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PROBLEMS OF TERMINOLOGY IMPROVEMENT IN METROLOGY

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Abstract − The paper is devoted to some problems related to the development of an international vocabulary of terms in metrology. Using terms from Section 3 of VIM, it is shown that in many cases, on one hand, the same terms are interpreted in a different way; but on the other hand, different terms are used to express the same ideas. The origins of ambiguity are analyzed. Proposals which could contribute to softening the problems of terminology development are given.

Keywords: international vocabulary of metrology, evolutionary method, sensor

1. INTRODUCTION

Change-over of the society from an industrial stage to a post-industrial one, resulted in emergence of new abilities to design new measuring instruments on the basis of new components and computer technologies.

A field of multiparameter measurements enlarged significantly. Measurements have become necessary to transfer to objective quantitative estimates in determining traditionally subjective characteristics, such as a taste of foodstuffs, “mood” (spirits) of music, human talents, etc.

Enrichment of a spectrum of problems the specialists encountered in the field of measurements, inevitably resulted in enrichment of their vocabulary of terms in order to provide:

- systematization of knowledge;
- generalization of various conceptions;
- designation of new concepts;
- formulation of regulations of the legislative metrology, etc.

This tendency has been embodied in the third edition of the international vocabulary VIM [1].

However, a pace of development of needs for new terms is too high. As a result, with regard a number of concepts an effect takes place that is similar to the effect that stopped construction of the Tower of Babylon: specialists started speaking “different languages”. On one hand, the same terms are differently interpreted, and on the other hand, different terms are used to express the same ideas [2-11].

A search of technical decisions in the Internet, exchange of experience and, finally, choice of measuring instruments with optimum characteristics, in many cases all this is impeded due to terminology ambiguity. And this ambiguity is increasing, which results in significant financial losses.

In metrology, it is possible to mark out two spheres of terminology development. One of them is connected with the development of ideas in the field “pure knowledge”, i.e. to epistemology, the other one relates to the field of technology.

This paper mainly orients itself towards the second field. This paper is aimed at the development of proposals which could contribute to softening the problems of terminology.

2. THE AMBIGUITY IN INTERPRETATION OF WIDELY SPREAD TERMS

One would think that the birth of concepts does not require any urgent legalization of new terms. Any new concept can be defined with the help of a known term supplemented with a set of qualifying determinations. However, if for new concepts the usage of which quickly increases, a number of additional required definitionsis more than 2, a new term will inevitably appear.

The fact is that in scientific and technical papers and particularly in advertisement booklets, a part of the definitions added, will be voluntarily or involuntarily omitted. Depending on what specific definitions have been excluded from the text and what is the experience of a reader, the text interpretation can appear to be different.

The situation is redoubled by the fact that some terms which were defined many years ago, due to the development of technology have lost their unambiguity.

Let us consider this situation using an example of widely spread terms which refer to Section 3 “Devices for measurement” of VIM [1].

2.1 Term “sensor”

In paragraph 3.8 of VIM [1], the term “sensor” is defined as an “element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured". (In the previous edition of VIM the “sensor is an element of a measuring instrument or measuring chain that is directly affected by the measurand”).

Some elementary examples give an explanation of this term in VIM: “sensing coil of a platinum resistance thermometer, rotor of a turbine flow meter, Bourdon tube of a pressure gauge, etc.” In p. 3.9 of VIM, it is stated that in some fields the term “sensor” is replaced with the term “detector” which according to VIM has another meaning.

Interpretations of the considered term in various normative documents are different.

In p. 3.2.3 of [12], the term “sensor” means “a transducer that converts a physical, biological, or chemical parameter into an electrical signal”. According to [13], “sensor” is a “device that picks up physical measurement variables and converts them to standardized output signals”. In p. 6.18 of the Russian guide [14], “sensor” is a primary measuring transducer (a primary transducer) that is directly affected by a physical quantity to be measured, i.e. “sensor” is the first transducer in a measurement chain of a measuring instrument (setup, system). The term is illustrated by examples similar to those which are given in VIM, p. 3.8.

In practice this term is applied for designating:

a) one sensitive element;

b) primary measuring transducer that can include a sensitive element or a group of sensitive elements, for example, an array;

c) measuring transducer that consists of a number of separate transducers, connected in-series, e.g. a primary transducer and amplifier;

d) isolated unit that in its case can contain any component or a group of components according to items a)-c);

e) unit, according to item d), which in its case contains also additional signal processing units (analogue-to-digital converter, interface, microcontroller, and indicator in any combination).

Correspondingly, the term “sensor” becomes vague. In this connection, in some publications the explanation of specific terms is given. For example, at the beginning of [15], it is written that "for the aim of this paper a sensor is the device consisting of one or more transducers and a transmitter that converts the transducer signals into a form recognizable by the control or monitoring system".

Realizing that the term “sensor” does sufficiently reflect the needs of practical work, in p. 6.19 of [14], the term “datchik (giver)” has been introduces. It is defined as an isolated primary transducer that generates measurement signals at its output (it “gives” information). In the Note, it is emphasized that the “datchik” can be placed at a distance with regard to a measuring instrument receiving its signals. The similarity between this definition and the definition of the term “sensor” given in [15], is noticeable.

Ambiguity of the term “sensor” becomes stronger if we take into account changes of its definition as compared with the previous edition of VIM, as well as a vague definition of the measuring system concept.

Since according to paragraph 3.1 and 3.2 of [1], a "measuring system may consist of only one measuring instrument”, it is possible to describe the measuring system consisting of one sensor (see item e) of the list), i.e. of one element of the same system. The above sensor may contain a number of sensors according to item c) of the list, each of them containing a group of sensors according to item b) and each sensor of the last group containing a group of sensors according to item a).

2.2 Term “measuring system”

According to p. 3.2 of VIM [1], the measuring system is a “set of one or more measuring instruments and, often, other devices, including any reagent and supply, assembled and adapted to give information used to generate measured quantity values within specified intervals for quantities of specified kinds.

Note: A measuring system may consist of only one measuring instrument”.

According to p. 6.14 of [14], the measuring system is a set of functionally combined material measures, measuring instruments, measurement transducers, and other technical means located in various points of a controlled object with the purpose of measuring one or a number of physical quantities peculiar to this object.

The definition emphasizes the most important feature of a measuring system: the fact that it is a multichannel means.

The same feature has been introduced into the Russian standard [16], where the measuring system is a set of measuring, linking, computing components forming measuring channels, as well as of auxiliary devices (components of the measuring system), operating as a single whole, intended to provide:

- information about the state of an object (in a general case, about a set of quantities changing with time and distributed in space, which characterize this state);
- computer processing of measurement results;
- registration and display of measurement results and of computer processing results;
- conversion of these data into output signals of the system in various purposes.

Note: A measuring system has features of the measuring instrument and belongs to the variety of measuring instruments.

At the same time, in scientific literature for English speaking readers, the terms “sensor system” [17] and “multi-channel sensor system” [18] are used. This is the evidence of needs for a term designating the multichannel measuring instruments not only in Russia.

It is obvious that ambiguity of the definitions given in normative documents can not satisfy users to date.

2.3 Term “intelligent sensor”

The tempo of updating terminology vocabularies, including VIM, remains behind the pace with which new terms appear. Names of new concepts are born and started to spread in numerous scientific publications, which creates certain difficulties in trying to put the terminology in order.

As an illustration, a family of definitions (by interpretation of item e)) applied for sensors being developed and produced by many companies in the world can be used.

In scientific literature of the world (including national normative documents) many terms are applied for designation of the devices to which an artificial intelligence can be attributed; for example, the terms "intelligent sensor", "smart sensor", "adaptive sensor" and others [11]. In VIM, there is no such a term.

At first, terms of this kind were used for designating the sensors which were able to realize automatic switching of a sub-range of measurements, depending on the level of input signals, to introduce corrections when a change of influencing factor values took place.

Recently, the same terms are used to name significantly more advanced sensors which can be automatically verified with respect to metrological serviceability (self-validating, self-checking, self-diagnosing, self-calibrating, fault-tolerant sensor) [11]. In many cases, such terms as “smart sensor” and “intelligent sensor” can be referred to the ambiguous terms too, since the abilities inherent in them and in an “adaptive sensor” are similar or the same.

Thus, in a number of cases, various terms selected in a random way are used to designate new concepts.

Development of science and technologies results also in vagueness of definitions and ambiguity of metrological terms being used in the sphere of epistemology, e.g. such as “measurement”, “true value of a quantity”, “intelligence of a measuring instrument” and so on.

3. SUGGESTIONS ON IMPROVEMENT OF TERMINOLOGY

As it follows from the examples given above, the main problems in developing terminology vocabularies are caused by an underestimate of tendencies and rate of measuring instrument and metrology development. The terms are being blurred, acquiring the polysemy, since when they were established, the tasks which had to be solved in future, were not taken into account. The same reason can explain the polysemy and inconsistency of a nascent terminology.

Therefore, one of the main problems in developing the concept of the international vocabulary of terms is taking into consideration progress trends and revealing the problems which will determine the vocabulary of specialists in the field of measurement technique and metrology over many years.

To our point of view, in preparation of the vocabulary, it is possible to use methods of drawing an analogy between biological organisms and technical means, as well as between processes of their evolution, which are developed in the evolutionary cybernetics [19, 20]. These methods permit to get sufficiently informative forecasts with regard to future measuring instruments and metrological activities [21]. A corresponding conception of development may become a reference point in establishing terms and associated definitions suggested for correcting the previously established concepts and designating the new ones. Use of the suggested methodical tool ((hereinafter referred to as an evolutionary method) is effective, because the technical means are on a significantly lower stage of development.

3.1 Biological sensor system

In any systems of environmental effect perception, the modern biology permits to distinguish the following:

- intrinsic sensitive elements, usually named as receptors or stimulus detectors (e.g. rods and conuses of retina, which percept light parameters; inner hair cells responding to timbre and pitch of acoustic vibrations; taste papillae and so on);
- primary perceptive centers where information from receptor groups is gathered;
- secondary perceptive and integrating centers which receive information from a set of primary perceptive centres.

In more complicated biological objects, the integrating centres are connected with each other too. Interaction of the secondary centres generates a multiparameter “image”

The receptor is an analogue of the “sensor” in interpretation of item a), which corresponds to the definition of the term “sensor” given in VIM [1].

In some cases, the sensors which perform similar functions, are sensitive to the parameters, which differ in quality (e.g. the taste papillae on the tip of the tongue are sensitive to a sweet or sour taste, and the taste papillae near the base of the tongue are sensitive to a bitter or salt taste).

For perception of vitally important external influence, in complicated biological objects the “isolated” organs were formed (for example, an eye, ear and so on). They include extra converters, in addition to receptor groups.

For example, an eye, in addition to the receptor apparatus, contains a refracting apparatus, as well as an apparatus focusing an image. Some organs of the same type are usually combined in a system. In such a system, “measurement information” is processed jointly, which permits to get additional information, for example, an estimate of the distance from the subject to an object being visually observed or of the direction to a source of sound.

The joint processing of information received from the group of receptors and from the “isolated” sense organs which percept various physical quantities provides the possibility for a biological object to create a multiparameter “image” and evaluate the environmental situation.

The analogy mentioned above shows that in measuring instruments the establishment of particular terms for a number of measurement information conversion steps is important. Taking into account this analogy, we believe that is possible to suggest the following.

3.2 Terms “sensor” and “datchik”

The term “sensor” should be interpreted as the simplest sensitive element (in accordance with item a) of the list), i.e. the element of a measuring instrument or measuring system, which is directly affected by a phenomenon, body, or substance carrying a quantity to be measured.

Evidently, in the nearest future, particularly taking into account the development of nano-technology, other components of the similar designation will find wide application: isolated groups of sensors, which have to get their names. In case when a group of sensors perceive the same physical quantity, then they can be named, for example, as “multisensors”, and if they perceive various physical quantities, then such a group of sensors can be named as “polysensors”.

For an isolated device containing one or a number of sensitive elements (sensors, multisensors, polysensors), and in some cases, a number of additional transducers of signals, including processing devices (e.g. an amplifier, ADC, micro-controller, interface and so on), a special term is needed too. It is very important because such a unit often is sold as a separate product, metrological characteristics being assigned to it.

There is no appropriate generally accepted term. For devices of this type it would be possible to use the term “primary module”, applying the concept “module” in the interpretation given in [23, 24]: “Module is an identifiable part of a measuring instrument or of a family of measuring instruments, which performs a specific function or functions and can be separately evaluated according to prescribed metrological and technical performance requirements in the relevant Recommendation”.

However, in this definition the isolation of the unit is not emphasized. At the same time, the concept itself, as it will be explained below, often requires additional definitions. This is the cause, in which it is desirable to have a term consisting of one word.

In the Russian language such a term exists. It is the word “datchik” (giver of measuring information) [14]. (Application of a Russian-language term in the international practice is not a unique event. As the Russian language is being enriched with foreign words, in the same way other languages, including the English one, have adopted Russian words, e.g. "shuba", "vodka", "dacha", "intelligentsia", "sputnik", and many others.

Examples of “dathciks”:

- platinum resistance thermometer;
- pressure “dathcik” that contains a sensor including a diaphragm with a tensoresistive bridge;
- pressure “dathcik” containing, in addition to the diaphragm and tensoresistive bridge, an extra temperature sensor (for correcting a complementary error caused by temperature influence), as well as an amplifier, ADC, microcontroller;
- “dathcik” that contains two independent resistance thermometers or two thermocouples the measurement signals of which are jointly processed in a remote device.

3.3. Term “measuring system”

The above examples related to the use of “combined” or “joint” measurements in biological objects, testify that sensor systems, unlike individual organs, permit to determine not only a value of a “measurand”, but moreover, to evaluate the distribution of the “measurand” in multiparameter field and to form a “muliparameter image”, e.g. in space. This fact provides a criterion for separation of the concept corresponding to the name of “measuring system” and names of other measuring instruments.

The possibility to determine a multiparameter value is provided by usage of a number of sensors or of “datchiks” of one and/or several quantities and by availability of a common processing center (The last circumstance does not exclude any possibility and usefulness of realization of primary information processing inside the “datchik”). More often the sensors or “datchiks” are distributed in space and used for evaluating field parameters.

As a definition of “measuring system”, in our opinion, it is possible to suggest the following: “measuring system” is a set of sensors, other components connected with them and integrated means for data processing, which is assigned for providing information related to multiparameter value”.

Taking into account the above, note 1 (p. 3.1) and note (p. 3.2) in [1] should be excluded.

3.4 Term “intelligent sensor” and terms connected with it

While using the concept “artificial intelligence” as applied to a measuring instrument, the method of evolutionary cybernetics presupposes bringing out an ultimate purpose of intelligence in the Nature and determining its analogue for a measuring instrument. In such a way, it will be possible to single out a minimum necessary set of features which allows the measuring instrument to be identified as the “intelligent” one [11, 21].

An analysis shows that the ultimate purpose of intelligence is to ensure the survival of its carrier.

Evolution of methods to solve this task for biological objects and measuring instruments have similar stages:

- use of conservative methods (a shell, sheath);
- application of adaptive methods (the adjustment of the insulating properties of an animal’s pelt with the season, the active thermoregulation of measuring instruments);
- development of intelligence.

Just intelligent methods permit to forecast initiation of dangerous situations. Accordingly, the most important task of the artificial intelligence of a measuring instrument is an increase of its lifetime (calibration interval), during which the uncertainty is kept within specified limits.

Evolution of intelligence is accompanied by the development of sense organs as well as with an increase of the number and variety of receptors, including those which provide identification of illness.

Accordingly, a measuring instrument which could be named "intelligent" shall have the abilities to perceive and process additional information (relatively to the unintelligent one) about measurement conditions, to differ from it by the ability to check (to diagnose) its own metrological condition.

In a "datchik", the "cognition" of environmental conditions, as well as estimation of their influence on functioning can be realized with the help of redundant elements artificially introduced into the "datchik" structure. Processing of the corresponding additional information they generate, can be performed in a microprocessor or microcontroller.

Using this additional information, it is possible to check the stability of metrological characteristics during a calibration interval and to get an estimate of metrological serviceability of a sensor. In order to form this information, it is useful to take into account the experience of application of sensor redundancy for improving metrological characteristics, which has been gained within the frames of the invariance theory [25, 26].

The idea to apply the evolutionary method was used as the basis for developing a draft of Russian state standard “Intelligent Sensors and Intelligent Measuring Systems. Basic Terms and Definitions”. In the process of its development, an attempt is being made to combine the concepts which are connected with modern and perspective changes both in methods and instruments providing the traceability of measurements. Some of the terms and definitions introduced into the draft of the standard and presented for discussion in [11], are given below.

Metrological self-check of "datchik" implies an automatic procedure of testing the "datchik" metrological serviceability in the process of its operation, which is realized with the help of additional (redundant) embedded elements. The metrological self-check of a "datchik" can be realized in the form of metrological calibration self-check or metrological diagnostic self-check.

The metrological calibration self-check of a "datchik" is a metrological self-check of the "datchik", performed by means of evaluating the deviation of a "datchik" signal value from the value of a reference signal formed by an additional embedded element (redundant measuring transducer or material measure) of a higher accuracy.

The critical (dangerous) error component is a dominant error component or component inclined to fast increase over specified limits. The critical error component is detected on the basis of metrological studies at the stage of the "datchik" development.

The metrological diagnostic self-check of a "datchik" is a metrological self-check of the "datchik", performed by evaluating the deviation of a reference parameter from its value established in a previous procedure of verification or calibration. The reference parameter of a "datchik" is formed with the help of additional (redundant) embedded elements and characterizes a critical error component. Metrological diagnostic self-check of a "datchik" is performed without any embedded elements of a higher accuracy.

Examples:

- The metrological diagnostic self-check of a temperature "datchik" that contains two thermocouples of different types, which have close accuracy.

Let us assume that the critical error component is a non-identical drift of thermocouple parameters, then a difference of output voltages of the thermocouples at an operational temperature measured with the help of one of the thermocouples, can be used as the reference parameter.

- The metrological diagnostic self-check of a temperature "datchik" that contains several equally accurate thermocouples of the same type, which have close accuracy.

Let us suppose that a critical error component is a non-identical drift of the thermocouple parameters, then a deviation of a thermocouple output voltage from a mean value of voltages of all thermocouples at a temperature corresponding to the mean value of voltages of all the thermocouples, can be chosen as the reference parameter.

The microprocessor "datchik" is a "datchik" that includes a microprocessor that provides processing of signals and/or storage of current data, as well as the possibility to interact with the upper level equipment of a measuring system. The microprocessor "datchik" can perform the function of self-identification.

The adaptive "datchik" is a "datchik" that contains additional elements which provide an improvement of sensor efficiency by taking into account measurement conditions and/or sensor state. Improvement of the efficiency (the measurement accuracy and level of confidence, as well as the decrease in man-hours during operation) is realized, e.g. by automatic variation of the measurement range or measurement time, by correction of the scale "zero", etc. Such changes can be provided with the help of signals from an influence quantity transducer and/or of other signals. An adaptive "datchik" can be carried out on the basis of a microprocessor sensor.

The intelligent "datchik" is an adaptive "datchik" that includes at least one additional (redundant) primary measuring transducer or material measure, and performs a function of metrological self-check.

Example:

A capacitive "datchik" of distance between the "datchik" and a conducting flat body, which contains at least, two flat electrodes (main and additional ones), as well as a microprocessor. The additional electrode is shifted with respect to the main electrode in a direction perpendicular to its surface. Let us suppose that the critical error component is caused by contamination of the electrode surfaces. Then the voltage difference evaluated for the shifted electrodes at a distance measured with the help of the main electrode can be chosen as the reference parameter.

An intelligent "datchik" can:

- transfer information about metrological serviceability;
- perform automatic correction of an error resulting from ageing of components and effect of influence quantities;
- perform, in a number of cases, the self-recovery of a "datchik" if a single defect appears in it;
- forecast metrological serviceability and provide necessary preventive steps;
- provide an increase of metrological reliability and of a calibration interval.

3.5 A remark concerning metrological terminology in the epistemology field

The evolutionary method can be useful in formation of terms in the field of epistemology. The history of knowledge shows that the concepts characterizing the environment, including ideas about object properties, significantly change as the science develops. It follows from the above that any quantity can be measured with the accuracy caused by today's comprehension, as well as by a model accepted.

Even fundamental concepts, such as “measurand”, i.e. the “quantity intended to be measured” (p. 2.3 [1]), and “true quantity value”, i.e. “quantity value consistent with the definition of a quantity” (p. 2.11 [1]), change in time and, consequently, are conventional.

We think that the approach connected with the uncertainty conception better reflects this circumstance as compared to the classical one.

3.6 Organizational proposals

It is known that a change of paradigms causes resistance [27]. Terminology is a product of agreement. Therefore, it is necessary to discuss the proposals suggested and to explain and argue the advantages of new approaches, as it is done, e.g. in [2, 9].

The position of metrologists from various countries in the field of terminology, is determined by many factors, including specific features of their experience, depending on what role the state plays in management of economical and metrological activities.

An assistance in approaching the positions would be provided by activating the discussion wit regard to the concepts connected with formation of terms and their definitions at the stages of editing new versions of the vocabulary.

From our point of view, such discussion can be arranged by creating a special VIM site in the Internet and publishing there a periodically updated list of the terms being suggested with their brief reasoning, as well as by arranging a continuing forum for discussing these terms. In a year, after publication of these terms in the Internet, WG 2 of the JCGM would be able to recommend the most successful terms for their usage, and then in a year or two, if there is no new and well-grounded objections, to include them into a new edition of the vocabulary.

4. CONCLUSIONS

Under the conditions of economics globalization, the technical language improvement should be considered as one of the economically important tools of development. Therefore, the development of terminology should be based on some conception connected with forecasts of metrology development and take into account the experience of specialists of various countries.

REFERENCES

[1] *International Vocabulary of Metrology — Basic and General Concepts and Associated Terms (VIM)*, JCGM, 2008.

[2] C. Ehrlich, R. Dybkaer, W. Woger. "Evolution of philosophy and description of measurement (preliminary rationale for VIM3)" *Accreditation and Quality Assurance*, vol. 12, n^o. 3-4, pp. 201–218, 2007.

[3] M. Priel, "Guide du vocabulaire le concept de la valeur", *Mesures 804,* Avril, pp. 20-22, 2008.

[4] R. Dybkaer. "Recovery revisited", *Accreditation and Quality Assurance*, vol. 10, n^o. 6, pp. 302–303, 2005.

[5] R.L. Kadis. "Metrological and statistical meaning of the concept "accuracy" in chemical analysis. Accuracy, true value, and taken reference values", *Zavodskaya Laboratoriya. Diagnostika Materialov*, vol. 71, n^o. 12, pp. 53-60, 2005/ Р.Л.Кадис. "Метрологический и статистический смысл понятия "точность" в химическом анализе. Точность, истинное значение и принятое опорное значение", Заводская лаборатория. Диагностика материалов, т. 71, n^o. 12, стр. 53-60, 2005 (in Russian).

[6] P. De Bièvre. "The beginning of the end of the confusion in concepts and terms? The new international vocabulary of basic and general concepts in metrology (VIM)", *Accreditation and Quality Assurance*, vol. 12, n^o. 6, pp. 279-281, 2007.

[7] O. Velychko, T. Gordiyenko. "The use of metrological terms and SI units in environmental guides and international standards", *Measurement*, vol. 40, n^o. 2, pp. 202-212, 2007.

[8] K.H. Ruhm. "Expectation - A fuzzy term in metrology?", *AMUEM 2007 - Proceedings of the 2007 IEEE International Workshop on Advanced Methods for Uncertainty Estimation in Measurement*, art. n^o. 4362570, pp. 53-58, 2007.

[9] P. De Bievre. "Essential for metrology in chemistry, but not yet achieved: truly internationally understood concepts and associated terms", *Metrologia*, n^o. 45, pp. 335-341, 2008.

[10] G. R. Nezhihovsky, A.B.Diatlev. "About new terminology in metrology", *Legal and Applied Metrology*, n^o.5, pp. 15-21, 2007/ Г.Р.Нежиховсий, А.Б.Дятлев. "О новой терминологии в метрологии", Законодательная и прикладная метрология, n^o.5, стр. 15-21, 2007 (in Russian)

[11] R. Taymanov, K. Sapozhnikova. "Problems of terminology in the field of measuring instruments with elements of artificial intelligence", *Sensors & Transducers journal*, vol.102, n^o. 3, pp. 51-61, March 2009.

[12] *IEEE Standard for a Smart Transducer Interface for Sensors and Actuators-Network Capable Application Processor (NCAP) Information Model, Std 1451.1*, 1999.

[13] *NAMUR Recommendation NE 107. Self-monitoring and Diagnosis of Field Devices*, 2005.

[14] *RMG-29. State System for Ensuring the Uniformity of Measurements. Metrology. Basic Terms and Definitions*, Minsk, Intergovernmental Committee on Standardization, Metrology, and Certification, 2000/ *РМГ-29. ГСИ. Метрология. Основные термины и определения*. Минск, Межгосударственный совет по стандартизации, метрологии и сертификации, 2000 (in Russian).

[15] M. Duta, M. Henry. "The fusion of redundant SEVA measurements", *IEEE Transactions on Control Systems Technology*, vol. 13, n^o. 2, pp. 173-184, 2005.

[16] *GOST 8.596-2002. State System for Ensuring the Uniformity of Measurements. Metrological Assurance for Measuring Systems. Main Principle*, 2002/ ГОСТ *8.596-2002. ГСИ. Метрологическое обеспечение измерительных систем. Основные положения*, 2002 (in Russian).

[17] *Smart Sensor Systems*, edited by G.C.M. Meijer, John Wiley & Sons, Ltd., Chichester, UK, 2008.

[18] N. V. Kirianaki, S. Y. Yurish, N. O. Shpak, V. P. Deynega, *Data Acquisition and Signal Processing for Smart Sensors*, John Wiley & Sons, Chichester, UK, 2002.

[19] V.F. Turchin, "*The Phenomenon of Science. A Cybernetic Approach to Human Evolution*", New York, Columbia University Press, 1977.

[20] V.G. Red'ko, "*Evolution. Neural Networks. Intelligence. Models and Concepts of the Evolutionary Cybernetics*", Moscow, KomKniga, 2007.

[21] R. Taymanov, K. Sapozhnikova, "Metrological self-check and evolution of metrology", *12th IMEKO TC1 – TC 7 Joint Symposium,* Annecy, France, pp. 212-217, Sept. 2008.

[22] K.U.M. Smith, *Biology of Sensory Ssystem*, John Wiley & Sons, 2000.

[23] *OIML B3:2003. Certificate System for Measuring Instruments*, OIML, 2003

[24] *OIML R76-1:2006. Non-automatic Weighing Instruments. Part 1: Metrological and Ttechnical Requirements - Tests*, OIML, 2006.

[25] E.M. Bromberg, K.L. Kulikovsky, *Testing Methods of Measurement Accuracy Improvement*, Energia, Moscow, 1978.

[26] B.N. Petrov, V.A. Viktorov et al., *Principles of Independence in Measurements*, Nauka, Moscow, 1976.

[27] T.S. Kuhn, *The Structure of Scientific Revolutions*, Chicago, University of Chicago Press, 1962.