Interval computations in the metrology

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The modern informational world is antagonistic to the absolute precision [1]. The using of the concept 'the absolute accuracy' is possible only for mental theoretical constructs, but it isn't possible for the real-life applications because we need to take into account the used data uncertainty. The human's reasoning in the engineering practice and the decision-making in the automatic control systems are based on the measurements results that are distorted by the errors and that are often used as the initial data. Moreover, in practice, we operate with the inaccurate results of the uncertain data mathematical processing, so our decisions should take this circumstance into account, otherwise we may be wrong in our conclusions. We often obtain the empirical data about object under observation in the interval form from the direct measurements results, the metrological assurance and the accuracy of which are provided by the metrology. When this derived uncertain information is mathematically processed, the accuracy estimation of its results is also assigned to the metrology. The solution of this problem for the big amount of heterogeneous initial data is difficult because of the big number of their possible values combinations. However, at present time, this problem turns out to be solvable in the area of metrology of computer programs because of using the theory of fuzzy sets and the interval calculus.

The interval age in computational techniques began in the 60-ies of the XX century with the IFIP's (that was headed by Wilkinson) propositions on the accompanying the data processing software with the interval-valued estimation of the results inaccuracy. In 1962, Moore systematically considered the interval arithmetic [2] and offered the first practical manuals for its applications. In the 70-ies of the XX century, the first software shells (Linpack, for example) and libraries appeared for the linear computations. They allowed users to get the final results as the intervals of their possible values.

L. Zadeh expanded the scope of the term 'uncertainty' from only instrumental causes (rounding errors) to the initial data inaccuracy and the expert a priori information by introducing the fuzzy variables. To represent the measurement results and a priori information about them and their uncertainty as the intervals, L. Reznik introduced the fuzzy intervals [3]. V. Kreinovich and H. T. Nguyen considered the nested intervals as the measure of the fuzzy variables uncertainty [4]. This development trend expressed the real-life applications' necessity to operate with the inaccurate initial data.

The expanding using of the computational techniques in the measurement systems and the data processing performed by them caused the problem of the metrological software tests organization. This circumstance induced the metrological community to take into account the success of the interval computations and the fuzzy variables and to include them into the metrological practice. The first step in this direction was made in 1985 with the special issue of the magazine "Measurement Techniques" that was dedicated to the problem of the metrological support of the data processing in the metrology and the measuring.

To date, the different interval approaches and methods were proposed and used in the various metrological applications, particularly the method [5,6] that corresponds with the requirements of the metrological norms and standards.

To illustrate how deeply the interval computations and their expansions can be spread in the real life, we consider the example from our everyday practice: the calculations in the systems of heat metering.

We cannot measure the consumed heat quantity directly, so its value is calculated from the indirect measurement results by the computational block of the meter (that is called calculator). The initial data for these calculations are received from two sensors signals of the heat conveying liquid amount in the forward and return directions of the flow, two sensors signals of the temperature in the forward and return flows of heat-transfer agent, the signal of the temperature difference between these two flows and the sensor signal of the pressure of the liquid. The instrumental inaccuracy of all used sensors is standardized by the special European normative document [7]. The uncertainty of the measured heat amount value results to the inaccuracy in determining how much the heat was really consumed and how much the consumer should pay.

For the heat calculator, only the uncertainty of temperature perception is normalized, but not of any other signals mentioned above. This circumstance draws some criticism. That's why the real commercial task is to estimate uncertainty of the heat calculator results with taking into consideration the uncertainties of all initial data, not only the temperatures difference. In full, this problem can be solved only using the interval computations tools in the sense of the works [5,6]. In the report, the particular examples are presented for the interval computations that provide the reliable intervals of the uncertainty of the consumed and paid heat.

References:

[1] V. Knorring, *History and mthodoloy of science and technics: informarmational scope of human's agency from from aincient times to the beginning of XVI cent.*, St.Petersburg State Polytechnic University, St.Petersburg, 2013 (in Russian).

[2] R. Moore, *Interval arithmetic and automatic error analysis in digital computing*, a thesis submitted for the degree of Doctor of Philosophy, Stanford University, 1962.

[3] L. Reznik, Mathematical toolkit for processing fuzzy information of experimenter in data processing systems, *Proceedings of*

All-Russian Scientific Research Institute on Electrical Instrument-Making, 1983, pp. 45–55 (in Russian).

[**4**] H. Nguyen, V. Kreinovich, Nested intervals and sets: concepts, relations to fuzzy sets, and applications, *Applications of interval computations*, 1996, pp. 245–290.

[**5**] K. Semenov, G. Solopchenko, Combined method of metrological self-tracking of measurement data processing programs, *Measurement Techniques*, 54 (2011), No. 4, pp. 378–386.

[**6**] K. Semenov, L. Reznik, G. Solopchenko, Fuzzy Intervals Application for Software Metrological Certification in Measurement and Information Systems, *Int. Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, 23 (2015), Suppl. 1, pp. 95–104.

[**7**] European Standard prEN 1434, *Heat meters*, In 6 parts. European Committee for Standardization, Brussels, 2006.