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PERSPECTIVE OF METROLOGY QUALITATIVE DEVELOPMENT

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Abstract − Metrology, as a system of scientific and practical activity, is developed under the influence of practice requirements. These requirements are directed at all-systematic broadening of its subject by necessity to measure non-physical quantities of objects and to study objects closely and hence to operate with new measuring apparatus. Metrology subject broadening will require assimilating the experience of using non-traditional types of scale for measurable quantities and mathematical tools, and methods of information means modelling.

Keywords: metrology, development, subject, system, broadening.

1. INTRODUCTION

Metrology development peculiarity is caused by two fundamental circumstances. Firstly, metrology object, i. e., measurement, is not a nature phenomenon but a procedure, which is made by human being in an effort to achieve human aims. Secondly, metrology is both a scientific discipline and a variety of practical activity, too. Therefore metrology development takes place not by intrinsic conceptional factors but under the action of external incentives, which are closely connected with metrology practice.

Metrology, as an every system, is developed extensively and qualitatively. Extensive development is determined by detailing measurable physical properties of object and by increasing a requisite accuracy of measurement. The latter factor, after achieving the definite critical level, provokes qualitative changes of scientific and practical metrology.

However, the main reason for metrology qualitative development is that practice presses permanently on measurement, and the pressure causes necessity to broaden the content of this basic term of metrology. The borders expansion of metrology subject afforded by the latter requires assimilating the experience of using fundamentally new methods and means.

2. MEASUREMENT AS A SYSTEM

As an integral object, measurement is a system of interconnected real and model elements [1]. The real elements are (a) measurement object, (b) physical property under measurement, (c) measurement conditions, (d) measurement operator, (e) measuring instrument, (f) data processing means (Fig. 1). The model element line includes (a) object description, (b) measurand model, (c) metrological characteristics of measuring instrument (in special situations, of measurement operator, too), (d) data processing algorithm. Measurement method (procedure) and software fit into the element group of mixed, real-model, type. All above-mentioned elements are combined into a single whole, from the outside, by measurement aim and, from the inside, by data processing procedure.

3. FACTORS AFFECTING DEVELOPMENT

3.0. General

All factors affecting metrology development would be arbitrarily divided into two groups. The first one lists factors which are linked to the fact that new practice requirements influence the above-mentioned measurement elements, and these influences has various degrees. These requirements are due to four circumstances being considered below.

The second group lists factors which are linked to the fact that metrology, as a practical activity system, is incorporated in two super-systems. The latter are standardisation and quality assurance. These incorporations are discussed below.

3.1. Factors stemming from the measurement elements under new practical requirements

3.1.1. First of all, the case in point is the measurand. The multitude of all potentially measurable properties, i. e., all the qualitatively distinguishable and quantitatively determinable properties, is vastly greater than one, which is caused by the content of the term "physical quantity" [2]. Practice requires to goes far beyond this term and accordingly to cover procedures for quantities evaluation in medicine, psychology and sociology, which quantities are "underdefined" as compared with the term "physical quantity". Besides, there are measurements of technical and technical-economic parameters, which characterize techno-sphere objects, like efficiency and other indexes of technical system proficiency. In all instances the case in point is the transfer from estimation in metrical scales only to evaluation in ordinal and perhaps nominative ones. This transfer will require to builds up standardizing principle in metrology.

3.1.2. The second circumstance is linked with necessity to carry out many-sided studies of complicated natural and man-made objects. These investigations lead to measurement of multidimensional (vectorial, tensorial) quantities, and the generalization for this measurement, i. e., system-type (systematic) measurement. Both of the above-mentioned measurements exemplified accordingly by dynamic measurement [3] and measurements in marine navigation [4]. System-type measurement is the measurement of quantities of various physical characters, which are interconnected by system-type dependence, for instance, by equation system. The quantities are equivalent as measurands but they are measurable in the aggregate only. System-type measurement model can be represented as follows. Let $Z_1, Z_2, ..., Z_L$ are measurands, which are connected by known relation

$$\Phi(Z_1, Z_2, \ldots\ldots, Z_l) = 0. \quad (1)$$

Quantities Z_j, in the aggregate, are connected with directly measurable (observable) quantities $X_1, X_2, \ldots, X_m$ by known relation

$$\Psi(Z_1, Z_2, \ldots\ldots, Z_l; X_1, X_2, \ldots\ldots, X_m) = 0, \quad (2)$$

which generally is not "split" into set of individual dependences like

$$\begin{aligned} Z_1 &= f_1(X_1, X_2, \ldots\ldots, X_m); \\ Z_2 &= f_2(X_1, X_2, \ldots\ldots, X_m); \\ Z_l &= f_l(X_1, X_2, \ldots\ldots, X_m). \end{aligned} \quad (3)$$

Interconnection of quantities Z_j (and X_i, too) do not permit to consider every quantity measurement separately as one, which is independent from others. On the contrary, the result of any quantity measurement affects results of other quantities measurements. So, these measurements are named "system-type" ones.

As an example, the determining of direction cosines $c_{\mu\nu}$, which characterize mutual positioning ship co-ordinate system *Oxyz* and geographic system $O\xi_r\eta_r\zeta_r$. Cosines under determination are interconnected by Poisson equation

$$\frac{dC}{dt} = C\,\Omega\,, \quad (4)$$

where

$$C = \begin{Vmatrix} \cos K \cos\psi & \cos K \sin\psi \sin\Theta_k - \sin K \cos\Theta_k & \sin K \sin\Theta_k + \cos K \sin\psi \cos\Theta_k \\ \sin K \cos\psi & \cos K \cos\Theta_k + \sin K \sin\psi \sin\Theta_k & \sin K \sin\psi \cos\Theta_k - \cos K \sin\Theta_k \\ -\sin\psi & \cos\psi \sin\Theta_k & \cos\psi\cos\Theta_k \end{Vmatrix}; \quad (5)$$

K, ψ, Θ_k – course, rolling and pitching angle, accordingly;

$$\Omega = \begin{Vmatrix} 0 & -\omega_z & \omega_y \\ \omega_z & 0 & -\omega_x \\ -\omega_y & \omega_x & 0 \end{Vmatrix}; \quad (6)$$

ω_x, ω_y, ω_z – directly measurable projections of instantaneous ship velocity ϖ onto axes of co-ordinate system *Oxyz.*

Velocity projections are interconnected and connected with directing cosines by kinematic Eulerian equations:

$$\left.\begin{aligned} \omega_x &= \dot{\Theta}_k - \dot{\varphi}_p \sin\psi; \\ \omega_y &= \dot{\varphi}_p \cos\psi \sin\Theta_k + \dot{\psi}\cos\Theta_k; \\ \omega_z &= \dot{\varphi}_p \cos\psi \cos\Theta_k - \dot{\psi}\sin\Theta_k. \end{aligned}\right\} \quad (7)$$

If one measures both velocity components along the axes of its own co-ordinate system and yawing angle, it is possible to determine, by above-mentioned equations, desired direction cosines. But it is important, that neither of cosines can be separated as a quantity, which is independent from others and to bring so measurement to indirect one.

In particular cases, system-type measurement reduces to well-known measurement categories: direct, indirect, joint and aggregate measurements. For carrying out these measurements, metrology must to assimilate the experience of using new mathematical tools and methods for measurement experiment planning.

3.1.3. The third circumstance is that new categories of measuring instrument appear i. e., virtual and intellectual ones [5]. An essential or even crucial part of these apparatus is software for data processing (Fig. 2). A demand arises to carry over metrological principles and procedures to these means. In turn, this requires interpenetration of methods for modelling and evaluation of measuring instrument metrological properties, on the one hand, and methods for evaluation of data processing software quality, on the other hand.

3.1.4. The fourth circumstance is that technical systems for decision-making and control are gathering force in industry. As a rule, these systems include measuring channels, which is no way frequently to separate from the system neither functionally nor structurally for (Fig. 3). This induces to consider such measuring-information and measuring-control systems as technical means for conversion of information [6]. A change over quantity estimation to information evaluation requires assimilating the experience of using methods from information sciences. Information should be evaluated as semantic one (for the decision-making sphere) and as pragmatic one (for the sphere of control) [7].

3.2. Factors stemming from the practical metrology being incorporated in other activity systems

3.2.1. The association of metrology with standardisation is usually treated as if the latter is basic method for consolidation of results which are achieved in metrology. But the association is much more complicated. To reveal this association standardisation and metrology must be considered in systematic and scientific methodological aspects.

As systems, both of kinds of activity are of interdisciplinary character. In substance, they are meta-disciplines.

Accordingly to the definition [8], standardisation is a universal way to put in order any activity. The aim of this ordering is an achievement of general saving. Metrology is a way to put in order the activity in the field of measurements. The immediate aim of metrological activity is an achievement of measurement uniformity and required accuracy, and it is a base of industrial interchange ability, which leads to the general saving. Therefore metrology is, in a systematic aspect, the part of standardisation.

Comparing standardisation and metrology in a scientific methodological aspect, we must consider the content of basic concepts - object, subject, and method, as applied to every discipline.

In standardisation, an object is any thing, which has property under our interest. As a subject, we fix recurring action under the object in order to use the above-mentioned property. General method of standardisation is classifying, which include establishing the scale for properties (objects) and locating the object (the property) in this scale. Specific methods are unification, typification, specialization, aggregation and other ones, which are combinations of above-mentioned parts of classification.

Regarding to metrology, an object is any thing with the property, which can be pronounced quantitatively using a scale or a unit. Measurements, and their unity and accuracy, are metrology subject. Metrology has unification as general method, and unification is treated as concordance, which is achieved by reduction of variety.

Therefore, as it was shown above,

(a) metrology subject is a part of standardisation subject;

(b) universal method of metrology is one of standardisation methods;

(c) there is intrinsic connection between standardisation methodology and metrological methodology; the connection is caused by scale as a central concept and central factor in both kinds of activity.

The latter clause implies the following. Standardisation is the field, where soft (poor) scales are used. Metrology is a sphere of using mainly strong (rich) scales. There is a necessity to measure non-physical peculiarities of objects (see 3.1.1), so standardisation principles and methods are to be introduced directly into metrology.

On the other hand, development tendencies in standardisation exert some influence on metrology development directions. There is, in standardisation, the tendency to separate obligatory and voluntary regulation spheres, and to liberalize the second one. So, in metrology, it causes the tendency to decentralize the measurement unity system.

3.2.2. The association of metrology with quality assurance is now the main factor, which determines role and significance of metrology practically in all applied fields and branches of industry.

Creation of quality assurance system in accordance with the Standards ISO 9000 and, more widely, with TQM principles puts metrology in the central place in the management system of an industrial enterprise and of a firm giving services. The reason is that the quality assurance system, as any one, needs reliable quantitative data about the object under regulation. These data are given mainly by measurements, and metrology ensures their reliability.

Inclusion of metrological procedures in the quality management processes leads to widening the content of metrology subject. Because measurements, in technological process, are introduced, as a rule, into testing and measuring control, it is demanded to carry over metrological principles and methods to the field of tests and control.

To solve the above-mentioned problem we have to decide the following tasks:

(a) to develop ways for evaluating integral characteristics of test and control procedures on a base of measurement accuracy characteristics;

(b) to devise methods for presenting and estimation of test and control equipment characteristics, which methods are directed to solving the task (a).

4. CONCLUSIONS

From the above discussion follows that metrology development perspective appears as generally systematic broadening of its subject. It will be happen properly (and it is happen by now) increasing a volume of the term "measurement" content as a result of generalizing basic terms for measurement elements: (a) measurement object, (b) measurand, (c) measuring instrument, (d) data processing in measurement. The dominant bulk of the predictable process of metrology development is increasing an information component of metrology subject, in particular, algorithmic one and software. It will require to extend metrological methodology to general information technology and to control technology, and to assimilate the experience of using methods from these disciplines.

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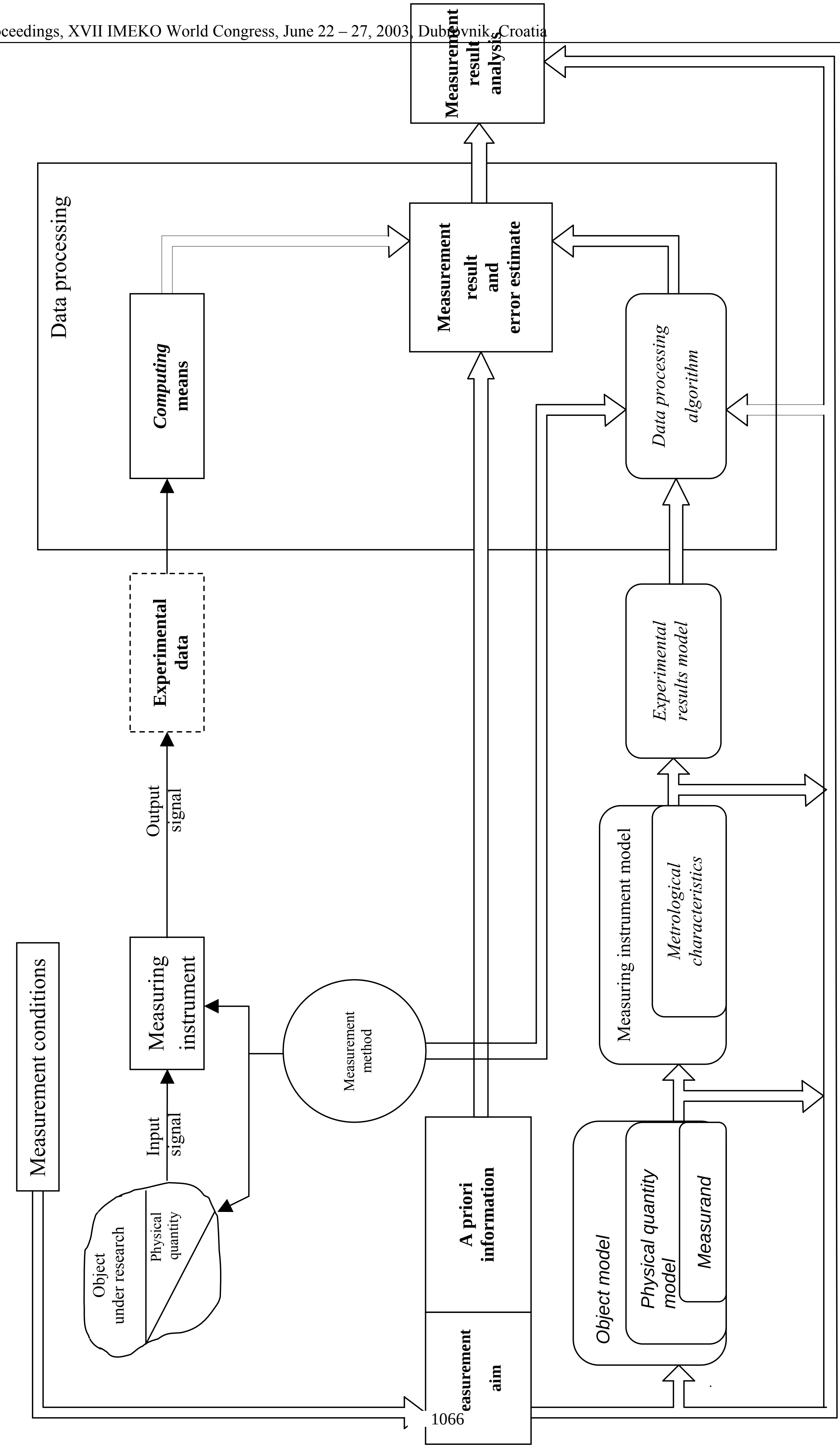

Fig. 1. General measurement structure (simple measuring instrument)

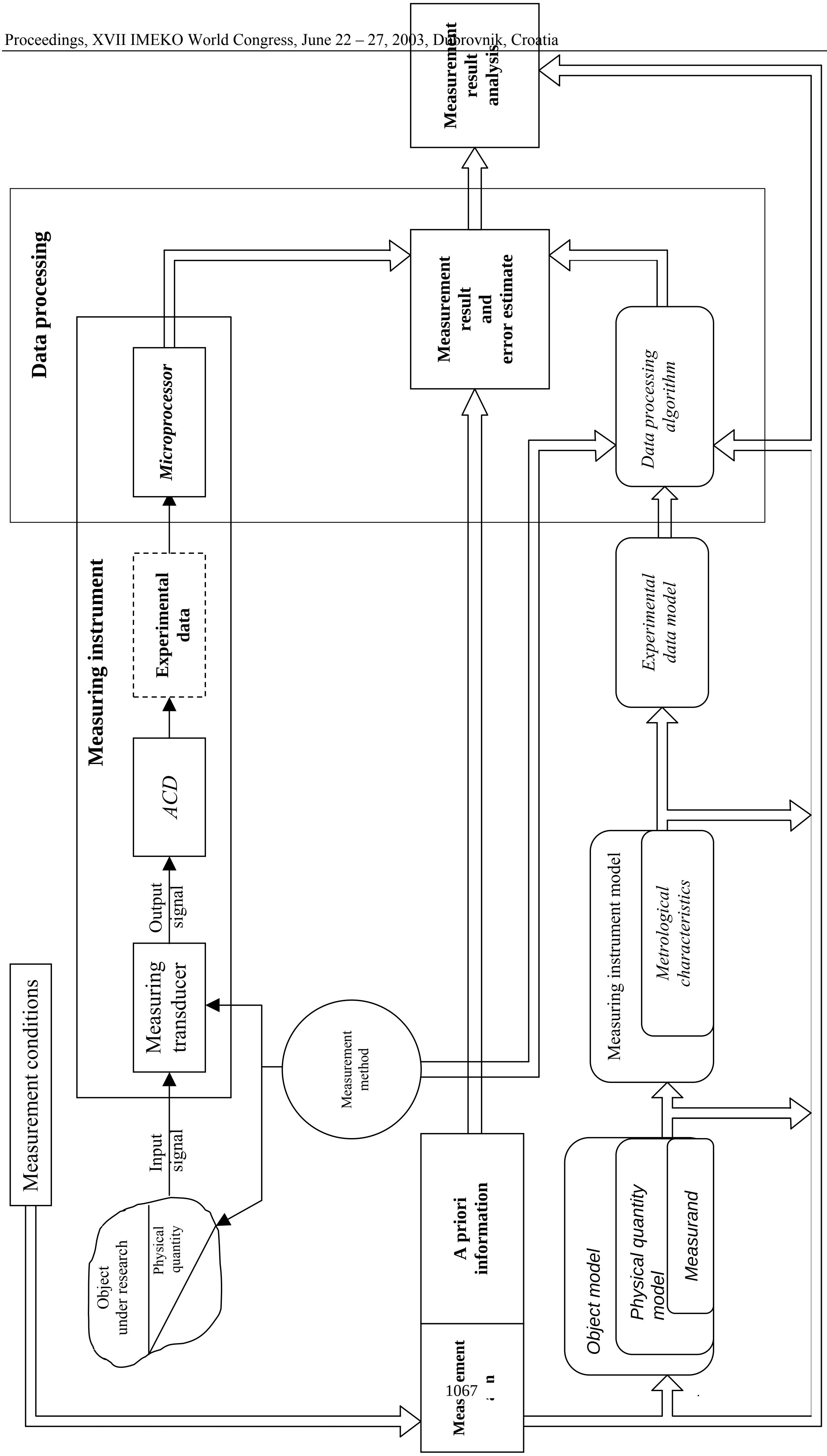

Fig. 2. General measurement structure (the measuring instrument including a microprocessor)

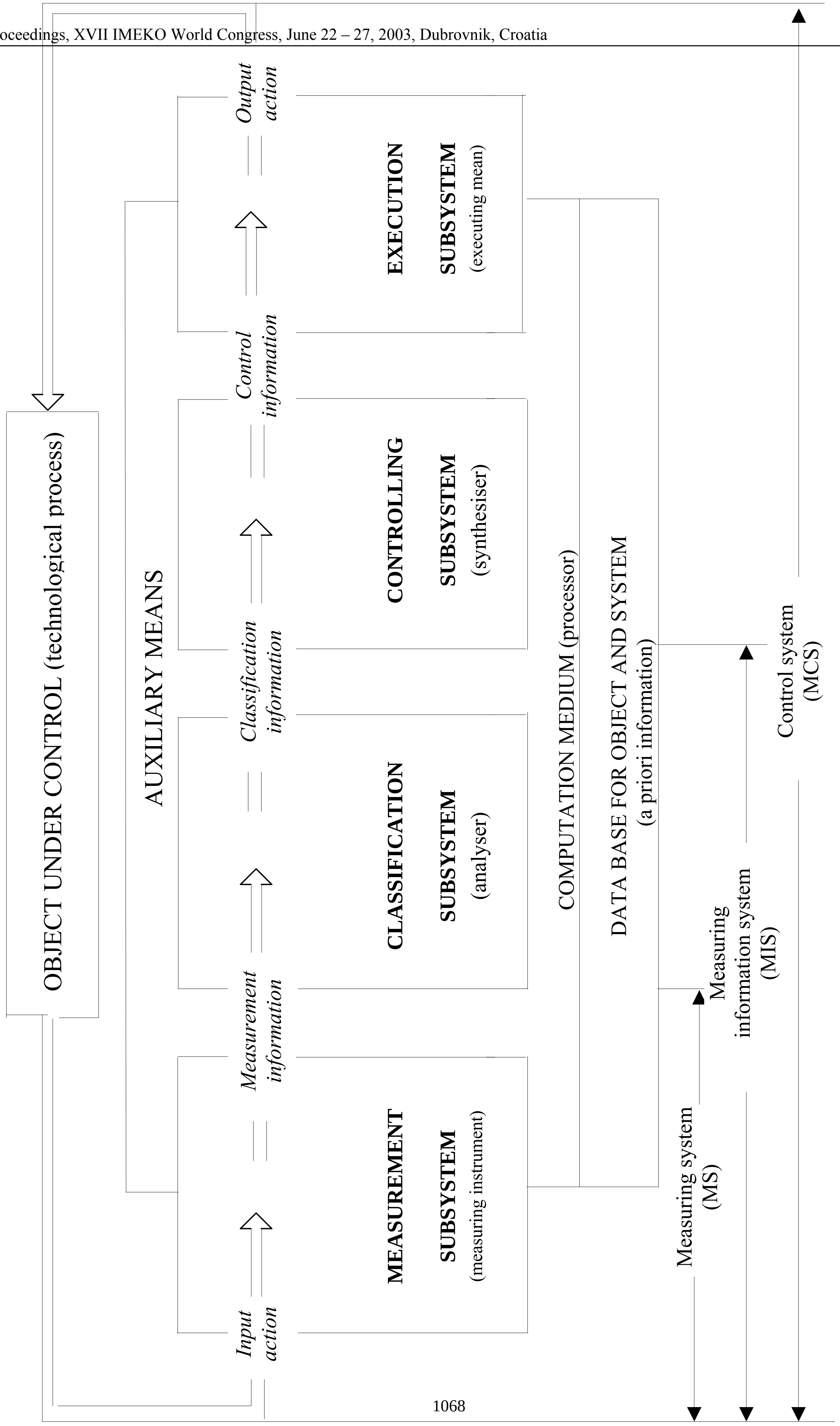

Fig. 3. MS - MIS – MCS general structure