Testing the Accuracy of Determining 3D Cartesian Coordinates Using the Measuring Station S8 Trimble DR Plus ROBOTIC

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Summary

Prerequisite for responsible implementation of geodetic activities and to obtain reliable results is to work with the device for which it is possible to say with certainty that it meets the required accuracy specified for the selected type of work. For this purpose it is possible to carry out the testing of the device, both in the terms of a set of norms ISO 17123, or application of other test methods and procedures. In the present paper there are results of testing of the stability of robot universal measuring station (RUMS) S8 Trimble DR Plus ROBOTIC published, which is in scientific research and teaching activities in the Department of Geodesy (KG) STU in Bratislava used.

Keywords: Trimble S8, STN ISO 17123-5, testing, stability of parameters

1. Introduction

The current geodetic measuring equipment contains a large number of electronic components, which greatly facilitate and automate the work in the field and saves time. Increasing number of manufacturers and models logically leads to losing the overview of the quality of the available technology for the users. Different manufacturers in order to best promote and sell their product at the expense of established brands are resorting to tendencies of indicate a higher degree of accuracy than is realistically achievable. Also, there is a presumption that the stability and quality of surveying instruments is due to the amount of used electronic components changing in time and by its using.

1.1. Trimble S8 DR Plus ROBOTIC

Manufacturer of instruments Trimble S8 classifies them into second-class of precision. The device is available in two basic configurations; namely DR Plus and DR HP. The difference between these model series lies in the accuracy of the rangefinder (HP CDS configuration contains more accurate rangefinder). It is also possible to modify the configuration according to the amount of features integrated in the universal measuring station (UMS) for SERVO, AUTOLOCK and ROBOTIC. The RUMS for testing was available in DR Plus ROBOTIC configuration. The tested model includes technologies from Trimble company such as MagDrive, Vision, SurePoint and Autolock. Trimble S8 device finds its application in precise outstaking, building point fields, measuring displacements and deformations in tunnel construction works, automated managing of building machines and other geodetic and related applications. Technology of Trimble and Trimble instruments describes [2].

The specific parts of the instrument with its controls are described in Figure 1.1 and in [3].

1.2. Configuration design of the test point field

Test point field in the shape of a triangle was located in the area of the Freedom Square in Bratislava. In the triangle corner points tripods with adjusting bases were placed. Side lengths of a triangle on the size of about 100 m were chosen, taking into account the various mutual cants between endpoints. Configuration of the test field was selected in accordance with the ISO 17123-5 standard. Test field points distribution within the site is located in Fig. 1.2.

2. Measurement of rectangular coordinates

The measurement was carried out twice in the three series in a day. The measured sets of results obtained by manually and automated targeting were

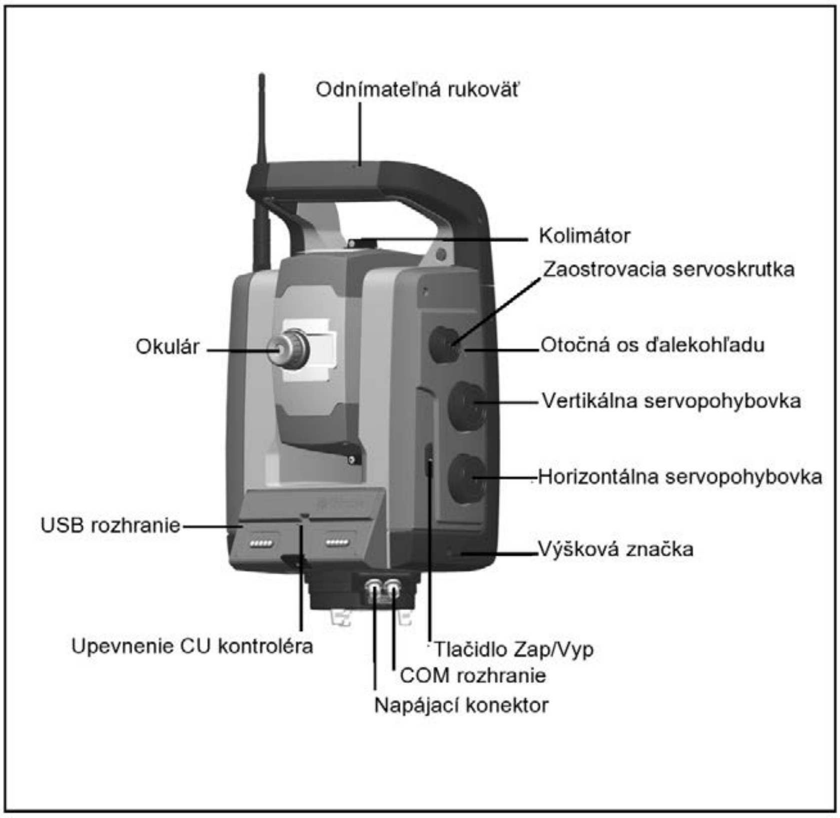

Fig. 1.1. The basic controls and the design features (the view from the position of the operator)

Rys. 1.1. Podstawowe urządzenia sterujące i cechy konstrukcyjne (widok z pozycji operatora)

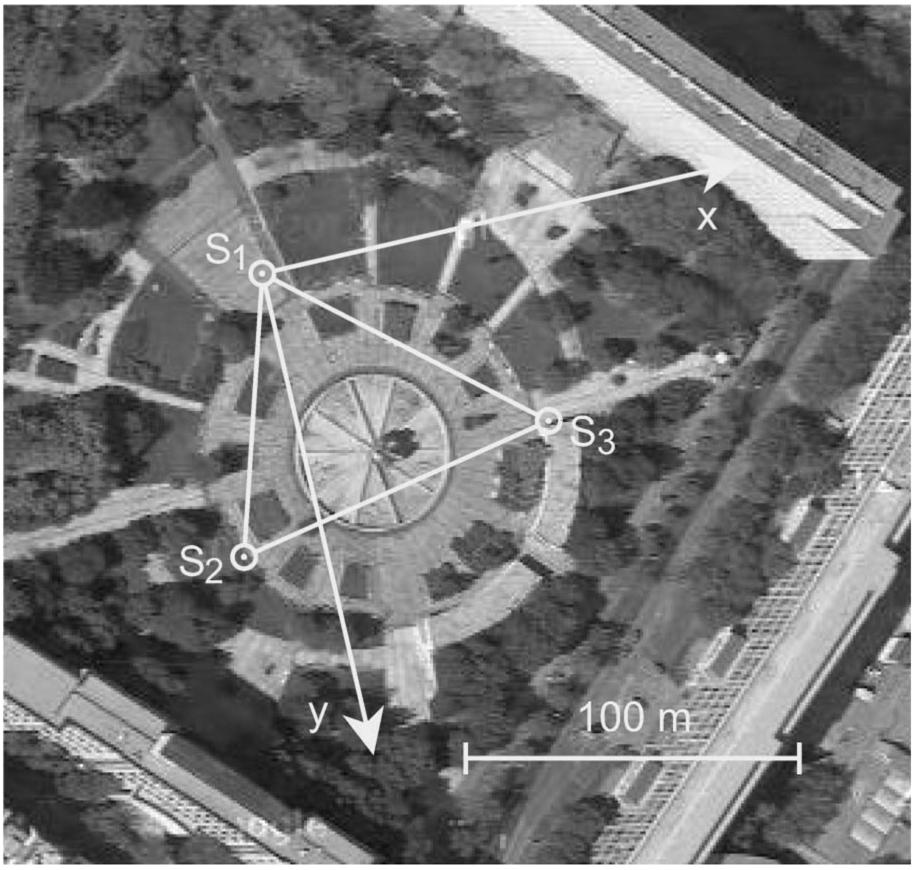

Fig. 1.2. Distribution of points in test field

Rys. 1.2. Rozkład punktów w polu testowym subjected to testing. At each position of the device, zero rectangular coordinates were set. The values of temperature, pressure and atmospheric moisture were registered, serving to correct the measured lengths. For this purpose GREISINGER electronic GFTB 100 device was used. In terms of suppression of centering errors the method of dependent centration was used during the measurement. Coordinates were always determined in both positions of the telescope. The target used in measuring was the reflective prism from the production of the Trimble company with the PN58026007 type designation. In the measurement we have proceed in accordance with the method of [1] and Table 2.1.

2.1. Evaluation of measured parameters

In evaluating the results of the testing the procedure was followed as described in [1] – ISO 17123-5. The calculation was carried out in Microsoft Office Excel. Observed mean errors of once measured coordinate x or y in two positions of the telescope and mean error of once measured coordinate z are found in Table 2.1.

The observed mean error of once measured coordinate x or y in two positions of the telescope for the Standard mode of lengths measurement is $s_{XY} = 1.1\ mm$ and for the Tracking mode $s_{XY} = 0.7\ mm$; the mean error of once measured z-coordinate for the Standard mode equals $s_Z = 0.5\ mm$ and for the Tracking mode $s_Z = 0.5\ mm$. The mean location error for the Standard mode $s_P = 1.2\ mm$ and for the Tracking mode $s_P = 0.9\ mm$.

The calculated mean location errors s_P confirmed, that the chosen lengths measurement mode by static targets has no influence on the degree of accuracy of the lengths measurement.

2.2. Statistical analysis of the acquired results

The necessary part of evaluating of the acquired results is the realization of a statistical testing, which consists of answers on two questions, specified in the STN ISO 17123-5 norm. The questions are as follows:

1. Is the calculated mean error s smaller than the a priori mean error σ, specified by the manufacturer, or smaller than any other predetermined mean error?
2. Are the two mean errors s and $\tilde{s}$, which are determined from the two different sets of measurements from the same area, providing, that the samples have the same degree of freedom υ?

It is necessary to execute the testing separately for the mean error s_{XY} and s_Z. It is also necessary to execute the tests on the $1 - \alpha = 0.95$ significance level. To the mean error s_{XY} corresponds the significance level $\upsilon = 24$, and to the mean error s_Z the $\upsilon = 15$.

The mean error of the measured coordinates is not specified by the manufacturer of the device, however it is possible to determine it by application of the law of accumulation of the mean errors. For this purpose a knowledge about the a priori mean error of measured length σ_d and the mean error of measured horizontal (σ_α) or vertical angle (σ_β) is needed. For the tested device the following a priori characteristics of the second order are valid: $\sigma_d = 1\ mm + 2\ ppm$ (Standard mode), $\sigma_d = 4\ mm + 2\ ppm$ (Tracking mode), $\sigma_\alpha = \sigma_\beta = 4.4^{cc}$.

The derivation of mean errors is based on the formulas for individual rectangular coordinates x, y and z, which are the functional relationships of the length d, the horizontal angle α and the vertical angle β.

$$x = d \times \cos\alpha \times \cos\beta\,, \tag{2.1}$$

$$y = d \times \sin\alpha \times \cos\beta\,, \tag{2.2}$$

$$z = d \times \sin\beta\,. \tag{2.3}$$

By application of the law of the accumulation of the mean errors from (2.1), (2.2) and (2.3) we obtain the formulas for the determination of the mean errors of individual coordinates.

The mean location error can be determined as follows:

Table 2.1. Mean errors of once measured coordinate x or y, mean error of once measured coordinate z *according to* STN ISO 17123-5

Tabela 2.1. Srednie błędy wzdłuż koordynat x lub y, błąd średni pomiaru współrzędnej z zgodnie z normą STN ISO 17123-5

Set	Standard mode					Tracking mode				
			Average of 2 sets					Average of 2 sets		
i	s_{XY_i}	s_{Z_i}	s_{XY}	s_Z	s_P	s_{XY_i}	s_{Z_i}	s_{XY}	s_Z	s_P
	(mm)					(mm)				
1	1,2	0,5	1,1	0,5	1,2	0,7	0,4	0,7	0,5	0,9
2	1,0	0,4				0,7	0,5			

$$\sigma_x = \sqrt{(\cos\alpha\times\cos\beta\times\sigma_d)^2 + (-d\times\sin\alpha\times\cos\beta\times\sigma_\alpha)^2 + (-d\times\cos\alpha\times\sin\beta\times\sigma_\beta)^2}\ , \tag{2.4}$$

$$\sigma_y = \sqrt{(\sin\alpha\times\cos\beta\times\sigma_d)^2 + (d\times\cos\alpha\times\cos\beta\times\sigma_\alpha)^2 + (-d\times\sin\alpha\times\sin\beta\times\sigma_\beta)^2}\ , \tag{2.5}$$

$$\sigma_z = \sqrt{(\sin\beta\times\sigma_d)^2 + (d\cos\beta\times\sigma_\beta)^2}\ . \tag{2.6}$$

$$\sigma_{xy} = \sqrt{\sigma_x^2 + \sigma_y^2}\ . \tag{2.7}$$

In (2.4), (2.5), (2.6) and (2.7) the a priori accuracies of the device parameters and the maximum values of the inclined length, horizontal and vertical angle were substituted, which occurred by the measurements taken. The values of the horizontal angle, vertical angle, inclined length and the calculated 4mean errors are shown in Tab. 2.2.

The subject of examination in the first question is the finding of equality between the achieved mean error s and the a priori mean error σ. There is a null hypotesis H_0 given, which states, that the mean error s is smaller or equals the predetermined mean error σ.

For the testing of the mean error s_{XY} the fulfillment of the following requirements applies:

$$s_{XY} \le \sigma_{xy} \times 1.23\ . \tag{2.8}$$

For the testing of the mean error s_Z applies:

$$s_Z \le \sigma_z \times 1.29\ . \tag{2.9}$$

Otherwise the null hypotesis H_0 is rejected.

After the substitution of known values to the formulas (2.8) and (2.9) the following values for the Standard mode of lengths measurement are obtained:

$$s_{XY} \le 1.4mm \times 1.23\ , \qquad s_{XY} \le 1.72mm\ , \tag{2.10}$$

$$s_Z \le 0{,}7mm \times 1.29\ , \qquad s_Z \le 0.90mm\ . \tag{2.11}$$

To the Tracking mode of lengths measurement belongs:

$$s_{XY} \le 4.3mm \times 1.23\ , \qquad s_{XY} \le 5.29mm\ , \tag{2.12}$$

$$s_Z \le 0{,}7mm \times 1.29\ , \qquad s_Z \le 0.90mm\ . \tag{2.13}$$

If we compare the values from the Tab. 2.1 with the formulas (2.10), (2.11), (2.12) and (2.13), we can assume, that the mean errors s_{XY} and s_Z obtained by processing the measurements are smaller ar equal than the calculated a priori mean errors shown in Tab. 2.2. The risk of such decision is 5%.

In the answer on the second question it is examined, if the mean errors s and $\tilde{s}$ are coming from the same area. The proposed null hypotesis H_0: $\sigma = \tilde{\sigma}$.

For the testing of the mean error s_{XY} applies:

$$0.44 \le \frac{s^2}{\tilde{s}^2} \le 2.27\ . \tag{2.14}$$

Fr the testing of the mean error s_Z applies:

$$0.35 \le \frac{s^2}{\tilde{s}^2} \le 2.86\ . \tag{2.15}$$

Otherwise the null hypotesis H_0 is rejected and the alternative hypotesis H_1: $\sigma \ne \tilde{\sigma}$ is accepted.

The testing of individual mean errors is shown in Tab. 2.3.

From the Tab. 2.3 we assume, that the partial mean errors obtained from individual sets of measurements (for the Standard and Tracking lengths measurement mode) are coming from the same collection. The uncertainty of such decision is 5%.

3. The review and user experiences with tested device

The used control unit Trimble TSC3 is characterized by a quality display, satisfactorily readable by all light conditions, that occurred during the meas-

Table 2.2. The calculated mean errors σ_x, σ_y, σ_z a σ_{xy}

Tabela 2.2. Wyliczony błędy średnie σ_x, σ_y, σ_z i σ_{xy}

	Standard mode				Tracking mode			
$\alpha \cong 118.55^g$	σ_x	σ_y	σ_{xy}	σ_z	σ_x	σ_y	σ_{xy}	σ_z
$\beta \cong 1.91^g$	(mm)				(mm)			
$d =\cong 99.75m$	0.7	1.2	**1.4**	**0.7**	1.4	4.0	**4.3**	**0.7**

Table 2.3. Statistical testing to the second question based on STN ISO 17123-5

Tabela 2.3. Ocena statystyczna drugiego zadania w oparciu o normę STN ISO 17123-5

Sets		Standard mode				Tracking mode			
		s	$\tilde{s}$	$\frac{s^2}{\tilde{s}^2}$	Result	s	$\tilde{s}$	$\frac{s^2}{\tilde{s}^2}$	Result
		(mm)				(mm)			
		s_{XY}				s_{XY}			
1	2	1.2	1.0	1.44	Hypotesis H_0 is accepted	0.7	0.7	1.00	Hypotesis H_0 is accepted
		s_Z				s_Z			
1	2	0,5	0.4	1.56	Hypotesis H_0 is accepted	0.4	0.5	0.64	Hypotesis H_0 is accepted

urement. The sensitivity of the display touch is very good also without using a stylus, the hardware keyboard is characterized by a good build quality. The radio connection of the RUMS with the control unit was proceeding smoothly.

The propulsion of the Mag Drive system can be marked as extraordinary silent, fluent and soft. The Autolock system of automatic targeting is reliable in favorable conditions of the environment, in which the measurement is taken. The deficiencies of Autolock system were observed during measurement in windy environment, where in the consequences of the wind impacts the device registered outliers on the angle ring.

The Autolock system is not a priori bad, the indispensable use of it can be found in precise measurements of angles on very long distances, but it cannot be considered as a "be-all and end-all" product. It is necessary to know its pitfalls, restrictions and weaknesses to obtain the satisfying results. Using conventional geodetic methods by robotic universal measuring station for the purposes monitoring of deformation special civil construction describes [4], [5], and for the creation micro – network in industrial surveying then article [6]. Properties of thermal insulating plaster which is applied on the test panel [5] are given in articles [7], [8].

Conclusion

In this paper we deal with the problem of determination of the stability of the Trimble S8 DR Plus ROBOTIC device. The subject of the testing was to specify the precision of the measurement of the three-dimensional Cartesian coordinates. The testing was carried out based on the procedure prescribed by the STN ISO 17123-3, STN ISO 17123-4 and STN ISO 17123-5 norms. For all examined parameters solely the complete testing method of determining the accuracy characteristics was applied in the test. In the testing of accuracy of measurement of the three-dimensional Cartesian coordinates, the Standard and Tracking mode of lengths measurements were used.

From the realized testing it is possible to confirm, that the tested Trimble S8 DR Plus ROBOTIC device meets the accuracy for the determination of the three-dimensional Cartesian coordinates specified by the manufacturer.

Literatura – References

1. *STN ISO 17123-5: 2005: Optika a optické prístroje – Postupy na testovanie geodetických prístrojov. 5. časť: Elektronické tachymetre (Optics and optical instruments - Methods for testing of geodetic instruments. Part 5: Electronic tachymetres).*
2. *Květ Q. P. 2011 (PDF): Fascinujíci technologie Trimble (Fascinating technology of Trimble).*
3. *Záthurecký P.: Testovanie stability parametrov univerzálnej meracej stanice Trimble S8 DR plus robotic (Testing of the stability of the parameters of the universal measuring station Trimble S8 DR plus robotic). Diplomová práca, Stavebná fakulta STU v Bratislave, Bratislava 2013.*
4. *Šíma J., Ižvoltová J., Seidlová A.: Geodetic Measurements of Underground Gas Reservoirs, Acta Montanistica Slovaca, Ročník 16 (2011), číslo 4, s. 307-311, ISSN 1335-1788. Dostupné z: http: //actamont.tuke.sk/pdf/2011/n4/11sima.pdf*

5. *Václavík V., Valíček J., Novosad M., Staňková H., Bendová M., Daxner J.: Monitoring of Deformation of Thermal Insulating Plaster with Fillers from Recycled Polyurethane Foam Using Conventional Geodetic Methods. In: 12th International Multidisciplinary Scientific GeoConference SGEM 2012 : conference proceedings. Vol. I-IV. Sofia, Bulgaria: STEF92 Technology Ltd., 2012. ISSN 1314-2704. Dostupné z: http://sgem.org/sgemlib/spip.php?article2339&lang=en*
6. *Pospíšilová L.; Pospíšil J.; Staňková H.: Micro-network creation in industrial surveying, Geodesy and Cartography, Tailor & Francis, Co - Published with Vilnius Gediminas Technical University, Vol. 38, No. 2, p.70-74, 2029-6991 (Print), 2029-7009 (Online), 2012 DOI: 10.3846/20296991.2012.692216. Dostupné z: http://www.tandfonline.com/doi/abs/10.3846/20296991.2012.692216*
7. *Václavík V., Valíček J., Dvorský T., Hryniewicz T., Rokosz K., Harničárová M., Kušnerová M., Daxner J., Bendová M..: A Method of Utilization of Polyurethane after the End of its Life cycle. Rocznik Ochrony Środowiska. 2012, Vol. 14, p. 96-106. ISSN 1506-218X.*
8. *Václavík V., Dvorský T., Dirner V., Daxner J., Šťastný M.: Polyurethane Foam as Aggregate for Thermal Insulating Mortars and Lightweight Concrete. Tehnički vjesnik – Technical Gazette. 2012, Vol. 19, Issue 3, p. 665-672. ISSN 1330-3651.*

Badanie dokładności określania trójwymiarowych współrzędnych kartezjańskich przy użyciu uniwersalnej stacji pomiarowej S8 Trimble DR Plus ROBOTIC

Warunkiem właściwej realizacji działań geodezyjnych i uzyskania wiarygodnych wyników jest praca z urządzeniem, dla którego możliwe jest stwierdzenie z dużą pewnością wysokiej dokładności dla określonych obszarów badań. W tym celu możliwe jest przeprowadzenie testów urządzenia pod kątem norm ISO 17123 lub zastosowanie innych metod badawczych i procedur. W niniejszym artykule przedstawiono wyniki testów stabilności automatycznej uniwersalnej stacji pomiarowej (robot universal measuring station – RUMS) S8 Trimble DR Plus ROBOTIC, która używana jest w Wydziale Geodezji uniwersytetu STU w Bratysławie w celach badawczych i naukowych.

Słowa kluczowe: Trimble S8, STN ISO 17123-5, testowanie, stabilność parametrów