CALIBRATION OF THE TERRESTRIAL LASER SCANNER

Nikolina Mijić
Technical department for the implementation of European projects, flood risk, EKO EURO TIM ltd., Banja Luka, Bosnia and Herzegovina, nikolinamijic7@gmail.com

Keywords: TLS, calibration, accurancy, metrology, instrument, measurements

ABSTRACT:

Laser scanners offers coustomers new opportunities for effective work, but in the professional community there is no still consensus for testing accuracy and calibration of the laser scanner. On the field of calibration of laser scanners we are using analogies with remote sensing methods where the calibration is considered to determine the external orientation parameters and systematic errors of all the images, which are given with a project. Before delivery, the manufactures usually calibrate laser scanners, and also recommends that users re-calibrate it, at regular periods. Results of calibration are directly entered into the instrument, so that users don't have access to the value of calibration parameters, and also don't know the method of their determination. Intention of these paperwork is to examine terrestrial laser scanner, based on measurements performed in Metrology laboratory Faculty of Civil Engineering in Belgrade and analysis of the results which are obtained by experimental measurments.

1. INTRODUCTION

The rapid technological development in the field of electronic measuring length resulted in using pulse method which allows high speed reflection measuring length. Further development in this direction resulted new instruments called laser scanners. The application of terrestrial laser scanner can be really tight, starting from measurements of buildings, measuring strain on dams, topographical survey, industry survey, archaeological measurements, capture fasade, measuring cultural facilities up to modern 3D cadastre drive [1]. To determine the accuracy of 3D laser systems in the laboratory performs the test results of measurement and calibration using the test fields, and it is done by comparison with etalon values. For the purpose of providing meteorological laser scanner is necessary to critically evaluate the performance of the instrument, using independent procedures, such as the comparison of scan results with the test field control points [2]. There are different methods of the calibration procedure terrestrial laser scanner, but one stands out as the most likely basis for future standards, which is the use of the number of control points [3].
Experimental measurements were made in the Laboratory for metrologic measurements, at the Faculty of Civil Engineering in Belgrade. In terrestrial laser scanning was developed a unique approach for calibration of terrestrial laser scanner, which is applied to the instrument series Leica Scan Station P20 [3].

2. PROCEDURE OF CALIBRATION 3D LASER SCANNER

The experimental part of this paperwork is related with examination of the 3D laser scanner. Model of the scanner which has been examined is the Leica ScanStation P20 [4]. Test field for the metrological control of the laser scanner is realized in the Metrology laboratory Faculty of Civil Engineering in Belgrade. The test field is formed by 46 black and white signal stamps (Figure 1).

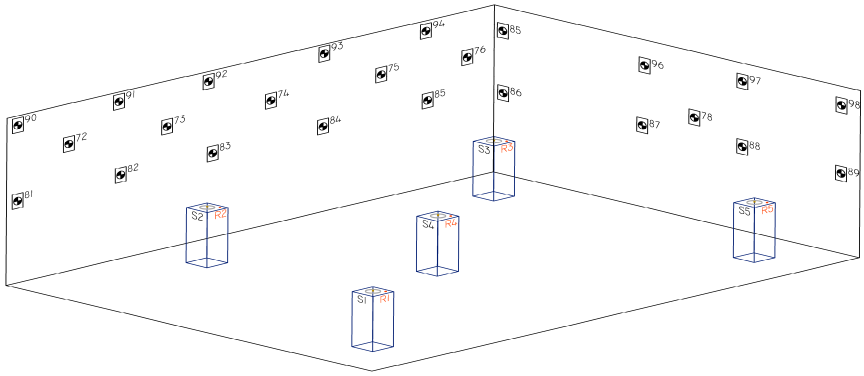

Figure 1: Polygon for testing 3D laser scanner

The appearance of the test fields or polygons to determine the Cartesian coordinates stamps polygons in coordinate system of laboratories. The stamps are made on paper which has a good quality, with such traits to allow reflection total station measurements and to recognize them with scanner. Stamps are well distributed in the laboratory and they are located on the walls, which is important for the assessment of precision measuring horizontal and vertical angles. The laboratory is located with five collumns with forced centering equipment for surveying benchmarks [5]. Checking the criteria as a whole as well as the control of operation.

A rough test criteria includes:

1. Labor positional screws pedestal instrument.
2. Validity of the screen (Display) and keyboard (Keyboard) criteria.
3. Regularity of contacts power source and connection (USB, Bluetooth, WLAN).
4. Adjust of the postition rotating mirrors (field of view).

3. DETERMINATION OF CARTESIAN COORDINATES MARKED WITH STAMPS

Each point in a scanned point cloud is defined in spherical coordinates (r, φ, θ) or rectangular coordinates (x, y, z) in the coordinate system of the scanner and has a value of the intensity of the laser intensity. The link between the results of measurements (r, φ, θ) and the coordinates (x, y, z) has the form:

$$\mathbf{X}_i = \begin{bmatrix} x_j \\ y_j \\ z_j \end{bmatrix} = \begin{bmatrix} r_j \cos\varphi_j \cos\theta_j \\ r_j \sin\varphi_j \cos\theta_j \\ r_j \sin\theta_j \end{bmatrix} \tag{1}$$

where are r_j, φ_j, θ_j measured size - length, horizontal direction and vertical angle for the j-th point in the cloud of points. Rectangular coordinates of a point in the coordinate system of the scanner mounted on the collumn number 1 are (x_j, y_j, z_j), indicated by i = 1 in vector coordinates X_i.

3.1. Assessment of the external orientation parameters of the scanner

Georeferencing the point cloud transformation from the coordinate system of the scanner in the external (geodetic) coordinate system, the coordinate system of laboratories. In the training ground used three or more stamps with known 3D coordinates, these points are called control points. Their coordinates are determined by the total station. Geometry of the stamps is such that they are arranged at different distances and do not lie on the same line.
The translation vector form:

$$\mathbf{\Delta X}_{ie} = \begin{bmatrix} \Delta X & \Delta Y & \Delta Z \end{bmatrix}^{\mathrm{T}} \tag{2}$$

rotation matrix between the coordinate system of the scanner to the laboratory coordinate system. Rotation matrix represents a rotation between different coordinate systems. The Matrix is a functional connection angles of rotation r, φ, θ, about x, y and z coordinate axes. Rotation matrix is calculated as:

$$\mathbf{R}_1(\omega) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{bmatrix}, \tag{3}$$

$$\mathbf{R}_2(\phi) = \begin{bmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{bmatrix}, \tag{4}$$

$$\mathbf{R}_3(\kappa) = \begin{bmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{5}$$

where are R_1 (ω), R_2 (φ) and R_3 (κ) rotation matrix around x, y and z coordinate axes.
The georeferencing transformations between scanner and external coordinate system are described as:

$$X_e = X_{scanner} + R_{ie}(\kappa) X_i \tag{6}$$

where are: $X_{scanner}$ is the coordinate center of the Coordinate system of the scanner, in external coordinate system, $R_{ie}(\kappa)$ is the matrix of the rotation between two Coordinate systems. The matrix of the rotation is the function of the only corners for orientation (azimuth). Practically the angles of the rotation ω and φ are equal to zero.
Parameters of transformation coordinate system of the scanner in coordinate system of the laboratory are determined with equation (6), by the method of the least squares [6]. Calculation of parameters of the transformation are based on counts on the walls of the laboratory (total 46 points).

4. THE PROCESS OF DETERMINATION UNCERTAINTY OF 3D LASER SCANNER

The geodetic instrument in this case 3D laser scanner, made by Switzerland company Leica Geosystems, series Leica ScanStation P20, was set and fixed on the pillar number 1. The instrument make self-leveling immediately after he was switched on. This procedure was repeated when the instrument was set on the pillar number 4, because with this pillar performed observations too [7].
Observations are made in the closed polygon, where the stamps are marked as targets. Testing ground for terrestrial laser scanner comprising the signal on stamps which are obtained on the walls, ceiling and pillar of the laboratory. Scanning is performed with a single scan on the pillar number 1. All signal marks are seen from the pillar number 1, but geodetic instrument in this case 3D laser scanner could not scan the signal stamps, which was on the ceiling [8]. Moving from the signal stamp number

61, in the direction of the clockwise was made scanning of the all other stamps. The procedure was repeated for the measurment with the pillar number 4 [9].

5. EXPERIMENTAL RESEARCH

Data entry and processing the measurement was made in Microsoft Office Excel and verification of the measurement results were done in software package MATLAB, which is specifically designed to record the coordinate transformation and determination of measurment uncertainty. The values of the measurment of lenght, horizontal and vertical angles are tested on the pillars number 1 and 4. On the pillars 1 and 4 were carried out a combination of the measurement from these pillars to determine the number of the points with which must it be evaluated the standardization [9]. In the Table 1 are shown results which are obtained with measuring of length on the pillar 1 and 4.

Table 1: Values of uncertainty from the measuring length from the pillar 1 and 4

Measurement from the pillar 1	
Number of stamps	m_r [mm]
32	0.96
20	0.76
15	0.63
10	0.59
5	0.20
4	0.22

Measurement from the pillar 4	
Number of stamps	m_r [mm]
32	2.00
20	2.03
15	1.87
10	1.85
5	1.51
4	1.59

Declared accuracy of measurment uncertainty in measuring lenght is 2 mm [9]. All values that are calculated are within of the accuracy [9]. The values of measurement uncertainty of horizontal directions are shown in the Table 2.

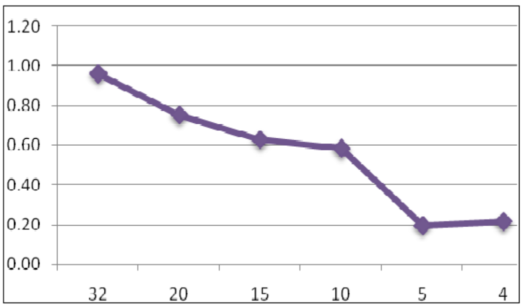

Figure 2: Dependence of the measurement uncertainty of length changing the number of the stamps

Accurancy of the measurement uncertainty of the horizontal directions is 8 " [9]. All values which are calculated from the pillar number 1 and 4 are within the declared accurancy. The values of measurement uncertainty of horizontal directions are shown in the Table 2.

Table 2: Values of uncertainty from the measuring horizontal directions from the pillar 1 and 4

Measurement from the pillar 1		Measurement from the pillar 4	
Number of stamps	m_φ ["]	Number of stamps	m_φ ["]
32	8.78	32	10.84
20	7.26	20	10.59
15	7.02	15	10.56
10	6.72	10	10.34
5	6.99	5	12.07
4	7.70	4	13.48

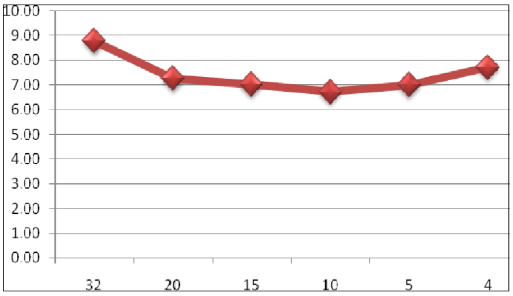

Figure 3: Dependence of the measurement uncertainty of the horizntal directions changing the number of the stamps

Declared accuracy of the measurement uncertainty of the vertical angles is 12". Accuracy of the measurement of vertical angles in the indication of the standardization is 12" [9]. All values are obtained experimentally, and they are within declared accuracy, as recommended by the principe of the standardization METAS [9].

Table 3: Values of uncertainty from the measuring vertical angles from the pillar 1 and 4

Measurement from the pillar 1		Measurement from the pillar 4	
Number of stamps	m_θ ["]	Number of stamps	m_θ ["]
32	10.20	32	15.79
20	10.38	20	14.71
15	10.94	15	12.58
10	10.96	10	12.40
5	10.01	5	10.90
4	5.08	4	7.64

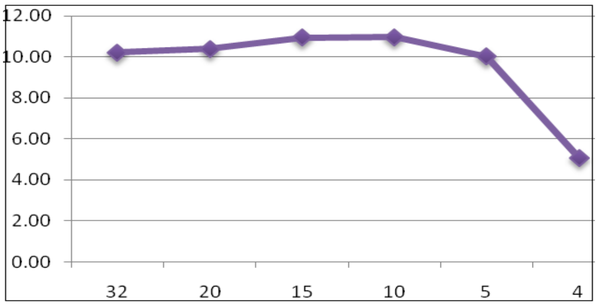

Figure 4: Dependence of the measurement uncertainty of the vertical angles changing the number of the stamps

Combination of the measurements were carried out in order to determine the number of points with which is the best to perform the calibration of the terrestrial laser scanners.

6. CONCLUSION

In the field of the calibration laser scanners there are used an analogy with photogrammetric methods, which are considered to determine the external calibration parameters of orientation and systematic errors of all the images in a given project. Each instrumental error investigates individually, using specific experimental measurements, adjusting instrument and registration of values which are influencing on the process of measuring terrestrial laser scanner. For achieve millimeter accurancy it is necessary to test terrestrial laser scanner in laboratory field conditions, because there are big differences that influences on the level of measurements results. Technic of the terrestrial laser scanning developed a unique approach to standardization, which is applied to the instruments series Leica ScanStation P20. Calibration of a terrestrial laser scanner is a process that in a addition to knowing instrument and work on it requires a knowledge in other areas of geodesy, which are should be applied during the processing of measurement data. All values that are obtained by a combination of measurements are declared in the context of the accuracy. The proposal is that the calibration carried out with 10 points (stamps), and that is concluded on the basis of the diagram as the value of the code both pillars and for all values of breaks diagram. Measurement results are traceable to the national standard units of length and angle of the national standard unit of Switzerland (METAS) through laboratory number 02-025.

7. REFERENCES

[1] Yuriy Reshetyuk: Self-calibration and direct georeferencing in terrestrial laser scanning, doktorska disertacija, Royal Institute of Technology, Stockholm, 2009.

[2] Jasmina D. Nedeljković Ostojić: Analiza metode premera građevinskih objekata 3D laserskim skenerima, doktorska disertacija, Banja Luka, 2010.

[3] Marko M.Pejić: Tačnost modeliranja objekata tehnologijom terestričkog laserskog skeniranja, Beograd, 2013.

[4] J. G. Lahoz, D. G. Aguilera, J. Finat, J. Martinez, J. Fernandez and J. San Jose, “Terestrial laser scanning metric control assessment,” Land and Cartography Engineering Department, Univ. of Salamanca, Spain.

[5] Fabio Remondino, “From point cloud to surface the modeling ,” Institute of Geodesyv and Photogrammetry, ETH Zurich, Switzerland, 2014.

[6] Leica ScanStation P20, User Manual Version 1.1, English, Leica Geosystems, Switzerland, 2013.

[7] W. Boehler, M. Bordas Vincent, A. Marbs, “Institute for spatial information and surveying Germany Technology,” FH Meinz, Holzstrasse 36, 55116 Meinz, 2013.

[8] Rudolf Staiger, “Terestrial laser scanning, technology and systems ,” 2nd Fig Conference, Marocco, 2003.

[9] Jelena Gučević, Siniša Delčev, “Etaloniranje terestričkih laserskih skenera - radno upustvo”, Metrološka laboratorija za etaloniranje merila ugla i dužine, Beograd, 2014.