Measurement 126 (2018) 65–71

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

The new concepts of measurement error's regularities and effect characteristics

Ye Xiaoming[a,b,*], Liu Haibo[c,d], Xiao Xuebin[e], Ling Mo[c]

[a] School of Geodesy and Geomatics, Wuhan University, Wuhan, Hubei 430079, China
[b] Key Laboratory of Precision Engineering & Industry Surveying, State Bureau of Surveying and Mapping, Wuhan, Hubei 430079, China
[c] Institute of Seismology, China Earthquake Administration, Wuhan, Hubei 430071, China
[d] Wuhan Institute of Earthquake Metrological Verification and Measurement Engineering, Wuhan, Hubei 430071, China
[e] Wuhan University Library, Wuhan, Hubei 430079, China

ARTICLE INFO

Keywords:
Measurement error
Function model
Random model
Error's regularities
Uncertainty

ABSTRACT

In several literatures, the authors give a new thinking of measurement theory system based on error non-classification philosophy, which completely overthrows the existing measurement concept system of precision, trueness and accuracy. In this paper, by focusing on the issues of error's regularities and effect characteristics, the authors will do a thematic interpretation, and prove that the error's regularities actually come from different cognitive perspectives, are also unable to be used for classifying errors, and that the error's effect characteristics actually depend on artificial condition rules of repeated measurement, and are still unable to be used for classifying errors. Thus, from the perspectives of error's regularities and effect characteristics, the existing error classification philosophy is still incorrect; and an uncertainty concept system, which must be interpreted by the error non-classification philosophy, naturally becomes the only way out of measurement theory.

1. Introduction

In several literatures [1–3], the authors give a new thinking of measurement theory system based on error non-classification philosophy. The main logic of this thinking is briefly introduced as follows:

The concept of error is defined as the difference between the measurement result and its true value. Because the measurement result is unique, and the true value is also unique, so the error of the measurement result is the only unknown and constant deviation.

For a final measurement result, the constant deviation consists of two parts: 1, the deviation Δ_A between the final measurement result and mathematical expectation, which is the so-called random error in existing theory; 2, the deviation Δ_B between mathematical expectation and true value, which is the so-called systematic error in existing theory. Because both deviations are unknown and persist constant deviations, and do not have any difference in characteristics, therefore, having no characteristic difference must not cause any classification difference!

The standard deviation of deviation Δ_A is given by the statistic and analysis of current measurement data. The deviation Δ_B is also produced by measurement; its formation principle is actually the same as the current measurement; its standard deviation can be obtained by tracing back to its upstream measurement. Thus, the standard deviation of total error of final measurement result is equal to the synthesis of the two standard deviations according to the probability laws. This total standard deviation is uncertainty, which is the evaluation of the probable interval of the error of final measurement result (this give a more clear meaning to the uncertainty concept).

This constant deviation theory is completely opposite to the random variation theory of existing measurement theory, that is, in the opinion of the authors, it is obviously illogical that existing measurement theory interpret deviation Δ_A as precision but interpret deviation Δ_B as trueness, and the error classification definition and all the concepts of precision, trueness and accuracy should be abolished.

For example: in 2005, the Chinese surveying and Mapping Bureau gave that the elevation result of Mount Everest is 8844.43 m with standard deviation of ± 0.21 m. According to existing error classification theory, from the perspective of error's definition, the error of this result is a single constant deviation and should be classified as systematic error; however, from the perspective of standard deviation ± 0.21 m, it should be classified as random error. This is the logical trap of existing error classification theory. And the interpretation, according to error non-classification theory, is that this result's error (the difference between the result and the true value at implementing measurement) is an unknown constant, and that the standard deviation of ± 0.21 m is only the evaluation of the probable interval of the unknown

* Corresponding author at: School of Geodesy and Geomatics, Wuhan University, Wuhan, Hubei 430079, China.
E-mail address: xmye@sgg.whu.edu.cn (H. Liu).

https://doi.org/10.1016/j.measurement.2018.05.045
Received 28 April 2017; Received in revised form 3 May 2018; Accepted 10 May 2018
Available online 14 May 2018

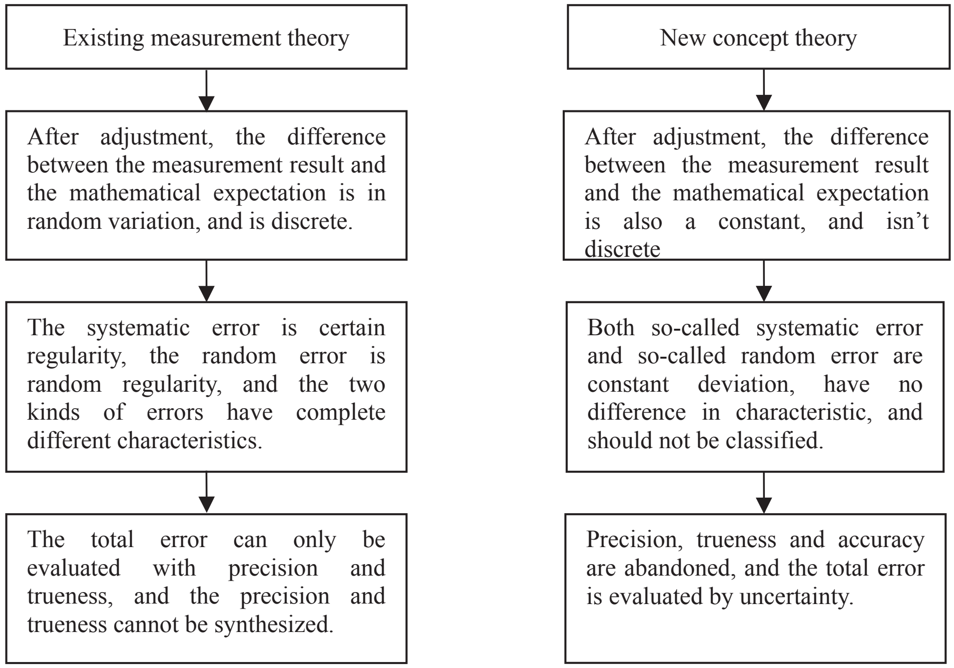

Fig. 1. The comparison of two theory's logic.

constant error. That's it.

The difference between the new theory and the existing theory is shown in Fig. 1.

Please note that the authors' emphasize on the concept of constant deviation is to focus on the measurement result instead of the original observation values before forming final measurement result. Of course, the authors recognize that there may be indeed a discrete error sample sequence before the measurement result is formed. However, these discrete error samples, which have certain numerical value, are the measured values of errors. They belong to the measurement result, and naturally cannot be mixed with the unknown error of final result to discuss the error classification. In addition, the dispersion and deviation of error sample sequences actually depend on the conditions of repeated measurements (Circuit noise is also a condition), naturally cannot be used to prove that the error can be classified.

The core difference between the two theories is, the existing theory considers that the error can be classified into systematic error and random error, while the new theory holds that the error has no systematic and random classification. Although document [1] has mentioned that the regularity and influence characteristics of errors cannot be used for classifying errors, the relationship between regularity and randomness, the formation mechanism of error's influence characteristics and related applications have not been interpreted in detail. Therefore, this paper will make a detailed interpretation on the regularity and influence characteristics of error.

2. Error's regularity

The concept of error is the difference between the measurement result and its true value. The error must be a constant deviation, that is to say, any single error is a constant.

The task of measurement theory is to study the methods of reducing and evaluating error. From the unknown and constant characteristics of single error, this task naturally faces difficulty. However, before the final measurement result is formed, our measurement is usually repeated, and there will be many error samples. When we observe a group of error samples, the errors can show some regularity, including certain regularity and random regularity. This provides paths for reducing and evaluating error: by certain regularity we can design some methods for compensating and correcting error; by random regularity we can design the statistic method for reducing error and obtain the evaluation method of error.

That is, the issue of error's regularity is actually aimed at a group of error samples before the final measurement result is obtained, instead of single error after the final measurement result is obtained.

However, it is important to note that the error's certain regularity and random regularity are actually from different perspectives. They are different error processing methods, and naturally cannot be used to achieve error classification. The same kind of error can be processed according to certain regularity, and also can be processed according to random regularity. There is still not error's classification issue according to certain regularity and random regularity. These are also the ideas from the new theory, which is totally different from the existing measurement theory.

For example: the measured frequency values of a quartz crystal at different temperatures are shown in Table 1.

According to Table 1, to observe the error values alongside the temperature values, we can get the certain regularity as shown in Fig. 2. However, the error value is observed alone, we can get random regularity as shown in Fig. 3.

Table 1
The measured frequency values of a quartz crystal at different temperatures.

Temperature (°C)	Frequency (MHz)	Error value $R_i = \Delta f_i/f_0 (\times 10^{-6})$
−40	4.999900	−30
−30	4.999975	−15
−20	5.000040	−2
−10	5.000085	7
0	5.000115	13
10	5.000110	12
20	5.000070	4
30	5.000035	−3
40	5.000010	−8
50	4.999995	−11
60	4.999995	−11
70	5.000010	−8
80	5.000045	−1
90	5.000125	15
100	5.000235	37