A non-standard mark’s center recognition correctness by a 3D laser scanner

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Abstract. Terrestrial laser scanners have sophisticated specialized software that makes it possible to measure three-dimensional coordinates of a huge number of points in a short period by registering vertical and horizontal angles. To determine the spatial position of the scanner and the coverage of the area of interest on one scan, special marks are placed around the scanner. These marks are used for further high-precision scan matching. The problem of the process of recognizing the center of black and white marks during field shooting, as separate from the scanning process itself, is a separate task, which has not been sufficiently studied. The purpose of the experiment is to establish the correctness dependence of the mark center recognition on its various characteristics. The technique is the experimental component and theoretical analysis of the obtained material. The experiment was carried out under the same conditions, so that the influence of the distance from the device to the mark, a change in the angle between the laser beam and the mark plane could not affect the recognition correctness of the mark center. In the course of the experiment, 8 marks were prepared with a non-standard view and size, as well as one standard black and white mark, to check the reliability of the data obtained (diameter 74.1 mm, two opposite sectors are black, and the other two are white). This experiment showed that the process of recognizing the mark center depends on the combination of the following characteristics: mark geometry, mark color, the opposite sectors of the mark.

1. Introduction
One of the most widespread geodetic instruments in the XXI century is a ground laser scanner, which is being replaced by an air laser scanner [1]. Laser scanners are increasingly used in various branches of human activity, including laser scanning data that can be used to create geographic information systems [2] and monitoring [3-5]. This is due to the growth in the number of scanners among the contractors and understanding of using three-dimensional laser scanning method possibilities among the potential customers. Laser scanners can directly measure three-dimensional coordinates of a huge number of points in a short period [6]. Such features of the method give an opportunity to talk about the possibilities of its application in any areas where information on the objects’ size and their spatial position is needed [7].

To determine the spatial position and coverage of the area of interest on one scan, special marks are placed around the scanner [8]. These marks are the points of the working space, and for the accuracy of the subsequent comparison of point clouds, multiple measurements of the centers of special marks are performed [9].

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Marks are required for stitching scans based on the laser scanning results. Such marks can solve two problems:

- difficulties during scanning (possible scanner orientation loss during scanning);
- problems associated with achieving high accuracy of matching point clouds.

By merging point clouds across marks, the ground-based laser scanning software organizes all scans using the unique geometry of the object as a reference. To do this, the complex calculation algorithms are used.

In [10], the author notes that when performing work with a ground laser scanner and the subsequent merging of the obtained point clouds, the optimal number of special marks is equal to 8, located in a circle around the scanner. The distance of marks from the scanner should be no more than 100 m. Due to violation of these requirements, stitching by marks does not always give an accurate result. Then, on the final merged point cloud, some defects may appear (ghosting, reversal of scans) [11].

The location of the marks and their distance from the scanner is of great importance, but first it is necessary to recognize the data center of the marks. The center mark recognition process can be done in two ways:

- in software [12,13];
- directly in the field when performing laser scanning.

For example, in [10], the author describes the stages of laser scanning. One of them is the identification and determination of the approximate coordinates of the special marks’ centers. The author also writes that, depending on the scanner model, these operations are performed either on the received scan, or on a digital image, if the scanner is equipped with a digital camera, but the process of recognizing the mark center itself is not considered.

In [14], the author divides special marks into two groups, flat and three-dimensional. At the same time, he claims that the determination of the center of special flat marks (Figure 1) is due to its contrast with respect to the surrounding background, and the volume mark (Figure 2) is based on their shape and size data.

![Figure 1. Types of flat special marks.](image1)

![Figure 2. Types of three-dimensional special marks.](image2)
However, production experience has shown that often surveyors have to use a more budgetary version of marks - flat black and white marks (Figure 3), however, it is not available to everyone. The process of recognizing the data center of marks during the field survey, as an individual task, separate from the scanning process itself, is not sufficiently studied.

![Figure 3. Standard Mark Result](image)

To study the process of recognizing the center of marks during field work, it is necessary to set the following experiment goal - to establish the dependence of the correct recognition of the mark center on its various characteristics, for the possibility of further use of marks of own production.

From the goal setting, the following tasks follow, which need to be solved:
- to check the dependence of the recognition correctness of the mark center on its size;
- to determine the recognition correctness dependence of the mark center on its geometry;
- to establish the correctness dependence of the mark center recognition on the color of the mark sectors.

2. Materials and methods
To achieve the set tasks, the process of recognizing the mark center was investigated using three-dimensional laser scanning technologies and a ground-based laser scanner Leica ScanStation C10. The experiment was based on the classic black and white mark used in production. This is a standard 74.1 mm black and white mark, two opposite sectors of which are black and the other two are white (Figure 3).

Before performing the experiment, the scanner was installed at a distance of 5 meters from the wall, the marks were glued to the wall so that the sighting beam was perpendicular to the mark plane. The experiment was carried out under the same conditions, without changing the scanner position and with the same instrument settings. Thus, the influence of the distance from the device to the mark, a change in the angle between the laser beam and the plane of the mark could not affect the correct recognition of the mark center.

3. Results
During the experiment with mark 1, no influence on the size of this mark was found (Fig. 4).

The influence of the mark geometry on the recognition of its center was tested on mark 2, mark 3 and mark 4 (Figure 4). Scanning these marks showed that center recognition is not based on orientation to the center of the circle (mark 2). Changing the geometry of the opposite sectors also does not affect the recognition of the center (mark 3). When initially aiming at the areas remote from the center, recognition passes without errors (mark 4).
From the work [15], it can be concluded that the process of recognizing the mark center depends on the wavelengths, by finding the maxima of the reflected signals in the mark center, or simply on the color. In this regard, a study of mark 5 was carried out, the center of which was absent, but the device could determine its center (Figure 5).

Since white surfaces have nonselective reflectivity (reflectance coefficient more than 60%), and black surfaces have nonselective absorptive power (reflectance coefficient less than 10%), it was assumed that it is the contrast of white and black that is necessary for the program to recognize the mark center.

To check this relationship, the color of the standard mark was changed to blue and yellow (mark 6), but the scanner recognized the center of this mark (Figure 5). Making an assumption about the possibility of the opposite white sectors’ influence, an experiment was carried out with mark 7 (Figure 5). In the experiment with mark 7, all sectors were replaced with primary colors with an optical spectrum: red 625 - 780 nm, yellow 565 - 590 nm, green 500-565 nm, blue 440 - 485 nm, the scanner could not determine the center of mark 7 (Figure 5).

Replacing the sectors of the standard mark with yellow, blue and two opposite ones with red, it was concluded that 2 identical opposite sectors are of great importance. This dependence was noticed earlier on marks 1-6, where it was necessary to find dependence on the size, geometry and color of the sectors (Figure 5).

**Figure 4.** The result of experiments with marks
4. Discussion

Thus, for correct recognition of the mark center by the scanner, all marks given during the experiment (with the exception of the mark 7) can be applied.

It should be noted that marks 1-4, 6 and 8 had the same opposite colors of the sectors, and based on these marks, a false assumption had initially been made. This assumption stated that the process of recognizing the mark center depends only on the wavelengths, by finding the maxima of the reflected signals in the mark center, or simply on the color of the opposite sectors, which could later be confirmed by an experiment with mark 7. However, the study showed that in the case of mark 5 having excluded the mark center with the assumed maxima, the scanner correctly recognized its center, refuting the false assumption. Thus, the use of special or standard black and white marks is not required. Since the changes in some characteristics do not affect the correct recognition of the mark center, and therefore the correctness of the point clouds’ comparison. However, this approach can only be relevant for determining the mark center in the field using the Leica ScanStation C10 scanner.

Summary

On the basis of the experiment carried out with a ground laser scanner Leica ScanStation C10, we checked the dependence of the correct recognition of the mark center on its size, determined the dependence of the correct recognition of the mark center on its geometry, established the dependence of the correct recognition of the mark center on the color of the opposite sectors of the mark. This experiment showed that in the process of recognizing the center of the mark, not individual characteristics of the mark are taken into account, but their totality.

For completeness of the study on this issue, it is useful to perform the additional studies on other terrestrial laser scanners. In the course of the research, the following tasks are required: determining the capabilities of scanners and further determining the dependences of the mark center identification during field shooting from the changes in the mark characteristics, as well as the possibility of using non-standard marks in work with these scanners.

References

[1] Benjamin Brede, Kim Calders, Alvaro Lau, Pasi Raumonen, Harm M Bartholomeus, Martin Herold, Lammert Kooistra 2019 Non-destructive tree volume estimation through quantitative structure modelling: Comparing UAV laser scanning with terrestrial LIDAR Remote Sensing of Environment, November 2019 233 111355.
[2] Gribkova I S, Dyakova N A, Tsarkova Yu A 2020 The use of GIS for managing a single real estate complex on the example of the oil and gas industry In the collection: Youth Science. Collection of the best scientific works of young scientists. Krasnodar 33-35.
[3] Gura D A, Dubenko Yu V, Markovskiy I G 2020 Monitoring of transport infrastructure facilities using scanning technologies Technosphere safety technologies 2 (88) 74-86.
[4] Gura D A, Dubenko Yu V, Dyshkant E, Pavlyukova A, Akopya G 2019 3D Laser scanning for monitoring the quality of surface in agricultural sector IOP Conference Series: Earth and Environmental Science 012184.
[5] Han W, Zhao S, Feng X, Chen L 2014 Extraction of multilayer vegetation coverage using airborne LiDAR discrete points with intensity information in urban areas: A case study in NanjingCity, China International Journal of Applied Earth Observation and Geoinformation 30 (1) 56-64. DOI: 10.1016/j.jag.2014.01.016.
[6] Schmitz B, Kuhlmann H, Holst C 2020 Investigating the resolution capability of terrestrial laser scanners and its impact on the effective number of measurements ISPRS Journal of Photogrammetry and Remote Sensing, January 2020 159 41-52.
[7] Seredovich V A, Seredovich A V 2011 Features, problems and perspectives of GLS application Geo-Siberia 1(2) 223-224.
[8] Liu L, Lim S 2018 A voxel-based multiscale morphological airborne lidar filtering algorithm for digital elevation models for forest regions *Measurement* 123 135-144.

[9] Komissarov A V 2015 Theory and technology of laser scanning for spatial modeling of territories (Dissertation for the degree of Doctor of Technical Sciences).

[10] Seredovich V A, Komissarov A V, Komissarov D V, Shirokova T A 2009 Terrestrial laser scanning (monograph, SSFU, Novosibirsk).

[11] Voronova K V, Akopyan G T, Schevchenko G G 2019 Experience in using the Cloud Constraint function in Cyclone to increase the links between scans when they are oriented relative to control marks *Electronic network polythematic journal "Scientific works of KubSTU"* 7 1-8.

[12] Gura D A, Kuziakina M V, Dubenko Yu V, Pshidatok S K, Shevchenko G G, Granik N V, Markovskii I G 2019 Classification and automatisation of laser reflection points processing in the detection of vegetation *Proceed. of the International Symposium "Engineering and Earth Sciences: Applied and Fundamental Research" dedicated to the 85th anniversary of H.I. Ibragimov. Groznyi. Atlantis Press Publ.* 593-596. DOI: 10.2991/isees-19.2019.117.

[13] Ma H, Zhou W I, Zhang L 2018 DEM refinement by low vegetation removal based on the combination of full waveform data and progressive TIN densification *ISPRS Journal of Photogrammetry and Remote Sensing* 146 260-271.

[14] Vistrchil M G 2014 Substantiation of methods for external orientation of digital models of mine workings obtained from the results of surveys by laser scanning systems (Dissertation for the degree of candidate of technical sciences).

[15] Gusyev V N, Aleksenko A G, Volokhov E M, Golovanov V A, Zvervich V V, Kiselev V A, Pravdina E A 2016 (St. Petersburg Mining University, SPb).