INVESTIGATION OF THE ACCURACY OF GEODETIC MEASUREMENTS USING REFLECTORLESS TECHNIQUES

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1. ABSTRACT

This paper presents the results of investigation of geometry accuracy using reflectorless techniques. Experimental measurements were carried out on the field polygon using new tacheometers and a monitoring application program.
The results of experimental measurements were analyzed and presented graphically in Surfer 8. Contour maps and isometric projections of the surface of imperfection are elements of the present study. It presents the results of investigation of measurements accuracy in geometry according to various geometry conditions.

2. INTRODUCTION

New instruments such as tacheometers and laser scanners measure direct distance to the object surface. Despite its obvious advantage of avoiding eccentric errors of the target, this technique is flawed by rangefinder eccentricity in respect of the measurement coordinate system. The extent of such errors depends on mutual nonaxiality of the system and on the incidence angle of a rangefinder beam on the reflective surface.

Perturbations of observed values may be significant both for inventory and surface-deformation measurements. The object of this case-study is the presentation of measurement errors obtained experimentally with a TCRP Leica precision tacheometer and a Z+F Imager 5006 scanner.

Inventory and control measurements with scanning tacheometers and scanners have become common practice recently. The assessment of construction quality and its compliance with the design can serve as an example.

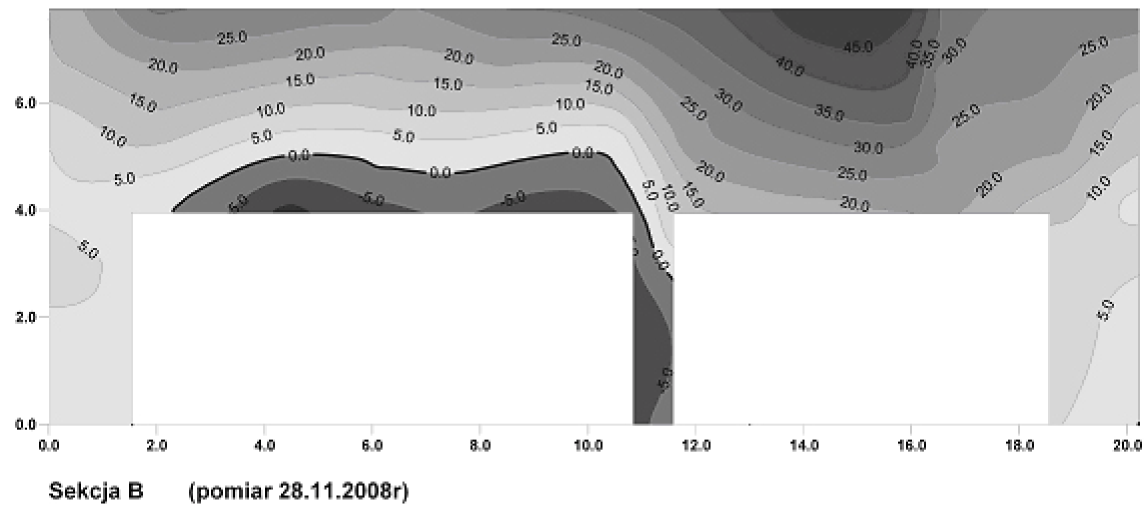


Fig. 1. View of a shape presentation of the wall.

The results of such measurements have to comply with high accuracy and infallibility standards. The accuracy provided by the equipment manufacturers falls in the ± 3-5 mm range. The coarseness of the object's surface results in an additional target identification error. The resulting numbers are not satisfactory for precision measurements. At the same time the instruments show internal conformity of <1 mm. In order to make use of their potential, an adequate technological regime is absolutely necessary for precision measurements.

In these measurements one must:

1. **carry out a scrupulous assessment of the rangefinder measuring the system's geometrical quality**
2. **avoid high incident angles of the beam by proper instrument positioning**
3. **in order compensate the beam's eccentric influence, always measure twice in different telescope positions**
4. **use an appropriate measurement program (e.g. a set of angles, monitoring measurements), when using unstabilised measurement points or the scanning mode.**

The following rules were applied in a standard object inventory control, shown on Figures 2-3. The second example was carried out, using both a tacheometer and a scanner. This comparison shows some discrepancy of results cause deliberately unfavourable aiming lines. In the case of scanner measurements the values of incidence angles reached even 80 degrees.

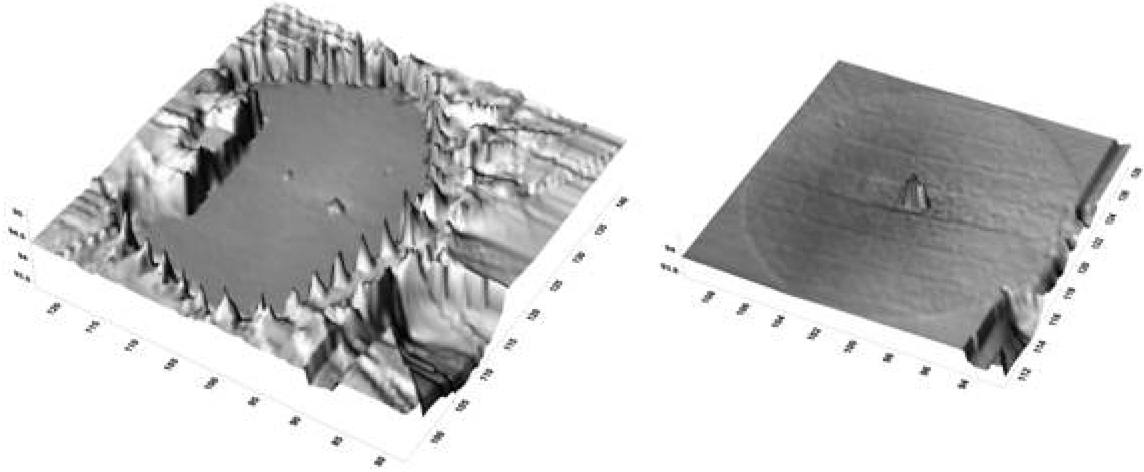


Fig. 2. 3D presentation of laser scanner measurements.

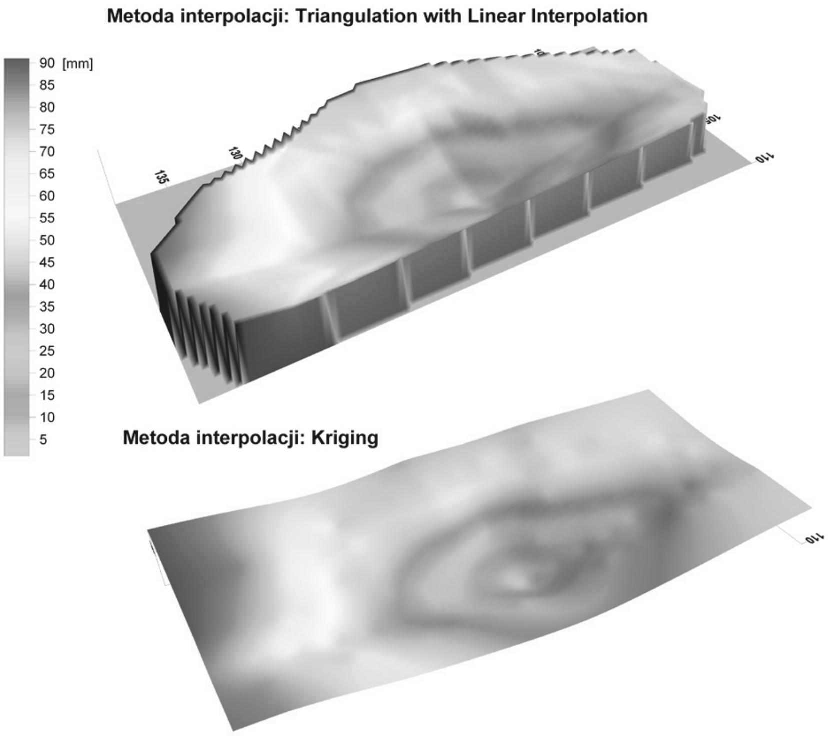


Fig. 3. Results of inventory measurements.

The results of the measurements were compared to the co-ordinates obtained from a tacheometer survey performed in a geometric configuration optimal for reflectorless measurements (Fig. 4).
Divergence errors significantly exceed standard measurement errors.

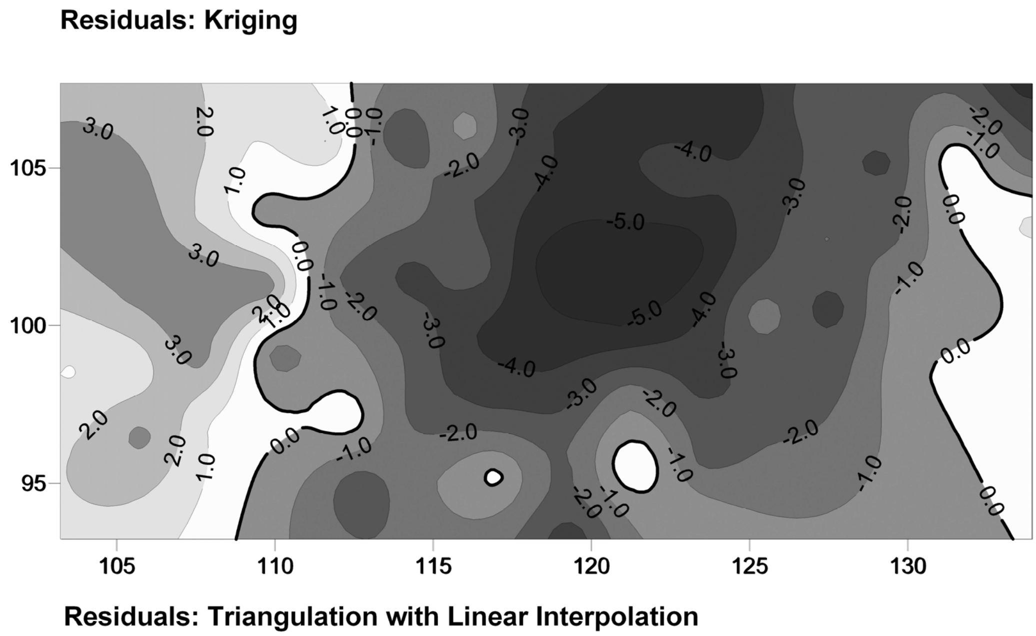


Fig. 4. View of residuals of Z coordinate.

Reflectorless measurements are commonly used to measure specific geometric properties of objects such as edges. Figure 5 shows an inventory of control results for the edges of a building elevation parts obtained by laser scanning verified with RMS measurements (a set of T2002 theodolites supervised by SPACE program).

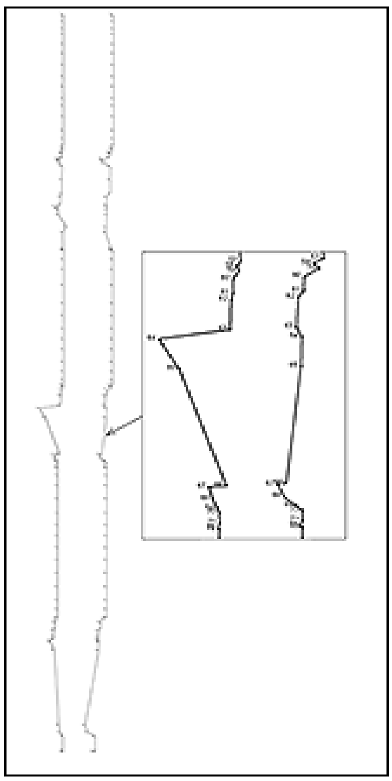
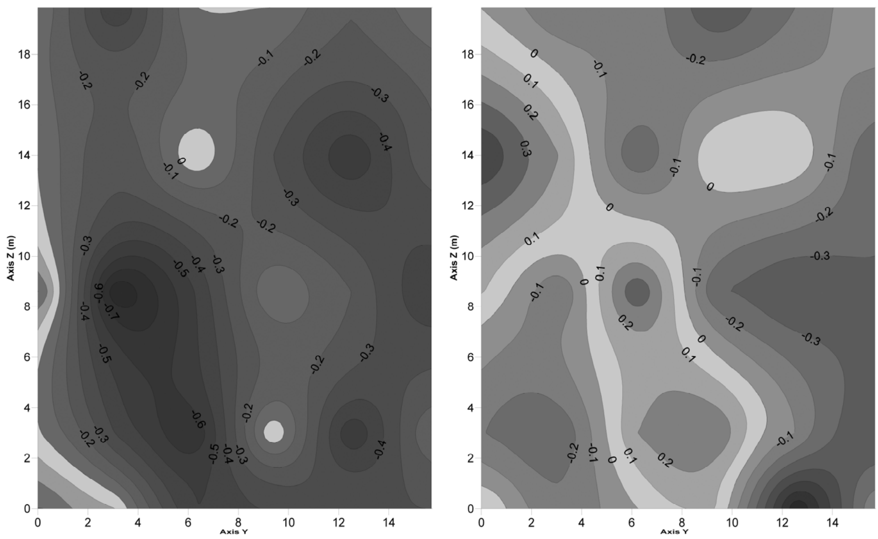


Fig. 5. View of a profile of the wall using RMS and laser scanning techniques.

Edges which are characteristic lines of the vector image of an object are quite difficult to measure, particularly by instruments without a reflector. One can obtain undesirable reflexes disturbing measurement results. In scanning measurements of edges the scanner sensitivity is of great importance for the accuracy. The most accurate method for edge measurement is the Remote Measuring System supported by a laser eyepiece. The RMS technique was applied to evaluate accuracy of measurement results.

The accuracy of a given measurement technique can be assessed in two ways:
a'priori, where error analysis is based directly on the physics of each phenomenon,
a'posteriori, where error analysis is based on real or relative errors obtained through actual measurements.
Previous investigations show that measurement errors are caused by the eccentricity of a distance measurement segment against the angle segment.
To evaluate the accuracy of reflectorless measurements for chosen instruments and measurement techniques the following experiments were carried out. Special software for automation of multi-set observation has been used. This software is similar to that used for displacement monitoring. The measurements have been carried out to the inner courtyard of the WUT - AULA polygon, on a geodetic net of very high accuracy.



Differences between coordinatesfor 1st and 4th station (mm)			
NR	dX	dY	dZ
100	0	0	-0,51
101	0	0,7	0,79
102	0,2	1	-0,41
103	0,2	0	-0,61
104	0,4	0,2	-0,81
105	0	0	-1,91
106	0,6	0,9	-0,51
107	0,5	1,1	0,79
108	-0,1	-0,2	-0,61
109	0,3	0,2	-0,41
110	0	0,1	-0,01
111	-0,1	-0,9	0,09
112	0,7	0,3	1,09
113	-0,6	0,3	0,59
114	0,3	0,8	1,59
115	-0,1	0,2	-0,81
116	0,1	0,3	0,19
117	-0,1	-1,3	1,49
118	0,2	1,3	-0,11
119	-0,3	0,2	0,29
120	0,2	-0,2	0,49
121	0,7	0	-0,01
122	-0,2	-0,9	0,79
123	0	-1,5	-0,11
124	0,6	0,5	-0,21
125	-0,1	0,3	-0,01
126	0	0,1	-0,01
127	-0,2	0,2	-0,11
128	-0,4	-0,9	0,99
129	0,5	-0,7	-1,91

Fig. 6. Shape differences of the wall obtained from different instrument stations.

Because of a large space it was possible to measure from different instrument stations. The observations were carried out from the AULA at different levels - 10 m and 19 m above the floor (Fig. 6). As a result, we obtained a desired distribution of spatial observation.
The obtained results allow us to evaluate the repeatability of measurement results from different instrument stations, all made in two faces, in several measurement sets, and to compare the result of spatial measurements made from different instrument stations.

Fig. 7. Differences of spatial measurements in two faces of a telescope.

8. CONCLUSIONS

The study confirmed the suitability of quasi-continuous monitoring of the structure for assessing how it works.

The analysis of observation results makes it possible to define correlation between changes in the structure geometry and its load.

The applied technology of measurement enables to define geometry changes of a structure with an accuracy of ± 0.4 mm.

The effect of local thermal anomalies on measurement accuracy were assessed along aiming lines.

The TC-calc system proved its suitability for continuous monitoring. It would have been impossible to carry out such measurements in a traditional way.

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