To measure or not to measure, that is the question
A reflection on the ontology of measurements

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Abstract.

For those of us that work in metrology, it would seem that '*in the beginning, there was measurement'* and most things —if not everything— were built around it. In fact, Galileo sentenced '*measure whatever is measurable, and make it measurable whatever is not*', and Lord Kelvin, another great metrologist said '*to measure is to know*'. More recently the gurus of quality, like E. Deming said '*what you cannot measure, you cannot improve'*.

Now, even beyond the limits of National Metrology Institutes or metrology laboratories, in the industrial field, we metrologists say that 'measurement is essential for knowledge, knowledge is essential for control and control is essential for quality and productivity'.

But some critical day of existential crisis, a metrologist asks him/herself: Is measurement really essential for control? And the dooms of existential doubt come about his/her conscious being: Do nature —the wisest mind— measures every process for being able to control it? Perhaps not… Does our body control its blood pressure and temperature in order to keep us stable and alive? We would say that the different glands and their feed-back systems make some type of measurement, but… this is a different type of measurement than that described in the International Vocabulary of Metrology! Does a water drop measures or controls its temperature on a hot day before it decides that it is time to evaporate? Certainly not, but other more basic control mechanisms take place and the process is controlled with no measurement or, if we force and stretch the definitions, with measurements considered in a very wide sense.

Out of examples as the perfect process of water evaporation, the existential anguish could produce, as an extreme, the reflection that for process control the best measurement is that that is not necessary! Though apparently extreme, this reflection is not far from the truth in some real cases like closed loop control systems and some others. In these cases, the fundamental role of metrology, traceability and other concepts could be seriously questioned, with very sound arguments.

The paper reflects on some real and some hypothetical situations in which the role of metrology has to be revised and reinvented. Fortunately, for our sake, metrology comes out even stronger because there seems to be always a role for it, inasmuch as there are conscious minds trying to understand the essence of nature, whatever that essence is.

1. Introduction

Premise: To measure is to know (L. Kelvin).

Tesis: Measurement is a sine qua non condition for quantitative knowledge and knowledge is a sine qua non condition for process control. Therefore, in any type of process, there should be measurements that control them and warranty certain characteristics of their output.

Aims:

a) First, this essay has the aim of analyzing in what sense is this argument true, and to try to define its scope an limits.

b) Second, a number of open questions still opened to debate, with no current convincing answer are posted for further discussion

c) Third, there is an attempt to try to apply the results of the analysis to situations of conscious processes controlled by humans.

2. Thesis: Measurement is a sine qua non condition for process control.

There are thousands of examples that confirm this argument, from the simple processes of cooking a meal to manufacturing and chemical processes and to the most complex industrial processes and research.

For industrial or organizational processes there are always intertwinned, at least, two types of capabilities, the process capability or actuation that makes things happen and the measurement capability or sensors that see what is happening. These two capabilities are governed by an analysis and decision capability that defines what to do, move the actuators to do it, take the feedback of the sensors and corrects or directs the whole process.

This seems to be true also in nature: human beings and animals have senses that allow them to live in relation with others. The senses are basically measurement systems with sensors, transducers and conditioning units, connected to processing units in the brain. The senses allow humans and animals to control most of our conscious processes such as eating or drinking, walking or writing. As for industrial processes, in these activities there are always two types of capabilities: a process capability combined with a measuring capability, the two connected to an analysis and control unit.

For the foregone, the thesis is still valid there: measurement is a sine qua non condition for process control, even in nature. However, in this discussion the concept of measurement has been expanded a little beyond its definition of the VIM, since the measurements usually performed by humans and animals in everyday activities, though involve some estimation of quantities and comparisons, these estimations are not usually expressed in terms of another taken as unit, even less in terms of SI units.

3. Some limits: Unconscious processes in living beings; when measurement becomes difuse.

The question arises in other types of processes that also happen in animals and human beings, the unconscious processes. These include processes such us breathing, that happen when the individual is sleeping, or even more unconscious such as the heart beat, the temperature control of the body or the content of sugar in the blood. All these processes are as essential for life, that nature through evolution did not leave them to the control of the individual, but established automatic mechanisms to control them and keep the being alive.

Though measurement in these cases is not explicit or obvious, medical science has now knowledge about many of the closed loop mechanisms that control a number of these processes. In these close loop mechanisms there still exist a process capability, a measurement capability and a control unit. In the heart beat, for instance, the process capability would be the heart muscle, the measurement capability its nervous sensors and the control unit is in the unconscious part of the brain. In the sugar content control, as in many other chemical processes that are continuously running in the body, the sensors are usually substances in the blood as enzimes, hormones and others, and the close loop mechanisms are very complex interactions of the endocrinal system.

Measurements, in these cases, are not explicit nor conscious. The very concept of measurement has to be stretched significantly to include in it the generic actions of automatic comparison and selection among substances that carry information for process control and allow certain processes to happen.

Measurements, if we allow ourselves to call them that, post some of the problems of chemical and biological measurements that humans are consciously trying to handle now.

4. Beyond the limits: When control is completely unconscious.

In vegetables, simpler processes of closed loop control exist, though measurement have a different meaning. Going down in the evolutionary chain, it is precise to look at plants, vegetables and other living beings with no relational life. Most processes in them are so strong, that became the basis of the evolutionary pyramid for the rest of living beings. These processes have robust closed loop controls because of very special unconscious biochemical mechanisms as the photosynthesis or the glucolysis, for mentioning just examples. These processes and closed loop mechanisms follow specific laws of nature and, given some specific conditions of development and situation, take from the surroundings specific forms and amounts of matter and energy and process them according to strict rules, following to the laws of physics, chemistry and biochemistry.

A usual condition for the continuity of these processes, the survival of the beings, the creation of an ecologically sustainable environment and their evolution, is that the processes and the beings that hold them take something from the environment and give back something to it that is useful for the rest of the beings or entities in the ecological system. But that is part of another story…

As mentioned before, but in a stronger way, in the referred cases there is some type of control and measurement. However, now the term measurement has to be even more stretched to include types of qualitative-quantitative knowledge. But the term knowledge usually refers to declarative assertions about representations of the material world that somebody assumes to be true and the relevant community does not find reason to rebate. Nevertheless, the terms measurement and knowledge, in these cases, could hardly be precise if there is nobody to look at the phenomena going on, to make a representation out of them, to identify the relevant variables and to compare them with a quantity of the same kind named as unit. But this is a question somehow similar to that posted to Boyle about sound: If a tree falls in the forest and there is nobody to hear its impact on the ground, is there sound there? Reality has so many perspectives to look at it and humans or scientists, in every branch of science, take only one perspective and discard the others. The physical or chemical reality is that there are phenomena going on out there, that they do work, and that our aim is to understand them, many times constructing some type of model to represent them. Measurement and metrology is a great tool to work out these models because, as Galileo said: The laws of nature are written in mathematical characters, and these characters have to be filled with data taken out of measurements.

Measurement, in these cases taken as qualitative-quantitative knowledge, now has to do with such as morphology and pattern recognition, levo-selection, simple counting of individuals of a specific type, etc. Measurements in chemistry and even more, in biochemistry or biology, are full of these type of phenomena and challenges that acompany them.

And there should be no surprise about this. Carrying on the analogy, even in conscious everyday processes, knowledge of this kind fills our lives. A person does not usually take the rule, a set of mass standards or a composition analyzer to find out whether the person they love is her in reality. What quantitative knowledge do we have about the people that surround us? About ourselves? Very little. Or, in other example, the simple but very complex processes of writing or speech recognition, what do they have to do with metrology? If, beyond the standardized definitions, metrology has to do with finding out data about physical-chemical world we live in, then metrology will, at some point have to address these challenges.

Testing is another activity where similar type of measurements are performed. So many times a test consist in finding out whether, under certain more-or-less-controlled conditions, a happening does occur or it does not. But there is more into it.

Once again, these are processes that, if metrology is to address them, force the discipline to stretch its frontiers to study these type of phenomena with techniques as pattern recognition, differentiation, simple counting and the like. In fact, it is already happening with chemical metrology and bio-metrology.

5. Far from live: natural phenomena of the material world.

In the completely unconscious and innanimated material world, there are other phenomena that further challenge the common views about process control. Many examples can be taken for discussion, for instance, the water cicle of heating-evaporation-cooling-condensation-precipitation and so on. From them the question arises: who controls this process or how is it

controlled? Is there a measurement involved? Does the little water drop feels the high temperature and specific pressure and decides "it is time to go up?" No, but the process is under control, it happens every time the same conditions occur. In fact, the regularity of these processes are at the basis of the once called causality principle: every time the same conditions happen to be, the same results will occur.

What is at the basis, at the hearth, of these processes? Who *measures* and/or *controls* these processes? What is at the basis of the causality principle? It would be possible to say that there are some philosophycal premises, as the *causality principle* and the *uniformity of nature principle*, that try to explain *this happens because it has to happen*.

But, why has it have to happen? Somebody said "the laws of nature are the will of God acting in the universe" (Augustin, Hipona, 300 AD). Somebody else, more recently, started a discussion about hazard and necessity (Monod, 1990), suggesting the laws of nature have led to evolution in a deterministic way, in the middle of hazardous happenings as they have occurred in the history of the universe, long before the representative knowledge of the conscious mind had appeared.

In any case, most will agree that what happens in these processes is due to the laws of nature and, of course, together with the universal constants. Here, apparently, metrology in the traditional sense of its role in representative knowledge, is rather far away.

6. Back to metrology: the basis of the universe.

However, in another sense, almost opposite in perspective, metrology has come back to its very origins in its encounter with the universal constants, basis and aim of the SI units. Current research as the string theory or the M-theory are based on models of the universe that have the specific values of the universal physical constants at the very origin of their simulations (Scientific American, March, 2006). A number of scientists would agree that, if the universal constants had different values, perhaps this universe would not be it, but another in a multiverse, or an impossibility in the n-possibilities of the cosmos modeled by them.

But, where normal or everyday metrology comes about? Perhaps, a lesson could be learned from the above discussion and referred examples. Unconscious processes are usually much more efficient than conscious ones: they simply follow the imbedded laws of nature and the outcome is always what it should be. No additional control is needed.

In some of these processes, the *minimum action principle* of nature seems to be clear. As Newton said once "nature does not do anything in waste, but rather everything is done with the lowest possible use of energy and matter". Natural unconscious phenomena seem to follow this principle. According to it, consciously controlled phenomena should tend to a similar condition of *minimum action* and energy to become effective and more efficient. As a consequence of it, also, every *measurement* should be as close as possible and every *control loop* should be as short as possible to achieve the maximum efficiency.

Some questions have been posted before and are left open also now:

- Could universal physical constants became units of the SI? (NCSLI, 2004)
- Are universal physical constants really constants? (SA, March 2006)
- Is the universe evolving in such a way that constants change?

7. A possible framework for the evolution of metrology

Perhaps the recognition of the different levels of knowledge that human kind has about the different phenomena in the universe would help to put a framework for metrological knowledge in them.

The following scheme is proposed to classify, depending on the complexity of the phenomena and the degrees of scientific, quantitative knowledge, to classify the different fields of science.

Formal Sciences	Phylosophy, Mathematics, Statistics…			
Degree of Quantitative Knowledge (QK)	Highest QK	Medium High QK	Medium Low QK	Lowest QK
	Physics	Chemistry	Biology	Sociology
Disciplinary knowledge	→ Fields of Science - Wide View- Evolution →			
	← Tendency of QK ←			

Table 2: Natural sciences, social sciences, formal sciences and quantitative knowledge

The extreme on the left is not only in the beginning of modern science with the classical mechanics of Galileo and Newton, but is also in the beginning of the evolution of universe, when only elementary particles existed and there where not the complex molecules of chemistry or the living beings of biology, even less the conscious beings studied by the social sciences. In the realm of physics, metrology is definitely clearer than in any other.

From that extreme, things become more complex as evolution and science move to the right. An so does metrology. Chemical metrology is more complex than physical metrology, and even posts some qualitatively different challenges. Biometrology is even more complex and, until know, there is a strong movement in National Metrology Institutes around the world to address its particular challenges in an organized world wide effort. Metrology has not gone into the social sciences yet, but who knows…

8. Conclusions and some practical considerations