GUEST EDITORIAL

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THE EVOLVING SCIENCE OF MEASUREMENT

This special issue of *Metrology and Measurement Systems* contains an updated and extended version of selected papers published in the proceedings of the XVIII IMEKO World Congress, held in September 2006 in Rio de Janeiro, Brazil. All those papers were presented and discussed during the sessions organized under the auspices of the IMEKO Technical Committee on Measurement Science (TC7). After the Congress, the presenters were invited to submit a new version of their papers, taking into account not only the progress in their research but also the outcomes of the Congress discussions. The final selection of papers was based on the results of a regular peer review process they were subject to.

TC7 was founded in 1973 under the name of Measurement Theory. Today, it may seem amazing that a theory dealing with centuries-old methods and techniques, such as those related to measurement, was then still in its initial phase of consolidation. According to the traditional interpretation, prevailing at that time, measurement was understood as an operation of discovering and extracting numbers, existing prior to measurement, from the empirical world. Consequently, the role of measurement was considered pivotal for research activity, but measurement itself was not necessarily perceived as a valid object of any science: during the first decades of the XX century the role of measurement in empirical sciences was discussed by some now classical works, *e.g.*, [2-4], apparently as if the only general problem of measurement were its structural distinction from ordering and classification, inferred by an even more fundamental distinction between quantities and qualities.

At the time of TC7 foundation, a conviction that any measurement requires appropriate, suitably calibrated, physical transducers was very widespread not only among engineers but also in the scientific communities. However, more and more frequently the question was risen: is it possible to measure, in a strict sense of this notion, non-physical properties, such as the perception of sound loudness, the intensity of pain, the technical skill in performing some task, the intelligence or the creativity? We know today that this is an epistemological question (not a nominal one, as declared in [5]), and the presence of physical transducers is a *sufficient* condition to obtain reliable information on the empirical world, but we have no grounds to state that it should be also a *necessary* condition. On the other hand, measurement results play the crucial role of input data for inferential processes that generally obey the so-called "garbage in – garbage out" principle: even the best inferential rule will produce useless or misleading results if fed with low-quality data. Therefore, the problem becomes of assuring the quality of the data carrying the information on the empirical world. Physical transducers can be a tool for solving this problem, but they do not provide a complete solution.

The awareness of the above-mentioned aspects of measurement, ignored or underestimated for a long time, has grown during last decades, and engendered two research approaches of measurement: the first of them was related to the structuralism, and the second – to the information revolution.

In the context of the structuralism, measurement was studied in its formal structure: first, in terms of structural invariance by the theory of scale types [6]; next, in terms of structural preservation and meaningfulness by the so-called "representational point of view" to the theory of measurement [7, 8].

By integrating in itself the theory of scale types and organizing a consistent framework in which measurement is formalized as a homomorphism between relational systems, that approach was able to describe measurement by a theory composed of sub-theories of measurements referring to specific scale types (absolute, ratio, interval, ... scales) and characterizing specific measurement processes. An important advantage of that approach was its potential to extend the applicability of measurement beyond the scope of the physical quantities. On the other hand, however, that approach spread the idea that measurement can be fully characterized by its formal properties [9] – despite its constitutive role of bridge between the empirical world, to which entities under measurement belong, and the information world, to which measurement results belong – also with the side-effect of neglecting the role of standards, calibration, *etc.*, in the theory itself.

In 1973, when TC7 was established, the information revolution was only making its first timid steps: an Internet protoplast was just born, but the idea of a world-wide web had still to wait 20 years for implementation. The traditional conviction, according to which each measurand has a "true value" that may be extracted by means of measurement with "some error", still dominated in the measurement community at that time. It has been, however, gradually marginalized in the following years, and – in the context of information revolution – it has been substituted with an information-related requirement: measurement result has to express at best the accessible information on a measurand. This conceptual evolution highlighted the insufficiency of the classical interpretation, which assumes that measurement can be fully characterized as an empirical operation, and at the same time stressed the need for considering any measurement operation in the context of a *metrological model*, in which the role of the measurer, of the influence quantities, of the traceability chain, *etc.*, may be properly interpreted in terms of measurement uncertainty [10].

The above-outlined historical background of Measurement Science has been provided to substantiate the conclusion that the foundational issues of measurement are not only of theoretical nature. Guided by this conclusion, IMEKO changed in 1993 the name of TC7 to Measurement Science. It is now clear that the development of Measurement Science engenders problems which cannot be interpreted in purely structural terms, such as:

- the feasibility of automated "intelligent" measurement, also performed by means of multi-measurands measuring systems with complex, distributed architectures;
- the role of the simulation in measurement and, consequently, the relation between measurement and computation;
- the modeling and expression of measurement uncertainty as the methods for formalizing the acquired information on the measurand.

Furthermore, it is now clear that measurement poses foundational issues even in the case of physical quantities, as the broad scope of the topics covered by the papers published in this special issue witnesses.

The papers published in this special issue may be subdivided into four topical groups:

- modeling of measurement processes and measurement results,
- design of measuring systems,
- measurement applications of advanced mathematical techniques,
- strategic role of measurement in society and economy.

In the first topical group, most fundamental issues are undertaken:

- S. V. Muravyov ("Rankings as ordinal scale measurement results") provides a new interpretation of the classical problem of ordinal-type scale measurement. According to this interpretation, a single measurement result is an entire ranking of a number of objects consistently ranked by several properties. S. V. Muravyov proposes a computational procedure that operatively defines a corresponding consistency criterion.
- T. Allevard et al. ("The transportation distance for fuzzy descriptions of measurements") propose a

concept of similarity relation and an associated bounded distance that can be used for processing fuzzy subsets of words, representative of measurement results; they apply this formal technique for the hand posture recognition.

In the second topical group, the methodologies of measuring systems design are discussed:

– S. H. Khan and L. Finkelstein ("Advances and generic problems in instrument design methodology") present some general issues of the methodology of measuring systems design, and outline a research agenda that is implied by those issues; they also describe recent advances in the computer-aided design of sensors and actuators.
– L. Benetazzo et al. ("Self-configuring measurement networks") propose to revise the PC-centric structure of computer-based measuring systems, by introducing and discussing a novel concept of self-configuring networked measuring systems.
– S. C. N. Töpfer et al. ("Automatic execution of inspection plans with the I++ DME interface for industrial coordinate measurements") present a novel concept of a measuring system for automatic execution of industrial inspection in manufacturing of micro- and nano-structures. It is based on the use of multiple sensors and coordinate measuring machines, integrated by means of a standard interface.

In the third topical group, measurement applications of advanced mathematical techniques are presented:

– M. Darowski *et al.* ("Hybrid modeling and symbolic biosignal processing for biomedical applications") report on the study devoted to hybrid – partially physical, partially symbolic – modeling of biological systems; they discuss the role of measurement in the modeling process, and – in particular – the problematic status of measurement in computational systems performing e.g., simulation.
– M. Barbosa *et al.* ("Measurement uncertainty contribution to the MLP neural network learning algorithm applied to an aerodynamic external balance calibration curve fitting") present a complex measuring system whose calibration is performed using a neural network, and – what is more important – demonstrate the possibility to explicitly include uncertainty information in the network training.
– J. E. Manzoli *et al.* ("Migration measurements from plastic packaging: a simulation study on influence of initial concentration profile") apply numerical techniques for evaluation of the behaviour of a complex system, and carry out metrological analysis of the obtained results, in particular their impact on public health.
– L. M. C. da Cunha *et al.* ("Development and validation of a selective method for the determination of chrysene using silver-enhanced room-temperature phosphorimetry") use statistics for the design, implementation and validation of a multivariate method of measurement data analysis when applied for quantitative identification of a specific compound on the basis of phosphorimetric data; they stress the issue of propagation of measurement uncertainty in this exercise.
– S. B. Melo *et al.* ("Reconstruction of radial catalyst concentration distribution in an experimental type FCC riser") provide a new solution of an inverse problem, viz. the problem of measurand reconstruction on the basis of data acquired by means of gamma-ray tomographic systems used in industrial applications.

In the last topical group, the strategic role of measurement in the society and economy is analyzed:

– M. N. Frota and J M. Ticona ("The Brazilian experience on product certification: a metrology-related function which produces economic impact") present some macro-economical data characterizing the impact of industrial products certification on Brazilian economy, to demonstrate that metrology and metrology-related services are essential for the quality of manufactured goods, their competitiveness and for effectiveness of trade.
– J. Grén *et al.* ("Optimal measurement policy for decision making: a case study of quality

management based on laboratory measurements") propose a conceptual and formal framework for the optimization of measuring systems providing data necessary for the decision making in industry; they exemplify its utility with a case study of decision making in paper industry.

As the Reader will readily understand, the papers published in this volume reflect diversified streams of thinking being the contents of the evolving Measurement Science, a body of knowledge whose subject is old but that is new in its status of science. We believe that a sound interpretation of the evolution of Measurement Science is a good guide for understanding some of its future developments.

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