The applicability of alternative point-targets for laserscanning of underground and surface formations

B. Petrétei
Institute of Geoinformatics, Alba Regia Technical Faculty, Óbuda University, Pirosalma u 1-3, 8000 Székesfehérvár, Hungary

Abstract - **In this paper a research of finding the best point type, replaces the professional Leica HDS, without losing accuracy, and enables automating possibilities of measurement and processing process, during terran and and subterranean laser scanning of natural formations like rock outcrops and caves will be presented. The research started 3 years ago with many possible target-candidate and by the time the list narrowed to the two best in practise options and proven to be almost as accurate as the professional targets but for fractions of costs.**

I. Introduction

In my research I studied that during the laser-scanning measure of caves, in addition to the four Leica HDS (2 pcs 3 "and 2 pcs 6") of the Geoinformatics Institute, what alternative, point clouds connection capable targets can be used, and how accurate they are compared to the solution of the Leica factory-solutions, and how it is possible to automate the processing of measurements at alternative point marks. [4.]

The test is useful because, in the measurement of caves, especially if they have multiple sidebranches, the four targets are often prove to be insufficient, but without easily identifiable discrete dots, aligning the point clouds manually can be a very cumbersome task.

During the measurement, the Leica HDS target used as a reference for the study and were placed with other discreet objects such as:

- printed HDS Black & White Targets,
- Table-tennis balls,
- Golfballs
- Tennis balls
- Sponge balls and
- Styrofoam spheres.

Figure 1. Target group

I applied anchorages that take into account the particularities of the site, to ensure that the targets were stationary.

The site I have choose for the first measurement was the Hospital-cave, part of the Tapolca-cave system in the town of Tapolca. The reason of this choice because it can be easily approached by walk, has a very high ceilings, so it was easy to move with the instrument and equipment, but I had also the opportunity to investigate how my methods work in narrow passages. The measurement took place on 2016.10.14.

The second phase of my research was in the Csákvár cave, which can be located in the western part of the Csákvár. Here, during the measurement I have already tried to focus on those point targets which based on last year's measuring achieved good results, and in addition of those I used a new target type, the geodetic reflector stickers, available at the

University, which I examined also, in laboratory measurements.
The third stage of my research site was a rocking stone, called "Woolenoch" near Sukoró. In the nature reserve of Velence Hills, one of the most unique sights. The location was easy to reach, and it was possible to go by car to the rocks to be measured. Here I only used the target types gave - based on my previous measurements the best results (ping-pong balls), and as a new point type the Styrofoam globes, which I choose its diameters to have almost identical of the Leica HDS Sphere, but for obvious reasons it has the advantage for being much less expensive.
The orientation of this research phase were also broken down into two measurements.

II. Phase One

First, there was a laboratory measurement in which I examined the usability and fitting accuracy of the Styrofoam sphere, and a field measurement where the new point type was tested, and the results were examined and compared against the ping pong balls and again in reference the HDS Targets .
To process the measured data, in all cases Leica Cyclone software were used where I have completed the various types of points for manual point-cloud joins and in the light of the results I made a proposal to use the most optimal point type for the laser-scanner measurement of caves.

The first results During the research Developed as follows:

The table shows that after the HDS targets, the ping pong balls and the sponge balls gave the best values. Of the two, however, the ping pong balls could be given minimal value in three categories, as compared to the two of the sponge ball, as there was a rough defect in the case of the ping-pong balls, so that I could not make it clear that it would be a better choice.

Aggregation of results						
	Ping pong	Bounce	Tennis Ball	Sponge Ball	Sheet of paper	HDS Target
Expected value	0.0018	0.0021	0.00200	0.0018	0.0031	0.0014
Mode	0.001	0.002	0.002	0.002	0.003	0.001
Minimum	0	0.001	0	0.001	0.001	0
Maximum	0.003	0.004	0.004	0.003	0.008	0.004
Number used	52	44	37	43	36	25

Table 1. Aggregated results of the first part of the research

Based on my results I couldn't give a definite answer which alternative point marks are the best choice in each field, so the research has continued. [1.]

III. Phase Two

In addition to the spring measurement in the second part of the research, apart of the ping pong balls and A5-size printed targets I used earlier I tried three new point signal type out

- White and yellow geodetic reflector signal
- A4-Sized printed mark
- Styrofoam Sphere

I have decided to test the advantages of using Reflectors as well-discernible high reflecciating signal in a point cloud, and study what accuracy can be achieved by this target type.
The A4 page was tested answer to which extent the signal is affected by the size of the targets the identification in automatic, semi-automatic and manual mode.
Finally, in addition I tested the Styrofoam sphere, for its size cheapness.

In the calculation of the fair resolution in the ground level, I created a program in Excel, in which by knowing the resolution (f), the resolution distance (t) and the instrument height (h) I determined with the plane of the position at a height at a given distance's (d) mid-point resolution (Fd).

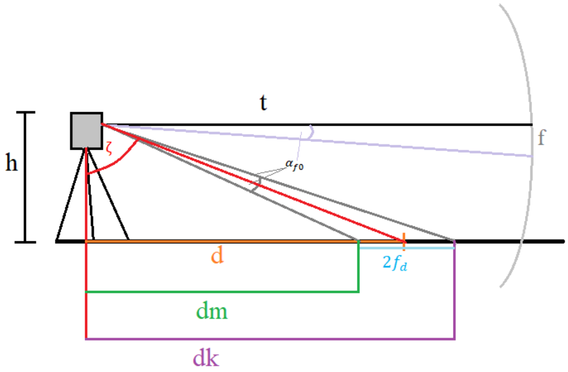

Figure 2.The geometrical representation of the calculation

The calculation developed as follows:

1. The laser head stepping angle (α_{F0}) is calculated at the resolution distance (t_{My}) and Resolution (f_{cm}) using

$$\alpha_{f0} = \frac{360\frac{f_{(cm)}}{100}}{2t_{(m)}\pi}$$

2. Then I count on the basis of the instrument height (h) and signal distance (d) (ζ):

$$\zeta = \tan^{-1}\frac{d}{\frac{h}{100}}$$

3. The third step is to calculate how many steps of the instrument should start from nadir direction, as defined in point α_{F0} to the respective ζ. Angle.

$$f_i \approx \frac{\zeta}{\alpha_{f0}}$$

4. Thereafter, it shall be calculated that previous $f_i - 1$ and the next $f_i + 1$ The Angles are:

$$\alpha_{fi-1} = \alpha_{f0} \cdot (f_i - 1)\ and\ \alpha_{fi+1} = \alpha_{f0} \cdot (f_i + 1)$$

5. Finally, the resolution (f_{ncm}) calculated on the basis of previous and subsequent stepping angles,(d_m) and (d_k).

$$f_{d(cm)} = \frac{d_k - d_m}{2}$$

Where:

$$d_m = \tan\alpha_{fi-1} \cdot \frac{h}{100}\ illetve\ d_k = \tan\alpha_{fi+1} \cdot \frac{h}{100}$$

The program's simple controlThe following illustration shows the stake:

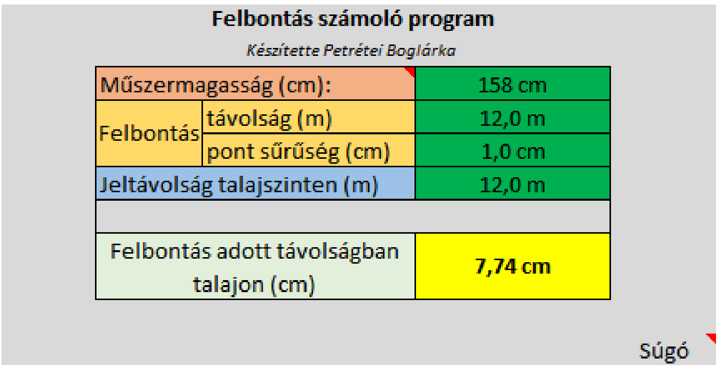

Figure 3. User interface of the resolution calculator

Overall, measurements and processing were successful. I received important results. It is important to create documentation of the placement of the ping pong ball for easy processing, because without it there have been some identification problems that could easily be repaired, but exploring is time consuming if there are multiple signs near each other.

Using paper targets may be justified, because they are partially auto-recognized (at a certain resolution, they are already identified during an import), there is a way to search semi-automatic (when the program searches and selects them automatically in the surrounding of a specific point) and manual selection, if seen on the point cloud identifying its center point is simpler than in the case of using the spheres. Problem alone was to place the marks in a location that can be seen on multiple positions. For this reason, it is usually only used for a maximum of 2 adjacent positions, as the program I developed demonstrates that the effective resolution at long distances for plain targets can be very low.

The most difficult to consider in terms of research is the perception of the reflectors. Due to its good reflective properties, they can be easily identified in the point cloud visually, but there are some situations where they cannot be seen, in which we haven't found explanations for the by now. Conversion to point target is also cumbersome because the instrument directional noise is significant for reflector stickers, the overall use of them is more work-intensive in the point of processing than the paper sheet, because of its strange reflective behavior, is unreliable. The use of this form only redundantly recommended, and their price is also not makes them ideal.

	Ping pong	*Reflector*	*Sheet of paper*	*HDS Target*
Expected value	0.006	0.017	0.002	0.001333333
Mode	0.005	0.017	0.002	0.002
Minimum	0.002	0.003	0.001	0
Maximum	0.016	0.036	0.003	0.003
Number used	11	8	4	9

Minimum

Reference

Table 2. Aggregated results of the second part of the research

From the table it can be read that the previously not-so-good sheet of paper jumped to the first position in all four tested categories, almost reaching the HDS Targets. The formal favorite ping pong ball with a larger error has produced a slightly weaker accuracy than before. The reflector can only be reached by a minimum of 3 mm in the exact same category compared to others.

Thus, in the minds of the results, further tests were needed, in order to find the most appropriate score. [2.]

IV. PHASE THREE

In the third part of the research, the objective pursued was double. First, consider whether is with similar than Leica HDS Sphere spherical diameters it is possible to perform this automatic measurement with styrofoam spheres and, if so, what accuracy.

The other objective was to try to automate the processing process, accelerate by own algorithm. This time, the area tested was on the surface and not in cave, it was a rocking stone, thus proving the universal applicability of the procedure.

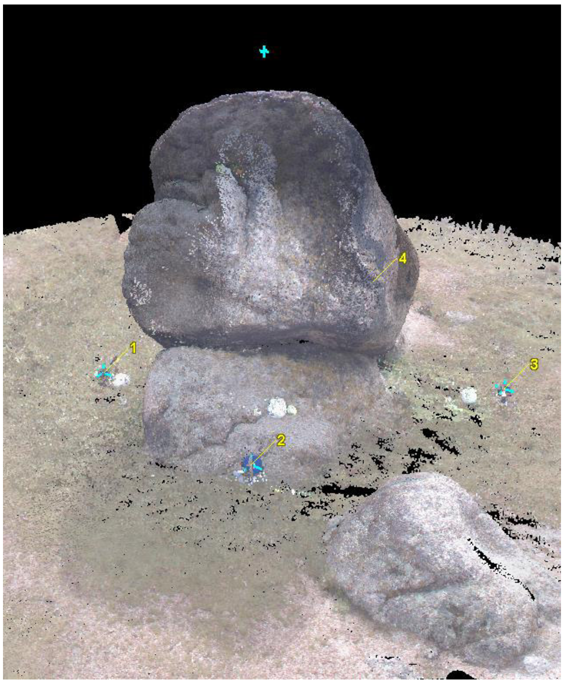

Figure 4. Pointcloud image of the third measurement

The first result for the question was that, at the measurement of target, even a few millimeters difference in relation to the standard diameter compared to HDS spheres can lead to significant errors.

#	S (152mm)						G (145mm)					
	x	y	z	Horz	Vert	Error	x	y	z	Horz	Vert	Error
12	0,009	0,000	-0,001	0,009	0,000	0,009	0,000	0,000	-0,003	0,000	0,000	0,003
9	0,010	0,000	-0,001	0,010	0,000	0,010	0,000	0,001	-0,001	0,001	0,001	0,001
6	0,009	0,000	0,000	0,009	0,000	0,009	0,001	0,001	-0,002	0,001	0,001	0,002
3	0,009	0,001	0,001	0,009	0,001	0,009	-0,001	0,001	0,003	0,001	0,001	0,003

Table 3. Results of processing spheres with different diameter

Apart from this, the spheres can be used well with a post-processing method, although the best results are achieved not the a sphere with the nominal radius, but with 145 mm which is less by 4mm. The reason for this could be the pole-orientation flattening of the sphere, which we were unable to justify, but we later plan to investigate with another instrument.

The second goal was realized with MATLAB, wherein to a Ply format exported point cloud were used to select the approximate location of the spheres, to be used to get a spatial midpoint for a join. The program is prepared for rough defective cases (when sphere is greater than a given value) or to write the results directly to a result file. [3.]

V. CONCLUSIONS

So comparing the above results I took a big step closer to be able to perform high precision laser-scanner measurement and processing not only substituting the targets but to provide an alternative for the processing software. [3.]

REFERENCES

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[4.]Berényi A., Lovas T., Barsi Á., Tóth Z., Rehány N., Tarsoly P. (2011): Földi lézerszkennerek minősítő vizsgálatának lehetőségei, Geomatikai Közlemények XIII/2, HU ISSN 1419-6492, MTA GGKI, Sopron, 2010, 87-95. oldal