IDENTIFICATION DEFORMATION AREAS OF SLOPES USING TERRESTRIAL LASER SCANNER – PRELIMINARY RESEARCH

Bartłomiej Ćmielewski[1]

Abstract

The identification of the deformation of superficial objects, not monolithic, requires to build a large control points network, what raises the costs of the investment and the obtain results of occurred changes on object are not exact. This is results of the point measure character using traditional geodesy methods and not always the optimum way of the distribution of points is achieved.

In the article is presented method using terrestrial laser scanner, as the tool to the identification of the areas of the deformation of slopes. Data from terrestrial laser scanning significantly can support the process of determine and the analysis of the deformation of slopes.

Keywords

laser scanning, HDS, deformation, slope

1 INTRODUCTION

Modern methods of determining the deformation of superficial objects, not monolithic, such as slope, 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 the case of monitoring rock fall or slope, choice of location points is dictated by the designers who, based on archival photographs, geological materials, geotechnical expertise.

Over time, the location of points is verified by the expert group, and if it is needed a network is being expanded with new sections which are designed to complement the existing control points network.

In the 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. 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 method using terrestrial **laser** scanner. It allows for identification of the deformation, in the case of monolithic objects, less than 1 mm [1,2].

2 SURVEYING INSTRUMENTS AND SOFTWARE

In research work author uses terrestrial pulsed laser scanner Leica HDS ScanStation II. Scanner field of view is 270 degrees horizontally and 360 degrees horizontally. Determine the 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. Used in the scanner laser is green, which allows to record subjects having a 18% albedo at a distance of 134m, while for objects whose 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 [4].

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, through which a short time after preparation to assess whether any changes have occurred on the object surface. The software allows exporting the whole point cloud and/or only selected fragments to the text file and further work in mathematical, statistical programs such as Matlab, Statistica, Surfer.

Additional tools to work with this software are the add-in to CAD software called CloudWorx, which allows working directly on a cloud of points.

[1] Bartłomiej Ćmielewski, M.Sc. Ing., Wroclaw University of Environmental and Life Sciences, The Faculty Of Environmental Engineering And Geodesy, Institute of Geodesy and Geoinformatics, ul. Grunwaldzka 53, 50-357 Wroclaw Poland, bartlomiej.cmielewski@igig.up.wroc.pl

3 THE RESEARCH OBJECT

Survey was performed on the facilities, 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.

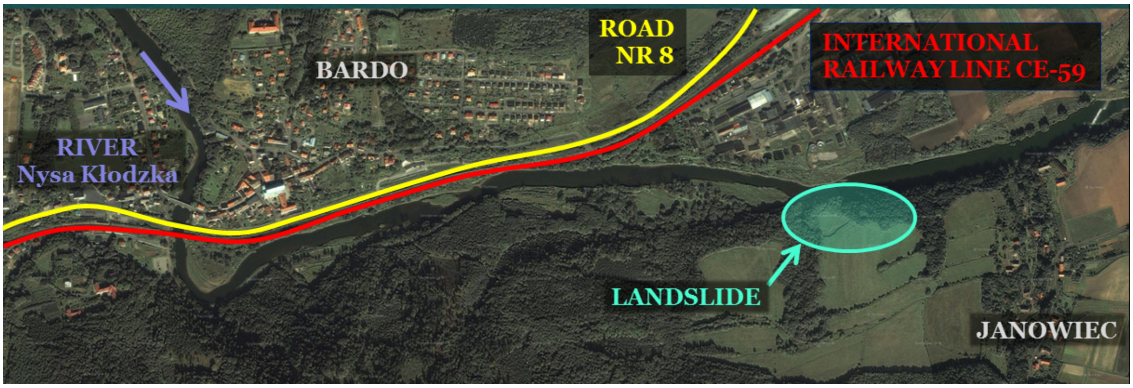

Fig. 1 *Location of landslide*

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).

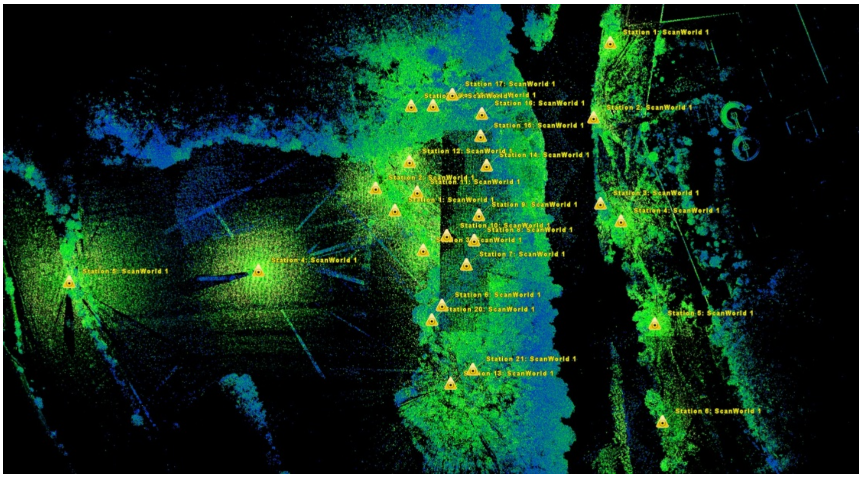

Fig. 2 *Scanned area with first survey campaign*

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).

Measuring of landslides continued working 5 days, during which survey of 27 positions of scanner were 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.

Fig. 3 *Front of landslide and area of investigation*

However, the range of the control measure focused only on the main slope landslides shown in the figure 3.

4 PREPARING DATA

The initial work consisted of an intimate "registration" stations process. This is nothing more than join together the places of measurement. It is done automatically and the process uses the least squares method. Because the data were collected from two subdivisions areas, among which the possibility of combining individual common points were limited, create field points, which were measured by RTK GPS-based system ASGEUPOS. Just set the warp points were imported to the Cyclone program and then transformed the coordinates of point clouds from the local to the Polish system state (in this case, the 2000). In the process of alignment excluded from the calculations the most outlying points were disabled and points having large errors have been given weight. As a result of the process achieved an average error of registration 6mm. The final stage of this process was to create a single space, which included all positions of scanner. On such prepared data was performed, and created a 3D model of the landslide. Fragment showing landslide model presented in figure 4.

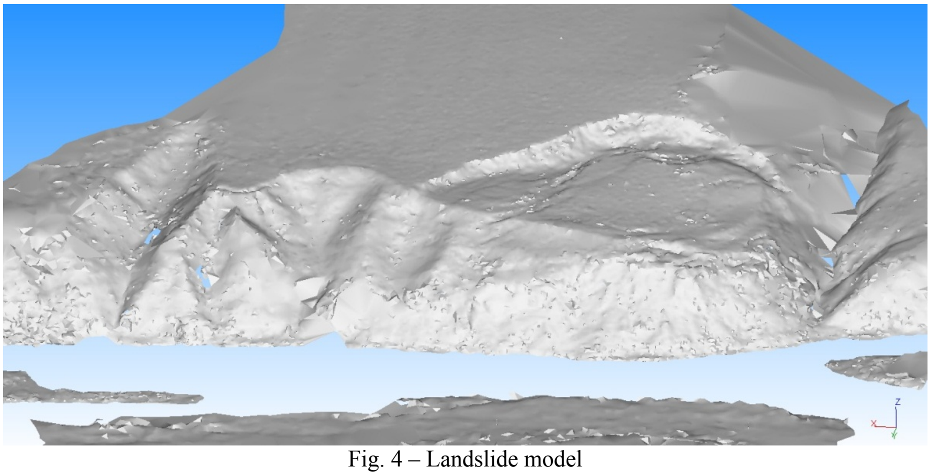

Fig. 4 – Landslide model

Attempt to determine the deformation occurring on the subject focused on the forehead of landslides presented in the figure 3 - an area marked by a red halo. Due to errors occurring during the registration process of determining the deformations that occur related to a single position. 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.

Measurements were taken in two periods. 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. Efforts were also made that the height of the device was as close as possible to the output measure.

Tab. 1 *Result of the registration process, the starting positions and control of the measurement.*

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

Result of the registration process, the starting positions and control of the measurement of forehead of landslide is presented in table 1. Two of points were disabled in calculations because their error was high. After this manipulation the worst point has 4mm error of transformation.

Tab. 2 *Transformation parameters obtained from the positions of the registration stations.*

Station 1	Station 2
translation: (0.000, 0.000, 0.000) m	translation: (-0.477, 3.045, -0.277) m
rotation: (0.0000, 1.0000, 0.0000):0.000 deg	rotation: (-0.0000, -0.0000, -1.0000):5.641 deg

In the table 2 are presented the parameters of the data transformation from the position of the control measurement to the first position. On such prepared data in a common space which can be carried out a preliminary process of identifying areas in which occur deformations [3].

5 GRAPHICAL METHOD OF DETERMINE AREAS OF DEFORMATION

As a result of the override of point clouds for each, the image is obtained by intersecting each registered by the scanner surface. Figure 6 shows override clouds; green color indicates the output measurement and the red color - control measurement.

The cross-section should be made perpendicular to the slope, so extending established lines cross-section 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 typed 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 change in topography have minimal impact on development outcomes achieved. In addition to the cross-sections generated by the program can analyze changes in the course of a cloud of points in a certain area - the study will be conducted at a later stage.

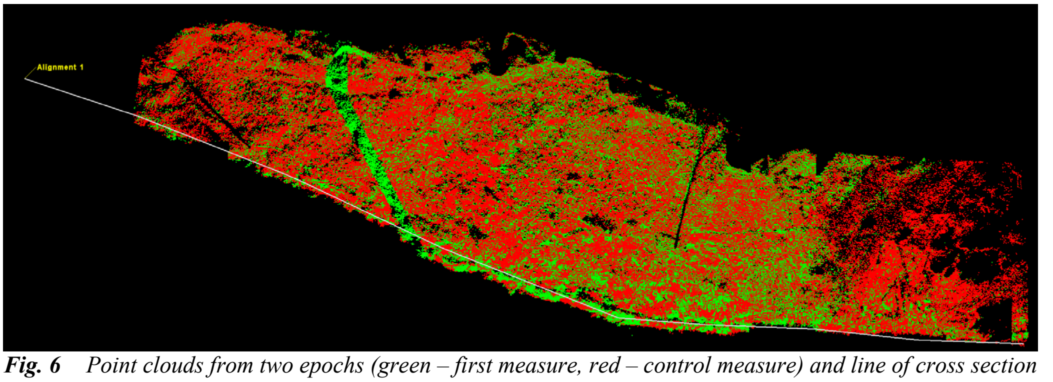

Fig. 6 *Point clouds from two epochs (green – first measure, red – control measure) and line of cross section*

As an example in this article was chosen cross-section number 75 signifying the 75 meter horizontal lines. The view of cross-section shown in figure 7, it has a size of 20 meters to 35 meters.

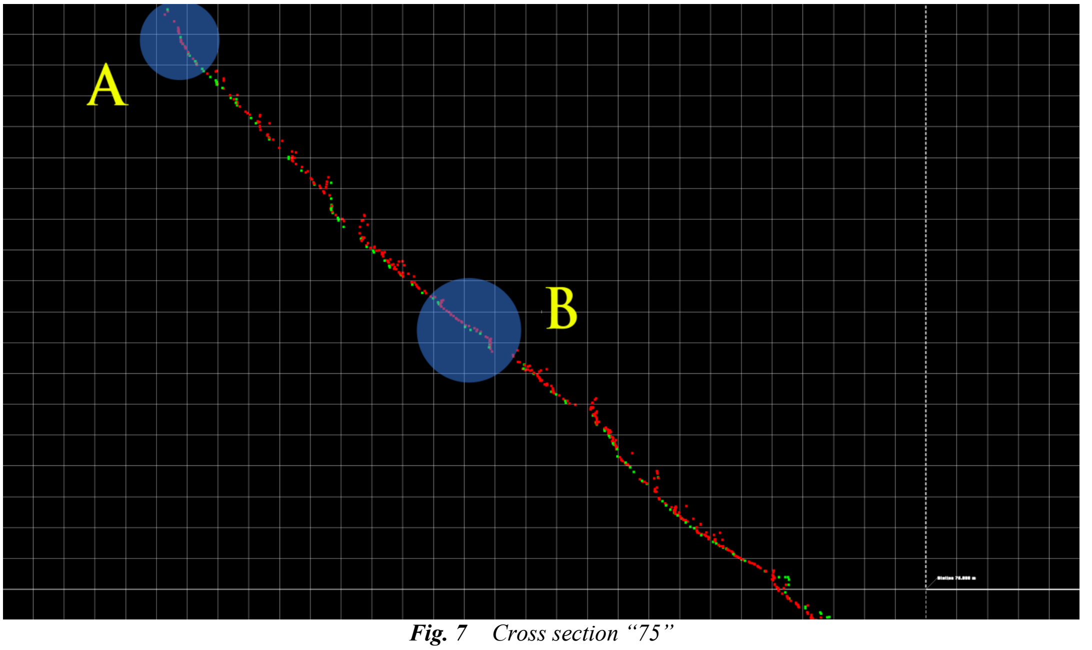

Fig. 7 *Cross section "75"*

As can be seen in addition to cross-section of the cloud of points is also a regular network of squares. Size of a single square is 1 meter on 1 meter. With a network of 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 was discriminated, one of them - "A" represents the minimum changes that occur on the object and the "B" - an area where there were significant changes.

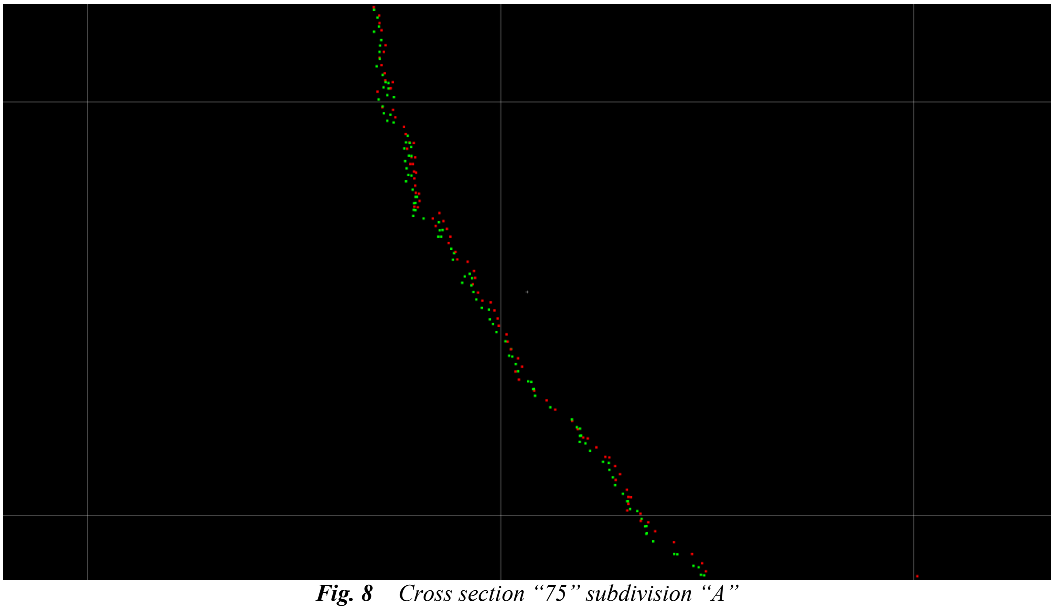

Fig. 8 *Cross section "75" subdivision "A"*

In section 75 and sub-area "A" interpenetrate 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 the accuracy of distance - physical characteristics of the soil or the laser spot size.

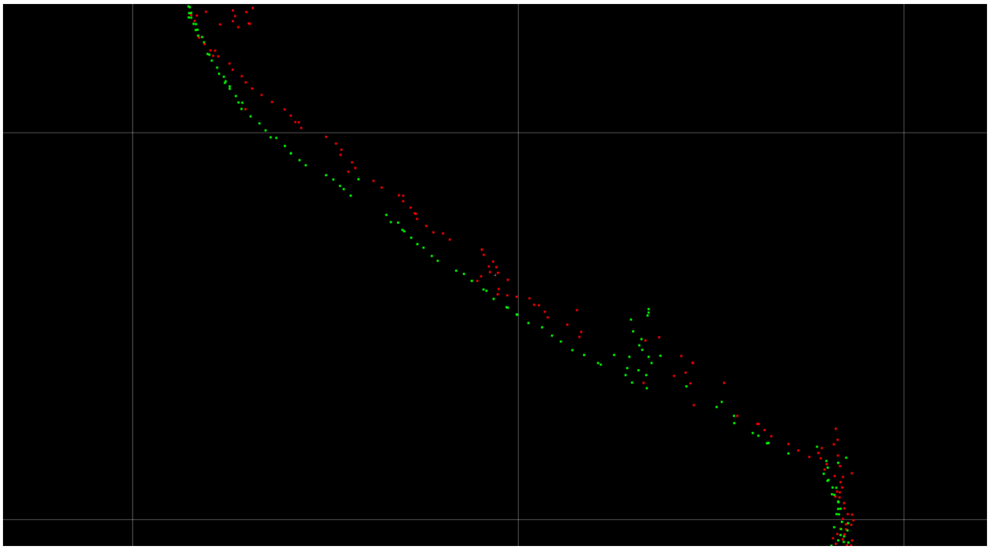

Fig. 9 *Cross section "75" subdivision "B"*

It is different in the case of 75 cross-section and sub-area "B" as shown in figure 9, where the observed deformations are 5-6 cm. 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.

6 Conclusion

Determination of deformation fields using terrestrial laser scanner for overgrown vegetation densely sites may be interesting, and also an important tool in monitoring such facilities. In the presented paper author focuses on the simplest and quickest to develop – the graphical method.

As can be seen using this method can give designers, drawing up the network installation of control points a lot of information by indicating the areas which were identified occurring deformations, which allows them to specify the place where it is needed to thicken the network points. This will allow for more detailed planning of the network right at the first time, and thus the results already achieved during the first cycle of observation, will be more valuable.

The very precision of this method depends on many factors - starting with the same characteristics of the object through the parameters of the point cloud processing - filtering, the pixel size shown on the clouds of points generated from the individual cross–sections on ortophotos, the thick of cross–sections. However, the results obtained during the tests are promising and further stages of the mathematical apparatus will be used.

Literature

[1] B.Van Genechten, T. Demeyere, S. Herinckx, J. Goos, L. Schueremans, D. Roose, M. Santana, Terrestrial laser scanning in architectural heritage – deformation analysis and the automatic generation of 2D cross-sections, 22nd CIPA Symposium, October 11-15, 2009, Kyoto, Japan

[2] M. Alba, L. Fregonese, F. Prandi, M. Scaioni, P. Valgoi, Structural monitoring of a large dam by terrestrial laser scanning, www.isprs.org/proceedings/XXXVI/part5/paper/1271_Dresden06.pdf, Proceedings of the ISPRS Commission V Symposium 'Image Engineering and Vision Metrology', Dresden, Germany 25-27 September 2006, ISSN 1682-1750

[3] Z. Othman, M.S. Rahim, M.Y.M. Khairani, M. Faizah, The use of high density scanner (HDS) for landslide monitoring – the preliminary stage, http://mapasia.org/2009/proceeding/surveying_Mapping/ma09_OthmanZainon.pdf

[4] www.leica-geosystems.com – Leica ScanStation 2 – Product Specifications

Reviewer

Bernard Kontny, professor, Wroclaw University of Environmental and Life Sciences, The Faculty Of Environmental Engineering And Geodesy, Institute of Geodesy and Geoinformatics, ul. Grunwaldzka 53, 50-357 Wroclaw Poland, bernard.kontny@up.wroc.pl