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Widely-defined measurement – An analysis of challenges

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ABSTRACT

The paper examines fundamental problems of widely-defined measurement that lie outside the representation concerns of measurement theory. It is intended as a starting point of a research agenda. It shows that measurement is applied in a wide range of diverse domains of knowledge and enquiry for which a wide-sense definition of measurement is necessary. It examines philosophical objections to the application of measurement. It considers in particular problems of measurand concept formation, validity, verifiability and of theories for the measurand. It concludes that Measurement Science should address the whole range of applications of measurement and should endeavour to provide a universal framework of concepts and principles to address all applications of measurement.

1. Introduction

Measurement, that is the descriptive representation of the attributes of objects and events of the real world by symbols on the basis of an objective empirical process, is a basic tool of modern human thought. It is the way in which we describe and reason about the world.

Measurement has been developed through the physical sciences, which serve as a paradigm. From this basis its application has been extended to virtually all domains of human knowledge and discourse. However, the concepts and methods of measurement in this wider and more diverse range of disciplines offer significant conceptual problems, compared with measurement in the physical sciences that is the normative view of much metrological discourse.

Some of these problems will be outlined in the present paper as a starting point of discussion and an agenda for research.

2. Historical development

The present concepts and principles of measurement are the product of a long historical development. An understanding of this process of development is very necessary to help the extension of the application of measurement to new domains, or to areas where measurement is still problematic. The literature of the history of mathematics and science does not, in general, treat the development of measurement explicitly in its general account. Some critical historical philosophical studies of the development of the concepts of measurement have, however, also been published. The subject should be an important item on the research agenda.

Only a brief outline of the historical development of measurement can be presented here. The references are illustrative rather than exhaustive [1–8].

Measurement originated in counting, at the very dawn of human culture. It developed in antiquity, on an intuitive basis, through applications in crafts, trade, surveying and calendar determination.

The rise of modern science was promoted by the advance of methods of measurement and in turn drove them forward. The 19th century saw the development of concepts and methods of measuring intangible physical variables, such as those of thermal and electromagnetic phenomena. There was established for physical phenomena an arsenal of measurement techniques, and a system of scales and units, based on comprehensive theories of the relevant domains of physics. A theory of measurement, based on the concepts of the physical sciences, was devel-

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oped by Helmholtz and Hoelder and presented in detail in the works of Campbell.

The descriptive and explanatory power of the physical sciences made them a model for endeavours to extend the same concepts and methods to psychological and social domains of knowledge. The classical view of measurement was inadequate for the purpose and a wider concept of measurement was developed.

This historical development is well described in the literature. The present author discussed it in outline in [9]. More detailed analytical discussions are presented by Diez [10,11] and Michell [12].

3. Measurement theory

Modern logical and philosophical understanding of the fundamental concepts of measurement is based on the representational theory. The theory is based on the viewing of the real world as empirical relational systems and measurement as a process of mapping them into symbolic relational systems.

The theory has been extensively presented in the literature [13–18]. An outline has been presented in [19]. The theory has been extensively considered and important contributions have been made by Mari and Rossi [20–23].

The theoretical the basis of the arguments in this paper is outlined below informally for convenience. The arguments have been presented in detail in [9,24].

Measurement will be defined in the wide sense as a process of empirical, objective assignment of symbols to attributes of objects and events of the real world in such a way as to represent them, or to describe them.

Description, or representation, means that when a symbol, or measure, is assigned by measurement to the property of an object, and other symbols are assigned by the same process to other manifestations of the property, then the relations between the symbols or measures imply, and are implied, by empirical relations between the property manifestations.

What is meant by an objective process in the above definition of measurement is that the symbols assigned to a property manifestation by the measurement process must, within the limits of acceptable uncertainty, be independent of the observer.

An empirical process in the definition of measurement presented above means, first, that it must be the result of observation and not, for example, of a thought experiment. Further, the concept of the property measured must be based on empirically determinable relations and not, say, on convention.

This wide definition of measurement is often disputed. Some consider the paradigm of measurement in the physical sciences as normative. Others require that, at least, measurement be a numerical representation that reflects an order. For this reason, it is convenient to distinguish between strongly and weakly defined measurements.

Strongly defined measurement is defined as a class of widely-defined measurement that follows the paradigm of the physical sciences. In particular, it has precisely defined empirical operations, representation by numbers and well-formed theories for broad domains of knowledge.

Measurement that constitutes representation by symbols of properties of entities of the real world based on an objective empirical process, but lacks some, or all, of the above distinctive characteristics of strong measurement, may be termed weakly defined.

4. Properties of measurement

The properties of measurement arising from the above wide-sense definition will now be analysed and discussed to provide an explanation of the usefulness of its wide and diverse applications.

Measurement provides an objective description of the measurand. The description is not merely a matter of opinion or feeling. It is invariant in rational discourse.

Measurement is verifiable. Given a specification of the measurement process the same symbolic description of a measurand should in principle be obtainable by any observer.

Measurement is based on a well-defined empirical process of observation. It is thus a basis of justified, true belief; in other words it is the basis of true knowledge.

Measurement is not naming. It provides descriptions of relations of the property manifestation measures to other manifestations of the same property.

The value of a measurement process depends upon the richness of the relations it can represent.

Measures are descriptions of great conciseness. A single number tells us what it would take many words to express.

Measurement gives, further, a description that is precise, pinpointing by a single number a particular entity, where a verbal description indicates a range of similar but differing things.

Measurement is description by a well-defined symbolism. A measure of a property gives us an ability to express facts and conventions about it in a formal symbolic language. Without the convenient notation of such a language, the complex chains of induction and deduction by which we describe and explain the universe would be too cumbersome to express.

It follows from what has been said that description by symbols is not good in itself. The only value of measurement lies in the use to which the information is put. Science is not just the amassing of numerical data; it depends upon the way in which the data are interpreted, analysed and organised.

Finally, measurement describes measurands by symbols, which can be realised as signals and can be acquired, processed and effectuated by information machines.

5. Applications of measurement

As was discussed above, measurement is extensively applied outside the physical sciences, in domains where widely-defined concepts of measurement are used. This outline of the range and diversity of applications illustrates the significance of measurement outside the physical sciences.