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Epistemology of measurement

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Abstract

The paper introduces what is deemed as the general epistemological problem of measurement: what characterizes measurement with respect to generic evaluation? It also analyzes the fundamental positions that have been maintained about this issue, thus presenting some sketches for a conceptual history of measurement. This characterization, in which three distinct standpoints are recognized, corresponding to a metaphysical, an anti-metaphysical, and relativistic period, allows us to introduce and briefly discuss some general issues on the current epistemological status of measurement science.

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1. Introduction

In the Plato's *Theaetetus*, Socrates explains the meaning of a principle attributed to Protagoras with the following words: "things are to you such as they appear to you, and to me such as they appear to me". The sophistic principle that Socrates was commenting on is the one, well-known, according to which "man is the measure of all things, of the existence of things that are, and of the non-existence of things that are not". In his analysis, Socrates considers that Protagoras was asserting the equivalence of *knowledge* and *sensation*: things can be known because they can be perceived, and they are known as they are perceived. It is interesting that this position, according to which "the same thing that *appears* warm to me and cold to you *is* warm to me and cold to you", establishes a paradigm of knowledge in reference to the concept of *measure*.

According to this meaning, measurement is simply synonym of evaluation, with the consequence that also estimations, personal judgments, and possibly even random assignments should be considered as specific examples of measurements. The issue here is only partly definitional (we could also be uninterested in definitions, although they sometimes maintain a useful role in guaranteeing some chance of mutual understanding). The fact is that this subjectivistic standpoint (that in its extreme form becomes solipsism) seems to be completely unable to justify the peculiar epistemic status usually recognized for measurement: Physics is, or was, paradigm for all the sciences mainly because of its ability to objectively measure quantities, and then define quantitative relations among them; the technological ability of system control is largely based on the quality of the adopted models and the data fed into them: both the models and the data depend on measurements.

Measurement is a specific kind of evaluation, i.e. it is an operation aimed at associating an *information entity*, the result of measurement, with the *state of*

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the system under measurement in reference to a given quantity, the measurand.

Even if not unconditionally adhering to the praises that can be easily found in the scientific literature about the role of measurement (e.g. “the progress of civilization is in strict relation to the development of measures” [1] or “a positive information about a system cannot be obtained but by a measurement” [2], up to the common myth according to which system control necessarily requires measurement: it is clear that nothing similar would be stated about generic evaluations), it is plausible that measurement has something special in comparison to a generic evaluation. We believe that the quest for this peculiarity can be aptly regarded as *the general epistemological problem of measurement*, that we synthetically formulate as:

Problem A. Provided that measurement is an evaluation, what characterizes measurement with respect to generic evaluation?

It should be clear that this *problem* relates to the issue of ‘what is it useful for?’ far more than of ‘what is it?’, and therefore its answer has operative, and not only terminological, implications. Indeed the quality, and sometimes also the quantity, of the information conveyed by measurement depends on the kind of the answer given to the *problem*.

In the course of history, the epistemic peculiarities of measurement have been found in at least three distinct areas:

- *Ontological reasons* (measurement is an evaluation able to determine those numbers that are essential properties of things)
- *Formal reasons* (measurement is an evaluation producing symbols that can be formally dealt with in a well definite way)
- *Informational reasons* (measurement is an evaluation whose results are informationally adequate to given goals)

Goal of this paper is to sketch some basics for a critical analysis of these three interpretations, presented in the diachronic perspective of a ‘history of ideas’, and then to investigate some consequences of such an epistemological reconstruction for the current status of Measurement Science. As a first step

let us analyze the premise of the Problem A, by shortly discussing the epistemological status of evaluation.

2. On the epistemological status of evaluation

Evaluations are operations aimed at associating symbolic entities, the ‘values’, with the things under evaluation. Provided that everything can be, in principle, object of evaluation (and perhaps the most socially evaluated things are the results of previous evaluations . . .), we will concentrate our attention on *physical* evaluation, of which physical measurement, our current interest, is a peculiar case according to the premise of Problem A. With this specification, evaluation is recognized to be a peculiar means to bridge the *physical world*, to which the evaluated thing belongs, and the *information world*, to which the evaluation result belongs.

The relations, and the distinctions, between these two worlds have been significantly analyzed by Karl R. Popper in the ‘theory of three worlds’: in his (metaphoric) view World 1 (W1) is the realm of physical things and processes; World 2 (W2) is the realm of subjective human experiences; finally, World 3 (W3) is the realm of objective knowledge. Popper himself presented such three Worlds as ‘some stages of the cosmic evolution’ [3] and exemplified them as follows:

World 1 (of physical entities)

1. Hydrogen and helium
2. Heavier elements; liquids and crystals
3. Living organisms

World 2 (of subjective experiences)

4. Sensitivity (animal conscience)
5. Conscience of self and death

World 3 (of products of human mind)

6. Human language. Theories of self and death
7. Products of art, technology, and science

The nature of W3 is complex. In Ref. [4], as examples of entities belonging to W3, Popper quotes automobiles and skyscrapers; while they can be actually thought of as ‘products of human mind’,

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