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ERROR IN DETERMINING THE PERMANENT CORRECTION OF THE MEASURED DISTANCE BY A GROUND LASER SCANNER

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ABSTRACT: *The subject of the research is to make a correct assessment of the error in determining the constant correction of the measured distance and to choose a model for their removal, which will allow achieving the required accuracy and high productivity with minimal material costs when performing laser measurements.*

KEYWORDS: *Instrumental sources, measurements, TLS.*

1. Introduction

The error in determining the constant correction of the measured distance m_C depends on the design characteristics of the ground scanner (phase angle, difference between mains voltage, nominal value, etc.) and the method of determining this correction when checking the device. Modern methods for metrological certification of electronic rangefinders include forced centering of the device and the reflector, which can be done with an error of the order of 0.1 mm. In fact, this value characterizes the marginal accuracy with which instrumental correction can be determined [4].

2. Instrumental sources of error

When working with scanners that measure distances at fixed frequencies, the error caused by the difference between the scale frequency and the nominal value m_f, consists of errors due to frequency instability and standard, which are approximately the same order. For terrestrial scanners with smooth change of frequency error m_f depends mainly on the way it is measured. The frequency error includes not only an arbitrary but also a systematic component due to inaccurate tuning of the frequency to the nominal value (standardization error) and slow frequency drift of the generator.

The mean squared error (MSE) in measuring distances along phase terrestrial laser system (TLS), similar to the pulsed ones, can be represented by the expression [3]

$$m_R = a + bR \, , \tag{1}$$

where:

a and b − coefficients determined empirically on the basis of measurements of the lengths of the reference lines, and for each rangefinder they have their own values.

The accuracy of measuring short distances with phase rangefinders is mainly influenced by errors in measuring and reporting the phase difference, as well as the error in the rangefinder constant. This is because the errors in distances, which depend on the errors in the frequency and speed of propagation of electromagnetic oscillations in the atmosphere, will be insignificant.

The accuracy of measuring the distances and angles of the TLS depends on a number of factors, including errors in the manufacture and centering of the device. The ground-based laser scanning system also includes control software. This makes it possible to eliminate some of the errors in the measured values, which are systematic. The values used to eliminate some kind of error in the measured angles and distances in software products designed to control ground-based laser scanners are called calibration parameters. For each scanner model, the number of calibration parameters and the type of mathematical model for eliminating systematic errors directly from the measurement results are different. However, the analysis of TLS calibration methods makes it possible to identify some of the parameters and errors common to the various scanners, the impact of which can be reduced, namely [1]:

a) scale factor b, взет taken into account in the measured distances [3];

b) instrumental correction [3];

c) non-coplanarity of the vertical axis of rotation of the device and the axis of rotation of the scanning mirror (prism);

d) non-coplanarity of the vertical axis of rotation of the device and the vector of propagation of the laser beam;

e) noncoplanarity of the axis of rotation of the scanning prism and the vector of propagation of the laser beam;

f) error in axial conditions;

g) vertical collimation error;

h) horizontal collimation error.

TLS software provides two options for reading the first two scanner calibration parameters. In the first variant, the instrumental correction and the scale factor are defined separately as calibration parameters, which exclude errors in the measured distances. In the second option, adjustments are made to the lengths of the lines for the overall influence of the calibration parameters, the values of which depend on a certain range of distances. The second way to exclude systematic errors from the results of laser scanner measurements is more preferred. This is explained by the following circumstance. Distances measured with scanners range from 1 to 1200 m. As a result, the strength of the received signal varies considerably over the entire range. Also, the signal strength is significantly affected by the reflectivity of the object. Therefore, when a strong signal arrives at the receiver, it may even break. In this regard, scanner manufacturers place devices in front of the receiver that artificially reduce the signal strength. The closer the scanning object is, the more the power of the received signal decreases, which in turn leads to distortion of its shape. As a result, it becomes difficult to calibrate the scanner using the first option.

The next factor influencing the accuracy of one-time measurement of angles and distances is the asynchrony of the recording of R, φ and θ. Because every measured value R, φ and θ in TLS it is fixed after a certain interval T_R, T_φ and T_θ, respectively, errors caused by asynchronous recording of values are a function that can be written in general as follows:

$$\Delta = f(R, T_R, T_\varphi, T_\theta, t)\,, \tag{2}$$

where:

$t -$ the time the scanner has been running since startup.

Errors caused by asynchronous registration of R, φ and θ, cannot be determined at the stage of processing ground-based laser scanning data, so the only way to eliminate this type of error is to ensure equality T_R=T_φ=T_θ at the stage of assembling the TLS.

In scanners manufactured by Riegl, Leica, Zoller+Fröhlich and others, the continuous rotation of the prism and optical head is used to scan objects in the horizontal and vertical directions. During this rotation, the laser source sends a signal to the prism, which is reflected in the direction of the object. Reflected by the subject, the beam returns to the receiver. Because the prism and optical head rotate continuously, the time the signal travels from the scanner to the subject and back, the readings on the vertical and horizontal circles change with angles $\Delta\varphi$ and $\Delta\theta$. Therefore, the question arises at what point in time it is necessary to fix the values of the angles. It is best to define:

– t_{out} – the moment at which the signal is applied to the source of laser radiation;

– t_{in} – the moment of reception of the reflected signal;

– calculate the average value of the angle $(t_{out} + t_{in})/2$.

To justify the need to take into account the corrections in the measured directions during scanning, we calculate the angle at which the prism will rotate during the time when the pulse travels from the TLS to the object and back. In this case, we will consider only the vertical scanning angle, since the scanning speed in the horizontal direction is several orders of magnitude lower than in the vertical.

The minimum and maximum vertical scanning speeds are 1 to 20 lines per second. This means that the minimum angular velocity of the scanning prism will be equal to

$$v_{min} = 1lin/s\frac{2 * 360^\circ}{3} = 240^\circ/s\ ,$$

and the maximum (3)

$$v_{max} = \frac{20lin}{c\frac{2 * 360^\circ}{3}} = \frac{4800^\circ}{s}.$$

3. Conclusion

Changing the focal length of the camera lens in the triangular TLS leads to a change in two parameters: the accuracy of obtaining the coordinates of the points of the object and the depth of field of the image on the matrix [4]. It is most advantageous to use short focus lenses that provide sharpness at great depths of the scanned area, but cause large errors due to lens aberrations.

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