AN INNOVATIVE TECHNOLOGY FOR CREATING AN ORTHOPHOTOPLAN

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ABSTRACT. The façade of the building of the Department of Physical Culture and Sports at the University of Mining and Geology "St. Ivan Rilski" was captured with a mobile phone (a smasrtphone using the Android OS). The main aim of the study was to create a model and also an orthophotoplan. The photos were photogrammetrically processed with the Russian software Agisoft Photo Scan. The results obtained were analyzed.

Keywords: close-range photogrammetry, digital photogrammetry, low-cost photogrammetric techniques

ИНОВАТИВНА ТЕХНОЛОГИЯ ЗА СЪЗДАВАНЕ НА ОРТОФОТОПЛАН

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РЕЗЮМЕ. Реализирано е заснемане на фасадата на сградата към катедра „Физкултура и спорт" на МГУ „Св. Иван Рилски" чрез мобилен телефон, тип смартфон с операционна система Android. Основната цел беше да се създаде модел, а също и ортофотоплан. Фотограметричната обработка на снимките е извършена в програмната среда на руският софтуер Agisoft Photo Scan. Получените резултати са анализирани.

Ключови думи: близкообхватна фотограметрия, цифрова фотограметрия, ниско струващи фотограметрични техники

1. Introduction

Technologies are evolving every hour, minute and second, and this leads to the appearance of increasingly sophisticated tools, instruments and devices which find usage not only in our lifestyles but in almost all spheres of our life. The creation of more and more simplified processing software allows us to save time and resources. It also provides us with the convenience of working and obtaining final products with the necessary precision and details. These two conditions predetermine the development of contemporary photogrammetry, namely digital photogrammetry.

Digital presentation and archiving of buildings requires simultaneous application of close-range photogrammetry, digital photogrammetry and image processing techniques. The main task that needs to be solved is the photometric and geometric reliability between the object and the model (Marinov, 2008).

Close range photogrammetry is applicable in creating 3D models and object surfaces. Since some aerial and satellite pictures are not readily available, digital cameras are a good alternative. The cheaper equipment and high precision are the basic prerequisites for its development. The high resolution and instant availability of the photos make the method particularly suitable for generating digital models and orthophotomaps of different objects with the required precision. Therefore, it can be concluded that close-range photogrammetry has low cost and is suitable for creating a photorealistic 3D object models. This is evidenced by a number of studies related to the use of digital close-up photogrammetry (Marinov and Hristova, 2001; Marinov, 2008; Draganova et al., 2004; Ramos et al., 2015).

There are also studies aimed at exploring the capabilities of close-range digital photogrammetry compared to other methods. The author Paul Koppel has conducted an experiment to determine whether photogrammetry is an alternative to Earth's laser scanning. It analyzes spatial differences between a test object (a model obtained by capturing a CANON EOS 6D digital camera and processed by Agisoft PhotoScan), and the randomly arranged control points measured with a non-reflex (laser) total station. Analysis of the results of the accuracy assessment is compared with the Cloud Compare software and shows that it is possible to achieve identical accuracy using the Agisoft Photo Scan digital imaging software (http://www.agisoft.com/pdf/articles/Paul_Koppel_Agisoft-PhotoScan_case_study_01.pdf).

Other studies confirm the capabilities of the Agisoft PhotoScan software for photogrammetric applications (Waas and Zell, 2013; G. Plets et al., 2012).

But can we capture with a smartphone and what results will be obtained?

2. Materials and methods

Digital close-range photogrammetry is a method for accurately measuring objects directly from photographs or digital images taken with a camera in a close range of no more than 300m.

The photographic design techniques are based on the basic relationships between the object and its image, i.e. the properties of the central projection. If the projected beam is restored with the inner orientation elements of the image, the construction of the image in perspective can be done using a plan or facade. For this purpose, two coordinate systems are formed (x, z) with the starting point of the image O and a modular spatial coordinate system in which the y-axis is identical to the shooting direction, where X and Y are parallel to the picture coordinates. And there is an S start in the camera's lens on the shooting station (http://w3.uacg.bg/UACEG_ site/fge/Disc/lek_ph_II/pdf/p2_7-8.pdf)

The determination of photogrammetric coordinates is based on the collinearity equation, which states that the point of the object, the center of the projection center of the camera, and the point in the image lie on one line. Determining spatial coordinates (3D) from a certain point is achieved by intersecting two or more straight lines. Therefore, each point should appear in at least two images (Kraus, K., 1992).

The multiple of overlapping images captured by different stations generate measurements that can be used to create accurate 3D object models (Cooper and Robson, 1996).

2.1. Object information and shooting

The study object is the façade (frontage) of the building of the Department of Physical Education and Sports which is part of the University of Mining and Geology "St. Ivan Rilski" in Sofia.

For the present study, we used a smartphone of the brand of Samsung Galaxy S5 SM – G 900F with 16 Mpix, focal length of 4.8 mm, and ISO (the sensitivity of the camera sensor to light) 100 and under 100. The capturing was executed on two levels corresponding to approximately the heights of 1.70m and 4m. The smartphone was attached on a lathe and a program called “Timer Camera” was used, which allows shooting at certain intervals - in this case, 15 seconds - with an approximate base of 1.5 m.

12 control points (for assessing the accuracy of the recovery/resulting model) and 2 reference points (points 29 and 28 are used for set a reference system) were uniformly distributed and marked onto the object. The positioning scheme of the points can be seen in figure 1.

Fig. 1. Scheme of the distribution of points

All marks are automatically recognized by the software. Figure 2 presents the type of two of the marks that were used for signaling in the present study.

1 2

Fig. 2. The type of two marks used for signaling

The control points were precisely measured with a total station - Trimble S6. The multifunctional and flexible total station is with servodrive, allowing the movable mechanical parts of the tool to move with little resistance. The Trimble DR Plus ™ technology allows an extremely wide range and accuracy of measurement to any surface and requires fewer stations and easier access to hard-to-reach objects, saving time and resources (http://www.solitech.bg/trimble-s6.html).

The capture was executed in a local coordinate system i.e. the total station has random relative coordinates (in this case, X = 2000 m, Y= 1000 m, Z= 500 m). After that they were reduced for convenience. The direction of axis Y was chosen to start from p.29 as it would be the beginning of the local coordinate system (x29 = y29 = z29 = 0) of the model. The second reference point in case 28 was also carefully selected in order to calculate the rotation angle, in this case **α** = $20^{g}.0660$. Figure 3 shows a scheme of the location of the total station relative to the building façade, and in table 1 – the data from the shooting and calculated rotated local coordinates.

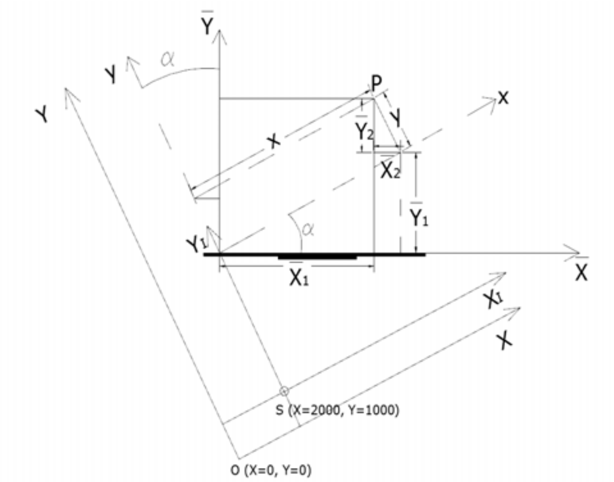


Fig. 3. Scheme of the position and orientation of the total station relative to the building façade

Table 1

Точка №	Относителни координати (m)			Локални координати (m)			20.06600	Завъртени локални координати (m)		
	X	Y	Z	x	y	z	0.310003	x'	y'	z'
29	0.000	26.477	1.890	0	0	0	0.950736	0	0	0
28	34.812	15.126	1.961	34.812	-11.351	0.071		36.616	0.000	0.071
25	-5.523	28.343	1.917	-5.523	1.866	0.027		-5.829	0.062	0.027
27	5.775	25.296	0.315	5.775	-1.181	-1.575		5.857	0.667	-1.575
30	14.608	18.668	2.330	14.608	-7.809	0.440		16.309	-2.896	0.440
31	21.740	16.313	2.133	21.740	-10.164	0.243		23.820	-2.924	0.243
32	18.750	16.860	1.933	18.750	-9.617	0.043		20.808	-3.331	0.043
33	12.626	19.324	1.395	12.626	-7.153	-0.495		14.221	-2.887	-0.495
34	11.062	19.840	3.107	11.062	-6.637	1.217		12.575	-2.881	1.217
35	11.050	19.843	1.382	11.050	-6.634	-0.508		12.562	-2.882	-0.508
100	1.612	26.374	6.895	1.612	-0.103	5.005		1.565	0.402	5.005
101	33.240	16.023	6.930	33.240	-10.454	5.040		34.843	0.366	5.040
102	40.682	13.294	2.703	40.682	-13.183	0.813		42.765	0.078	0.813
103	-5.906	28.544	2.173	-5.906	2.067	0.283		-6.256	0.134	0.283

2.2. Photogrammetric processing

The software "Agisoft – PhotoScan Professional Edition" was used for the photogrammetric image processing. It is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data. This data can be used in GIS applications, cultural heritage documentation, and visual effects production, as well as for indirect measurements of objects of various scales (http://www.agisoft.com).

2.2.1. Creating a project and generating a block

The project creation involves assigning a project name and the path of the directory where the work files will be stored. For the current experiment, 636 photos were reviewed and those which were redundant or erroneously selected were deleted from the project. 413 photos were used for processing at a maximum distance of 25 m from the subject of shooting. During project creation, the coordinates of the control points were also introduced. A scheme of the block's illustration, in two planes xz and xy, can be seen in Figure 4 and Figure 5.

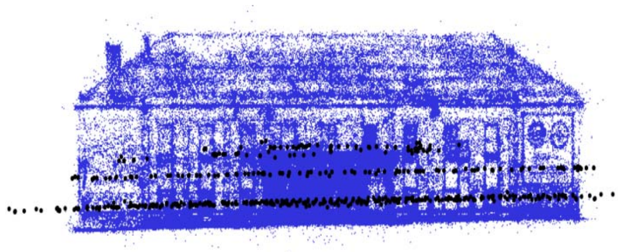


Fig. 4. Scheme of the block in the plane xz

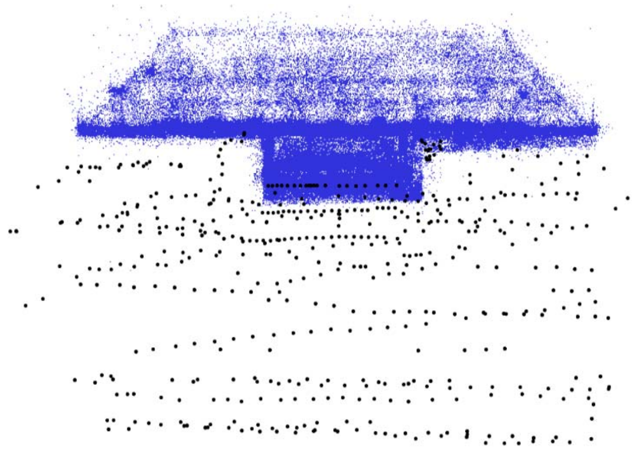
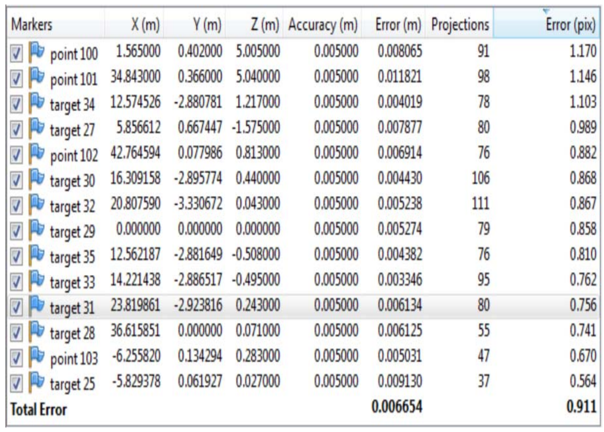


Fig. 5. Scheme of the block in the plane xy

2.2.2. Recognizing control points, performing alignment and then optimization

Once the block was created, each control point was recognized in all the photos where the point existed.. Parameters for the adjustment were set: process precision (the desired accuracy of the alignment) - in this case high, maximum number of points to be compared parallel in each picture - 50, 000, mask usage - a background elimination procedure was applied to some of the photos. Then, processing was performed, followed by optimization. Calibration with this software is done during processing by using the following parameters: fx, fy, cx, cy, skew, k1-k3, p1, p2. For the investigated object, the mean square error (absolute precision of the model) obtained after the alignment was about 1cm (6.7mm), which is shown in Figure 6.



Markers	X (m)	Y (m)	Z (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
point 100	1.565000	0.402000	5.005000	0.005000	0.008065	91	1.170
point 101	34.843000	0.366000	5.040000	0.005000	0.011821	98	1.146
target 34	12.574526	-2.880781	1.217000	0.005000	0.004019	78	1.103
target 27	5.856612	0.667447	-1.575000	0.005000	0.007877	80	0.989
point 102	42.764594	0.077986	0.813000	0.005000	0.006914	76	0.882
target 30	16.309158	-2.895774	0.440000	0.005000	0.004430	106	0.868
target 32	20.807590	-3.330672	0.043000	0.005000	0.005238	111	0.867
target 29	0.000000	0.000000	0.000000	0.005000	0.005274	79	0.858
target 35	12.562187	-2.881649	-0.508000	0.005000	0.004382	76	0.810
target 33	14.221438	-2.886517	-0.495000	0.005000	0.003346	95	0.762
target 31	23.819861	-2.923816	0.243000	0.005000	0.006134	80	0.756
target 28	36.615851	0.000000	0.071000	0.005000	0.006125	55	0.741
point 103	-6.255820	0.134294	0.283000	0.005000	0.005031	47	0.670
target 25	-5.829378	0.061927	0.027000	0.005000	0.009130	37	0.564
Total Error					**0.006654**		**0.911**

Fig. 6. The result obtained after the photo alignment

2.3.3. Generation Dense Point Cloud, Triangulated Irregular Network (TIN), Digital Surface Model (DSM), and orthophoto

Generation and visualization of 3D vector points, or the so-called Dense Point Cloud, are used for building a Digital Surface Model and orthophoto and are realized after finishing the Photo Align process. The parameters which were used at this stage of processing were medium quality and mild filtering. In the present study, the generated Dense Point Cloud included 8, 549, 412 points and can be seen in Figure 7.

Fig. 7. The result obtained after the photo alignment

After the cloud of points has been created, it goes to the automated generation of a Triangulated Irregular Network (TIN), from which a digital surface model is obtained later. In the program „PhotoScan“, this processing is fully automated by pre-setting the following parameters: surface type - arbitrary, source data for determining an Triangulated Irregular Network - Dense Cloud of Points, maximum number of polygons, which to participate in forming the network – high. A fragment of the network can be seen in figure 8.

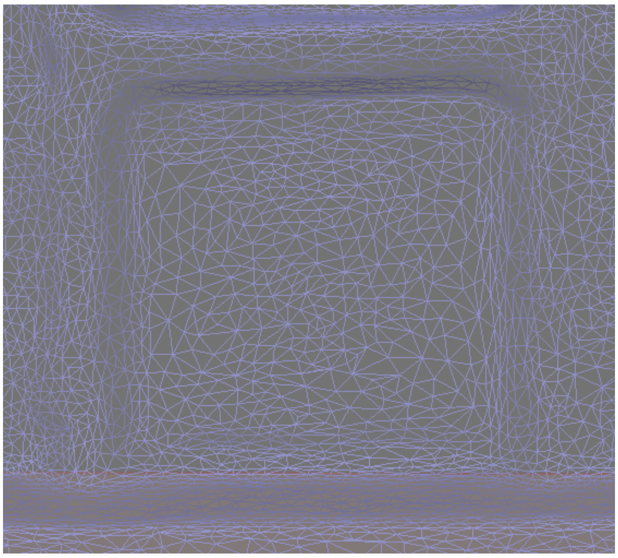


Fig. 8. A fragment of an irregular triangular network

One of the main tasks for photogrammetric software is to generate a digital surface model. It is based on image matching and autocorrelation algorithms. The automatically generated digital surface model can be seen in figure 9. Fig. 10 shows the final product, the orthophotoplan.

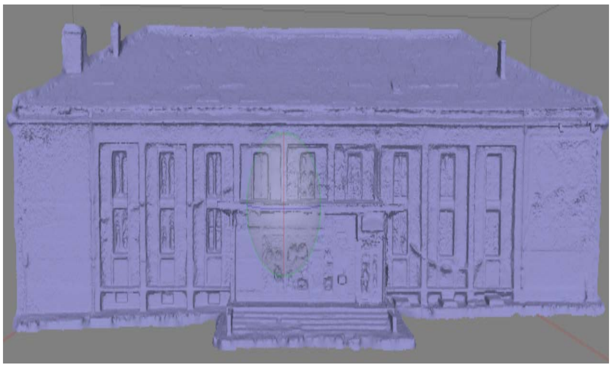


Fig. 9. The generated digital surface model

Fig. 10. The orthophotoplan of the façade of the building of the Department of Physical Education and Sports in M 1: 500

Some areas of the orthophoto plan have lighter areas, due to the use of .jpg, not a row format. In future, efforts should be directed to eliminating such areas by implementing procedures to improve the radiometric and color characteristics of images, and using a higher-class smartphone that not only supports row format, but also good optics and quality matrix.

The average arithmetic error obtained as the difference between the spatial coordinates measured with the total station and the orthophoto plan is in the order of 1 cm.

3. Conclusion

The obtained results suggest that the presented methodology for generating a building façade model and an orthophoto using a mobile smartphone can be used to create digital models, orthophoto plans of buildings and other objects, and to process monitoring. It can also be used to solve tasks of a different nature. The deficiency of the methodology is in the presence of vegetation in front of or close to the objects of capture: plants interfere with visibility and this gives rise to erroneous geometry. Another disadvantage is related to the parameters of the used hardware: high-end systems with a good configuration of the parameters are required for processing such digital images.

The proposed method for capturing different objects and processes, near which there is no vegetation, is a desirable method because it guarantees flexibility, accuracy and safety. The plant obstacle could be avoided if colored RGB sensors are used together with sensing sensors for other ranges of the electromagnetic spectrum, for example the infrared range.

The economic aspect is also one of the leading points because the cost of images taken from satellites and pilot or non-pilot airplanes is significantly higher than the cost of images from mobile devices.

The digital images obtained with the appropriately selected software can be used for creating accurate orthophoto plans and digital models of objects for most engineering and geomorphological projects. They can find their application among all the methods used so far in the practice.

A further sphere of interest for the researchers would be their application in mine surveying and geological purposes related not only to modeling and volume calculation, but also to determining the tectonic crack of rock masses and other tasks, such as underground extraction - why not?

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