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COMPARISON OF PHOTOGRAMMETRY AND LASER SCANNING METHODS ON THE CHOSEN ARCHITECTURAL OBJECT

Digitization of documentation of white cards is currently a key aspect of preservation of national heritage. Destructive processes of archival documentation, escalation of acts of vandalism, consequences of war operations that have left their stamp on architectural objects as well as monuments of nature contributed to adaptation and introduction of the fifth form of national heritage, which is "digitization". Digitization shall ensure the re-creation of not only lost national treasures in the future, but also shall enable researchers in architecture, archeologists, historians, conservators a research and an analysis of chosen objects and records related to it in a non-invasive and interactive way. Objects subject to digitization will be able to be analyzed more thoroughly since digital data rendered available by electronic means shall enable and facilitate an interdisciplinary research process. In the article, the author presents results that compare two methods for digitization of the chosen architectural object. Documentation consists in recording and preserving of the fragment of façade and the chosen architectural detail of the considered object. The object subject to analysis is the "Tenement under the singing frog" built in 1889–90 acc. to the project by Teodor Marian Talowski, in Kraków at Retoryki 1 St. For an analyzed example, research has consisted in application of photogrammetry and laser scanning methods to acquire information on spatial geometry of researched object and compare discrepancies of newly generated 3D models.

The object presented has undergone a comparative analysis, based on which the key aspects have been isolated and then demonstrated in a graphic way, as well as specific issues related to them, such as precision and effect of distortion have been discussed. The objective of the work has been presentation of possibilities of practical application of photogrammetry as a cheaper method of digitization of architectural objects in relation to scanning method, applicable in digitization and preservation of national heritage consisting in development of new interactive documentation (white card).

Keywords: digital image, inventory of monuments, digitization, white card, 3D documentation, discrepancy

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1. Introduction

Concepts of photogrammetry and laser scanning derive from surveying, where they are broadly applicable in documentation of shapes, dimension and space. *Photogrammetry is a field of science and technology, where researchers are engaged in re-creation of shapes, dimensions and relative position of objects in terrain based on photographic images* [1], out of which a point cloud is created. Laser scanning serves the purpose of determination of spatial position of vector elements, describing geometry of measured objects with radiometric sizes attributed to them. In this manner *"points of XYZ spatial coordinates, forming the so-called point cloud or triangular irregular net (TIN) describing the shape of measured surface"* are established [2].

Spatial measurement obtained from both methods may be used not only for saving of geometry of the registered object, but for acquisition of data and information of certain features of historical areas. Accuracy of performed measurements is dependent on conditions prevailing during measurements, properties of exact objects (complexity of structures etc.), and also on expectations of recipients of documentation-photogrammetry products [3].

Currently, while making measurements we are exercising guidelines of 1981, which require updating and adaptation to constantly developing technological possibilities, as well as new emerging market demands („*Wytyczne Techniczne G-3.4 pt.: „Inwentaryzacja zespołów urbanistycznych, zespołów zieleni i obiektów architektury*""[4]).

A continuous development of digital measurement techniques has created tools for reconstruction, reproduction and recreation of researched objects in a non-invasive way. Non-invasive process of digitization is a paramount quality of this method, allowing to protect [5] objects of national heritage. Thanks to establishment of the large database of objects, elements of cultural heritage can be protected in a new form from processes of biological destruction, lapse of time, consequences of warfare, as well as despoilment and devastation of property [6]. Therefore, preservation of national heritage properties is applicable in documentation, which is *sites and monuments record card called a "white card",* formulated in 1975 under the supervision of Prof. Wojciech Kalinowskiego. Apart from data included in a green card, it contains additional information. A well-prepared white card includes full, comprehensive information of the object adjusted to needs and scope of conservation measures. *Many most valuable objects have not been granted a white card until today, although it is regarded as a basic form of registration.* [7]

Therefore, diverse academic centers as well as scientific and research institutes [8] by using methods of digitization and computer-based technologies of varied degree of progression are making efforts to create new methodology of preservation of heritage (methodology of the "5th" generation) and creates „*digital white cards*" of objects.

2. Description of the research process

2.1. Methodology applied in the research process

The research process has been divided into two stages of work comprising the following activities:

a) Stage of field surveys:

- selection of surveying technology and deployment of the surveying scanner stations,
- doing surveys of characteristic façade elements by tachometric method,
- taking digital images of the building façade and the architectural detail from deployed stations.

b) Stage of inside works:

- calculation of coordinates of distinctive points on the façade of the building,
- recording and connecting of the scanner-acquired collection of points,
- creating a model in the form of mesh (TIN) of the building façade and architectural detail based on the collection of survey points from the surveying scanner. Points have been generated from photographic images by means of Agisoft Photo Scan software using distinctive points from tachometric surveying.

2.2. Characteristics of applied surveying instruments

For the research, the following instruments have been used for measurement of geometry of researched areas, based on which comparative models have been developed by means of specialist software.

The following equipment has been used for research:

- laser scanner – *Leica C10* impulse scanner,
- total station – *Leica MS50* – Surveying multi-station,
- camera – *Nicom D5000,*
- workstation *Fujitsu R920,*
- mobile workstation *XNOTE.*

Software used for data processing:

- *Cyclone 9.0* – software used for smoothing out of measurement data, generating orthophoto plans and coloring point clouds with digital images,
- *C-GEO* – software intended for calculation of the co-ordinates of points of reference based on tachymetry,
- *Agisoft Photo Scan Pro* – tool used to generate a collection of points based on photography,
- *Bentley Descartes V8i* – software for modeling based on TLS data
- *Geomagic Studio/ Control* – software developed for creating TIN model based on the collection of points, and for analyzing discrepancies in relation to the reference object.

3. Survey results of the chosen architectural objects

Results of surveys done using survey laser and impulse scanners as well as digital photogrammetry have been shown, applied for needs of comparative analysis of the fragment of the building façade, as well as the chosen architectural detail. The object considered is "Tenement under the singing frog" built in 1889-90, designed by Teodor Marian Talowski, situated in Kraków at Retoryki 1 St.

3.1. Analysis of the wall facade

Laser scanner and photogrammetry have been applied for comparative analysis of both methods in research using tachymetry of the fragment of the building façade.

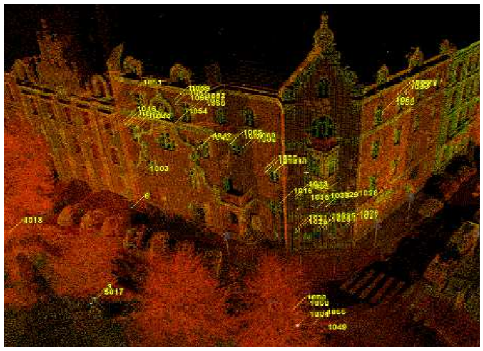

Fig. 1. Combined point cloud from a laser scanner, along with marked tachometric measurements

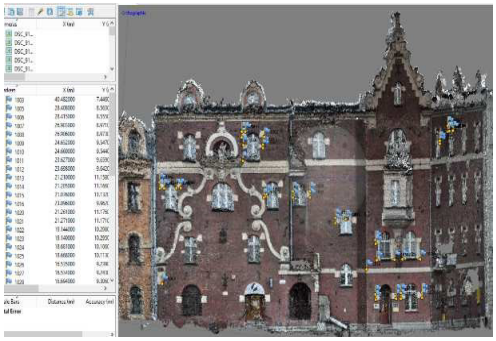

Fig. 2. Established photogrammetric point cloud with marked tachometric points

3.2. Analysis of architectural detail

Upon development of data from the total area of the object, the analysis of chosen architectural details has been conducted.

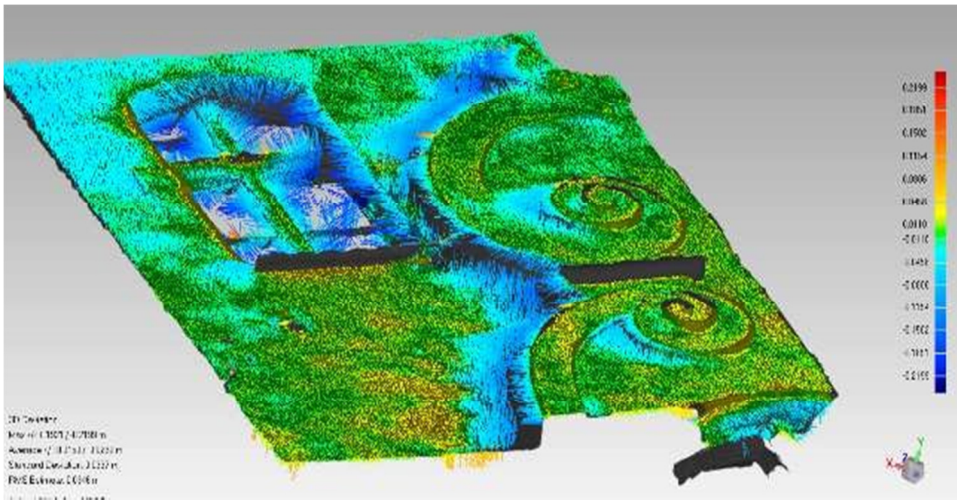

Fig. 3. Discrepancy analysis of architectural detail

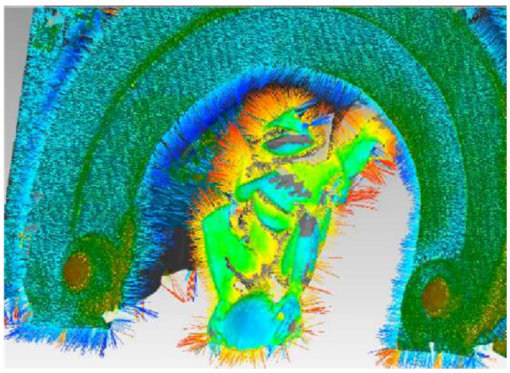

Fig. 4. The discrepancy of laser scanning and photogrammetry on the example of frog piece

Fig. 5. Model of architectural detail "Singing Frog" model TIN

4. Analysis of results

Based on conducted analysis, discrepancies in geometric parameters of obtained models can be presented in a graphic way. The model created from points acquired from laser scanner was used as a reference model. This model has been compared to photogrammetric model.

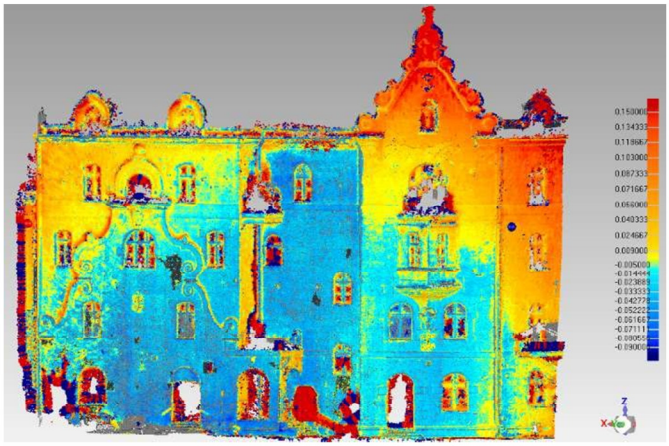

Fig. 6. A full analysis of discrepancies of laser scanning measurement in terms of photogrammetry on the example of the historic façade "Tenement under the singing frog"

Furthermore, results of comparative research by photogrammetric method with tachometric survey results as well as discrepancies in models obtained by these methods, have been presented.

Table 1. Table showing discrepancies of tachometric measurement of points in relation to points obtained by the photogrammetric method. A summary of the errors of each axis was presented as well as the number of overlapping images at reference points

Label	XY error (m)	Z error (m)	Error (m)	Projections	Error (pix)
1013	0.00845725	-0.0294726	0.0306621	48	2.507
1014	0.0177781	-0.0175875	0.0250076	47	2.984
1015	0.0133199	-0.00620727	0.0146953	46	2.137
1020	0.00917117	0.0200241	0.0220244	30	2.591
1021	0.0173721	0.014417	0.0225752	34	3.326
1022	0.0259006	0.0141942	0.0295349	31	2.265
1023	0.0271295	0.0203095	0.0338893	27	2.474
1024	0.0209427	0.0241801	0.0319887	26	2.043
1025	0.0260539	0.0145663	0.0298494	30	2.126
1026	0.0519761	0.008902	0.0527329	27	2.916
1027	0.0520016	0.0204739	0.0558869	25	3.249
1028	0.0388091	-0.00869272	0.0397707	39	3.966
1029	0.0226359	-0.00645667	0.0235388	36	2.078
1030	0.0171654	-0.00544268	0.0180076	43	2.740
1042	0.0429246	-0.0239622	0.04916	51	2.537
1043	0.0701864	-0.0156481	0.0719096	33	1.396
1044	0.0419124	0.00113345	0.0419277	34	1.839
1045	0.0343232	0.00247101	0.034412	34	2.120
1046	0.0599911	-0.01125	0.0610368	30	3.990
1047	0.0517507	-0.00531357	0.0520227	32	3.505
1048	0.0652882	-0.000251203	0.0652887	32	2.767
1054	0.0127437	0.0117995	0.0173675	50	1.541
1056	0.0410553	-0.00257303	0.0411359	57	1.446
1057	0.0218688	0.0114438	0.024682	56	1.858
1058	0.0383336	-0.00628536	0.0388455	53	1.689
1059	0.0400231	0.00238785	0.0400943	51	2.067
1060	0.0132394	0.0122283	0.0180225	43	1.561
1061	0.0292655	0.000107204	0.0292657	43	1.612
1062	0.0124575	0.0191868	0.0228762	41	1.831
Total	**0.0363607**	**0.0165669**	**0.039957**		**2.448**

Accuracies of models developed by method of data obtained from scanning and digital images combined with tachometric surveys have been compared:

a) in case of use of digital images and surveys by total station, the model accuracy has totaled 4 cm,
b) an accuracy of the model developed from laser scanning data has totaled 0,4 cm [4 mm].

Discrepancies have been compared by means of verification of position of points on the example of TIN mesh (mesh surface) created out of data from scanning and model generated from digital images and on the example of two TIN meshes.

5. Conclusions

By summarizing results of the research using the laser scanner and photogrammetry, the following conclusions can be drawn:

1) Based on comparison of obtained results of the research it has been found that with an increased distance of researched element vertically, error of photogrammetric measurement increases to a greater extent. It is due to a phenomenon of distortion of mapped plane on a digital matrix. The biggest errors (in the order of 15cm) occur in the top part of the façade.
2) Measurement error between both methods is acceptable for this type of solutions and is included within the scope of 0,4 cm for laser scanning and up to 4 cm for photogrammetry. When preparing inventories, the method of laser scanning seems to be an optimal solution. In the event of necessity to contain details requiring higher precisions (e.g. window woodwork, architectural detail) in documentation, supplementing the measurement with additional tachometric observations shall be advisable.
3) Coloring of digital images reflects real colors more advantageously and projects the coloring of facades more accurately than laser surveying.
4) Use of laser scanning and photogrammetry is applicable e.g. in digitization of national heritage as recommendation for a "digital white card" of the monument.
5) Application of photogrammetric surveys for uncomplicated architectural objects is less costly, and obtained survey results are negligibly worse than results acquired from laser scanning.

Finally, I would like to extend my thanks to research team of surveyors from the University of Science and Technology in Kraków*, and in particular to: Dr Eng. Rafał Kocierz, Viola Margasińska, Miłosz Janda and Jan Mądrzyk*, with whom I have co-operated in conduction of this research. Without their assistance, this research would not be possible to carry out.

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