UTILIZATION OF TERRESTRIAL LASER SCANNER LEICA SCANSTATION FOR STOCKTAKING MEASUREMENTS ON AN EXAMPLE OF A SPHERICAL DOME

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SUMMARY

The work presents results of using the technology of terrestrial laser scanning in stocktaking measurements of spherical domes. The parameter subject to special evaluation is the value of the dome's diameter set on primary level, which is compared with the theoretical value obtained from the technical project of the object.

The measurements in several variants were made with the use of Leica ScanStation laser scanner bought by the Geodesy Institute. In office works the original manufacturer's programme (Cyclone v. 5.6) was used. The programme enables modeling the obtained observation results and making basic measurements, such as, among other, measuring the value of the diameter on the cross-section subject to the analysis.

The results obtained with the use of laser scanning encourage to further detailed theoretically-empirical analysis.

Key words: Terrestrial laser scanner, spherical dome, modeling

1. INTRODUCTION

Modern building technologies enable designing buildings of diversified, non-standard shapes. The stocktaking measurement of such untypical buildings requires using appropriate measurement techniques. Most frequently, the stocktaking works were performed with the use of classic methods. The subjects of observation were the characteristic points of a building, which led to significant generalization and simplifying the examined elements. One of the classic methods of building parameters setting is area approximation of second level (Czaja, 1992). This method was used by, among others, Hejbudzka and Witkowski (2007), to measure the spherical dome being a part of the roof covering of Environmental Library at the University of Warmia and Mazury

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In recent years a new technology emerged, using a terrestrial laser scanner for field works. It is used in numerous sectors of economy. The advantage of terrestrial laser scanner is the speed of registering the examined object and the large number of observations, which allow a reliable reproduction of the measured construction. At present, it is possible to see the use of terrestrial laser scanning in deformation measurements of tunnels (Gosliga, Lindenbergh, Pfeifer, 2006), chimney cooler (Ioannidis, Valani, Georgopoulos, Tsiligiris, 2006) etc.

The measurements presented in this work, are aiming at pointing the usability of terrestrial laser scanner in stocktaking measurements. The realization of measurements and elaborating the results was carried out with the use of several possible options. The results obtained were compared with data included in the technical project of the examined construction.

2. THE OBJECT AND EXAMINATION PROCESS

The test object was a spherical dome (Figure 1) located at the Environmental Library at the University of Warmia and Mazury. It is a glass and metal construction. The measurement of the whole construction was carried out, focusing on the diameter of the dome on the level of the main cross-section (level 0 on Figure 2), which value was used for the analysis.

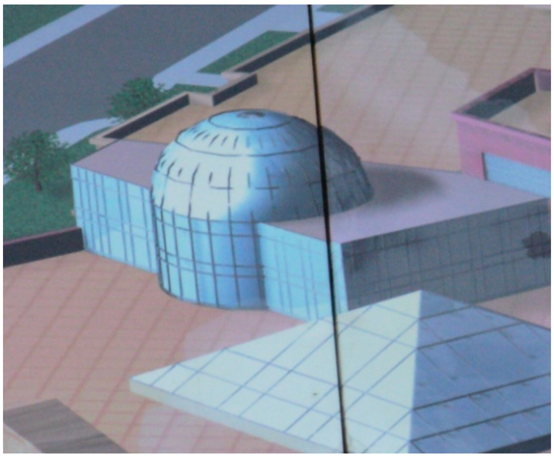

Fig. 1. The project of the dome (own collecion).

Fig. 2. The dome at present (own collection).

Figure 3 shows the localization of the examined object at university camp, the location of measurement stations and the target HDS necessary for further processing.

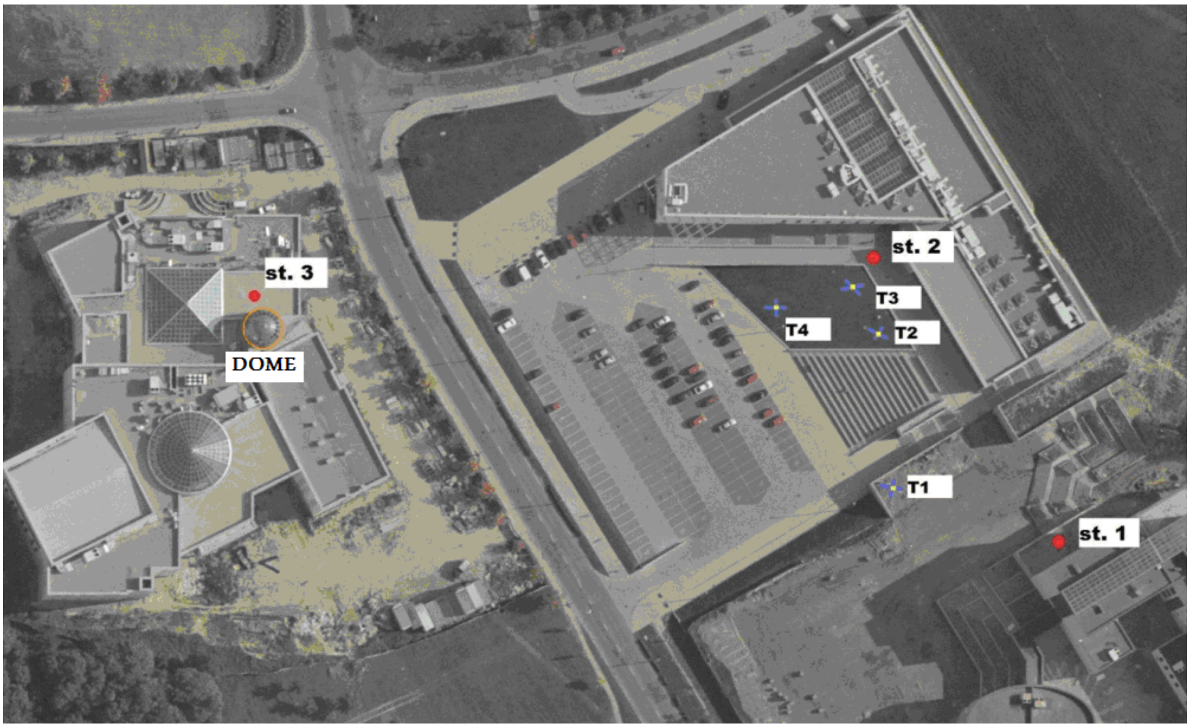

Fig. 3. Localization of the examined object, localization of measurement stations and target HDS (picture from fotogrammetric target run from the archives of Olsztyn Town Council).

Symbols in Figure 3:
T2- target HDS,
st.2- measurement stations.

The terrestrial laser scanner Leica ScanStation was used to carry out the stocktaking works. This instrument allows a measurement from a distance of up to 300 m with the albedo factor of 90% and maximal scanning resolution of 1 to 1 mm.

The spherical dome was measured both from the outside as well as the inside. From the outside, the observation with the use of the laser scanner was made form three independent stations placed around the examined object. In the examination, the orientational distances of stations from the construction took the following values, $d_{st.1}$=209 m, $d_{st.2}$=160 m and $d_{st.3}$=17 m. From each station, the dome was measured with the resolution 5 to 5mm and 1 to 1cm. The target HDS (used to link the scans) were located in such a way, that they could be seen from each of the three stations. Basing on the work of Elkhrachy, Niemeier (2006) the targets were placed in a zigzag configuration, what according to the opinion of the authors results in lowering the error of joining the scans.

The measurement inside the dome was carried out from one independent station. The instrument was placed under the dome and the registration of the construction was carried out, in the resolution of 5 to 5 mm and 10 to 10 cm.

3. PROCESSING AND ANALYSIS OF THE OBTAINED RESULTS

The program Cyclone v.5.6 was used for processing the observations obtained with the use of the laser scanner. Figure 4 presents the point cloud obtained during the dome measurement, whereas Figure 5 presents the modeled object.

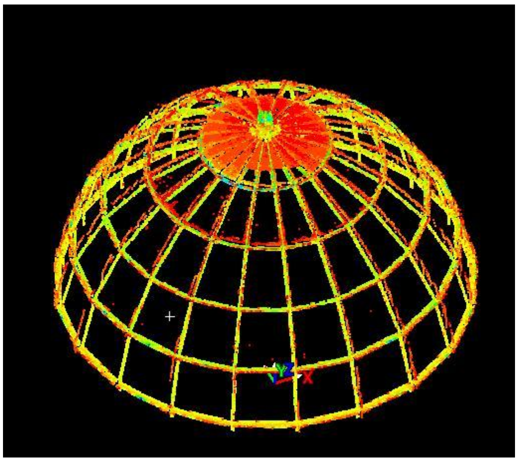

Fig. 4. The dome with point cloud.

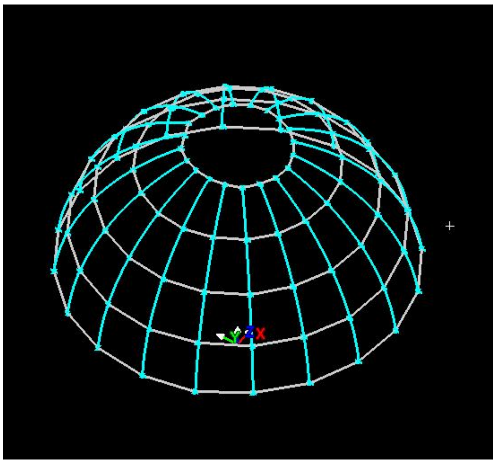

Fig. 5. The dome model.

While performing the research, it was analyzed according to two categories: measurement form the outside and measurement from the inside. During the measurements, two resolutions were used for registering the object. Processing the observations obtained from the outside of the object, we used the target HDS to join scans and the method cloud to cloud. The result of the experiment was differentiating 6 variants (Table 1), basing on which the analysis of the obtained results was carried out. Variants 1, 3, 5 applied the resolution of 1 to 1 cm, whereas variants 2, 4, 6 applied the resolution of 5 to 5mm.

Table 1

Variants of measurements outside the object

Registration scans / *Variant*	*1*	*2*	*3*	*4*	*5*	*6*
► registration 1*						
▪ with 3 targets HDS	X	X				
▪ with 4 targets HDS			X	X		
► registration 2**						
▪ with 2 targets HDS and point cloud	X	X	X	X		
► registration 3 ***						
▪ Cloud to cloud					X	X

* registration of point clouds from station no. 1 and no. 2,
** registration of point clouds obtained from registration 1 with point cloud from station no. 3,
*** registration of point clouds from station no. 1, 2, 3 with the cloud to cloud method.

Processing the observations obtained from the measurement inside the dome two variants were analyzed (Table 2):

Table 2

Variants of inside measurements

Scanning resolution / *Variant*	*1*	*2*
▪ 5 na 5 cm	X	
▪ 10 na 10 cm		X

In each variant (from the outside and from the inside) the following options of measuring the diameter of the dome were used:

a) **basing on the point cloud,**
b) **form the circle model, in 2D space, set by pointing in the program 3 points from the point cloud, reflecting circle,**
c) **basing on the modeled point cloud, reflecting the main circle in 3D space.**

Processing the results of the observations obtained from the outside measurement of the object the diameter of the dome was set (S_p), for all the options presented above. The obtained result was compared with the theoretical value of the diameter S_t= 9,485 m according to the technical project. The difference values $d = S_t - S_p$ is presented in Table 3.

Table 3

Differences between the theoretical and practical values from the outside measurement

variant	option	*d* (m)	variant	option	*d* (m)
	a	0,024		*a*	0,003
1	*b*	0,025	*4*	*b*	0,039
	c	-0,005		*c*	-0,004
	a	0,009		*a*	0,007
2	*b*	0,029	*5*	*b*	0,037
	c	-0,001		*c*	0,007
	a	0,015		*a*	-0,003
3	*b*	0,001	*6*	*b*	0,007
	c	-0,013		*c*	0,011

The data presented in Table 3 shows that the differences between the theoretical value and the value obtained from the office processing is contained in the range <-0,013; 0,039>m. The most favorable results were obtained in variant *2c* (-0,001 m) and in variant *3b* (0,001 m). The maximal value (least favorable) is represented by variant *4b* (0,039 m).

The results obtained in Table 3 were further processed, by stating the most favorable options and most favorable variants. Realizing the calculations concerning the pointing of the most favorable options it has been set for each of them (a, b, c) $\sum_{i=1}^{6} |d_i|$. The obtained results were presented in Figure 6.

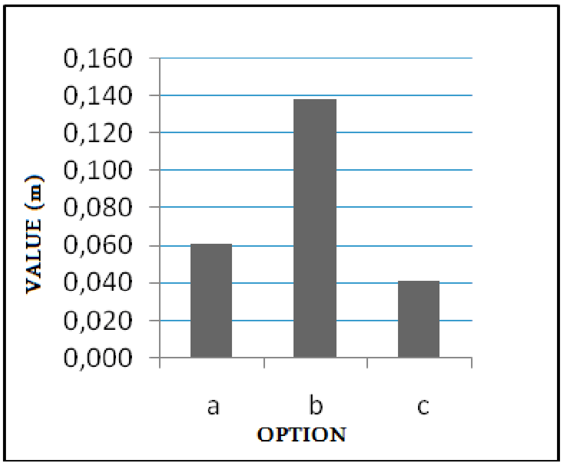

Fig. 6. The sum of absolute values of particular options for each variant.

Analyzing the data presented in Figure 6 we can observe, that the most favorable results were obtained at options *c*, therefore on the basis of the models obtained form the point clouds. Respectively the results obtained at options *a* and *b* follow.

Setting the most favorable variant it has been calculated for them that $\sum_{i=a}^{c} |d_i|$. The obtained results were presented graphically in Figure 7.

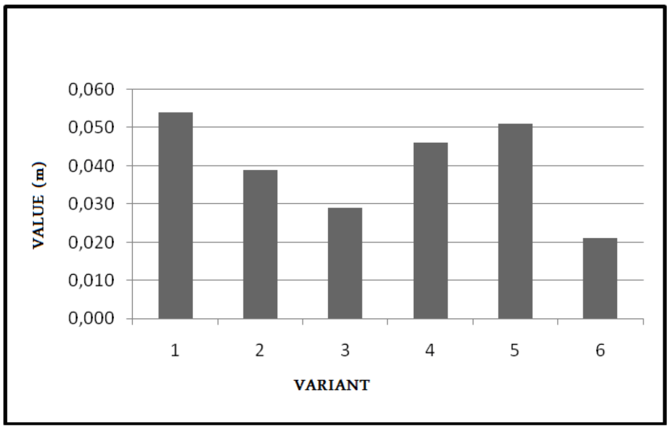

Fig. 7. The sum of absolute values of all options in each variant.

From the analysis of the Table 7 we can rule out, that the most favorable variant among all the examined is variant no. 6. It is based on combining scans with the use of cloud to cloud method with the scanning resolution of 5 to 5 mm. The least satisfactory result is variant 1.

This work analyses as well the influence of scanning resolution on the results obtained in particular options. In order to define the benefits of resolution the following cases were taken into consideration:

For resolution 5 to 5 mm- variants 2, 4, 6

Case I **option a** $\sum_{i=1}^{3}|d_i|$

Case II **option b** $\sum_{i=1}^{3}|d_i|$

Case III **option b** $\sum_{i=1}^{3}|d_i|$

For resolution 1 to 1 cm- variants 1, 3, 5

Case I **option a** $\sum_{i=1}^{3}|d_i|$

Case II **option b** $\sum_{i=1}^{3}|d_i|$

Case III **option b** $\sum_{i=1}^{3}|d_i|$

The results of calculations were presented in Table 4

Table 4

The sums of absolute values for each option in different resolutions

case / Resolution	*I* (m)	*II* (m)	*III* (m)	*Σ* *(m)*
5 na 5 mm	0,015	0,075	0,016	0,106
1 na 1 cm	0,046	0,063	0,025	0,134

Basing on the data presented in Table 4 we can conclude, that using the resolution 5 to 5 mm in two cases gave more favorable results that the resolution 1 to 1 cm. This conclusion concerns options a and c, that is the measurements of diameter from the point cloud and from the 3D model. For Case II (measuring the diameter form the 2D model) the resolution 1 to 1 cm was more favorable.

The observations obtained from the inside of the dome were also analyzed. Basing on the variants and options presented above the diameter S_p was set. The differences results $d=S_t - S_p$ were presented in Table 5.

Table 5
The differences in theoretical and practical values form the inside measurement

variant	option	*d (m)*
1	*a*	-0,005
	b	-0,009
	c	0,004
2	*a*	0,011
	b	-0,001
	c	0,004

From the data presented in Table 5. we can conclude that the differences between the theoretical value and the value obtained from the office processing are contained within the range <-0,009; 0,011>m. The most favorable result (d= -0,001 m) was obtained in variant *2b*. The least favorable result is represented by variant *2a* at the resolution of 10 to 10 cm and the dome diameter measurement from the point cloud (d= 0,011 m).

The data presented in Table 5. was further analyzed in order to show the most favorable option and variant (scanning resolution). In order to estimate the most favorable option it has been set for each of them that $\sum_{i=1}^{2} |d_i|$ (Table 6).

Table 6
The sum of absolute values for particular options

opcja	$\sum_{i=1}^{2} \lvert d_i \rvert$ (m)
a	0,016
b	0,010
c	0,008

Table 7
The sum of absolute values of all options from particular resolution

Rozdzielczość	Σ (m)
5 na 5 cm	0,018
10 na 10 cm	0,016

Commenting the results presented in Table 6, we can conclude that the most favorable options are options *c*, in which the measurement of diameter is done on the basis of the 3D models of the object.

To establish the most favorable resolution the absolute values for each option were summed and placed in Table 7. Basing on the presented data we can conclude, that in the two resolutions the results are comparably equal.

4. SUMMARY

In this work the authors presented the possibility of using the terrestrial laser scanner for stocktaking measurements. The obtained results were compared with data contained in the technical project of the object.

The problems of combining scans methods and different possibilities of processing the results (options) were examined. Basing on the performed analyses it is possible to formulate the following conclusions:

1. **Among all the examined outside object measurement variants the most favorable are those, in which the scans were combined with the cloud to cloud method (Figure 7).**
2. **On the basis of the outside measurement the 5 to 5 mm resolution turned out to be more favorable than the 1 to 1 cm (Table 4).**
3. **Among all the examined options (*a,b,c*) the most favorable, both for the outside and inside measurement, is option *c,* that is the measurement of the dome diameter from the 3D model.**
4. **Analyzing all the three aspects: measurement resolution, scans combining and the processing method, the most reliable results were obtained on the basis of the outside measurement for variants 2c and 2b (Table 3) and for the inside measurement for variants 2b (Table 5).**

The obtained results encourage to continue the research on the most beneficial propositions, for the purposes of geodesy stocktaking, the technologies of performing measurements and methods of processing them.

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