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TOPOGRAPHICAL SURVEYING USING SATELLITE MEASUREMENTS AND ASSESSMENT OF PLAN ACCURACY

Abstract: The purpose of the research is to study the methodology and accuracy of large-scale topographic survey based on experimental tests. For this purpose, a typical plot of land was selected for the test. Topographic survey on a scale of 1:500 was carried out using satellite measurements, processed the results and created a digital terrain model. Control measurements were carried out on the plan and on the ground to assess the accuracy of the planned position of the points of the solid contours of the terrain depicted on the plans.

Keywords: GPS receiver, topographic survey, RTK, error, accuracy, DOP.

Introduction. With the continuous growth of the world population, the need for the construction of residential buildings, cultural, domestic, industrial and transport facilities is increasing. To address these issues, the United Nations 2030 Sustainable Development Agenda defines the objectives of "Ensuring openness, safety and environmental sustainability of cities and towns" [6].

The purpose of the research is to study the methodology and accuracy of large-scale topographic survey based on experimental tests. For this purpose, a typical plot of land was selected for the test, on which the following works was carried out: (i) topographic surveys at a scale of 1:500 using satellite measurements, (ii) processing the results, and (iii) creating a digital terrain model; (iv) carrying out control measurements on the plan and on the ground to assess the accuracy of the planned position of the points of solid contours of the terrain depicted on the plans, and the accuracy of the relief image.

Methods. Field measurements, probability theory, mathematical statistics methods were used in the research.

Used instruments. The engineering-topographic survey of the plot of land was carried out using the Stonex S900T GPS receiver. Detailed information about the technical characteristics of the tool can be obtained from [7]. The base GPS Stonex S900T (S902131800713) fixed on the roof of UZGASHKLITI's Tashkent branch building served as the initial reference point for GPS measurements, and GPS Stonex S900T (S902131800700) receivers served as the rover.

Measurements. Before surveying the situation and terrain, the technical feasibility of satellite measurements was studied. Part of the object is an open area where measurements can be taken. The rest of the area is occupied by tall trees and buildings and does not allow for observations. The antenna height was measured using a tape measure, its value was entered through the controller. Particular attention has been paid to the DOP value to ensure accuracy.

After the connection between the receiver and the base station was established, the mobile receiver was placed at characteristic points (pickets) of the area, similar to traditional surveying. The distance between pickets was taken within the values specified in the standard [4] depending on the scale of the survey. GPS measurements were carried out in accordance with the requirements of the relevant regulatory documents [2, 3].

At the experimental site, GPS measurements in RTK mode were completed with observations at a known point. After completing the GPS survey, the measurement results were loaded into the AutoCAD program and a digital topographic plan of the experimental site was created.

For the purpose of assessing the accuracy of engineering-topographic plans, solid contour points were marked on the topographic plan of the tacheometric survey and the length of the segments between them was determined by scale and the lengths of the same lines were measured on the ground (Table 1). The differences module ΔS_i were calculated as follows [5]

$$\Delta S_i = S_{p,i} - S_{g,i}, \tag{1}$$

where $S_{p,i}$ and $S_{g,i}$ are, respectively, the horizontal distances between the contour points measured on the plan and on the ground.

Table 1.

Distances between contour points measured on the plan and on the ground and their difference

No.	Measured distance S, m		Diffe-rences ΔS_i, cm	ΔS_i^2	No.	Measured distance S, m		Diffe-rences ΔS_i, cm	ΔS_i^2
	on the plan	on the ground				on the plan	on the ground		
1	7.411	7.438	-2.7	7.29	21	18.951	18.96	-0.9	0.81
2	33.052	33.085	-3.3	10.89	22	23.382	23.36	2.2	4.84
3	22.232	22.249	-1.7	2.89	23	43.747	43.783	-3.6	12.96
4	23.489	23.473	1.6	2.56	24	45.478	45.473	0.5	0.25
5	21.907	21.891	1.6	2.56	25	31.156	31.196	-4	16
6	37.352	37.441	-8.9	79.21	26	21.613	21.593	2	4
7	8.897	8.906	-0.9	0.81	27	16.407	16.393	1.4	1.96
8	50.57	50.598	-2.8	7.84	28	15.334	15.318	1.6	2.56
9	32.119	32.129	-1	1	29	30.510	30.525	-1.5	2.25
10	34.655	34.689	-3.4	11.56	30	55.204	55.219	-1.5	2.25
11	21.08	21.065	1.5	2.25	31	58.603	58.653	-5	25
12	53.053	53.125	-7.2	51.84	32	50.547	50.502	4.5	20.25
13	56.682	56.66	2.2	4.84	33	58.851	58.956	-10.5	110.25
14	51.515	51.521	-0.6	0.36	34	35.897	35.904	-0.7	0.49
15	46.079	46.042	3.7	13.69	35	36.371	36.344	2.7	7.29
16	20.11	20.07	4	16	36	29.886	29.820	6.6	43.56
17	39.076	39.122	-4.6	21.16	37	36.906	36.802	10.4	108.16
18	35.577	35.608	-3.1	9.61	38	50.977	50.896	8.1	65.61
19	33.754	33.767	-1.3	1.69	39	55.007	54.935	7.2	51.84
20	33.397	33.369	2.8	7.84	40	26.058	26.104	-4.6	21.16
Σ			**-24.1**	**255.89**				**14.9**	**501.49**

Using the data in Table 1, the root-mean-square error of the differences (true error) and a single measurement was found from the following formula

$$m_{\Delta S} = \sqrt{[\Delta S^2]/n}, \tag{2}$$

where n is the number of lines measured on the plan and on the ground.

The normal distribution law is characterized by the distribution density of the random variable Δ [1]

$$\varphi(\Delta)=\frac{1}{\sigma\sqrt{2\pi}}e^{\frac{-(\Delta-a)^2}{2\sigma^2}}. \qquad (3)$$

The main parameters of a normally distributed random variable Δ in expression (3) $a=M(\Delta)$ and $\sigma^2=D(\Delta)$ are found by the following formulas

$$a=M(\Delta)=[\Delta]/n, \qquad (4)$$

$$\sigma(\Delta)=\sqrt{D(\Delta)}\approx m=\sqrt{[\Delta^2]/n}. \qquad (5)$$

Results. According to the table 1, $m_{\Delta S}=\pm 4,35\,cm$ were determined using formula (2). To confirm the reliability of this conclusion, the normal distribution of the series of differences found as a result of double measurements was checked using the laws of mathematical statistics.

Empirical values for constructing a normal distribution curve $\varphi(\Delta)$ were calculated using formulas (4) and (5): $a=-0{,}23$ cm; $m=+4{,}35$ cm.

The study of the distribution of a statistical series begins with the construction of a histogram. Based on the obtained data, an empirical distribution graph (histogram) was created (Fig. 1). The theoretical curve (Fig. 1) that smooths the histogram was built using the values calculated from the formula (3).

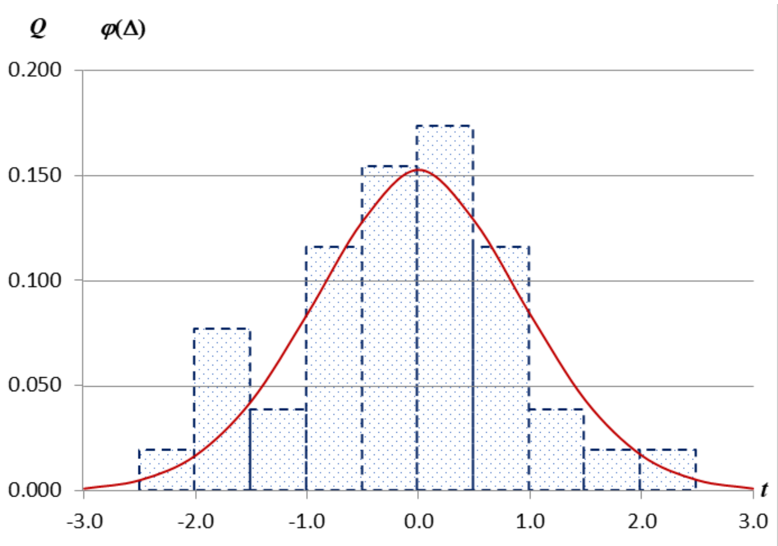

Figure 1. Histogram and theoretical curve

To assess the degree of approximation of the statistical distribution (histogram) to the theoretical normal distribution law (distribution curve), K.Pearson’s χ^2 value was used as a measure of their difference (Table 1).

$$\chi^2=\sum_{i=1}^{k}\frac{\left(m_i-n\,p_i\right)^2}{n\,p_i}. \qquad (6)$$

According to the number of degrees of freedom $r=10$ (k is the number of interval, s is the number of parameters) and $\chi^2=5{,}655$ values obtained from the formula (6), the probability value $p\left(\chi^2\right)=0{,}8416$ was obtained from [1].

Discussions. The root-mean-square error of the image on the plan of GPS-survey in RTK mode of the contours $m_s=\pm 4{,}35$ cm, which is two times more accurate than the standard value of ±10 cm, set for a scale of 1:500. Based on Pearson's χ^2 criterion, the probability of proportionality of empirical and theoretical distributions was $p=0{,}842$. The fact that $0{,}842>0{,}1$ confirms that the series of errors obeys the law of normal distribution.

References

1. Большаков В.Д., Маркузе Ю.И. Практикум по теории математической обработки геодезических измерений. – М: Недра, 1984. – 352 с.
2. ГКИНП (ОНТА)-02-262-02. Инструкция по развитию съёмочного обоснования и съёмке ситуации и рельефа с применением глобальных навигационных спутниковых систем ГЛОНАСС И GPS. М., ЦНИИГАиК, 2002. – 70 с.
3. ГККИНП – 17-079-05 «Инструкция по развитию съёмочного обоснования и съёмке ситуации и рельефа с применением глобальных навигационных спутниковых систем ГЛОНАСС и GPS». Т., НЦГК, 2005. – 69 с.
4. ГККИНП 02-067-03 «Инструкция по топографической съёмке в масштабах 1:5000, 1:2000, 1:1000, 1:500». Т., НЦГК, 2003. – 199 с.
5. Неумывакин Ю.К. Практическое руководство по геодезии для архитектурной службы района. Москва: Недра, 1979. – 168 с.
6. The Sustainable Development Goals // https://www.un.org/sustainabledevelopment/cities/

7. User Manual for Stonex S900T GNSS Receiver. 2018/ https://www.top-sys.de/app/download/15331708124/S900T_User_Manual[ENG].pdf?t=1548665568