TERRESTRIAL LASER SCANNER TECHNIC AS A METHOD FOR IDENTIFICATION AREAS OF SLOPS

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1. INTRODUCTION

Modern methods of determining the deformation of superficial objects, not monolithic, such as a slope, are based on observations of both sources: geodetic and geotechnical data. Surveying methods require investment in dense network of control points, which does not fully reflect the nature of occurring changes. This is the nature of the point observation and non-optimal distribution of points resulting from insufficient geological substrate. Geotechnical measurements also represent the point nature of the occurring changes.

In case of modern methods of surveying and remote sensing, we can indicate the methods which can provide data with high precision and at the same time showing changes over the entire surface of the object. The methods that can be used as a complement to the network design process and yet obtain quantitative information about the occurring changes are remote methods. In this paper will be presented and widely described a method using terrestrial laser scanner. It allows for identification of the deformation, in case of monolithic objects, less than 1 mm (M. Alba 2006, B.Van Genechten, 2009).

2. RESEARCH OBJECT

The survey was performed on the facility, which is located in a landslide in Lower Silesia near Bardo city. Landslide is located within the village Janowiec. It was established in July 1997, after torrential rains, and its area is about 2ha.
It is located directly above the river Nysa Kłodzka, in front of the former mills in Przyłęk. It is close to the international railway line CE 59 / 2 (domestic route No. 276) and the international route E67 (Warszawa - Wrocław - Kłodzko - Kudowa Zdrój - National Road No. 8 – Fig. 1).

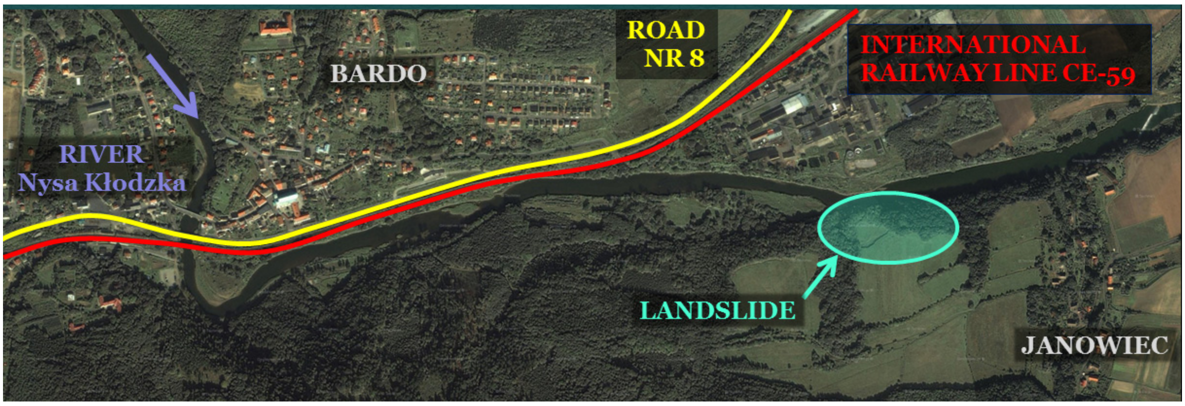

Figure 1. Localization of landslide.

Two measurements were carried out (the output and control) in April and early November. Measuring range was extended to April inventory of the landslide area and above it (Fig. 2).

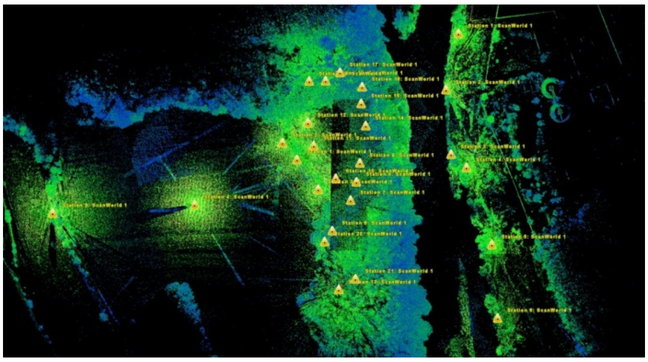

Figure 2. Points clouds of landslide.

Measuring of landslides continued 5 days working, during which the survey of 27 positions of scanner was taken. The position was assumed that the surrounding area will be measured with a resolution of 2.5 cm horizontally and 2.5 cm vertically at a distance of 25m.

3. ACQUISITION AND PREPARING DATA

In the research work the author uses terrestrial pulsed laser scanner Leica HDS ScanStation II. The scanner field of view is 270 degrees vertically and 360 degrees horizontally. The determined accuracy of the 3D position (for the range 1-50m) is 6mm, the distance measurement for the same coverage is characterized by an error of 4mm, while aiming for the signal error value designation means the target is 2mm. Laser used in the scanner is green, which allows to record subjects having a 18% albedo at a distance of 134m, while for objects which albedo is 90% of this distance increases to 300m, the size of the laser dot at 50 meters is 6mm. The scanner can measure and record the surrounding space at a speed of up to 50,000 points per second (Leica Geosystems).

Scanner control software as well as allowing the processing of acquired data (in literature called "point cloud") is manufacturer' software – Leica Cyclone 7.1. Using this application it could be made most of the chamber works. As a result after a short time preparation it is possible to assess whether any changes have occurred on the object surface. The software allows to export the whole point cloud and/or only selected fragments to the text file and further work in mathematical and geostatistical programs such as Matlab, Statistica, Surfer. Before working in geostatistical programs it was necessary to remove points which was not a ground. This operation was made in TerrraScan software and after cleaning the point cloud was export to ASCII file (x,y,z) for future analysis.

An attempt to determine the deformation occurring on the subject focused on the forehead of landslides is presented in the figure 3 - an area marked by a red halo.

Figure 3. Forehead of landslide.

The position, which was used in the tests, is in the middle facing slope landslides. This setting allowed for carrying out research over a wide area, where the influence of the distance measurement error resulting from the angle of the laser spot, was minimal.

Two measurements were carried out (the output in April and control early November). The April inventory measuring range was extended to the landslide area and above landslide (Fig. 2).

Measuring of landslides took consecutive 5 working days, during which the survey of 27 positions of scanner was taken. The position was assumed that the surrounding area will be measured with a resolution of 2.5 cm horizontally and 2.5 cm vertically at a distance of 25m. The size of landslide is presented on 3D model of landslide shown on figure 4, created from acquired point clouds.

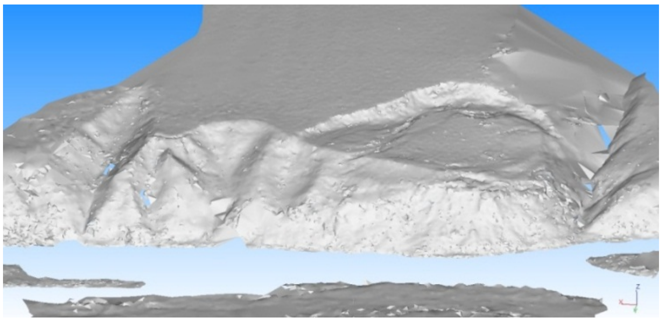

Figure 4. Landslide 3D model.

4. RESEARCH TESTS

The measurements were taken in two periods of time. Due to the characteristics of the object (a heterogeneous space and variable shape) measuring the position of the control was located in the approximate location of the position output measurement (Fig. 5). Efforts were also made so the height of the device was as close as possible to the output measure.

Figure 5. Scanner at the river Nysa Klodzka, in front of landslide forehead.

The result of the registration process, the starting positions and control of the measurement of forehead of landslide is presented in table 1.

Table 1. Result of registration process

Constraint ID	ScanWorld	ScanWorld	Type	Status	Weight	Error	Error Vector
TargetID: 44g	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	Off	1.0000	0.010 m	(0.007, -0.006, 0.001) m
TargetID: 44d	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	Off	1.0000	0.009 m	(0.005, -0.007, 0.000) m
TargetID: 43d	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.004 m	(0.003, -0.003, 0.000) m
TargetID: 42g	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(-0.002, 0.001, 0.000) m
TargetID: 42d	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(0.000, 0.002, -0.001) m
TargetID: 43g	Station 1: ScanWorld 1 (Leveled)	Station 2: ScanWorld 1 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.001 m	(0.000, 0.000, 0.001) m

Two of points were disabled in calculations because their error was high. After this manipulation the worst point has 4mm error of transformation.
Figure 6 shows override clouds; green color indicates the output measurement and the red color - control measurement.

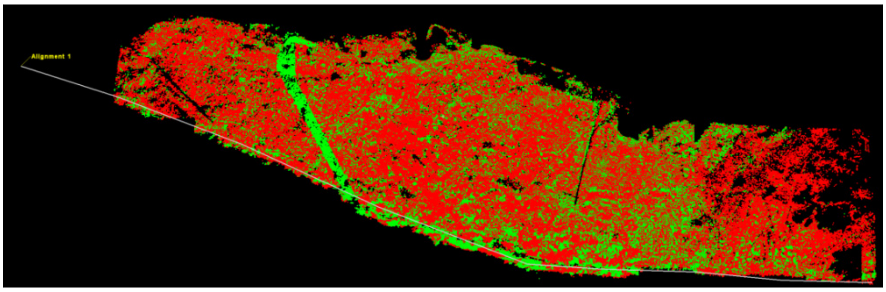

Figure 6. Point clouds from two measurements; green color indicates the output measurement and the red color - control measurement.

When we look at this picture we can easily point out places where dominated red color. This is the easiest method to determinate deformations areas.

The cross-section should be made perpendicular to the slope, so was made a cross-section line at the bottom of the slope along the slope. Using the program function, which is the implementation of cross-section in a given line, next step was typing the following parameters: cross section of 1 meter, the thickness of 2cm section - width allows the section closest to the assembly points, and any major changes in topography have minimal impact on achieved development outcomes. In addition to the cross-sections generated by the program, changes can analyze in the course of a cloud of points in a certain area - the study will be conducted at a later stage.

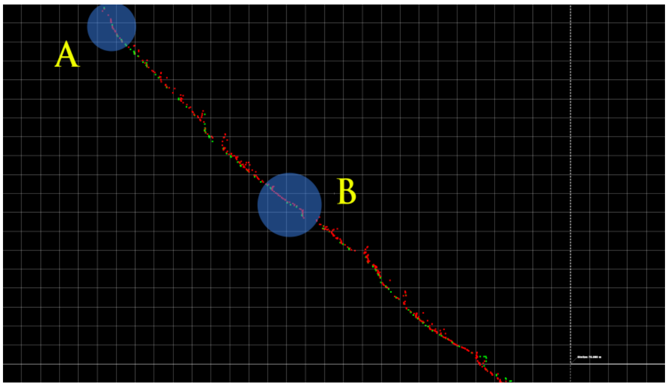

Figure 7. Exemplary cross-section.

As it can be seen, in addition to cross-section of the cloud of points, is also a regular network of squares. The size of a single square is 1 meter on 1 meter. With a network of the squares entered in the cross-section so we can process the non-metric image to metric. In the cross-section "75" (Fig. 7) that two sub-areas were discriminated, one of them - "A" represents the minimum changes that occur on the object and the "B" - an area where there were significant changes.

In section "75" and sub-area "A" interpenetrating of the clouds indicates that the ground deformations are small - at the level of 1cm should be remembered that the measurement was carried to the surface where it can have a big impact on the accuracy of distance - physical characteristics of the soil or the laser spot size.

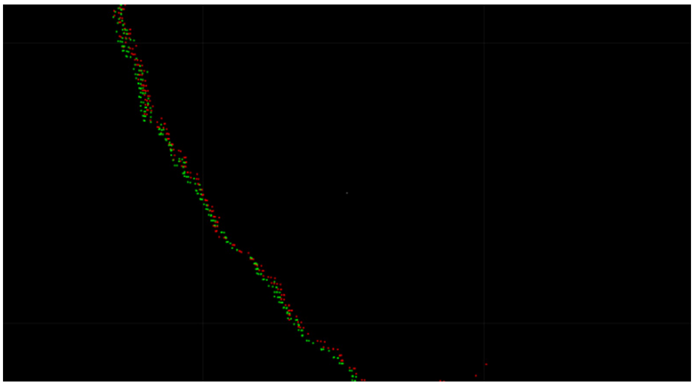

Figure 8. Cross-section and sub-area "A".

It is different in case of "75" cross-section and sub-area "B" as shown in figure 9, where the observed deformations are 5-6 cm. The measurement errors in comparison with the observed changes in terrain are negligible, and designing a network of classical control

and measurement would put the point in this area that the results obtained were characterized by a high accuracy.

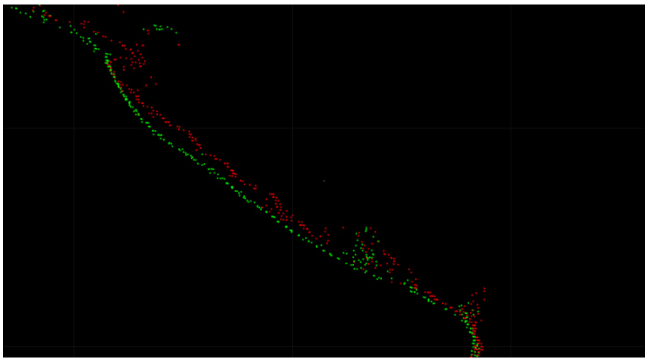

Figure 9. Cross-section and sub-area "B".

The use of geostatistical tools (eg. Matlab, Surfer) directly on the point cloud, due to the amount of data is time consuming. Operating on data drawn directly from objects such as rocks, where the cliffs are nearly vertical, requires an additional transformation of a point cloud. This procedure is to transform the coordinate system of the point cloud to the internal layout of the object, defined by the reference surface fits into the points.

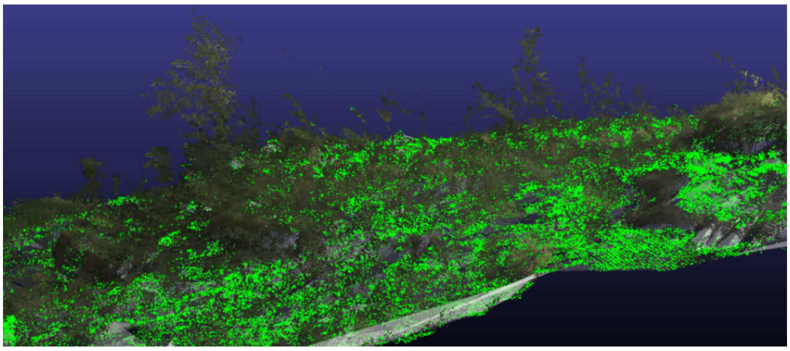

Figure 10. Filtering point clouds from landslide forehead.

Further work was carried out on a selected section of the landslide slope figure 11, where the average density of points is about 2500 per square meter, which corresponds to land cover grid of approximately 2 cm horizontally into 2 cm vertically. The selected data were subjected to a filtration process, as a result, the vegetation was removed (figure 10).

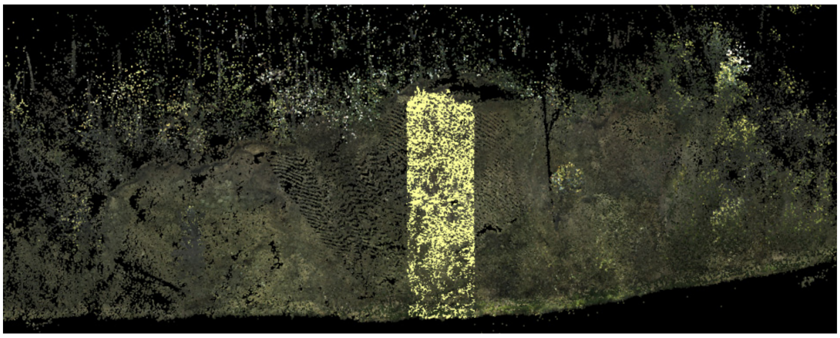

Figure 11. Landslide forehead and selected section.

The next step was the imposition of a regular network and interpolation grid values at important junctures, grid size was 10cm on 10cm. In this process was created a grid with a width of 17m and 26m in length, for the two measurements (baseline and control). Obtained in this way grid was subtracted from each other (the output is subtracted from the measurement control measurement) and their visualization was performed as shown in figure 12.

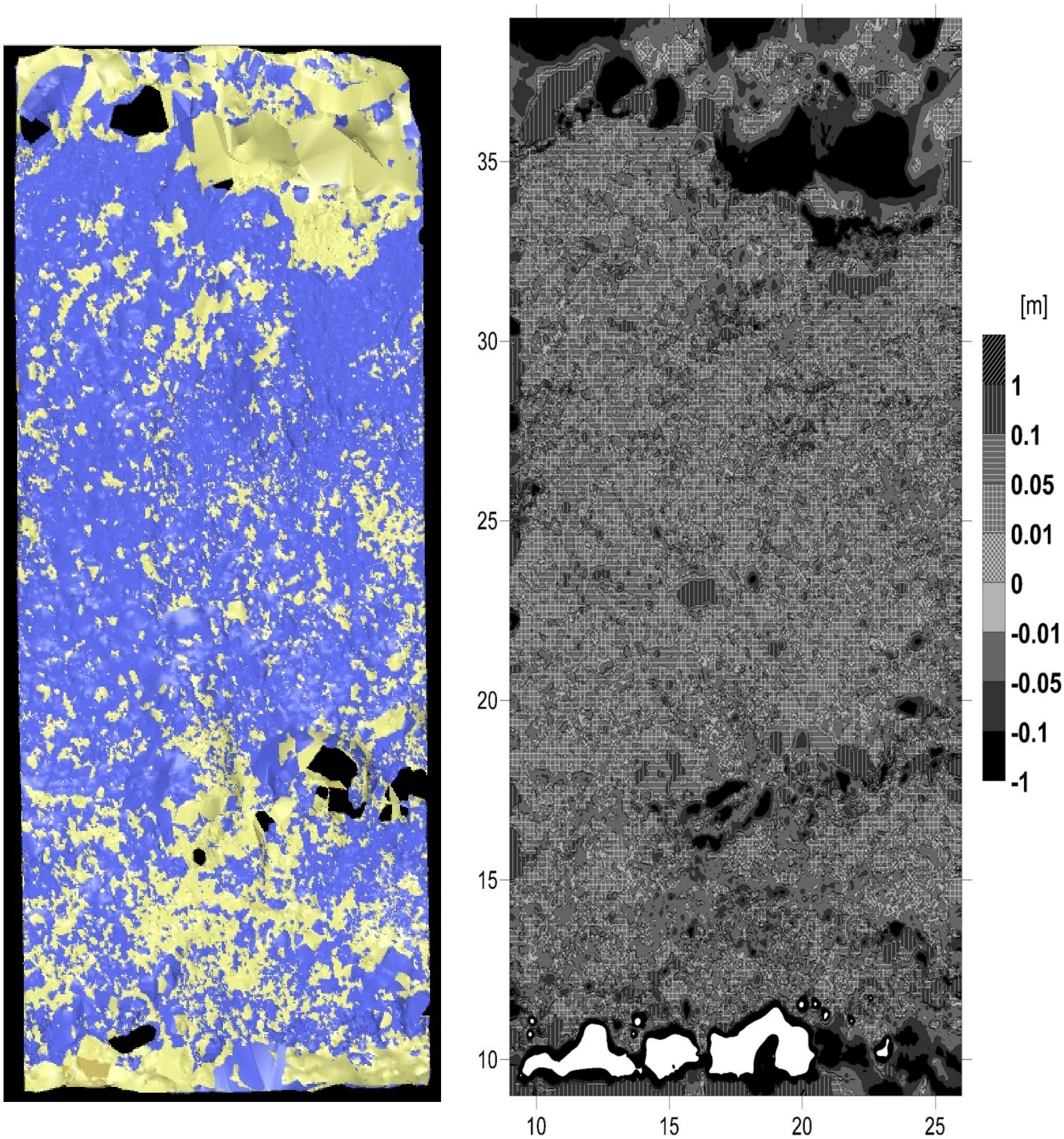

Figure 12. Visualization of changes occur on forehead of landslide, left side show TIN model where blue color represent control survey, right side show differential cartogram.

In the figure 12 – the right side scale is designs to show occurs difference between models, changes ±1cm are not represented because it could be measurement error, only higher changes are important.

SUMMARY

Terrestrial laser scanner technique is useful for measuring and monitoring deformation areas of slopes.
Using terrestrial laser scanner technique we can easily determine areas of deformation, and point out places where it should be more dense control points for classic survey methods.
Precision of this method depends on many factors - starting with the same characteristics of the object through the parameters of scanning and the point cloud processing - filtering, localization of coordinate system, methods of interpolation grid.

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