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INVESTIGATION OF MEASURING SERIES IN GEODETIC WORKS

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A B S T R A C T	K E Y W O R D S
This article highlights the issues related to the research of measurement series to determine the accuracy of measurement results obtained under certain conditions, and the regularities of the distribution of errors.	Geodetic instruments geodetic tools, true meaning, given accuracy, the distributions of the errors, equal-point and non-equal-point measurements, necessary and redundant measurement, the true error, studies of measurement series, mathematical expectation and standard, blunder, random and systematic errors.

Introduction

Geodesy is the science that studies the shape and size of the earth. Geodetic instruments play a key role in the reliability of the measurement results, but the methods of processing the performed measurements are also important.

By improving the measurement methodology, constructions of measuring instruments and equipment, as well as by improving the qualifications of observers, experience and practice will be a positive factor in reducing the deviation of the results of geodetic measurements from the real value. [1]

In order to determine the accuracy of measurement results obtained under certain conditions and the rules of distribution of errors, research of measurement series is carried out. In this case, an experiment is conducted or the results of production work are analyzed.

The sequence of the studied measurement series may depend on multiple measurements of the same quantity or on several homogeneous quantity measurements performed under approximately the same conditions.

The study begins with a series of studies where the actual values of the measured values are considered for unknown and known values. [1]

General information about measurements

All the quantities used in geodetic work can be divided into measured, i.e. approximate values obtained from the results of measurements, and calculated - i.e. measurements calculated by the function of measured quantities.

Measuring some arbitrary quantity means comparing it to a quantity with the same units of measurement and determining how much of this unit there is.

Measurement results are divided into measurements with equal accuracy and unequal accuracy.

We can take examples of measurements with equal accuracy, measuring horizontal or vertical angles with theodolites of the same accuracy, with the same method and the same number of points, and measuring triangulation angles of the same class with equal accuracy.

Examples of measurements that do not have the same accuracy are measuring angle values with the same method and the same values of inputs with different precision equipment, and measuring angle values with the same method and the same precision equipment with different values of values. we can get In complex cases, whether the measurements have equal precision or not have equal precision is evaluated by numerical precision criteria obtained from experience. [1]

Measurement errors . Any measurements are subject to errors. Deviation of the measurement results from the actual value happens differently every time.

From the total factors affecting the measurement results, i.e. from the effects *of the measured object, observer, tools and equipment, external environment, measurement conditions* , the fluctuations in the measurement results are constant. we can say that it reflects the measurement conditions.

The difference between the measured value and the true value of the measurand is *the measurement error* , often called *the true error* [1-5].

$$\theta_i = x_i - X \quad \textbf{(1)}$$

Classification of measurement errors . Measurement errors are divided into "instrumental", external or environmental and personal types according to their source of origin.

This classification (classification) is of great importance for *the sciences that study equipment and measurement methods* . *For the theory of measurement errors*, this (classification) is of secondary importance. An important place in the theory of measurement errors belongs to the classification (classification) of errors according to the laws of their occurrence .

A gross error . The theory of mathematical processing of measurements does not take into account gross errors that occur due to mistakes or incorrect calculations of the observer, malfunctions of equipment and devices, sudden changes in external environmental conditions, etc. Measurement results containing gross errors are identified and must be discarded.

Random and systematic errors . From the set of elementary errors in the component of the total error of measurements, errors are divided into two main categories: *random and systematic* .

Since elementary errors tend to change their value during repeated measurements , in turn, we can consider them as values of random variables with distribution parameters - *mathematical expectation and "standard"* .

errors , which represent the values of random variables with mathematical expectation , are very small differences from zero *random data* is called

Elementary errors representing the values of random variables with mathematical expectations significantly different from zero are called *systematic errors* . [6-10]

Measurement accuracy criteria.

m* - *mean square error is adopted as the main feature of measurement accuracy , its exact value corresponds to the following expression

$$m = \sqrt{m_{\Delta}^{2} + m_{\delta}^{2}} \qquad \textbf{(2)}$$

The root mean square error ***m of one measurement*** is characterized by the combined effects of [1]- random error and -systematic error m_{δ} of measurement . m_{Δ}

METHODS . Survey of measuring lines .

In order to determine the accuracy of the measurement results obtained under certain conditions and the laws of distribution of errors, the research of the *measurement series* is carried out. In this case, the experiment is conducted or developed release the results of their work are analyzed.

studied *measurement series* may depend on multiple (several) measurements of the same quantity or on several homogeneous measurements performed under approximately the same conditions.

If the true values of the measured values are unknown, then it is possible to estimate the effect of random errors from the study of a series of measurements, whose parameters are characterized by deviations of the measurement results from the arithmetic mean. In this case, the effect of systematic errors cannot be fully determined.

If the true values of the measured values are known, then the first consideration is to start with the study of the true errors of the measurements.

To determine which measurements contain gross errors, m it is necessary to know the root mean square error of a single measurement.

$$m_{m}^{2} = m_{\Delta}^{2} + m_{\delta}^{2} \qquad (3)$$

here, m_{Δ} - mean squared error characterizing the effect of random errors;

m_{δ} - root mean square error characterizing the effect of systematic errors.

In this case, $3m$ the mean squared error rule is accepted on the absolute value of errors $3m$ *Errors greater than* are considered gross errors. $3m$ the value is called ***the permissible limit (limit) error*** . If the root mean square error m is unknown, then coarse error detection is performed as follows.

1. From the series of true errors θ_i, the arithmetic mean value $\bar{\theta}$ ini is calculated in the following expression

$$\bar{\theta} = \frac{\sum_{i=1}^{n} \theta_i}{n} (i = 1,2,...,n) \qquad (4)$$

and the deviation is calculated by the following expression

$$\xi_i = \theta_i - \bar{\theta} \, . \, (5)$$

We take into account that

$$\xi_i = x_i - \bar{x}$$

here, x_i - measurement results, $\bar{x}$ while $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ to equal to In fact, X we denote the measured quantity by its true value and write as follows

$$\theta_i - \bar{\theta} = (x_i - X) - \frac{\sum (x_i - X)}{n} = (x_i - X) - (\bar{x} - X) = x_i - \bar{x}.$$

2. The approximate value of the mean squared error is calculated by the following expression

$$m_\Delta = \sqrt{\frac{\sum_{i=1}^{n} (\xi_i)^2}{n-1}}. \quad (6)$$

3. "finite error" is obtained, i.e

$$\xi_{chekli} = 3m_\Delta$$

greater than the values of ni ξ_i in absolute values ξ_{chekli} indicates the presence of gross errors; all measurement dependent results are analyzed and $\xi_{чеклu}$ measurement results greater than the "limit error" value are discarded*.

Then, according to the formula (6), the m_Δ final value of the root mean square error of random errors is calculated using the sorted measurement results [11-15]. The obtained m_Δ quantity is ***the quantity characterizing the random error of one measurement*** .

m_σ As for the (systematic errors mean square deviation) parameter, to obtain its reliable values, it is required to obtain a large number of measurements in various complex conditions and a range of true errors. Received errors suitable coming to complex conditions divided into groups according to For each group of errors, the arithmetic $\overline{\theta_i}$ mean is calculated and δ treated as the exact values of the random variable. Then we get the following expression

$$m_\sigma^2 \approx \frac{\sum_{j=1}^{K} (\overline{\theta_j})^2}{K} \quad (7)$$

where, K-complex conditions ga number of matching groups.

To analyze the reliability of the characteristics of the effect of systematic errors, $\theta_{o'rtacha}$ it is necessary to calculate the general arithmetic mean of the errors, i.e.

$$\theta_{o'rtacha} = \frac{1}{K} \sum_{i=1}^{K} \overline{\theta_j}.$$

The following inequality

$$\theta_{o'rtacha} < \frac{m_\sigma}{\sqrt{K}} \quad (8)$$

is one of the factors indicating that various complex conditions are good enough. [1]

RESULTS . *An example.*

32 triangles in Table 1.1 non-binding error given. Non-binding mistakes normal distribution of the series research do it [9]

Real value 180^0 to equal to has been triangles internal corners the total measured not to be attached because of size error $f_i = \sum_{i=1}^{3} \beta_i - 180^0$ the real error Δ_i to be considered s can.

Normal distribution to the law according to $\{\Delta_i\}$ non-binding line research to do we will do it .

Table 1

No	Non-binding error Δ_i	No	Non-binding error Δ_i	No	Non-binding error Δ_i	No	Non-binding error Δ_i
1	-0.76	9	+1.29	17	+0.71	25	+0.22
2	+1.52	10	+0.38	18	+1.04	26	+0.06
3	-0.24	11	-1.03	19	-0.38	27	+0.43
4	+1.31	12	0.00	20	+1.16	28	-1.28
5	-1.27	13	-1.23	21	-0.19	29	-0.41
6	-1.88	14	-1.38	22	+2.28	30	-2.50
7	+0.01	15	-0.25	23	+0.07	31	+1.92
8	-0.69	16	-0.73	24	-0.95	32	-0.62

Key in order research to do our performance for necessary was the following they gathered line identify we can

$$\sum(\Delta_i \rhd 0) = +12.40 \qquad \sum(\Delta_i \lhd 0) = -15.79 \quad [\Delta] = -3.39 \qquad [|\Delta|] = 28.19$$

$$[\Delta^2] = 38.75;\ [\Delta^3] = (-34.41 + 30.03) = -4.38;\ [\Delta^4] = 120.70$$

Solution :

1. ***Curvature density*** $\varphi(x) = \frac{1}{\sigma_x^* \sqrt{2\pi}} e^{\frac{-(x-M_x^*)^2}{2\sigma_x^{*2}}}$ ***in the form of equation through defined , normal distribution*** M_Δ ***and*** σ_Δ ***parameters assessment count*** :

$$M_\Delta = \frac{[\Delta]}{n} = \frac{-3.39}{32} = -0.106''*$$

$$\sigma_\Delta = m = \sqrt{\frac{[\Delta^2]}{n}} = \sqrt{\frac{38.75}{32}} = 1.10''.$$

*** M_Δ mathematician don't wait assessment from scratch difference with is coming Permanent systematic the error determination for the following criterion acceptance we do :**

$$|M_\Delta^*| \le t\sigma_\Delta^* / \sqrt{n}$$

this on t the ground (in n>30), $\beta = \Phi(t)$ probability with Annex B from the table is selected .

$\beta = 0,95$ **for the following** $t = 1,96$ **and** $t\sigma_\Delta^* / \sqrt{n} = 1,96 \times 1,10'' / \sqrt{32} = 0,38''$ **s let's find out .**

Calculations from the results apparently as it is criterion in progress , so by doing $\left|M_{\Delta}^{*}\right| = 0,106'' < 0,38''$ inequality own instead of have , therefore for constant systematic the error account not get and $M_{\Delta}^{*} = 0$ we consider that can.

2. ***Average error ϑ^{*} and his coefficient $k_{1_{amaliy}}$ s count*** :

$$\vartheta^{*} = \frac{[|\Delta|]}{n} = \frac{28.19}{32} = 0.88'';$$

$$k_{1_{amaliy}} = m/\vartheta* = 1.10 \big/ 0.88 = 1.25;$$

$$k_{1_{nazariy}} = 1.25.$$

3. ***Probable error r^{*} and his coefficient $k_{2_{amaliy}}$ count***

$r*$ the determination for real errors line absolute value according to in growth the following to the table we place :

Table 1.2

+0.00	+0.01	+0.06	+0.07	-0.19	+0.22	-0.24	-0.25	+0.38
-0.38	-0.41	+0.43	-0.62	-0.69	+0.71	-0.73	-0.76	-0.95
-1.03	+1.04	+1.16	-1.23	-1.27	-1.28	+1.29	+1.31	-1.38
+1.52	-1.88	+1.92	+2.28	-2.50				

We find :

$$r^{*} = \frac{|\Delta_{16}| + |\Delta_{17}|}{2} = (0.73'' + 0.76'') \big/ 2 = 0.74''$$

$$k_{2_{amaliy}} = \frac{m}{r*} = 1.10'' \big/ 0.74'' = 1.49$$

$$k_{2_{nazariy}} = 1.48.$$

4. ***Statistics grouped line build :***

in table 1.1 12 non - binding interval (interval) g a (interval the length medium quadratic of error by half equal to that acceptance we will :) $0,5m = 0.55''$ place (Table 1.3).

Table 3

Inter-liqs No	interval (interval) m lengths in shares	Interval lengths _ in seconds $\Delta_i = t_i m$	Errors number of m_i	Frequencies $Q_i = \frac{m_i}{n}$	That's right corners height $h_i = \frac{Q_i}{(0,5m)}$
1	2	3	4	5	6
1.	-3.0 m -2.5 m	-3, 3 0 -2, 7 5	0	0	0
2.	-2.5 m -2.0 m	-2, 7 5 -2, 2 0	1	0.031	0.056
3.	-2.0 m -1.5 m	-2, 2 0 -1, 6 5	1	0.031	0.056
4.	-1.5 m -1.0 m	-1, 6 5 -1, 1 0	4	0.125	0.227
5.	-1.0 m -0.5 m	-1, 1 0 -0.55 _	6	0.188	0.342
6.	-0.5 m 0	-0.55 0	5	0.156	0.284
7.	0 +0.5 m	0 +0.55	7	0.219	0.398
8.	+0.5 m +1.0 m	+0.55 +1.10	2	0.062	0.113
9.	+1.0 m +1.5 m	+1.10 +1.65	4	0.125	0.227
10.	+1.5 m +2.0 m	+1.65 +2.20	1	0.031	0.056
11.	+2.0 m +2.5 m	+2.20 +2.75	1	0.031	0.056
12.	+2.5 m +3.0 m	+2.75 +3.30	0	0	0
$\sum$		$\sum$	32	1,000	-

this table m_i, ***in the i*** -interval happen divisor errors the number means him initial data from table 1.1 directly counting is taken [16-20].

If any of error value intermediate to the limit suitable if it comes , then such the error theoretical in terms of more errors the number occurring the same that's it to the interval placing need.

5. **Normal distribution histogram and curvature density build** :

From columns 2 and 6 of Table 1,3 using of distribution histogram-empirical distribution draw (scale conditional is selected).

From the histogram Δ_i normal distribution of errors legality suitable to come let's see can _ that best corrects (smooths) the given statistical distribution is the following equation defined by :

$$\phi(\Delta) = \frac{1}{m\sqrt{2\pi}} e^{-\frac{\Delta^2}{2m^2}} = hy$$

this on the ground

$$m = \sigma_\Delta^* = 1.10'';$$
$$M^*(\Delta) \approx 0$$
$$t = \frac{\Delta}{m}; h = \frac{1}{m\sqrt{2}}; y = \frac{1}{\sqrt{\pi}} e^{\frac{-t^2}{2}}$$

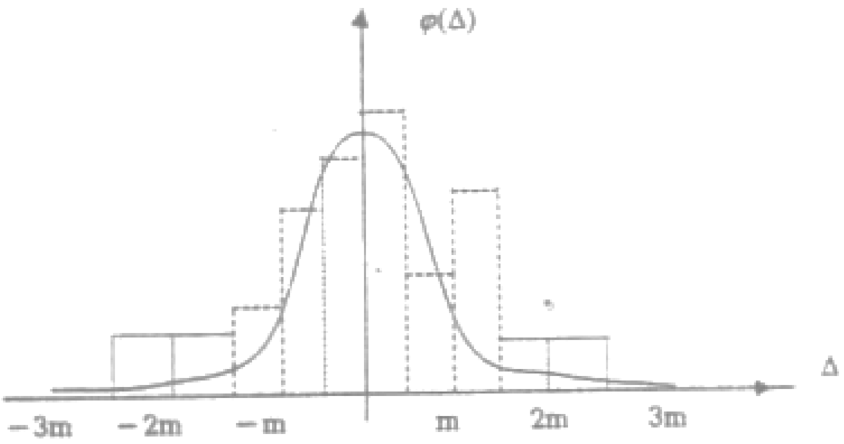

Figure 1.1. Histogram and $\phi(\Delta)$ of straightener curvature

A in the app given from the table using $\phi(\Delta)$ of curvature ordinate calculations we will do it .

For example ,

$y_2 = \frac{1}{\sqrt{\pi}} e^{-\frac{t_i^2}{2}}$ of value $t_2 = \frac{\Delta_2}{m} = \frac{0.5m}{m} = 0.5$ at ***A*** in the application given from the table using 0.498

_ we can $h_i = \frac{1}{m\sqrt{2}} = \frac{1}{1.10''\sqrt{2}} = 0.645$ get we can and finally

$$\phi(\Delta_2) = h_2 y_2 = 0.498 \times 0.645 = 0,32121 \approx 0,321$$

A app $t = \frac{\Delta}{m}$ **to the argument according to** $y = \frac{1}{\sqrt{\pi}} e^{\frac{-t^2}{2}}$ **of size schedule**

±t	Y	±t	Y	±t	y	±t	Y	±t	y
0,0	0,564	0,6	0,472	1,2	0,275	1,8	0,112	2,4	0,032
0,1	0,561	0,7	0,441	1,3	0,242	1,9	0,093	2,5	0,025
0,2	0,553	0,8	0,410	1,4	0,212	2,0	0,076	2,6	0,019
0,3	0,539	0,9	0,376	1,5	0,183	2,1	0,062	2,7	0,015
0,4	0,521	1,0	0,342	1,6	0,156	2,2	0,050	2,8	0,011
0,5	0,498	1,1	0,308	1,7	0,133	2,3	0,040	2,9	0,008
								3,0	0,006

Calculation the results 1. Place in table 4 .

From columns 2 and 6 in Table 1.4 using form 1.1 $[\Delta_i, \varphi(\Delta_i)]$ points line put we go out and that's it dotkal arni flat curve line with let's connect . Of curvature left side too that's it coordinates according to _ we build

From the chart apparently as $\phi(\Delta)$ curvature the histogram satisfactory is leveling .

Research to do from the results see outgoing Δ_i - real errors line , in fact too normal to the law approx submissive random errors row the fact that about to the conclusion we will come That's why for :

1) Given series for random of mistakes the following features running :

a) Medium arithmetic value $M^*(\Delta)$ in practice to zero equals (this measure results systematic from mistakes case that shows);

b) Negative and positive Δ errors absolute value according to equal to , given in line approx one different appearing (in the histogram) ;

d) absolute value according to small Δ mistakes , to adults relatively more happen is happening (to the histogram see);

e) at the given probability b Δ random errors , identified $t \times m$ to equal to has been happened in the interval it won't be . Given in line one $\Delta_{chekli} = 3m = 3{,}30''$ to equal to finite from error more than has been error there is it's not .

2) $k_{1_{amaliy}}$ and $k_{2_{amaliy}}$ coefficients their own theoretical values to ($k_1 = 1.25;\ k_2 = 1.48$). suitable is [9] coming

1. Table 4

Order number	Limits of intervals _ _ _ Δ_i	$t_i = \frac{\Delta_i}{m}$	$y_i = \frac{1}{\sqrt{\pi}} e^{-\frac{t_i^2}{2}}$	$h_i = \frac{1}{m\sqrt{2}}$	$\varphi(\Delta_i) = h_i y_i$
1	0	0	0.564	0.645	0.364
2	0.5 m	0.5	0.498	0.645	0.321
3	1.0 m	1.0	0.342	0.645	0.220
4	1.5 m	1.5	0.183	0.645	0.118
5	2.0 m	2.0	0.076	0.645	0.049
6	2.5 m	2.5	0.025	0.645	0.016
7	3.0 m	3.0	0.006	0.645	0.004

CONCLUSION

The specific goals of researching measurement series are as follows: ***firstly*** , to eliminate gross errors (sorting), ***secondly*** , to determine the accuracy of one measurement and, if possible, the characteristics of systematic (systematic) effects. and, finally , ***thirdly*** , to determine the criteria of conformity with the law of normal distribution. We should not forget that the first and second tasks are closely related need[1].

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