Using the fundamentals of the theory of measurement errors in performing geodesic measurement and calculation works

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Abstract.

In this article, the tasks of the theory of measurement errors during geodetic measurement and calculation practices, equal and unequal measurements and measurement errors, i.e. deviations from the actual values of the measured quantity as a result of measurement issues aimed at elucidating the work and their classifications are covered. Also, the criteria of measurement accuracy, expressions for their determination, as well as the procedure for processing one quantity measured with equal accuracy and a sample example of its implementation are given.

1 Introduction

Measurements play a very important role in all fields of technology, they provide basic information for exact sciences. Measurements are the main content of all works performed for the purpose of studying the surface of the cartographic and geodetic zone. Geodesy is an ancient science, which was created according to the requirements of people's living conditions and continues to develop in accordance with it. So, measurement practices in this science also go back to ancient human societies. The peoples of ancient Egypt, India, Central Asia, and other countries used measurement to solve issues necessary for irrigation networks, construction of various buildings, distribution of cropland, and similar needs.

Thinkers who lived in the 9th - 10th centuries - Al-Khorazmi, the author of the book "The Image of the Earth" and the founder of the science of algebra, Al-Farghani, the astronomer and geodesist, the author of the books "The Art of Astrolabia" and "The Basics of Astronomy" and "Geodesiya The author of the work, the encyclopedist Abu Rayhan Beruni, made a great contribution to solving the above problems in geodesy.

The measurement of any value is considered from two points of view: quantitative - representing the numerical value of the measured value and qualitative - representing the accuracy of the measurement. With the development of science and technology, especially geodesy, the accuracy of measurements increases and the methods of their mathematical processing are improved.

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There should be no gross errors in the measurements - no errors or miscalculations. In geodetic practice, at least two measurements of each value are always performed to determine the result, and in addition, mathematical relationships between the measured values are used. It is known from experience that multiple (repeated) measurements of any constant quantity, even with the most care and accuracy, always give different results and mathematically related quantities, i.e., measurement result differences will generate a no-connection error. The difference between the results of repeated measurements and the order of magnitude of the differences should correspond to the accuracy of the measurements, which indicates the absence of gross errors in the measurements. It is necessary to pay special attention to the issue of measurement accuracy and their mathematical processing. Excess measurements lead to an increase in the volume and time of work and an increase in their cost. Therefore, the problem of determining the appropriate, i.e., necessary and sufficient, accuracy of measurements and processing their results arises. The theory of mathematical processing of geodetic measurements, the quality of geodetic measurements, the occurrence of inevitable small errors and the laws of motion, the development of calculation rules for the assessment and calculation of the necessary accuracy, as well as calculation methods that allow obtaining the best final results with the economic expenditure of computational labor and related ways.

2 Discussion

2.1 Tasks of the theory of measurement errors

The main tasks of the theory of measurement errors are as follows: establishing the specified criteria, developing methods for obtaining and evaluating the criteria.

2.2 General information about measurements

All quantities used in geodetic work can be divided into measured and calculated measurements, that is, their approximate values are obtained as a result of measurements or calculated using the function of measured values. Quantification is the comparison of two quantities with the same units of measurement and the determination of how much of that unit there is. According to the accuracy of the measurement results or depending on whether the measurement conditions change or not, measurements are divided into measurements with equal accuracy and measurements without equal accuracy.

In the mathematical processing of measurements, the concepts of necessary measurements and excess measurements play an important role.
2.3 Measurement errors

As mentioned above, any measurements are accompanied by errors, that is, the deviation of the values of the measurement results from the true values of the measured quantity. These errors occur in the measurement process, in addition to the object being measured, the observer-measurer, measuring instruments and equipment, and the external environment. These complex conditions are constantly changing, and it is impossible to account for these changes without errors. Therefore, the deviation of the measurement results from the actual value happens differently every time.

The reflection of the fluctuations in the measurement results, which are among the total factors that appear in the measurement results, are permanent changes in the measurement conditions.

The actual value of the measured quantity by $X$, and the measurement result $x_i$ by $	heta (D) = x_i - X$. Having a large number of real errors in measurement, we can study the laws of their occurrence.

The results of the measurement of one quantity can be considered as discrete values of some continuous random variable obeying the law of normal distribution. At the same time, to describe the characteristics of the measurement results, it is necessary to know the main distribution parameters of the indicated random variable: mathematical expectation (arithmetic mean) and standard (mean squared deviation).

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

A gross error. The theory of mathematical processing of measurements does not take into account gross errors caused by mistakes or miscalculations of the observer, malfunctions of equipment and devices, sudden changes in external environmental conditions, etc.

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.

Elementary errors that represent the values of random variables with a mathematical expectation that differs very little from zero are called random errors.

Elementary errors, which are values of random variables with mathematical expectations significantly different from zero, are called systematic errors.

2.4 Measurement accuracy criteria

To assess the accuracy of measurements of certain quantities, it is necessary to determine the possible deviations of the measurement results from the actual value of this quantity. The deviation of the measured value of a certain quantity from its actual value is expressed in two different quantities: the deviation of the measured value from the mathematical expectation.
- The deviation of the mathematical expectation from the actual value

\[ m = \sqrt{m_\Delta^2 + m_\delta^2} \]

of one measurement

\[ m_\Delta = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}} \]

\[ m_\delta = \sqrt{m - m_\Delta} \]

2.5 Survey of measuring lines

Measurement series research are, firstly, to eliminate gross errors, secondly, to determine the accuracy of a single measurement and, if possible, to identify the characteristics of systematic effects, and finally, to obtain a normal distribution.

2.6 Procedure for processing a single quantity measured with equal precision

From the arithmetic mean \( \bar{x} - x \) the deviation

\[ v_i = \bar{x} - x_i \]

\[ [v_i] = \bar{x} - n[x] \]
Therefore, according to the last equation obtained

$$\bar{x} n = \frac{[x]}{n} n = [x]$$

In practice, the calculation of the arithmetic mean is usually obtained by rounding it to a given decimal unit. Therefore, the equality (IV.7) does not hold exactly.

The correction magnitude is found by rounded values, i.e.

$$\Delta = \bar{x} - \bar{x}$$

Summing all the values of , we get the following known, then

$$\Delta x = \sum x_i$$

where, 

$$- \text{ is some (exactly chosen) rounded value, which is chosen in such a way that it is in all small positive numbers.}$$

In that case, we get the following formulas to control the calculation of deviations.

We can simplify the arithmetic calculation in the following way.

$$x_i = x - \varepsilon_i$$

$$\varepsilon_i = x - x$$

$$\bar{x} = \frac{[x]}{n} = x + \frac{[\varepsilon]}{n}$$

$$\varepsilon_i = x - x$$

$$\varepsilon_i = x - x$$
and finally we get the following

\[ [v^+] = [e^+] + n \frac{[e]}{n} - \frac{[e]}{n} \]

\[ [v^+] = [e^+] - \frac{[e]}{n} \]

\[ \overline{x} = x + \frac{[e]}{n} \]

\[ \Delta = \overline{x} - \overline{x} \]

\[ e_i = x_i - x \]

\[ n \]

\[ \Delta_0 = \Delta \]

\[ v = \frac{[e]}{n} \]

\[ m_\Delta = \sqrt{\frac{[v^+]}{n}} \]

\[ M_\Delta = \frac{m_\Delta}{\sqrt{n}} \]
2.7 An example of processing a single measured quantity

The results of measuring one angle with equal accuracy in two complex conditions (morning and evening) are given (Table 1): the number of measurements is \( n = 9 \).

### Table 1. Results of measuring one angle with equal accuracy in two complex conditions

<table>
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<tr>
<th>Measurement results ( x_i )</th>
<th>( \varepsilon_i )</th>
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\[
M = \sqrt{M^2_{\Delta} + M^2_{\delta}} = \sqrt{\frac{m^2_{\Delta}}{n} + \frac{m^2_{\delta}}{K}}
\]
4 Conclusion

With the development of science and technology, especially geodesy, the accuracy of measurements increases and the methods of their mathematical processing are improved. There should be no errors or miscalculations in measurements. In geodetic practice, at least two measurements of each value are always performed to determine the result, and in addition, mathematical relationships between the measured values are used. The theory of mathematical processing of geodetic measurements, the quality of geodetic measurements, the occurrence of inevitable small errors and the laws of motion, the development of calculation rules for the assessment and calculation of the necessary accuracy, as well as the calculation methods that allow obtaining the best final results with the economic expenditure of computational labor and related ways.

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