

MEASUREMENT THEORY: VIEW FROM METROLOGICAL PRACTICE

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Abstract – Measurement theory is developed as partial theory of uniform quantities group measurement and as general measurement theory. In contrast to this, the applied metrology has to ensure the quality of practical measurements supporting industrial, technical, or research activity. The mission of the measurement theory is to serve as a base for applied metrological methods and procedures. But actually the measurement theory pays just a little attention to the practical problems, and affects weakly and indirectly the applied metrology. General measurement theory has the abstract measurement equation as its object and studies special kinds of the equation. Partial measurement theory addresses to metrological measurements, which serve for unit transportation from reference standard to measuring instrument. This transportation goes on during normal conditions. Applied metrology problems are connected with that it is impossible to realize the unit with the necessary accuracy in any unique measurement act because of affecting object peculiarities and/or measurement conditions. So, there are two general methodical problems arising in practice: (i) to realise unit in the conditions different from the normal ones, and (ii) to compare the unit with the inherent characteristic of real object, which is quite different from the abstract general model of the physical quantity. So the approach to uniformity of measurements, which is alternative to the traditional one, is to use “reference object” and to certificate it metrologically under the working conditions.

Keywords: measurement object, conditions, reference object

1. INTRODUCTION

Relations between science and its application are generally not simple. Abstract models are designed and used by scientific theory to study real objects. Actually, all scientific statements are referred to the models but not to real objects. Therefore it is especially important to formulate the scientific task as closely as possible to the corresponding practical problem. In other words, the problems under solving in the context of scientific theory must be generated not only by theory itself but by practice as well.

Natural sciences are abstracted from practice long ago so the problem of disagreement between practical demands and theoretical answers could be seen as usual one. But natural sciences have accumulated so many results as the problem is not so acute one.

In contradiction to natural sciences, metrology is the synthetic, or complex, discipline yet. In other words, it could

be anticipated that the theoretical and practical parts of metrology are joined inseparably. Then tasks under theoretical solving would be come in directly from measurement and metrological practice.

Unfortunately we have a completely different situation in modern metrology, theory and application spheres of which usually are kept apart. Actually there is no such cooperation as it is necessary due to organizational reasons and the tradition. The real situation is discussed later. Basically the case in point is measurement practice associated with utilisation of completed measuring instruments, so instrumentation problems will be omitted in the discussion.

2. THE MAIN THEORETICAL TOPICS

First of all we may recognize that there is, in metrology, the evident division a theoretical sphere into two parts, or topic groups.

The one group covers properly metrology topics. They are: (a) theory of units; (b) the teachings of scales; (c) theory of etalons; (d) traceability theory; (e) the teachings of metrological systems.

The other group of theoretical topics includes topics integrated into the measurement theory.

The above-mentioned situation have been illustrated earlier by the IMEKO structure including TC8 “Metrology” and TC7 “Measurement theory” [1]. Now, there is another division of topics between these committees: TC7 “Measurement science” and TC8 “Traceability in metrology” [2]. But the examples of papers presented in TC8 [3, 4] show that the topic division is illusory.

As for properly metrological topics, relevant problem statements and methodology of its solution are based on the following main idea. To ensure measurement uniformity, i. e., to regularize corresponding practical actions, the special, metrological, system is overbuilt “above the practice”. The system is constructed according to plan and so conditions of solution of arising partial tasks are under our full control. If it is necessary for effective solution, the conditions and even problem statement would be changed. In other words, the metrological situation on the whole is under our absolute management. The theory of units could be served as an example of the above-mentioned statement, which theory elaborates foundation for one or other decision, which is accepted, however, by agreement.

Measurement theory is developed in two forms: (a) partial theory, whose object is the measurement of uniform quantities group; (b) general theory, which addresses to measurement as a cognitive act disregarding the physical nature of the measurand.

Partial measurement theory is interested, in the first line, in principles and methods of measurement.

Here, we are essentially dealing with study of physical or physico-chemical (if it has to do with analytic measurements) basics of signal transformations and their system integration to form the measurement method. Users of theoretical results are, in the first line, instrument designers, which aim to actualize, in engineered measuring instruments, transformations outlined. Measurement peculiarities are indubitably taken into account in the process of the methods elaboration. But by virtue of inescapable abstracting actual measurement situations, it can be said about some basic list of typical methods. Of course, this list is far from to be in position to exhaust all possible situations.

General measurement theory has the abstract measurement equation as its object and studies special kinds of the equation, which fit the traditional measurement types.

It is evident that the abstracting measure for practical situations is mostly high in this sphere. So results prove practically useful only if such problems are under solution, which are intrinsically, by their nature, suitable for formalisation. Among these are, first of all, experimental data processing problems by measurement. So data processing methods and algorithms have been the focus of attention of the general theory.

But such an important general problem as taking into account a priori information by measurement for achievement of accuracy required could not be stated essentially just because fundamental difficulties with formalisation.

3. THE MAIN PROBLEMS OF APPLIED METROLOGY

The goal of the applied metrology is to ensure the quality of measurements supporting some industrial, technical, or research activity.

In the contrary, applied metrology is compelled to analyse, and to take into account specific features of measurement object and conditions.

By virtue of the fact that practical measurements are carried out in the interests of one or other sphere of people activity, first of all, economic one, then these measurements are, as a rule, measurements with accuracy required. The sole exception is provided by measurements, which are carried out within the framework of scientific researches where mostly high accuracy must be achieved. So the main task under solution in the process of measurement is to assure the accuracy required. It is fundamentally important that measurement conditions, as a rule, could be hardly, or even impossible, changed. So measurement conditions are to be considered as given ones.

Regarding to measurement accuracy as the object of metrological procedures, it has to be underlined that practical metrology is directed not so much to error evaluation as to affecting errors for bringing down their level below value required.

Applied metrology problems, which emerge in the process of handling the concrete measurement task, are connected first and foremost with that it is impossible to realize the unit with the necessary accuracy in any unique measurement act. The reason is object peculiarities and/or measurement conditions. The peculiarities can be shown itself regularly as well as extra-regularly, in particular stochastic. So, general methodical problem arises to realise unit in the conditions different from the normal ones. The latter are those, which unit is transferred via the chain "reference standard – working measurement instrument" in. The usual approach is in that the additional errors are to be analysed

and taken into account separately. In contrast to this, methodology should be developed for unit transfer in conditions, which are more closed to working measurement conditions.

4. COMPARISON

From the above discussion it follows that measurement theory, on the one hand, and measurement practice, hence applied metrology, on the other hand, differs not only in topics but in direction of efforts, too.

The measurement theory deals with model situations and model objects. It strives to establish mostly exact statements regarding the objects and relationships between them. Besides, it makes efforts to estimate accurately quantitative characteristics of the above-mentioned model objects.

In contrast to this, measurement practice must solve any actual measurement task, i. e., plan, and prepare, and organise, and carry out measurement so as to get the estimate for the value in question, which accuracy lies above the predetermined level. Often applied metrology endeavours to decrease the measurement error, sometimes to possible minimum.

In two words, fundamental contradiction between measurement theory and applied metrology is:

study and estimate vs. carry out and ensure.

As the result, the measurement theory and the applied metrology develop independently of each other, so that the theory pay just a little attention to the practical problems, and, on the other hand, affects the applied metrology weakly and indirectly, at best via normative documents.

5. CONCLUSION

Metrology is determined as science concerned with measurement, and methods for measurements uniformity assurance, and means for achievement of accuracy required. So applied metrology deals with the practically acceptable methods and means.

The above-mentioned fundamental contradiction would be overcome only by movement of the theory toward practice, first of all, bearing in mind assurance of accuracy required.

The mission of the measurement theory—partial and general—is apparently to serve as a base for applied metrological methods and procedures. This is only possible if it is the applied metrology that is the main source of the problems that should be generalized and solved in theory.

The object peculiarities are taken into account traditionally by use a priori information when measurement task is formulated, and measurement method is chosen, and data are processed. Taken together these partial tasks, it involves formalisation a priori information. But the attempts to solve the latter problem had failed. So the alternative method of attack is of interest, which lies in making and use "reference object" much as the reference work piece is used in precision machinery construction. In contrast with traditional reference standard, which is carrier of necessary physical property, and other properties of which are eliminated, the "reference object" may reproduce as many as possible properties of actual type of objects without separation of ones into useful and hindering but with the possibility to control both of them.

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