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A quest for the definition of measurement

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ABSTRACT

Since in the scientific and technical literature multiple, sometimes incompatible, definitions of 'measurement' can be found, identifying a single conceptual framework is a significant target for measurement science, towards a generalized concept of measurement, in compliance with the notion of widely-defined measurement proposed by Ludwik Finkelstein. This paper introduces the subject with a structured review of some paradigmatic positions and then proposes to characterize measurement as an evaluation process able to produce objective and inter-subjective information on the measurand. A justification is given that this standpoint encompasses the evaluation of both physical and non-physical properties.

1. Introduction

The problem of establishing the definition of 'measurement' has surely something to do with conventions, and indeed it is common today to be skeptic about the existence of "true meanings" for terms and "true definitions" for concepts. As a consequence, any related discussion might be assumed as mainly of interest for the construction of a lexical system, a task customarily considered outside the scientific endeavor. The remark of the multiple, sometimes incompatible, definitions of 'measurement', widespread in the scientific and technical literature, might be simply assumed as the proof that measurement is a many-faceted activity, and that this multiplicity is somehow irreducible.

On the other hand, the question *what is measurement?* is compelling for at least two reasons.

First, the fundamental nature of measurement, acknowledged to be a (or even *the*) basic process to acquire and formally express information on the world, makes it an inter-disciplinary tool, thus emphasizing the usefulness of a global understanding of the basic and general concepts (hence not only 'measurement', but also, e.g., 'measurand', 'measurement result', 'uncertainty', 'accuracy', etc.), where the relation among concepts and the associated terms should be as much shared as it is possible.[2] Consider the example of properties such as the quality of industrial products, the complexity of software systems, the user satisfaction about social services and the individual attitude over given tasks/jobs. It is a fact that all of them are routinely evaluated, i.e., the information available on them is represented by means of values, usually numbers. But are such value assignments ("evaluations" for short henceforth)

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[2] This is precisely the purpose of the *International Vocabulary of Metrology – Basic and general concepts and associated terms* (VIM3) [1], a guidance document published by the Joint Committee for Guides in Metrology (JCGM), an inter-organizational committee currently composed of eight leading international organizations: International Bureau of Weights and Measures (BIPM), International Electrotechnical Commission (IEC), International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), International Laboratory Accreditation Cooperation (ILAC), International Organization for Standardization (ISO), International Union of Pure and Applied Chemistry (IUPAC), International Union of Pure and Applied Physics (IUPAP), International Organization of Legal Metrology (OIML). The VIM3 "is meant to be a common reference for scientists and engineers – including physicists, chemists, medical scientists – as well as for both teachers and practitioners involved in planning or performing measurements, irrespective of the level of measurement uncertainty and irrespective of the field of application. It is also meant to be a reference for governmental and inter-governmental bodies, trade associations, accreditation bodies, regulators, and professional societies." [1: Scope].

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specifically measurements, as it is usually claimed? Or are they only, e.g., "subjective evaluations", in the form of guesses, assessments by experience, etc. And what is the nature of the so-called soft measurement [2,3], or weakly-defined measurement, or widely-defined measurement [4]? In these terms, the problem loses most of its conventionality, at least because only in the case of measurements the sometimes significant resources required to accomplish such evaluations would be accepted. The issue is about the "special reliability" (just to use a very generic term for now) of measurement, a feature which has nothing to do with lexical issues and whose justification eventually requires a common understanding of the concept.

The second general reason of interest for the question 'what is measurement?' is that an investigation on this matter reveals a strong, systematic correlation between the conceptions of measurement and the underlying standpoint that in different periods and fields have been assumed on the nature of scientific and technical knowledge. Hence, the definitions of 'measurement' may be considered significant indicators for general issues such as the very possibility of true knowledge, and the relation between experiment and modeling. In a situation in which many traditional distinctions have become blurred (a good example is the idea of fully automatic measurement, that in the past would have been plausibly rejected under the assumption that only human beings are properly able to deal with information), measurement science can maintain its role, instead of dissolving in a myriad of technical sub-disciplines, only by recovering a shared fundamental background.

This paper is aimed at presenting and interpreting such multiple definitions and standpoints on the basis of a single conceptual framework allowing to compare them and, finally, to argue in favor of the adoption of what could be called an encompassing *generalized concept of measurement*.

The quest for the definition of measurement is a subject to which prof. Ludwik Finkelstein has given a significant contribution. This paper is written in admired, grateful acknowledgment of his work in measurement science, and in memory of his personality.

2. Multiplicity

The scientific, technical, and philosophical literature includes many different definitions of 'measurement', thus witnessing the interest for the subject and, at the same time, its complexity. This multiplicity can be interpreted according to several complementary criteria, for example as follows.

Criterion	Exemplary definition
– Is measurement characterized by the structure of the process	"To measure a quantity means to define a unit and to establish how many times the unit is contained in the given quantity. The measurement result is expressed by a number, which expresses how many times the given quantity is greater (or possibly smaller) than the selected unit." [5] (translated from Italian)
or by the results it produces?	"Measurement is essentially a production process, the product being numbers." [6]
– Does measurement imply the comparison to a reference, possibly a unit,	"Measurements are executions of planned actions for a qualitative comparison of a measurement quantity with a unit." [7]
or not?	"Measurement is the process of empirical, objective assignment of numbers to the attributes of objects and events of the real world, in such a way as to describe them." [8]
– Are numbers required products of measurement	"Measurement of magnitudes is, in its most general sense, any method by which a unique and reciprocal correspondence is established between all or some of the magnitudes of a kind and all or some of the numbers, integral, rational, or real, as the case may be." [9]
or not?	"The only decisive feature of all measurements is symbolic representation; even numbers are in no way the only usable symbols. Measurement permits things (relative to the assumed measuring basis) to be presented conceptually, by means of symbols." [10]
– Are experimental activities required to perform a measurement	"Measurement is the set of empirical and processing operations performed by means of suitable devices interacting with the measured system with the purpose of assigning a value of a quantity assumed as parameter of