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Toward the next Edition of the International Vocabulary of Metrology

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Abstract

The International Vocabulary of Metrology (VIM) is presently available in its 3rd Edition (2012) (VIM3). VIM3 has been a major achievement, with numerous comments found in the literature concerning the assessment of it that will be taken here as references for future developments.

The present paper is mainly based on the concept that such a Vocabulary is assumed to be of great help for practitioners in metrology, i.e., in general for people that must correctly apply the idiom of metrology according to the current meaning of its terms.

The core of VIM3, i.e., its few basic terms, which are those currently used in metrology (defined according to the paper's Glossary), are identified, and their current meaning will be recalled together with the rationale of having chosen them.

The Author's position will be given, as assuming that the Metrology Vocabulary is not supposed to be of much interest for the scientists whose activity already develops under the discipline of metrology, since they are supposed to be well-informed on its terminology. Rather, such a Vocabulary is assumed to be of great help for practitioners in metrology, i.e., in general for people that must correctly apply the idiom of metrology according to the current meaning of its terms.

In addition, the International Vocabulary is assumed being used in every Country of the World, accounting for the need of easy and unambiguous translations in many different languages as much as possible, when the local metrological idioms may be expressed differently, which is a major difficulty.

The core of VIM3, i.e. its main basic terms, which are those currently used in metrology, are identified as being: "Quantity" vs. "Amount", "Magnitude"; "Quantity" vs. "Property"; "Value" vs. "Scale". Their current meaning will be recalled, together with the rationale of having chosen them. The above-mentioned terms are compared with recently proposed changes for several of them, including some new terms to be introduced.

The analysis will also account for the fact that, for the basic terms, any substantial change in their meaning, or the suppression of some of them, should be carefully pondered for being strictly necessary, because it may entail unnecessary confusion for many users. In fact, it is possible and reasonable that in other disciplines the same terms might express different concepts and express differently according to the specific idiom of those disciplines – e.g., according to an idiom basically originating from branches of philosophy of science or from set theory, where important differences in the meaning could be inappropriate or difficult to understand in measurement science, and in metrology particularly.

Keywords: VIM3; VIM4 preparation; quantity; amount; magnitude; property; value; scale; instance; attribute.

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Introduction

Since 1983, The BIPM-JCGM-200 Committee has been preparing the International Vocabulary of Metrology (VIM), presently existing in its 3rd Edition (2012) – a major achievement done with an important contribution of Paul De Bièvre [1–2]. Numerous comments can be found in the literature concerning the assessment of VIM3 that will be taken here as references for future developments, in particular [3] and a recent paper [4] containing proposals of changes for the current Edition, formulated in view of the next one, now in preparation.

The present paper is based on the Author's position that the Metrology Vocabulary is not assumed to be of much interest for the scientists whose activity already develops under the discipline of metrology, since they are supposed to be well-informed on its terminology. Rather, such a Vocabulary is assumed to be of great help for practitioners in metrology, i.e., in general for people that must correctly apply the idiom of metrology according to the current meaning of its terms.

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"Quantity", "Amount", "Magnitude"

As fully discussed in [6], the meaning of the term "quantity" is a puzzle, especially in the English language.

Historically, in VIM1, it was defined as: "an attribute of a phenomenon, body or substance, which may be distinguished qualitatively, and determined quantitatively", according to its inherently possible double interpretation.

In VIM2, it was defined similarly: "attribute of a phenomenon, body, or substance that may be distinguished qualitatively and determined quantitatively".

In VIM3, [1] it became "property of a phenomenon, body, or substance, to which a number can be assigned with respect to a reference", where the term "attribute" is replaced by "property", and its double nature, "distinguished qualitatively and determined quantitatively", which in VIM2 was explicit, is not specified.

The problem arises from the fact that in English the term quantity is paralleled by the term amount, an issue that in other languages does not occur. According to [6]: "None of the three [Editions] refers to 'quantity' as being a synonym of 'amount'. In fact, in all the brochures about the SI system of units, the term 'quantity' was – and is – continuously used to designate the phenomena, bodies or substances that we (intend to) measure... In other languages, two different terms exist for 'quantity' and 'amount': 'Groesse' and 'Menge' in German, 'grandeur' and 'quantité' in French, '(meet) grootheid' and 'hoeveelheid' in Dutch, 'grandezza' and 'quantità' in Italian".

Therefore, the term "amount" is not used in VIM3 except in the term "amount-of-substance", disliked in English just for that reason!

The issue mainly involves the possible double nature of the meaning of "quantity", but possibly only in English where, on the other hand, "quantity" becomes clearly derived from "quantification", whose normal occurrence means "quantified by a number", e.g., expressed in "quantitative scales".

A similar difficulty occurs in other languages, while not in English, for the term "magnitude", that has no exact correspondent in French and Italian, where "size" (not necessarily great) can only mean "ordre de grandeur" or "taille" in French and "dimensione" or "taglia" in Italian. "Extent" can also be used in English instead of magnitude, and this fact might allow easier translations ("degree" in French). However, like "quantity" vs. "amount" in English – but instead "grandeur" vs. "quantité" in French – the fact that also other terms, e.g., magnitude, can be translated in apparently contrasting ways in different languages cannot be taken as a sufficient reason for omitting them in the measurement idiom in future – or basically altering their meaning in the original two VIM languages, English and French.

According to the Merriam-Webster Dictionary [7], those terms are reported as follows:

A property is: "a quality or trait belonging and especially peculiar to an individual or thing" (and, in [8] "A property is a feature of anything perceivable or conceivable").

A magnitude is: "a great size or extent; b(1): spatial quality: size, b(2): quantity, number" [not necessarily numerical].

A quantity is: "1a: an indefinite amount or number, b: a determinate or estimated amount, c: total amount or number, d: a considerable amount or number; 2a: the aspect in which a thing is measurable in terms of greater, less, or equal or of increasing or decreasing magnitude, b: the subject of a mathematical operation" [non necessarily numerical].

Amount is: "1a: to be the same in meaning or effect as, b: to reach in kind or quality: to turn out to be; 2: to reach a total: add up" [not numerical].

(Note that "quantity" here is equivalent to amount, while in measurement science it is the property of "something" – or "anything perceivable" (ISO), which is an example of possible very basic differences among different idioms).

The definitions in [7] bring the definitions in [4] to the following consequences: "(a) a property

of a phenomenon, body, or substance is a qualitative concept, (b) the magnitude of a property of an individual phenomenon, body, or substance is a quantitative concept, and (c) a quantity is a quantitative concept." The Author acknowledges limitations of the arguments presented in [4] based on the other simple definitions given, as it is possible that inspection of more complete language references will reveal other alternative interpretations.

Notice that there is the lack of the use of "amount". In addition, notice that the property is qualitative there, while a new term "individual property", where, as introduced in [4], the term quantity is used instead and therefore is quantitative, i.e. has a magnitude. However, should the magnitude be necessarily intended to be expressed numerically?

The same question applies to "amount". For example, an "amount of material" can be considered equivalent to a "material portion". However, "amount" could mean portion − i.e. fraction − of a material only with no direct reference to a quantification of the relevant property of the material − though the portion could be expressed not only in terms of a property of the quantity, e.g., portion of mass, or of weight, or of volume, but also in terms of other non-quantitative instances of the portion. Actually, the Author considers Merriam-Webster's definitions of these terms as not necessarily quantitative, at least in the sense of using numerical values to express them.

In addition, according to the above considerations, the VIM3 definition of quantity is still sufficient to handle without ambiguity of the above issues.

In fact, in measurement science, a quantity is understood as in VIM1 and VIM2. In VIM3, instead of specifying its double nature, qualitative and quantitative, it makes first explicit its general qualitative feature by making explicit the "attribute" as a "property", and then it makes explicit its possible (i.e., when relevant) individual quantitative feature by saying: "to which a number can be assigned with respect to a reference". By explicitly indicating not only "a number", but also that it depends on the chosen "reference", VIM3 definition eliminates any ambiguity about the fact that the meaning of magnitude and amount is: (a) first of all always generic − actually a general fact for any concept, having a generic declination; (b) then specific − since it can possibly be applied to any individual declination "of the same kind", i.e. pertaining to that same quantity.

For the above reasons, in metrological idiom, it is not strictly required to create new terms to distinguish quantities like "individual" quantity, "individual" property, "specific" quantity, "real" quantity, etc. The new definition of quantity in [3–4] has been proposed because both natures of quantity, qualitative and quantitative, in the VIM3 definition are not retained: it is a useless complication, at least in the measurement frame and idiom. In VIM3, they are simple types having different properties.

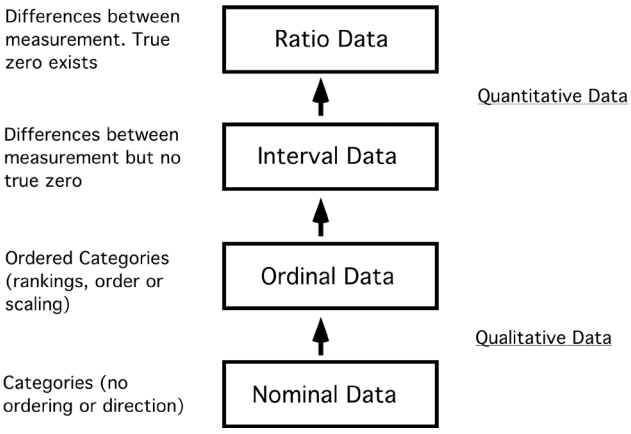

Fig. 1. Types of data and their respective categories and scales

"Quantity", "Property"

Summarizing, one calls "quantities" a class of "properties" of something (e.g., observations, counting) having the common characteristic specified in the VIM3 definition: for certain uses, a number can be associated with it as the result of a measurement or, at least, pertaining to a quantitative scale. It also means that the properties can be subdivided in several different classes, categories, or kinds. Consequently, the definition of quantity in VIM3 unambiguously considers only quantities possibly expressed by numbers.

An important feature of VIM1 to VIM2 is that they do not consider the case of ordered or nominal categories of properties (of data), i.e. those that in Fig. 1 below require non-quantitative scales.

Should VIM4 intend to include the definitions to "non-quantitative" categories, like the ordered and nominal ones, they cannot be labelled "quantities", not being quantitative by definition, but in fact often labelled "qualitative": that would introduce an irresolvable confusion in the meaning of the term "quantity".

The basic difference in the metrology frame between the terms "ordinal" and "nominal" seems to be in the following:

i) the "ordinal" is for properties having an 'objective' order (e.g., small, big, very big, ...) of their instances (Note: here the possible use of numbers does not indicate quantitative instances, specifically numbers, but only the position of each instance on the ordinal scale);

ii) the "nominal" needs an 'inter-subjective' convention (e.g., good, bad, ... − instances − for a property), that can be called equivalence relation. The instances are not values of the nominal scale, but indexes.

In the case i) above, a peculiar use of the term order is the expression "order of magnitude", quite common while using the somewhat controversial term "magnitude". Here above, the term "order" indicates

that magnitudes can be referred to ordered – increasing (or decreasing) – sets of numerical values. The above expression indicates the appropriate way to identify one of these sets (e.g., a specific decade in the decimal system). Instead, the expression "order of a quantity" is ambiguous. It is clear that the term "order" has two meanings: a) approximate amount; b) on a scale: consequently, it can only be referred to a "property" – as "ordinal properties", because "ordinal quantities" instead would be a contradiction in terms. "Property" is always of something, while "quantity" is something.

The terms "kind" is used in VIM3 for the term "kind of quantity", meaning "aspect common to mutually comparable quantities".

"Value", "Scale"

The meaning of the term "value of a quantity" is probably the most simple and important among the terms needing to be deeply understood in metrology.

In VIM3, clause 1.19 tells: "quantity value, number and reference together expressing magnitude of a quantity";

Clause 1.20 tells: "numerical quantity value, number in the expression of a quantity value, other than any number serving as the reference".

In VIM3, clause 1.8 tells: "quantity of dimension one dimensionless: quantity for which all the exponents of the factors corresponding to the base quantities in its quantity dimension are zero" (NOTE 3: "Some quantities of dimension one are defined as the ratios of two quantities of the same kind") – is important because in NOTE 4 it tells "Numbers of entities are quantities of dimension one. EXAMPLES ..., number of molecules in a given sample, ..."

Therefore, an extremely important metrological term "number of entities", which is the result of a counting, is relegated to a Note, and the term "integer value of a quantity" has not a specific clause too. These terms, together with other terms related to discrete-kind quantities, are very important omissions in VIM, considering the importance of counting in certain frames of metrology, see e.g. [9].

On the other hand, apparently, in VIM3 all numbers are considered real, as explicitly spelled out in the Section "Conventions" and in clause 1.9 (measurement unit: "real scalar quantity ...").

Read together with the above definition of the term "quantity", "value" very clearly indicates that the "number and reference" in the definition of the latter is the quantity value magnitude. The term magnitude is not defined in the VIM3 being considered a "primitive" concept, and "the use of non-defined concepts (also called "primitives") ... unavoidable" [1].

However, it might be useful to have a specific term for magnitude, "... a fundamental concept in metrology" as fostered in [4], where a definition however is not provided, except in its Summary as: "The magnitude of a property is indefinite before measurement. The target of the measurement is that indefinite magnitude." In [4], there is another definition of quantity value: "a definite magnitude that may be assigned to a quantity".

However, as said in [4], "In the [current] JCGM, a viewpoint that has gained popularity is to avoid the term magnitude. This is unfortunate." The reason is apparently due to the difficulty to translate it in some languages (see above). In order to avoid its use, a current idea is to resort to the idioms of other disciplines, specifically to the same tool used in some branches of philosophy of science: to replace the sub-ordination of hierarchically lower concepts with a set of individual concepts, one per each subordinate. This exercise is explicitly proposed in [3], and has been already partially discussed above for the term "quantity", when split into additional "individual quantities": "Position 1: values are individual quantities identified as multiples or submultiples of units, which are themselves individual quantities".

In the case of quantity value, that position might bring to consider instead each value as a distinct quantity, spelling it, e.g., as follows (see also [3]).

A number and a reference identify the value of a quantity, individual quantity. The Author's position in this paper is that this way out would be unnecessary and highly confusing the readers. (Note. The reason of the VIM3 expression "number and reference" is that the write-up of the number and the unit (the reference) is *not* a product, but a logical operation, as BIPM recommended: the dot has not to be used. Now, in [10], the BIPM accepts both space and dot).

A basic advancement in science has been obtained when it was understood that, in order to compare different magnitudes, it was necessary that all measurement results were expressed on the same scale of values. In VIM3, this concept is spelled out in clause 2.9: "measurement result: set of quantity values being attributed to a measurand together with any other available relevant information" (boldface added), where quantity values are correctly indicated as attributes of the quantity.

On the contrary, should one introduce a definition like the above "Value of a quantity", it would look quite odd due to the fact that the numerical result(s) of the measurement of a quantity is not an attribute of the quantity, but a distinct quantity (one per each measurement in a set), i.e. that the magnitude of a quantity is not quantified in the frame of the quantity definition.

It is also questionable the position expressed in [3], of limiting the meaning of quantity value to each individual quantity, because, e.g., a quantity value can also be attributed by means other than a measurement.

Avoiding the introduction of individual quantities does not contradict the fact that, when using a quantity as a variable in any equation (see Footnote 5),

as illustrated in the VIM3 clause 1.25 (numerical value equation), there is no intention to refer to any specific quantity value. As said above, the concept of quantity intrinsically expresses a double nature, non-quantitative and quantitative, not contradicting with each other because they are two different aspects occurring in different instances. That does not create any ambiguity or confusion to the users.

Coming finally to the term "scale", one of the effects of defining instead each "value" as a distinct "quantity", would be that a scale is not composed of values but of quantities (of the same kind). Another effect would be that the clause "quantity-value scale" (clause 1.27 in VIM3) could not be used anymore, while "ordinal scale" could still be used, which is a little intuitive issue.

In summary, in general sense, Quantity is: a property that has certain attributes and instances expressing numerical values. Each particular Quantity is a (set of) instance(s) (each) having a magnitude, according to one (or more) scale(s) (all) having a unitary value.

(Note: not all the attributes of a property necessarily apply to all individual quantities "of the same kind").

Conclusions

The paper has illustrated the current meaning in measurement science − and namely in metrology − of the main basic terms that have been so far included in the International Vocabulary of Metrology. As a result, most of the advanced choices made in VIM3 seem to correctly express the intended meaning and to provide an adequate understanding for the vast majority of the readers/users.

The analysis also included current proposals that can be found in the literature for modified or newly introduced terms for the next Editions of the Vocabulary. In most cases, a deviation from the current metrological idiom is, in the Author's opinion, not only useless, but may bring to an unnecessary confusion for the users/practitioners.

Glossary

Quantity: as in VIM3, 1.1 [1]. Property of entities, whose main function is to convey a quantitative meaning to the estimates of the values of the entities, the measurand (VIM3, clause 2.3), at different times, in different situations, on different scales, etc... The property is formed by one or several attributes. The numerical values are its basic attribute: they are ordered according to one or more specific scales, each characterized by a unit value (ratio or interval scale). To a quantity instance, a magnitude − a generic term for extent − can be associated as an attribute.

Value: as in VIM3, 1.19 [1]. A basic attribute of the property associated in general sense with Quantity, indicating the nature and the quantification of the information provided by the property. When a specific numerical value is indicated, it pertains to a particular instance of a Quantity ["value" is not a distinct quantity].

Scale: as in VIM3, 1.27 [1]. Attribute of a sub-sets of Quantity instances. Its function is to order the set of values and determine the position of the unit value on it. ["scale" it is not a quantity].

Magnitude: attribute of a quantity instance, expressing the ratio between the specific value and the value of another quantity instance measured for the same attribute of the property, on a scale. If the latter value is the unit value, the magnitude coincides with the unit value. [it is not a quantity].

Entity: phenomenon, body, substance, ...

Instance: one example of a quantity or kind of quantities.

Attribute: one example of a property.

Kind of quantities: as in VIM3, 1.2 [1]. Set of quantities with mutually comparable properties.

До питання про наступне видання Міжнародного словника з метрології

Ф. Павезе

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Анотація

Міжнародний словник з метрології (VIM) наразі існує у своєму 3-му виданні (2012) (VIM3). VIM3 є великим досягненням, і в літературі можна знайти численні коментарі щодо його оцінки, які будуть узяті тут як посилання для майбутніх розробок. Відповідно до глосарія статті визначено ядро VIM3, тобто кілька його основних термінів, які зараз використовуються в метрології, разом із їхнім поточним значенням та обґрунтуванням їхнього вибору. Подано позицію автора, виходячи з припущення, що VIM не має викликати особливого інтересу серед учених, чия діяльність вже і так розвивається в рамках такої дисципліни, як метрологія, отже вони апріорі мають бути добре обізнаними з її термінологією. Скоріше передбачається, що такий словник буде дуже корисним для метрологів-практиків,

тобто загалом для людей, які мають правильно застосовувати метрологічні терміни відповідно до їхнього поточного значення. Крім того, передбачається, що цей міжнародний словник використовується в кожній країні світу, тому дуже складним завданням є знаходження легких і однозначних варіантів перекладу багатьма різними мовами, для яких характерне різне тлумачення. Ядро VIM3, тобто його основні базові терміни, що зараз використовуються в метрології, становлять такі терміни, як: "величина" – "кількість", "магнітуда"; "величина" – "властивість"; "значення" – "шкала". Згадано їхнє поточне значення разом з обґрунтуванням їхнього вибору. Наведені вище терміни порівняно з нещодавно запропонованими змінами кількох із них, включаючи деякі нові терміни. Під час аналізу враховано, що для основних термінів будь-яка суттєва зміна їхнього значення або відмова від деяких із них має бути ретельно обміркована, оскільки це може спричинити непотрібну плутанину для багатьох користувачів. Насправді цілком можливо й розумно, щоб в інших дисциплінах ті самі терміни виражали різні поняття та в інший спосіб, згідно з конкретним вживанням у межах відповідних дисциплін, наприклад, відповідно до лексикону, який в основному походить із філософії науки або з теорії множин, де суттєві відмінності в значенні можуть бути недоречними або важко зрозумілими в науці про вимірювання, зокрема в метрології.

Ключові слова: VIM3; підготовка VIM4; величина; кількість; магнітуда; властивість; значення; шкала; примірник; атрибут.

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