OUTLINE OF THE CURRENT STATUS OF MEASUREMENT SCIENCE:

FROM THE POINT OF VIEW OF THE INTERNATIONAL VOCABULARY OF METROLOGY (VIM)

Luca Mari, lmari@liuc.it
Università Cattaneo – LIUC, Italy

Dimensions of measurement
Bielefeld, 14 – 16 March 2013

ABSTRACT

The *International Vocabulary of Metrology – Basic and General Concepts and Associated Terms* (VIM) (JGCM 200:2012; http://www.bipm.org/en/publications/guides/vim.html) is produced by the Joint Committee for Guides in Metrology (JCGM), which currently gathers eight international organizations working in the field of metrology and aimed at addressing the general metrological needs of science and technology through the development of guidance documents (together with the VIM, the Evaluation of measurement data – Guide to the expression of uncertainty in measurement (GUM) (JCGM 100:2008)).

A comparison of the three editions of the VIM (published in 1984, 1993, 2007 respectively) highlights that measurement science is a moving target, and some of its foundational topics, such as the concepts of quantity, measurement result, and measurand, have significantly changed even in a relatively short time. With reference to some cogent examples, the lecture will emphasize the current understanding of measurement as a knowledge-based, pragmatic process, in which models play a primary role.

MY PROFILE

Luca Mari received the M.Sc. in physics from the Milano University, Italy, in 1987, and the Ph.D. in measurement science from the Torino Polytechnic in 1994. Since 2006 he is full professor of measurement science at the Cattaneo University – LIUC, where he teaches courses on measurement science, statistical data analysis, system theory. At LIUC he heads the Ph.D. school and the laboratory on RFId Systems.

He is currently the chairman of the TC1 (Terminology) and the secretary of the TC25 (Quantities and units) of the International Electrotechnical Commission (IEC), and an IEC expert in the WG2 (VIM) of the Joint Committee for Guides in Metrology (JCGM). He has been the chairman of the TC7 (Measurement Science) of the International Measurement Confederation (IMEKO).

He is the author or coauthor of several scientific papers published in international journals and international conference proceedings. His research interests include measurement science and system theory. He is the designer and a main developer of the software simulation engine STGraph.

SOME OF MY RECENT PUBLICATIONS

- LM, A.Giordani, Quantity and quantity value, Metrologia, 2012
- LM, P.Carbone, D.Petri, Measurement fundamentals: a pragmatic view, IEEE Trans. Instr. Meas., 2012
- A.Giordani, LM, Measurement, models, uncertainty, IEEE Trans. Instr. Meas., 2012
- A.Giordani, LM, Property evaluation types, Measurement, 2012
- A.Frigerio, A.Giordani, LM, Outline of a general model of measurement, Synthese, 2010
- D.Macii, LM, D.Petri, Comparison of measured quantity value estimators in nonlinear models, IEEE Trans. Instr. Meas., 2010
- LM, V.Lazzarotti, R.Manzini, Measurement in soft systems: epistemological framework and a case study, Measurement, 2009
- LM, A computational system for uncertainty propagation of measurement results, Measurement, 2009
- LM, On (kinds of) quantities, Metrologia, 2009
- LM, The problem of foundations of measurement, Measurement, 2005
- LM, Epistemology of measurement, Measurement, 2003
- LM, Beyond the representational viewpoint: a new formalization of measurement, Measurement, 2000

JOINT COMMITTEE FOR GUIDES IN METROLOGY (JCGM)

(established in 1997)

(BIPM) Int.l Bureau of Weights and Measures
(IEC) Int.l Electrotechnical Commission
(IFCC) Int.l Federation of Clinical Chemistry and Laboratory Medicine
(ILAC) Int.l Laboratory Accreditation Cooperation
(ISO) Int.l Organization for Standardization
(IUPAC) Int.l Union of Pure and Applied Chemistry
(IUPAP) Int.l Union of Pure and Applied Physics
(OIML) Int.l Organization of Legal Metrology

JCGM GUIDANCE DOCS

VIM: International vocabulary of metrology
Basic and general concepts and associated terms

GUM: Evaluation of measurement data
Guide to the expression of uncertainty in measurement

http://www.bipm.org/en/publications/guides/[vim.html|gum.html]

VIM 1, 2, AND 3

First edition, **1984** (with corrections: 1987),
BIPM, IEC, ISO, OIML:
International vocabulary of basic and general terms in metrology

Second edition, **1993**
[ISO Guide 99:1993]
ISO/TAG 4 (BIPM, IEC, IFCC, ISO, IUPAC; IUPAP, OIML):
International vocabulary of basic and general terms in metrology

Third edition, **2007** (with corrections: 2012)
[JCGM 200:2008] [ISO/IEC Guide 99:2007]
JCGM:
International vocabulary of metrology
Basic and general concepts and associated terms

THE VIM AS A WITNESS OF CHANGE

The transition has been much more than
a matter of increase of political support and lexical fixes

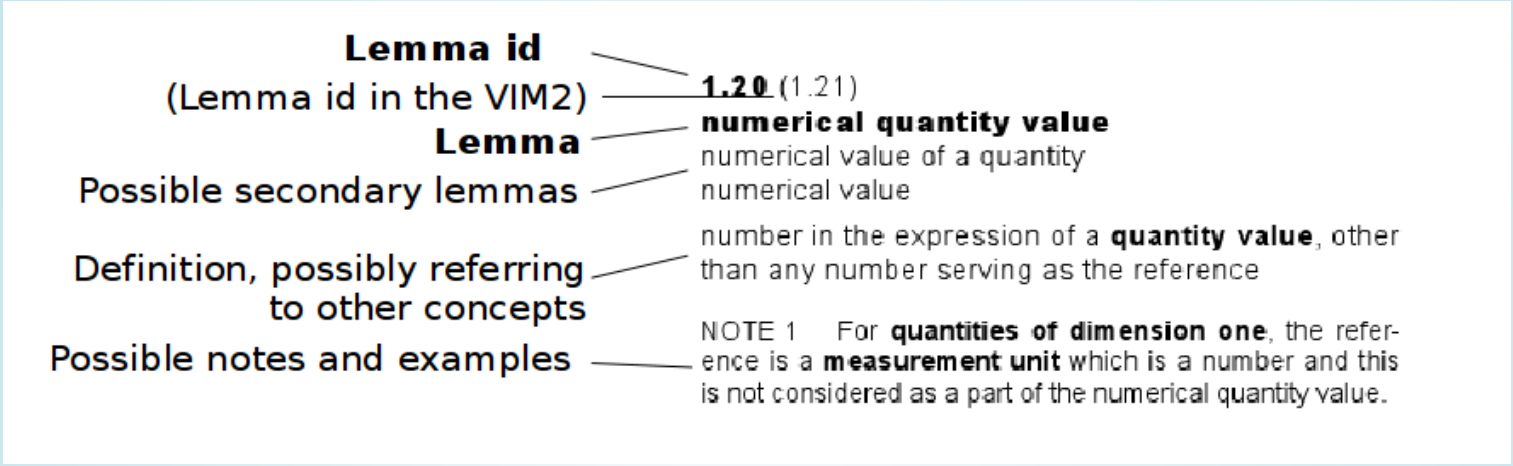
**It witnesses that
fundamentals of measurement science
are a moving target**

At least three related drivers can be identified:

1. the vocabulary is becoming a concept system / an ontology
2. and its scope is widening
3. and its concepts are under revision

1. THE VIM AS A CONCEPT SYSTEM

"Its title is now *International vocabulary of metrology — Basic and general concepts and associated terms*, in order to emphasize the primary role of concepts in developing a vocabulary"



"The *substitution principle* applies; that is, it is possible in any definition to replace a term referring to a concept defined elsewhere in the VIM by the definition corresponding to that term, without introducing contradiction or circularity."

"In some definitions, the use of non-defined concepts is unavoidable. In this Vocabulary, such non-defined concepts include: system, component, phenomenon, body, substance, property, reference, experiment, examination, magnitude, ..."

2. THE VIM SCOPE

"In this Vocabulary, it is taken for granted that there is no fundamental difference in the basic principles of measurement in physics, chemistry, laboratory medicine, biology, or engineering. Furthermore, an attempt has been made to meet conceptual needs of measurement in fields such as biochemistry, food science, forensic science, and molecular biology."

WIDENING THE SCOPE

The main consequence:

ordinal quantity:
"quantity, defined by a conventional measurement procedure, for which a total ordering relation can be established, according to magnitude, with other quantities of the same kind, but for which no algebraic operations among those quantities exist"

(note that 'ordinal quantity' was not defined in the VIM2)

Properties for which a measurement unit cannot be defined can be nevertheless measurable

WIDENING THE SCOPE?

The VIM3 introduces the definition of **nominal property**:
"property of a phenomenon, body, or substance, where the property has no magnitude"

On the other hand
"Measurement does not apply to nominal properties"
(and the term "examination" is introduced to denote the process of value attribution to nominal properties)

But
"Measurement implies comparison of quantities or counting of entities",
and objects can be both compared with each other and counted in reference to nominal properties...

3. THE CONCEPTUAL FRAMEWORK

"Development of this third edition of the VIM has raised some fundamental questions about different current philosophies and descriptions of measurement."

measurement is a "process of experimentally obtaining one or more **quantity values** that can reasonably be attributed to a **quantity**",
where:

- quantities are properties "having a magnitude"
- the quantity under consideration is the **measurand**
- the attributed quantity values are the **measurement result**
- typically including a **measured quantity value** and a **measurement uncertainty**

CONCEPTS ARE CHANGING...

... while terms are (usually) maintained

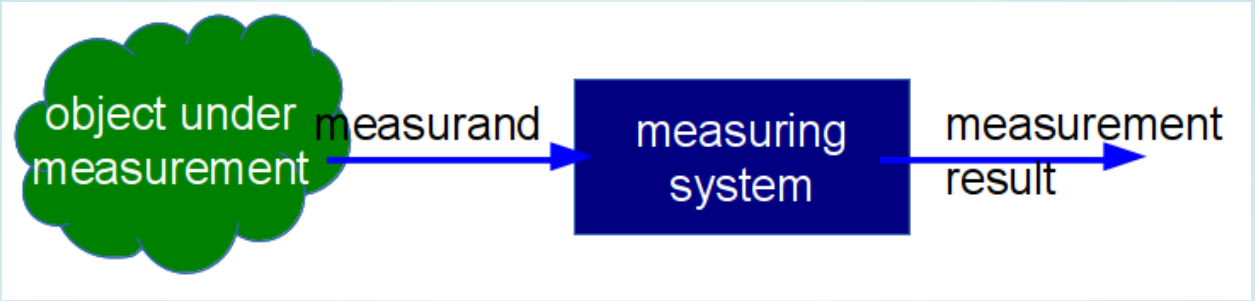
An interesting and critical case: **measurand**:

- VIM2: "quantity subject to measurement"
- VIM3: "quantity intended to be measured"

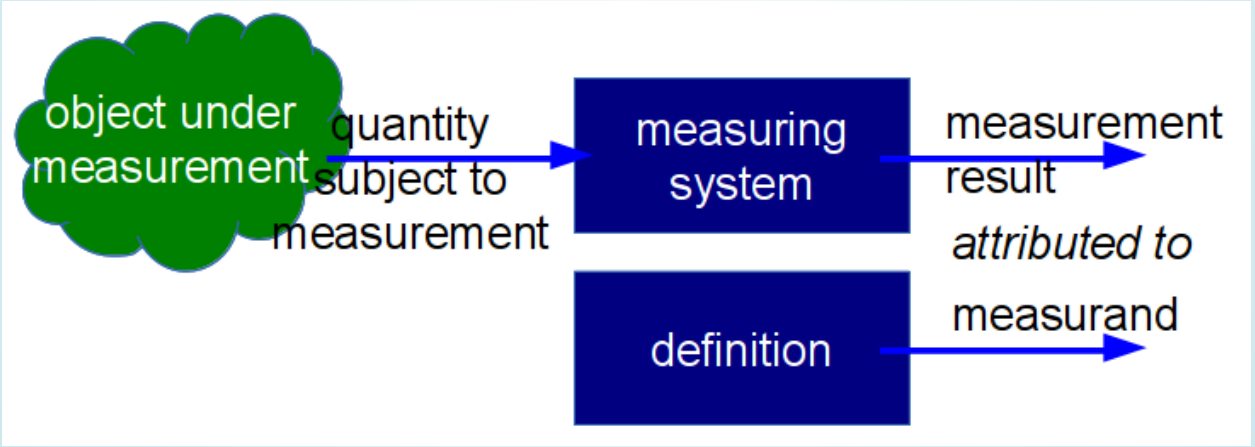
The idea: we do our best to let the measuring instrument interact with the quantity we want to measure, but the measurement result will be attributed to the quantity as we have defined it, not to the (unknown) quantity with which the instrument actually interacted.

WHAT IS A MEASURAND?

According to the VIM2:



According to the VIM3:



A CONSEQUENCE

Measurement uncertainty takes into account
both the experimental and the definitional components:

definitional uncertainty [*concept introduced in the VIM3*]:
"component of measurement uncertainty resulting from the finite amount of detail in the definition of a measurand"

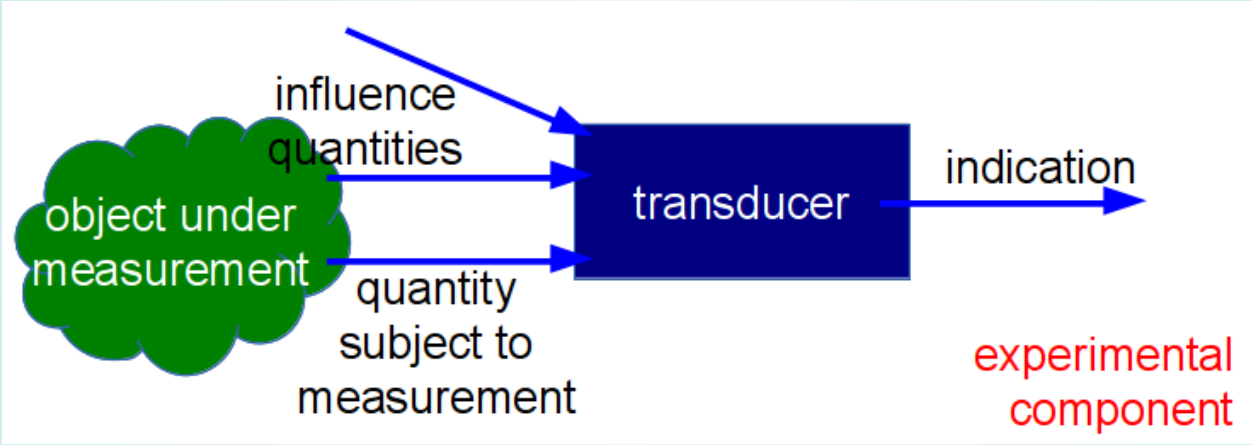
and indeed:
"Definitional uncertainty is the practical minimum measurement uncertainty achievable in any measurement of a given measurand."

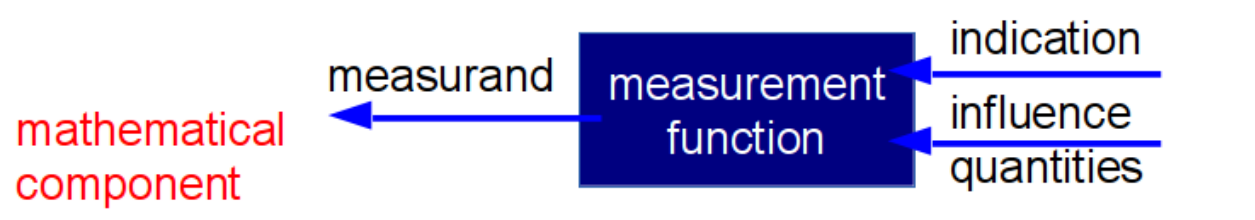
Measurement results depend on definitional issues...

A MODEL-BASED PROCESS

measurement model [*concept introduced in the VIM3*]:
"mathematical relation among all quantities known to be involved in a measurement"

... specialized in the **measurement function**:
`measurand = f(indication, influence quantities)`





PROBLEM

How can the measurement function be known?
How is it obtained?

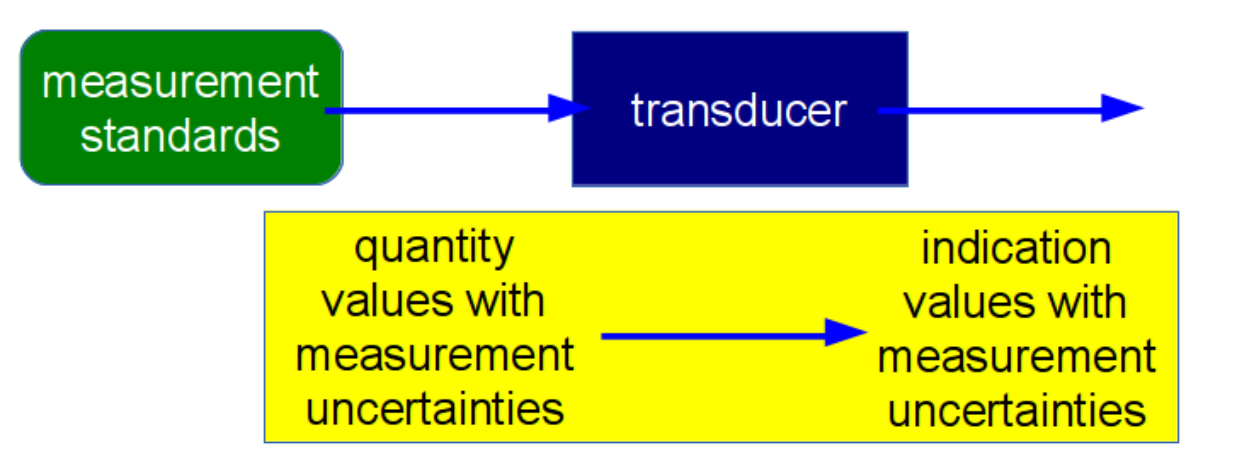
THE FUNDAMENTAL CONCEPT: CALIBRATION

[*definition significantly changed in the VIM3*]

"operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication"

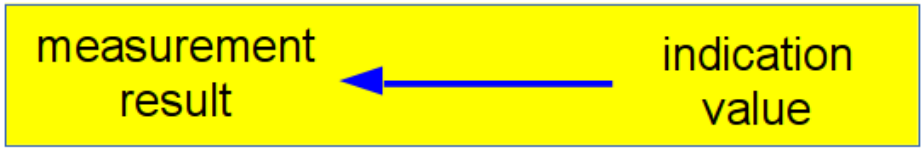
CALIBRATION: IN A FIRST STEP...

"establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties"



... AND IN A SECOND STEP

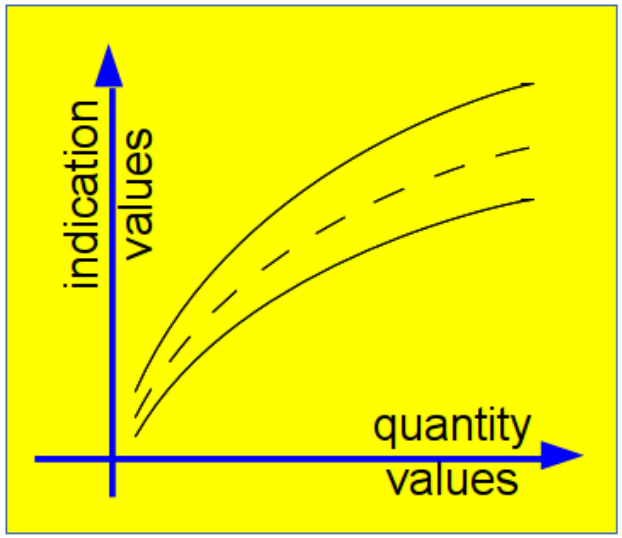
"uses this information to establish a relation for obtaining a measurement result from an indication"



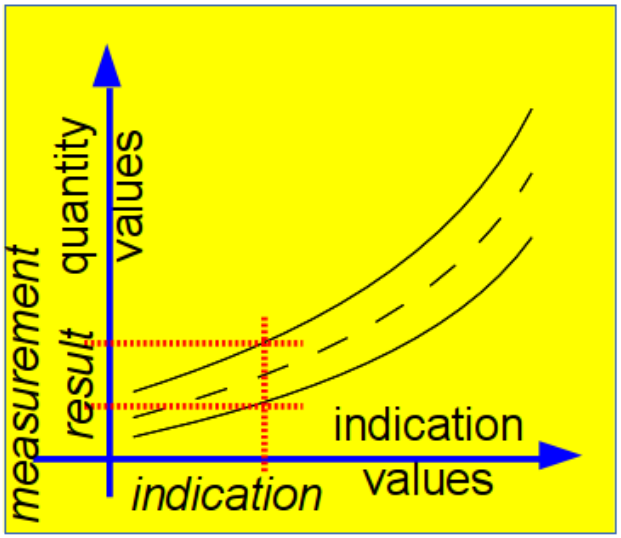
CALIBRATION DIAGRAM

[*concept introduced in the VIM3*]

"graphical expression of the relation between indication and corresponding measurement result"



first step



second step

MEASUREMENT AS PRAGMATIC PROCESS

Measurement uncertainty is the overall parameter to assess the quality of what a measurement produces in a costs-benefits analysis...

... and it is aimed at being compared to the
target uncertainty [*concept introduced in the VIM3*]
"measurement uncertainty specified as an upper limit and decided on the basis of the intended use of measurement results"

TOWARDS THE VIM4...

The current edition of the VIM is still a half-refined document,
and the JCGM is planning to revise it

Some open (philosophically related) issues are...

Should measurement be generalized
to **nominal properties**?

i.e.: What is the relation between quantitative evaluation and measurement?

The VIM3 defines **true value**
as "quantity value consistent with the definition of a quantity":

is it a correct definition?

and how should an individual quantity / property
be defined?

Moreover, the VIM3 states that "there is not a single true quantity value
but rather a set of true quantity values consistent with the definition":

is this concept of 'multiple true values' correct?

More generally,

are the concepts 'measurement uncertainty' and 'measurement error' compatible with each other?

Note that the VIM3 defines **measurement error** as "measured quantity value minus a reference quantity value" (instead of "minus the true value")...

Is it possible (and reasonable, and useful)
to extend the scope of the VIM
so to include measurement of non-physical properties?

Is it possible (and reasonable, and useful)
to build a concept system
of the fundamentals of metrology
independently of philosophical positions / presuppositions?

How can the scientific community of philosophers be involved in this endeavor?

THANK YOU
FOR YOUR KIND ATTENTION

Luca Mari, lmari@liuc.it