

ABOUT A NEW CONCEPT DIAGRAM FOR THE MEASUREMENT PROCESS AND RELATED TERMS

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Abstract

According to a possible different method to classify random and systematic effect, and to build-up a measurement model starting from the prescriptive measurement model, a new Concept Diagram for the VIM Measurement Process is proposed.

Key words: measurement; concept diagram; metrological terms; systematic error; bias; prescriptive model; descriptive model.

Introduction

It is since 2010 that a question has been placed concerning the existence of some inconsistencies in the international measurement standards in metrology, namely the Vocabulary of Metrology (VIM), at that time at its 2008 edition, [1] and about the Guide for Uncertainty in Measurement (GUM) [2]. In particular, the author's analysis concerned the concepts related to the measurement process, namely about the need for a distinction between random and systematic effects, and between input quantities and corrections. [3] At present, that analysis has brought to a new way to describe the structure of the measurement process, for which a modification is required of the present VIM (2012) Concept Diagram for "Measurement" (Fig. A.3 in [4]), here shown in Fig. 1.

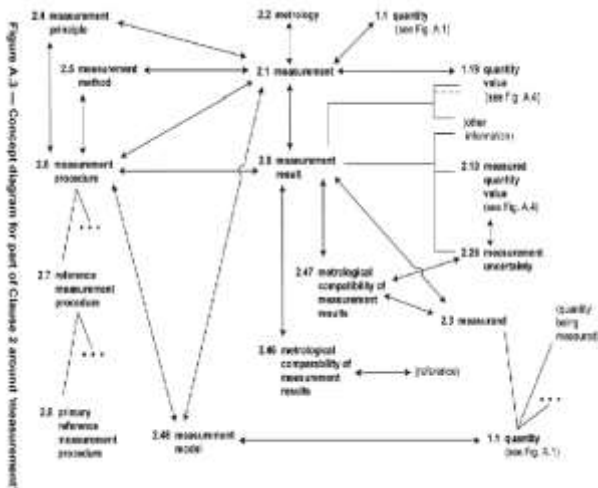


Fig. 1. VIM concept diagram for "measurement". [4]

The paper, after a short illustration of the present VIM diagram, will first summarise the differences between the measurement process in its traditional set of concepts and the new one (both concerning their meaning and their sequence or relationships). Then, the proposed new concept diagram is presented, in two forms, and the differences with the previous illustrated.

VIM concept diagram for the term "measurement"

Any "measurement" (clause 2.1) needs a "measurement method" (2.6), and to be operated by

means of a "measurement procedure" (2.6) based on a "measurement model" (2.48), and is intended to output a "quantity value" (1.19)—see Fig. 2— called "measurement result" (2.9).

The "measurement result", which is the key goal of the measurement, provides a "measured quantity value" (2.10) with its associated "uncertainty" (2.26)—see also Fig. 3—where the quantity is called "measurand" (2.3), defined the "quantity intended to be measured" in VIM 2012.

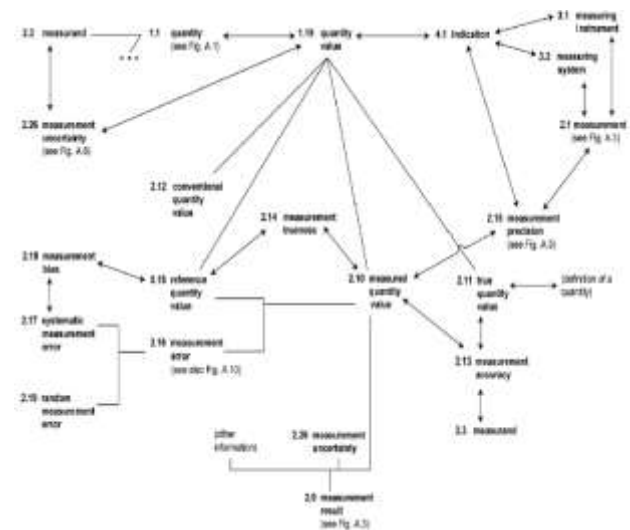


Fig. 2. VIM concept diagram for "quantity value". [4]

The measurement uncertainty is the next critical issue, since it determines, e.g., the "metrological compatibility of measurement results" (2.47), and is essential for the "metrological comparability of measurement results" (2.46). The lower part from here on of Fig. 2 illustrates the VIM position concerning critical terms, such as "true value" (2.11) and "measurement accuracy" (2.13), "measurement bias" (2.18) and "systematic measurement error" (2.17) or "random measurement error" (2.19).

In Fig. 2, the "quantity value" is originated from the "indication" (4.1) of a "measuring instrument" (3.1) that contributes to determine the "measurement precision" (2.15), unless it is a "conventional quantity value" (2.12).

A compound of Figs. 1 and 2 on "uncertainty budget" can be found in Fig. 3.

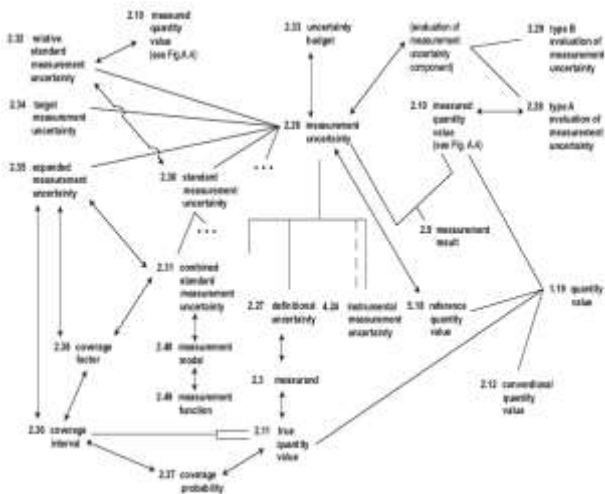


Fig. 3. VIM concept diagram for “uncertainty budget”. [4]

A new concept diagram for the term “measurement”

The new diagram, compounding and rearranging the Figs. 1–3, showing additional new relationships (—), is reported in Fig. 4.

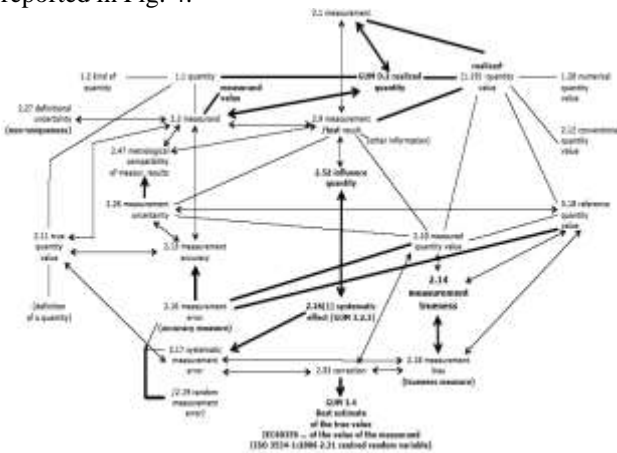


Fig. 4. New concept diagram for “measurement” based on previous Figs. 1–3.

Now (from top to bottom) the term “measurement” is first extended to the term “test” for the result, and the *basic* distinction is made between “quantity” (whose value is the “true” one (2.11), and the aim only (1.19) of the realisation) and the effectively “realized quantity”, as taken from GUM (clause D.2), according to the measurand definition (quantity *intended* to be measured) and the “measurand value” obtained.

The measurand (2.3) is in fact related to the *realized* quantity. A “definitive uncertainty” (2.27), taken from Fig. 3, has been added as associated to the measurand, inducing a “non-uniqueness” in it.

The concept of “influence quantity” (2.52) is added as the content of the measurement (model). They are responsible for the (added concept of) systematic effects (GUM 3.2.3), responsible for the “systematic measurement error” (2.17).

The concept of “measurement trueness” (2.14) has been added too below the “quantity value” (2.10) as a necessary one to understand the meaning of

“measurement bias” (2.18) (“trueness measure” in GUM), responsible for the “systematic measurement error” (2.17).

The “measurement error” (2.16) is a factor in determining “measurement accuracy” (2.13)

Notice that “measurement error” (2.16) is different from “measurement uncertainty” (2.26) in VIM 2012, and is not used in GUM.

Finally, “measurement bias” (2.18) induces systematic measurement errors (2.17), which are generally required to be *corrected* (2.53).

In Fig. 5 the different types of used fonts represent the *type of information* concerning each term.

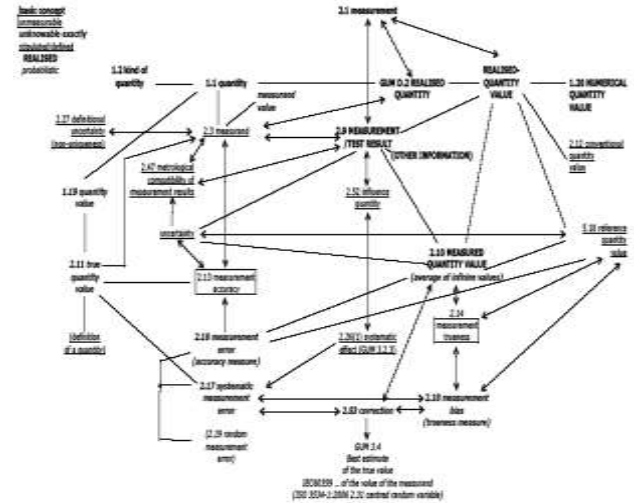


Fig. 5. As Fig. 4, but with the *type of information* of each term indicated by the different fonts in the Legend.

In [3] it is proposed to eliminate the use of the term “systematic” concerning error and uncertainty (2.17, 2.26, GUM 3.2.3) and thus also the term “correction” (2.53).

A *prescriptive model*, is, according to [6], a model whose meaning is “socially” *shared* by the relevant Community (of scientists in this case). Sharing a model is indispensable if the results of the measurements made in different experiments must be compared with each other, as necessary in science. In the following, the shared understanding of the meaning of each quantity in the model is considered to correspond to the “reference state” for the quantities. The superscript \ominus , taken from physical chemistry, means “ideal state”—here in the “prescriptive” state.

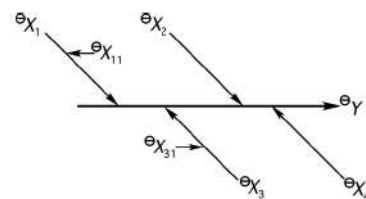


Fig. 6. Cause-effect diagram of a generic *prescriptive model* of the measurand.

In Fig. 6, the model, where all the quantities are thus considered to be in the corresponding “reference state”, is represented by using the *Ishikawa cause-effect diagram*, which shows the logical links between terms without the need to introduce numerical values. The subordinate lines show (with arrows added for clarity) the direction of the

logical flow of the input-quantities influence on the output quantity Y , irrespective to the direction of their slope. There are input quantities directly influencing Y (single subscript), others subordinated to other influence quantities (double subscript); further levels are possible, according to the complexity of $f(X_i)$.

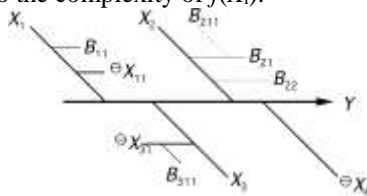


Fig. 7. Generic *experimental model* with distinction between unbiased (X) and biased (B) influence quantities.

However, that is *not* the “experimental model” (or *descriptive* model [6]), in general needing to be much more complicated and that is specific for *each* experimental setup. A generic one is shown in Fig. 7. It comprises *all* the influence quantities judged to be *significant* by the experimenter (i.e., influencing the measured *value* of the measurand). The $\ominus X_{ij}$ are the input quantities that are already in the respective “reference state”, the B_{hkl} are the input quantities that are not measured in their reference state, thus traditionally considered as being affected by a “bias”. If a subordinate quantity is affected by bias, the quantity influenced by it *cannot* be in its reference state too.

In actuality, according to what can be found fully explained in [4], what is generally called *bias*, is simply an *out-of-reference condition* at the measurement time of those quantities. What is called bias is supposed to be, in general, *corrected*, c being an *correction value* $\neq 0$ and affected by an uncertainty: this operation is *assumed* to compensate for the *estimated value* of the bias, i.e., $c =: -b$, and $B + c =: \ominus X$.

Finally, in a real experimental setup, the same quantity X can be “localized” in different parts of the experimental setup, indicated with an asterix $*$ in the figure (e.g., temperatures T_i^* in different parts).

The final *descriptive model* in Fig. 8 (see [4] for the full derivation) is the *only one* that can be equivalent to the initial *prescriptive model*, because it is the only one where the state of “reference” is reached for each and all influence quantity. Therefore, $\ominus Y$ in it is the same quantity as in Fig. 6, and exclusively that value can be compared with the values found in other experiments (if they follow the same kind of roadmap).

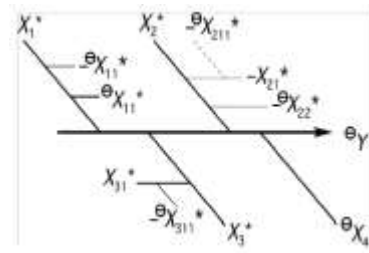


Fig. 8. The *final* experimental model for the *specific* measuring system and *compatible with the measurand*.

Conclusions

The model in Fig. 8 brings to the correct measurement result that can be compared with replicated measurements of the same measurand.

Should one abandon the concept of “true value”, then it can be argued that one should also abandon the concepts of “systematic error” and “correction” all together, simply replacing them by the need to express all the influence quantities in their respective “reference state”. Consequently, also the distinction, made in the GUM [2], between “input quantities” and “corrections” becomes unnecessary.

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