coordinates of the projection centers and the geometry of the image are known, then each imaging beam can be defined in the 3D object space. The point of the object that is defined in the three-dimensional space can be obtained from the interception of at least two corresponding (homologous) spatially separated rays.

The main objective of a photogrammetric measurement is the three-dimensional reconstruction of an object in a digital or a graphical form (images, drawings and maps). Photogrammetry is closely related to such sciences as photography, computer graphics and vision, digital image processing, GIS, cartography, automated computer design, etc. (Luhmann et al., 2006). Nowadays, data used in photogrammetry are in a numeric form and this predetermines the use of digital processing methods. Digital photogrammetry is applied both in the processing of air and ground imaging and in solving various tasks in mine surveying and geodesy. All this proves the significance of the training and preparation of students in the field of digital photogrammetry.

In addition to the theoretical knowledge of students, practical training in a given course of study is essential. The use of presentations, information from the Internet, implemented projects, educational aid materials, and other tools are inherent to the process of learning. Practical training should include the implementation of the basic stages of photogrammetric processing within the digital environment.

The methods for image measurement and interpretation make it possible for a point from the captured object to be identified in terms of its shape, brightness, or colour distribution. Radiometric data (intensity, grey value, colour value) and geometric data (position within the image) can be obtained for each point in the image. Converting the information from the set of images to he stage of receiving a digital model requires systems with the appropriate geometric and optical processing quality. The degree of automation and adaptation of these systems varies according to their application direction. This also determines their diversity. The most common software products with full processing capacities are: PHOTOMOD, ERDAS, PCI GEOMATICS, AGISOFT PHOTOSCAN, PHOTOMODELER, CONTEXT CAPTURE, and iWITNESS. A research has ben carried out that present different software products and analises their capacities for the purposes of photogrammetry education. (Draganova et al., 2004). The creation of increasingly simplified software results in saving time and resources and makes the working process convenient. The end products obtained are with the necessary precision and detail. One of the most popular software products for photogrammetric processing and generation of 3D spatial data is Agisoft PhotoScan. The fact that it is not used only by specialists makes it suitable for employing in the educational process as well. The capacities of the program allow the operator to adjust the workflow to various specific data and tasks (http://www.agisoft.com). This software is used for the processing of images obtained through the methods of close–range photogrammetry.

Photogrammetry began its development with ground photogrammetry which has always accompanied this development in one way or another. Ground photogrammetry deals with determinaing the shape, dimensions and position of different objects based on photographss taken from the earth's surface. Today, in a modified form, ground photogrammetry has focused its application on close-range photographic (non-topographic) photogrammetry (Кацарски, 2002). The coordinates of the projection centers and the elements of internal and external orientation can be specified very precisely. This also predetermines their application in various areas of geodesy and mine surveying. The capturing of façades of buildings or of various architectural objects, as well as the monitoring of facilities, are just a small part of the applications of terrestrial photogrammetry. In open-cast and underground mining, the generation of digital models of surfaces, pillars, parts of galleries, etc. can provide data to be used in performing various mine surveying tasks. For example, for geological mapping, for determining joint tectonics of rock masses, for tracking deformations and landslides, for calculating volumes, etc. The safety and the low-cost equipment are the other advantages of the methodology proposed.

Research materials exist that examine the effects of information processing technologies in the course of education and also how they affect the abilities to think and to easily solve mathematical problems. Training students through software products allows them to explore the optimised simulation of physical, social or mathematical systems (Katz, 1995).

The main objective of this study is to develop such methods for generating surfaces that are suitable for educational purposes. Seminars are introduced into the curriculum where one of the most common software products is used nowadays. These seminars will introduce students to the main stages in modeling and will train them to model. They will also be able to create such models themselves and to develop their creative thinking, to learn how to solve various problems, and to improve their analysis skills.

Modern methods in the educational process

Does the educational process need to be changed and what modern methods are used at present? A specialist, trained with modern equipment and processing methods, would be employed sooner and would feel satisfied both from an economic perspective and from a purely human point of view. This brings to a new level the competitiveness of the graduates of a given university and also improves its status.

A contemporary photogrammetric method is presented for generating digital surfaces, which is applied in solving various engineering tasks.

A study related to the generation of a digital model of a building façade presents the methods for capturing by using a smartphone. Photogrammetric processing of data is performed using the Russian Agisoft PhotoScan software. The results obtained show that the methods presented can be employed to create digital models and orthophoto images of buildings and other objects and to monitor different processes (Gospodinova et al., 2017).

The creation of a three-dimensional photorealistic model of a quarry based on digital images is presented by Borisov and colleagues. A digital camera and photogrammetric processing software are used. The control points are measured by a total station. The method is not optimal for large-size objects but is applicable to medium- and small-size objects. Based on the data obtained discontinuities and shear zones in the model can be determined, the geometry of fissures and slope faults can be assessed, unstable pillars can be evaluated, and the geotechnical and geological characteristics of objects can be determined (Borisov et al., 2012).

Are these methods also applicable to capturing objects inside the buildings themselves or generally in enclosed spaces? This would greatly facilitate the educational process and would make it independent of the weather conditions.

Research studies exist that are related to the capturing of excavation walls and pillars in underground mines for the purposes of extracting geological and geotechnical information. These studies examine the feasibility of digital models for monitoring deformations, for updating mine mapping, for volumes calculation, for assessing the stability of the rock mass, etc. (Benton et al., 2016, Slaker et al., 2017).

The essential advantage of close-range stereo photogrammetry is that it allows comprehensive geological mapping in a digital environment. The various digital surfaces can be tied during excavation work without measuring reference points only by elements that are visible in single images. To achieve greater accuracy, geodetically measured control points are used whose purpose is to orient the model within the coordinate system of the object (http://3gsm.at).

Based on the above studies, the methods for capturing enclosed spaces by means of digital photogrammetry are proposed to be implemented it in the process of training in different courses units.

First stage

The object of the study is part of the corridor wall in the building of the University of Mining and Geology “St. Ivan Rilski”. The purpose was to make attempts to capture the wall during the day with and without the using a tripod and artificial lighting. Afterwards, the results obtained were analyzed. The capture was performed with a smartphone Huawei P10.

Fig. 1. Visualisation the of model for the right-hand side of the corridor

Fig. 2. Visualisation of the model for the left-hand side of the corridor

It is clear from the results obtained that the illumination of the object influences the quality of the generated model. Therefore, there is a darker area in the left corner in Figure 2 because the light from the windows affects the initial few pictures. To avoid this, some of the photos should be pre-processed using Photoshop, Adobe Photoshop Lightroom, or similar software packages. Such areas will be eliminated when the illumination of the object is uniform and well-balanced.

The condition for the direction of the rays to be perpendicular to the object was met, but some of the exposures were slightly sloped towards the ceiling and the floor. Marks were placed, but during the first capture they were not geodetically determined. 65 photos were obtained which were then processed by using the Agisoft PhotoScan software product in observation of the processing steps described in the Agisoft PhotoScan User Manual Professional Edition for version 1.2. Processing was completed within less than an hour without filtration of the images. The model was not geodetically attached. The result after image processing is shown in figure 1 and figure 2

Photos from the working process are presented in Figure 3.

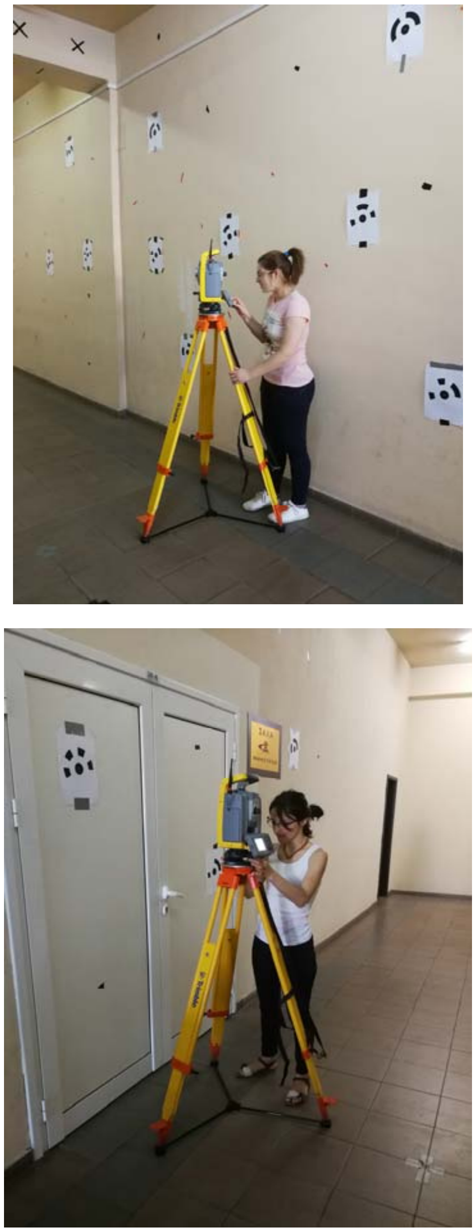

Fig. 3. Photos from the working process

Second stage

The purpose of the second capture was to obtain digital surfaces (digital models) which would in a local coordinate system and to analyse the results. Fifteen marks were placed on the object to indicate the control points. They were measured with a Trimble S6 total station. The multifunctional and flexible station is characterised by a wide range and accuracy of measurement to various surfaces and provides a standard square error when measuring distance of 2 mm + 2 ppm (0.0065 ft + 2 ppm) and accuracy of angular measurement of 2’’ (0.6 mgon). All marks are automatically recognised by the software in the photogrammetric processing.

136 photos were used for image processing. The resulting average square error of the model after equalising was 0.0181m and it ispresented in Figure 4. The visualisation of the generated model of smartphone is presented in Figure 5.

Markers	X (m)	Y (m)	Z (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
target 21	1999.491000	1002.437000	501.771000	0.005000	0.005600	21	0.490
target 32	1994.753000	1002.402000	501.623000	0.005000	0.006980	30	0.372
target 3	2000.649000	1002.441000	501.818000	0.005000	0.007134	23	0.808
target 23	1998.473000	1002.446000	501.645000	0.005000	0.012561	23	0.839
target 9	1998.924000	1002.458000	500.802000	0.005000	0.013398	22	0.485
target 14	1998.518000	1002.422000	502.719000	0.005000	0.013830	25	0.535
target 7	1994.913000	1002.392000	502.729000	0.005000	0.014052	32	0.319
target 13	2000.890000	1002.419000	502.775000	0.005000	0.016073	29	0.421
target 2	2001.158000	1002.453000	500.874000	0.005000	0.017538	25	0.485
target 33	1996.201000	1002.386000	501.575000	0.005000	0.018050	25	0.463
target 10	1993.581000	1002.402000	501.896000	0.005000	0.019143	19	0.502
target 8	1996.908000	1002.360000	502.811000	0.005000	0.021515	26	0.558
target 25	1997.265000	1002.372000	501.663000	0.005000	0.023243	26	0.720
target 22	2001.847000	1002.444000	501.693000	0.005000	0.027460	27	0.481
target 34	1993.005000	1002.415000	500.929000	0.005000	0.032684	15	0.216
Total Error							
Control points					0.018149		0.536

Fig. 4. Coordinates of the control points and the average square error of the visualised model

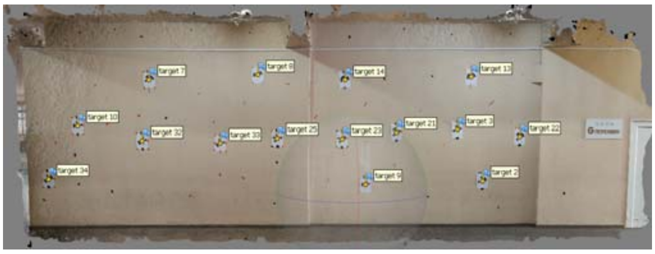

Fig. 5. Visualisation of the digital model of the surface obtained by a Huawei P10 mobile phone with 20Mpix resolution

The model obtained by means of a smartphone displays some curvature in the upper left corner. This is mainly due to the illumination and the daylight effect of the windows.

The same study was also carried out with a Canon EOS 600D digital camera with a resolution of 16 Mpix using a tripod. Capturing was performed during the day under artificial lighting (with lamps switched on). 53 frontal and sloping images were taken. Fifteen control points were used for the photogrammetric processing. The marks' coordinates were measured with the same total station. The average square error of the model after the equation was 0.0088m. It is presented in Figure 6. The model generated is given in Figure 7.

Markers	X (m)	Y (m)	Z (m)	Accuracy (r	Error (m)	Projectic	Error (pix)
target 2	2001.161000	1002.443000	500.874000	0.005000	0.012843	6	0.228
target 3	2000.652000	1002.432000	501.818000	0.005000	0.002709	11	0.239
target 7	1994.913000	1002.392000	502.729000	0.005000	0.008958	8	1.473
target 8	1996.908000	1002.360000	502.811000	0.005000	0.012521	6	0.277
target 9	1998.927000	1002.454000	500.803000	0.005000	0.013052	5	0.469
target 10	1993.581000	1002.402000	501.896000	0.005000	0.008212	12	0.473
target 13	2000.893000	1002.411000	502.776000	0.005000	0.007914	9	0.177
target 14	1998.521000	1002.420000	502.719000	0.005000	0.010577	6	0.159
target 21	1999.491000	1002.437000	501.771000	0.005000	0.008390	10	0.224
target 22	2001.850000	1002.432000	501.694000	0.005000	0.005552	14	0.395
target 23	1998.476000	1002.444000	501.645000	0.005000	0.007816	10	0.224
target 25	1997.265000	1002.372000	501.663000	0.005000	0.004332	10	0.999
target 32	1994.753000	1002.402000	501.623000	0.005000	0.004683	10	1.588
target 33	1996.201000	1002.386000	501.575000	0.005000	0.001688	7	1.061
target 34	1993.005000	1002.415000	500.929000	0.005000	0.012001	6	0.151
Total Error							
Control points					0.008837		0.731

Fig. 6. Coordinates of the control points and the average square error of the model

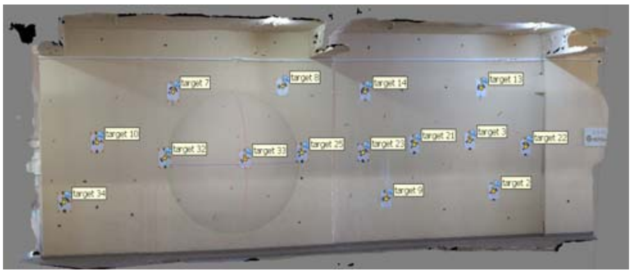

Fig. 7. Visualisation of the digital surface model obtained by a Canon camera

The obtained accuracy indicates that the results can be used by the mining engineers to solve different tasks. During shooting, the lighting must be positioned opposite the object in order to produce a good-quality digital model and an orthophoto image.

For this object, a larger number of pictures taken by a smartphone rather than by a digital camera are needed in order to get a better geometry of the model.

Conclusion

It can be concluded that the presented methods can be used in underground mining for generating digital surfaces.

The proposed methods will enrich the knowledge of students trained in the course of studies of Mine Surveying and Geodesy, as well as of other specialists in various fields. Students will be given the opportunity to learn and apply this contemporary method of capturing as early as during the stage of university education.

From an economic perspective, good lighting and the characteristics of the digital camera are essential for the implementation of the methods in real-life conditions. To a great extent, they determine the quality of the end product, the way of processing, and the processing time. The advantage of the method is the low cost of the equipment, the safety, and continuity of the data compared to the traditional apparatuses and methods of capturing.

The future studies will focus on the generation not only of surfaces, but also of digital models of various objects (e.g. side walls, props and supports, pillars) and enclosed spaces, such as galleries, mine workings, tunnels, etc. This will bring about thorough geological mapping within a digital environment and will allow the acquisition of data on the excavation work in underground mines.

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