GEODESY AND CARTOGRAPHY
ISSN 2029-6991 print / ISSN 2029-7009 online
2014 Volume 40(1): 8–13
doi:10.3846/20296991.2014.906923

UDK 528.718

APPLICATION OF TERRESTRIAL PHOTOGRAMMETRY TO THE CREATION OF A 3D MODEL OF THE SAINT HEDWIG CHAPEL IN THE KAŇOVICE

Milan Mikoláš[1], Petr Jadviščok[2], Vlastimil Molčák[3]

[1]Institute of Mining Engineering and Safety, Faculty of Mining and Geology, VSB – Technical University of Ostrava, 17.listopadu 15, CZ 708 33 Ostrava, Czech Republic
[2, 3]Institute of Geodesy and Mine Surveying, Faculty of Mining and Geology, VSB – Technical University of Ostrava, 17.listopadu 15, CZ 708 33 Ostrava, Czech Republic
E-mails: [1]milan.mikolas@vsb.cz (corresponding author); [2]petr.jadviscok.st1@vsb.cz; [3]vlastimil.molcak.st@vsb.cz

Submitted 13 February 2014; accepted 24 February 2014

Abstract. The present article focuses on application of terrestrial photogrammetry for the purposes of creation of photogrammetric documentation of building structures with the use of digital camera – a widely accessible device. First, the article briefly describes the individual intermediate operations of the whole process leading to the creation of a three-dimensional structure. Next, attention is given to operations related to camera calibration, reconnaissance of the locality of interest, photographing itself, creation of the 3D model as well as to presentation of graphical output. In conclusion, the article focuses on determining the accuracy of photogrammetric measuring.

Keywords: calibration, terrestrial photogrammetry, photography.

Reference to this paper should be made as follows: Mikoláš, M.; Jadviščok, P.; Molčák, V. 2014. Application of terrestrial photogrammetry to the creation of a 3D model of the Saint Hedwig Chapel in the Kaňovice, *Geodesy and Cartography* 40(1): 8–13.

Introduction

Terrestrial photogrammetry ranks among the methods that can be used to survey building structures and assess three-dimensional models. This method finds its use in the field of documentation of buildings, particularly historical sites characterized by their rugged ground plan and extensive number of decorative architectural elements. Such a survey is usually performed with the use of the intersection method or the single image method in cases where only a photomap (two-dimensional, e.g. for purposes of facade measurement) is required in terms of documentation. The objective of photogrammetric surveys is to determine the dimensions and the shape of the structure of interest including the visualization of three-dimensional or two-dimensional output. Photogrammetric documentation has significance mainly for documentation purposes, it allows for evaluation of the current state of the surveyed structure or for comparison of the results of periodic photogrammetric survey; that can be particularly convenient for monitoring of structures subject to horizontal as well as vertical deformations due to the negative impact of the underground mining activity.

1. Software and instrumental equipment

The purpose of the photogrammetric documentation is always a decisive factor for the selection of instrumental equipment and realization of the photogrammetric survey of any structure. Among other criteria of the appropriate instrumental or software equipment selection are issues related to the expected accuracy of any survey and of the 3D model and as well as the requirements regarding the visualization or presentation of the 3D or 2D photogrammetric output. For the purposes of a simple photogrammetric documentation; it is adequate to realize the photogrammetric survey using any widely accessible non-survey digital camera. In the case of increased requirements on the accuracy or quality of the processed photographs, it is necessary to use a professional digital single-lens reflex camera producing photographs with high resolution. The photographs that served as a basis for the creation of the 3D model of the structure were taken with the Samsung S760 digital camera (see Fig. 1) with resolution 7.2 million effective pixels. An indispensable part of the instrumental equipment and software is comprised of tools necessary for the calibration of the camera and for the connection of the 3D model to the scale. Among these tools are in particular the following: a geodetic control serving the automatic digital camera calibration by means of the PhotoModeler 6 software and a survey tape for the control side measurement serving to connect the model to the scale as well as to test the accuracy of the photogrammetric survey.

Fig. 1. Digital camera Samsung S760

2. Digital camera calibration and photographing of the structure of interest

One of the preconditions for successful creation of a 3D model of the structure is compliance with certain rules that apply to the photographing of the structure of interest which will be mentioned hereafter, and the use of a properly calibrated digital camera.. The term "calibration" refers to a set of operations leading to the determination of important parameters of the camera which are indispensable for the evaluation of the surveyed photographs. The calibration process results in elements of internal orientation, such as the camera constant, the position of the principal point of the photograph, the distortion of the lens system, and the dimensions of the digital chip (Kapica, Sládková 2011).

For purposes of the digital camera calibration, it is possible to use either a 2D geodetic control or a 3D geodetic control. This article focuses on the process of calibration by means of a 2D geodetic control of the PhotoModeler 6 software depicted in Fig. 2. The 2D geodetic control is constituted by a grid of points represented by black circles with four control points in the corners of the control (Sužiedelytė-Visockienė 2012). To evaluate the calibration, it is necessary to take 8 photographs before the photographing of geodetic control itself; furthermore, it is imperative to comply with the following rules: a) the geodetic control must be placed on a horizontal mat, b) the geodetic control should be without any shadows, c) all photographs must be taken with a constant focal length (do not use the ZOOM function), d) the maximum resolution must be set, e) the photographs must be constant, f) the calibration field must fill the maximum possible space of the photograph, as the automatic calibration

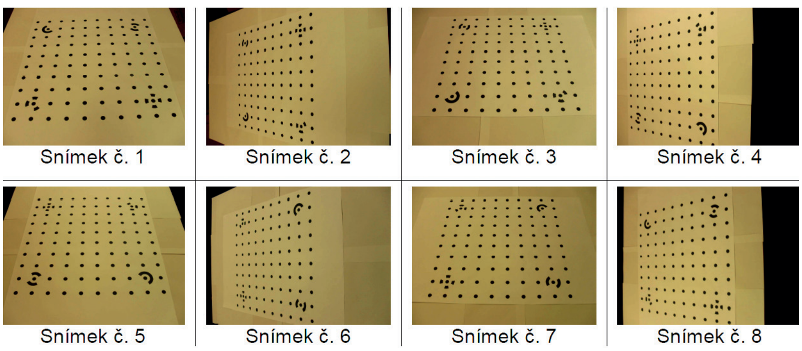

Fig. 2. Photographs of the 2D geodetic control

might cause the program to include erroneously dark points on the background of the geodetic control to the calculations, g) the camera should not be switched off (inner orientation elements might change).

The next step is to take a total amount of 8 photographs of the geodetic control under the angle of approximately 45° while complying with the following rule: the photographs must be taken in couples, one landscape, then the camera should be turned by 90° and a portrait should be photographed from four stations (see Fig. 3). The PhotoModeler 6 software allows for automatic calculation of all required parameters. Following the import of photographs, the calibration process will be initiated, resulting in a calibration message that includes the required parameters of the camera; it is possible to set these parameters for the project in the framework of which the structure photographs will be processed. When this is completed, it is possible to proceed to the next stage of work (Kapica 2009).

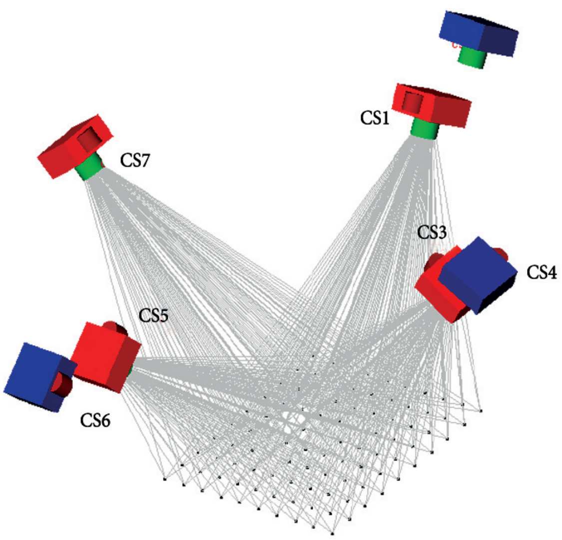

Fig. 3. 3D model of the calibration field including the station position

The following stage is related to operations resulting in photographs of the modelled structure. In this case, the structure of interest is the Saint Hedwig Chapel in Kaňovice dating back to 1868. The municipality of Kaňoviceis located approximately 8 km to the North from the town of Frýdek-Místek (see Fig. 4). The structure is owned by the Catholic Parish of Bruzovice and is used for regular church services (Oficiální stránky obce Kaňovice 2011).

Prior to the photographing itself, it is necessary to perform operations related to the terrain reconnaissance and operations resulting in the appropriate choice of position of photogrammetric stations depending on surrounding terrain, vegetation, and the spatial character of the structure. In the process of photographing of the structure, it is necessary to comply with the rules of intersection photogrammetry, in particular to make sure that the angle of the intersection of individual photographs' axes approaches the ideal value, which is the intersection angle of 90°. To ensure the continuity of individual photographs, it is necessary to provide a sufficient overlapping so that each point of the structure is represented at least on three photographs. Though it is not always possible to respect all rules of photographing due to local conditions in the vicinity of the modelled structure the surveyor should always try to comply with the required rules as closely as possible. Fig. 5 depicts a demonstration of

Fig. 4. Structure localization (GPS 49°44´31´´ N, 18°23´20´´ E)

Fig. 5. Demonstration of photographs of the Saint Hedwig Chapel

photographs taken of the structure. We took a total of 21 photographs.

For control purposes, for the purposes of connecting the 3D model to the scale as well as defining the accuracy of the created model, it is necessary to survey the control side measurements with a survey tape, in case of higher accuracy requirements, it is convenient to choose ground control points and survey and evaluate these by the standard geodetic method. In this particular case, the survey of the control side measurements with a survey tape was sufficient (Kapica, Sládková 2011).

3. Creation of 3D model of the structure

The processing of photographs and the creation of the requested 3D model of the structure was preceded by the selection of photographs to be used for processing in the PhotoModeler software. It is always convenient to take more photographs in the terrain and make the selection afterwards, if necessary. We selected 13 photographs out of the total number of 21 for subsequent processing.

The following operation is related to the referencing of the points on individual photographs. The photographs of the structure must be oriented; orientation of two photographs requires at least 6 common points to be referenced on the photograph. The orientation of three photographs requires the same condition of 6 identical common points to be referenced while the three oriented photographs must necessarily have at least one common point. It is therefore convenient, for purposes of the photographs' orientation with respect to the abovementioned conditions, to take identical points on conveniently selected pairs or trios of photographs. The referencing is performed as follows: the photograph of departure is defined, a point on the photograph of departure is taken, and then identical points on other photographs are taken. As soon as the number of taken points is sufficient, points of the 3D model are calculated. A similar method is used to reference all points constituting the basis of the 3D model. In the course of the referencing process, a "wireframe model" is created (connecting of already calculated points of the 3D model by lines directly on the photograph or in a 3D representation). The connection of the model to the scale is performed by defining the real lengths measured in the terrain corresponding to the line element in the 3D model. To connect the model to the scale, we used the longest sides of the structure. We subsequently defined the coordinate axes (Kapica 2009).

The final process in the creation of the 3D model of a structure is the connection of surfaces to the wireframe model. It is possible to connect real textures directly from the photograph to the wireframe model or to use predefined materials that approximate the real appearance of the structure. In this case, we used our own colour definition of surfaces for individual elements of the structure (windows, facade, roof, entry doors, etc.) according to the colour scheme on the photographs. We used our own materials of surfaces for reasons of local deformations of real textures on photographs. The use of real textures for surfaces of the 3D model is not always possible as it is conditioned by high resolution photographs (Mikulenka, Kapica, Sládková 2011). Demonstration of graphicaloutput to see Figs 6–11.

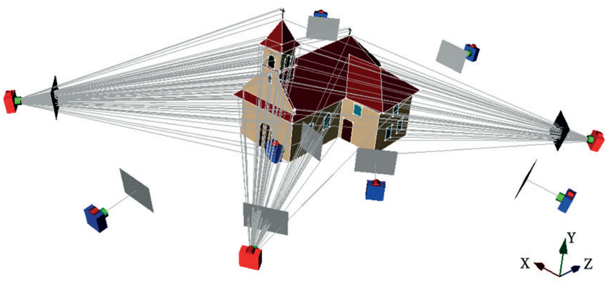

Fig. 6. 3D model with the position of photogrammetric stations (view 1)

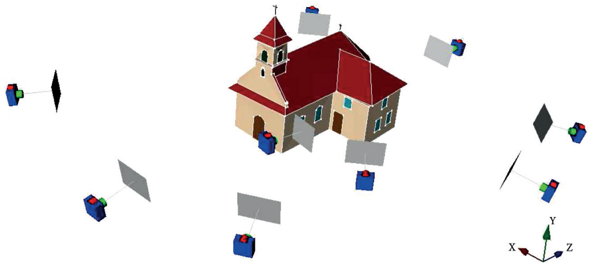

Fig. 7. 3D model with the position of photogrammetric stations (view 2)

Fig. 8. Wireframe model connected with the photograph

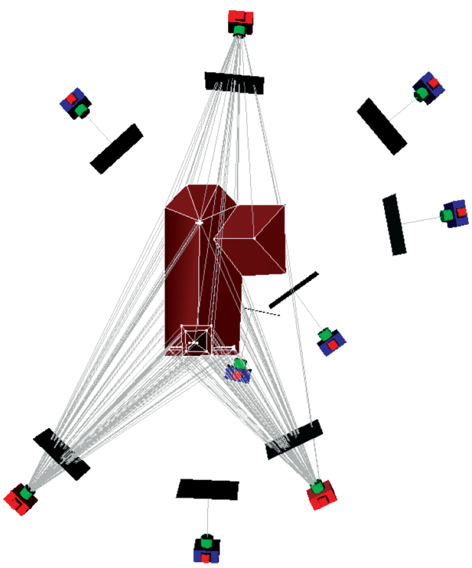

Fig. 9. 3D model (ground plan + photograph stations)

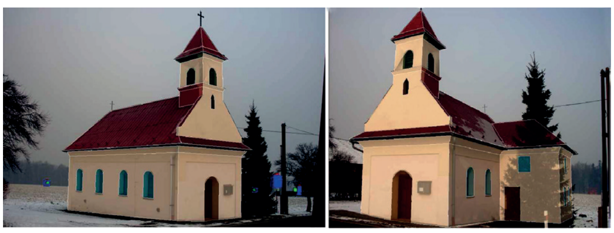

Fig. 10. 3D model of the chapel connected to photographs taken

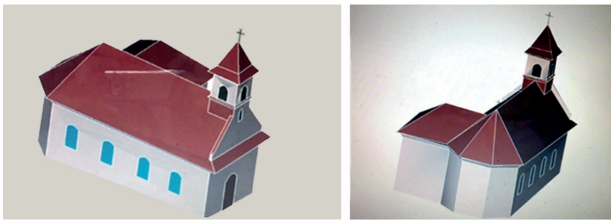

Fig. 11. 3D model of the Saint Hedwig Chapel (3D visualisation)

4. Accuracy evaluation of the 3D model of the chapel

To evaluate the accuracy of the created 3D model of the Saint Hedwig Chapel it is possible to use the side measurements that were measured in the terrain (type H: horizontal, V: vertical, see Table 1) while the structure was photographed. The real lengths (measured by the survey tape) are compared to lengths calculated by the PhotoModeler software from the 3D model. The deviations and accuracy characteristics are summarized in the table below. The accuracy characteristics of the 3D model of a structure are defined as empirical (experimental) mean error of the model **m** (see Table 1). The calculation of the mean error did not include the length by means of which the model was connected to the scale.

Table 1. Accuracy evaluation of the 3D model

n	type	Terrain [m]	PhotoModeler [m]	*v* [cm]	*vv* [cm^2]
1	H	5.26	5.27	-1	1
2	H	2.23	2.24	-1	1
3	H	2.23	2.20	3	9
4	H	2.21	2.20	1	1
5	H	3.68	3.66	2	4
6	H	4.85	4.83	2	4
7	H	3.72	3.69	3	9
8	H	6.36	6.36	0	0
9	V	2.15	2.14	1	1
10	V	2.95	2.99	–4	16
11	V	1.45	1.44	1	1
12	V	2.65	2.63	2	4
13	V	0.80	0.79	1	1
14	V	2.18	2.20	–2	4
15	V	2.97	3.00	–3	9
Σ					65

Mean error of the 3D model m = 2.1 cm

Conclusions

The objective of the present article was to outline concisely the issue of photogrammetric survey and to present the possibilities of the graphical output in which the PhotoModeler software allows to produce the survey results. The article explains individual operations related to the photogrammetric survey as well as the processing of the 3D model from the theoretical (rules of calibration, structure photographing, creation of the 3D model) and practical perspective (in the form of graphical demonstrations of the digital camera calibration, photographing of the structure, creation of the 3D model of the structure, and the presentation of results of a particular photogrammetric survey). Furthermore, the article focuses on evaluation of the accuracy of the 3D model from which we can note that for the purposes of general documentation, evaluation of the current state of a structure or 3D presentation of the structure of interest, the photogrammetric survey and evaluation is sufficient with a widely accessible camera and a survey tape. In the case of increased requirements on accuracy in mm, it would be necessary to use a survey camera (camera with stable inner orientation elements) in combination with the survey of ground control points by the standard terrestrial geodetic method. Beside the abovementioned forms of graphical output, the PhotoModeler software offers other possibilities of presentation of results in the form of 3D animations or connection and inclusion of a created 3D model to the environment of Google Earth applications, including the option of exporting the results to various other formats.

This article was written in connection with grant project SGS No. SP2014/13 – The use of UAV device for creating 3D models in geodetic practice.

References

Kapica, R. 2009. *Fotogrammetrie Návody do cvičení I., II.* Česká republika, Vysoká škola báňská, Technická univerzita Ostrava, 57 s. ISBN: 978-80-248-2067-5

Kapica, R.; Sládková, D. 2011. Photogrammetric analysis of objects in undermined territories, *Geodesy and Cartography* 37(02): 49–55. ISSN 2029-6991 print, ISSN 2029-7009 online. http://dx.doi.org/10.3846/13921541.2011.586440

Mikulenka, V.; Kapica, R.; Sládková, D. 2011. The potential of photogrammetry for object monitoring in undermined areas, *Acta Montanistica Slovaca* 16: 262–269. ISSN 1335-1788.

Oficiální stránky obce Kaňovice. 2011. Informace o obci Kaňovice [online], [cited 11 May 2011]. Available from Internet: http://www.obec-kanovice.cz/?page=obec&set=cz-34686

Sužiedelytė-Visockienė, J. 2012. Photogrammetry requirements for digital camera calibration applying TCC and MatLab software, *Geodesy and Cartography* 38(3): 106–110. http://dx.doi.org/10.3846/20296991.2012.728895

Milan MIKOLÁŠ. Doc. Ing., Ph. D. VŠB – TU Ostrava, Institute of Mining Engineering and Safety, Faculty of Mining and Geology, VSB – Technical University of Ostrava. 17. Listopadu 15, CZ 708 33Ostrava, Czech Republic. Ph+ 420608533231, e-mail: milan.mikolas@vsb.cz
Research interest: mining engineering and safety.

Petr JADVIŠČOK. Ing. VŠB – TU Ostrava, Institute of Geodesy and Mine Surveying, Faculty of Mining and Geology, VSB – Technical University of Ostrava, 17. Listopadu 15, CZ 708 33 Ostrava, Czech Republic. Ph+420724087561, e-mail: petr.jadviscok.st1@vsb.cz
Research interest: the issues of precision GNSS technology in surveying practice.

Vlastimil MOLČÁK. Ing. VŠB – TU Ostrava, Institute of Geodesy and Mine Surveying, Faculty of Mining and Geology, VSB – Technical University of Ostrava, 17.listopadu 15,CZ 708 33 Ostrava, Czech Republic. Ph +420728365563, e-mail: vlastimil.molcak.st@vsb.cz
Research interest: verification of the coefficients of theoretical calculations of movements and deformations in the mining area Staric.