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ANALYSIS OF THE ACCURACY OF THE SPATIAL MODEL OF THE TOWER FROM PHOTOS TAKEN BY UAV SUPPLEMENTED BY GROUND PHOTOS

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INTRODUCTION

The paper presents an analysis of the possibility and accuracy of developing 3D models of a building structure based on various measurement techniques.
The photogrammetric measurement of the tower was carried out three times using different measurement techniques. In the first of them, a UAV raid was performed. A series of photos were also taken with a classic digital camera and a mobile phone.
Data processing and construction of 3D models of the towers were done in Agisoft Metashape Professional software. Then, a comparative analysis of the obtained 3D models was carried out in CloudCompare software. The analysis of the results made it possible to conclude, among other things, the accuracy and efficiency of the tested technologies. It was also possible to verify the geometric parameters of the towers in comparison to the architectural and structural design.

RESEARCH AREA

The object of the research was the observation tower located in the quarries in Józefów in the Lubelskie Voivodeship in Poland (Fig. 1). The 18.5-meter-high structure is built of irregular limestone rocks. It is topped with a gallery and a roof made of wood. Wall thickness varies from 0.4 m to 1.4 m.
As part of the preparatory work, 4 control points were established near the tower. RTK GNSS technique was used to survey and determine the coordinates of these points. Then, 25 photo points were glued onto the tower up to a height of 3.5 meters. The determination of the coordinates of the photo points was possible thanks to the use of tachymetric measurements.

Fig. 1. Tested object - observation tower in Józefów (Poland)

MATERIALS AND METHODS

The following technologies (equipment) were used in this study: UAV - Parrot Anafi, Sony DSC-R1 digital camera, and Apple iPhone 11 Pro Max smartphone (Tab. 1). The preparatory and measurement works and their effects are presented in Table 2

Tab. 1. basic technical data of the devices used in the research.

	UAV - Parrot Anafi	Sony DSC-R1	iPhone 11 Pro Max
			
Camera	21 Mpix	10.2 Mpix	three 12MP cameras - with ultra-wide, wide-angle and telephoto lenses
Matrix	1/2.4” CMOS	21,5 x 14,4 mm CMOS	no data / CMOS
Aperture	f/2.4	f/2,8 - 4,8	ultra wide-angle lens: ƒ/2,4; wide-angle lens: ƒ/1,8
Camera viewing angle	69°	-	ultra-wide-angle: 120°
Camera stabilization	3-axis gimbal	none	optical image stabilization
Photo resolution	4608x3456 (RGB)	3888 x 2592 (RGB)	no data / HDR

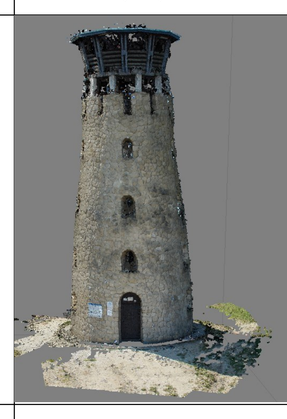
Tab. 2. Basic technical data of the devices used in the research.

	UAV - Parrot Anafi	Sony DSC-R1	iPhone 11 Pro Max
preparatory works	a few minutes	about 3 hours (Sony+iPhone)	
			
proper measurement	about 2 hours	about 12 hours (Sony+iPhone)	
preparation of data for the construction of a 3D model	• selection of 168 photos from a total of 207 photos	• selection of 109 photos from a total of 1802 photos • fulfillment of the specified condition by 23 of 25 photopoints located on the tower	• selection of 117 photos from a total number of 623 photos • fulfillment of the specified condition by 22 out of 25 photo points located on the tower

RESULTS

The prepared materials were used to build 3D models for each of the three measurement methods. Table 3 contains the necessary information about the accuracy of the obtained results.

Tab. 3. Accuracy of built 3D models

	UAV - Parrot Anafi	Sony DSC-R1	iPhone 11 Pro Max
number of points in a dense cloud	2,295,935	9,022,121	8,862,773
			
The Mean Square Error of the indication of photo points in the photos	0.032 m 0.8 pix	0.006 m 0.2 pix	0.019 m 1.0 pix

Additionally, the accuracy of the generated model was analyzed for the devices from which ground-based photos were taken. The comparisons were performed in CloudCompare software and the results are shown in Table 4. The most accurate cloud was obtained from photographs taken with the Sony DSC - R1 camera. It was taken as a reference cloud and distances between its points and other clouds were compared. Also, a cloud was constructed combining data obtained from the UAV and Sony camera. Then the comparison of distances of points between all clouds was done. The largest distance between points occurred in the relationship of clouds from the UAV and Sony camera. The reason was the lack of points forming a roof in the reference model from the Sony camera.

Tab. 4. Results of comparisons in CloudCompare software

Compared	Reference	Min dist.	Max dist.	Avg dist.	Sigma	Max error
UAV	Sony	0.000	2.562	0.067	0.219	0.080
iPhone	Sony	0.000	1.471	0.010	0.049	0.073
UAV + Sony	Sony	0.000	2.535	0.051	0.184	0.080
iPhone	UAV + Sony	0.000	1.427	0.006	0.040	0.079
UAV	UAV + Sony	0.000	1.487	0.006	0.058	0.078
iPhone	UAV	0.000	1.857	0.023	0.082	0.079

The constructed tower was also compared with the data from the architectural and construction design. Two horizontal sections at a height of 4 and 10 meters were selected (Fig. 2).

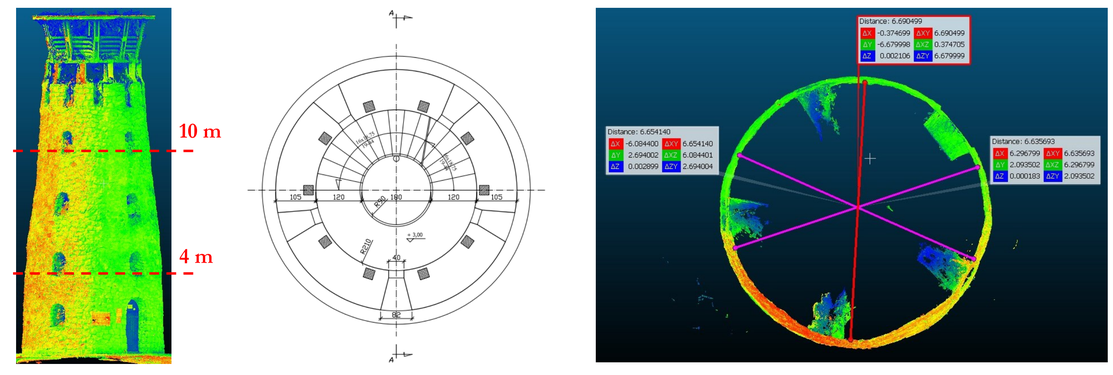


Fig. 2. Horizontal projection and horizontal sections of the model at the height of 4 meters

Tab. 5. Comparison of lengths of cross-section diameters

	average length of cross-section diameters	
	horizontal projection at the height of 4 m	horizontal projection at the height of 10 m
the architectural and construction design	**6.30**	**5.30**
Sony DSC R-1	6.66	5.45
UAV	6.67	5.43
iPhone 11 Pro Max	6.66	5.41
Sony + UAV	6.67	5.46

DISCUSSION AND CONCLUSIONS

Analysis of the results allowed us to draw several conclusions:
- The highest accuracy was obtained for the model created from the data of the Sony DSC-R1 camera, and the least accurate model was created based on data from the iPhone 11 Pro Max
- only based on UAV data (Parrot ANAFI) it was possible to generate the model of the upper part of the object i.e. the roof and the wooden housing of the observation balcony,
- the biggest errors of the model occurred in the recesses of the tower and its upper part (wooden structure),
- geometric parameters of particular models (e.g. diameter of the tower at different heights) are very similar to each other
- the geometric parameters of the tower determined from the models differ from the assumptions of the architectural-construction design.