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Cutting-edge measurement science for the future
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On the importance of maintaining a distinction between measurement and computation

L. Mari[1], A. Maul[2], M. Wilson[3]

[1] School of Industrial Engineering, Università Cattaneo – LIUC, Castellanza, Varese, Italy
[2] Gevirtz Graduate School of Education, University of California, Santa Barbara, Santa Barbara, CA, USA
[3] Graduate School of Education, University of California, Berkeley, Berkeley, CA, USA

https://www2.isep.ipp.pt/imekotc7-mathmet-2022

Tentative justification

(why maintaining a distinction between measurement
and other, related processes – computation, simulation, etc –
is important today)

“Measurement is an integral part of modern science
as well as of engineering, commerce, and daily life.
Measurement is often considered a hallmark of the scientific enterprise
and **a privileged source of knowledge**” (Tal, 2020)

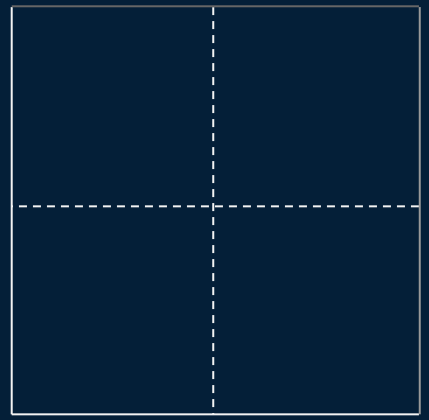
But “**what [is] the source of [this] special efficacy**” of measurement?” (Kuhn, 1961)

And is the concept itself of <measurement> changing,
in the current “dataist” context?

What is measurement, then?

Let us explore some strategic options…

Q1: **empirical** conditions



Q2: **mathematical** conditions

1. The Greek tradition

“A magnitude is a part of a(nother) magnitude, the less of the greater, when **it measures** the greater” (Euclid, 300 BC)

This seems to justify the claim that the Elements are “the earliest contribution to the philosophy of measurement available in the historical record” (Michell, 2005)

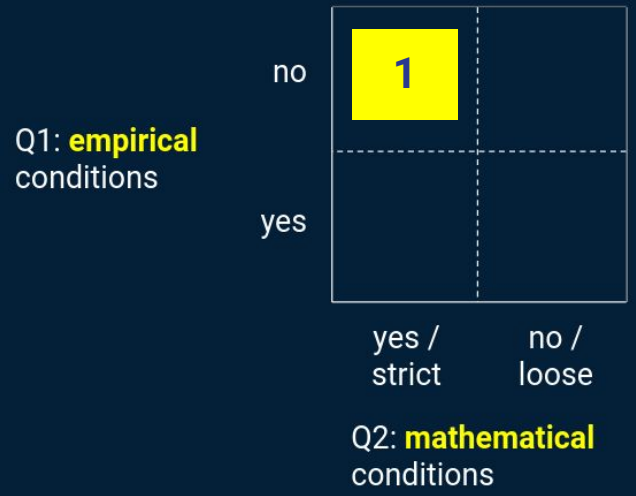
Yes, but…
“A number is part of a(nother) number, the lesser of the greater, when **it measures** the greater” (Euclid, 300 BC)

“The term ‘**measure**’ is used [by Euclid] conversely to ‘multiple’ ” (De Morgan, 1836)

To settle the issue:

“in the geometrical constructions employed in the Elements [...] **empirical proofs by means of measurement are strictly forbidden**”
(Fitzpatrick, 2008; in the introductory notes to his translation of Euclid’s Elements)

This is about <measure>, not <measurement>:
the source of the special efficacy of measurement
is hardly in the Euclidean concept of measure



2. The experimental method

Before Galileo, “no one had the idea of counting, of weighing and of measuring; or, more exactly, no one ever sought to get beyond the practical uses of number, weight, measure in the imprecision of everyday life” (Koyré, 1948)

The experimental method was grounded on empirical processes,
but about measurement maintained a geometric, and therefore Euclidean, focus:

MEASURING, the same as MENSURATION.

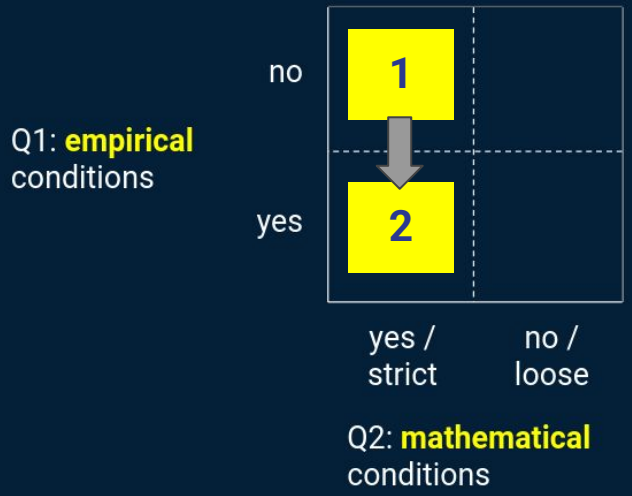
MENSURATION, the act, or art, of measuring figured extension and bodies; or of finding the dimensions and contents of bodies, both superficial and solid.

(Hutton, 1795)

And indeed, what about, e.g., temperature?
(Hutton uses the term “observation” for its evaluation...)

Plausibly, this focus was based on the assumption that
additivity is necessary for measurement,
as for example in the outcomes of the Ferguson committee (1940):
“the main point against the measurability of the intensity of a sensation
was the impossibility of satisfactorily defining **an addition operation** for it” (Rossi, 2007)

This is about <measurement>
of a specific class of quantities only:
the source of the special efficacy of measurement
can possibly be found for a broader scope



3. Representationalism

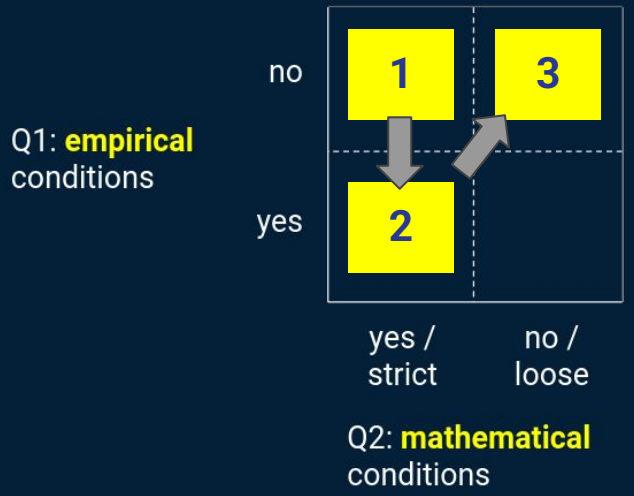
From the seminal claim that “measurement is the process of assigning numbers **to represent** qualities” (Campbell, 1920) …

… the idea of measurement as a “well-behaved” representation arose...

… up to the position that a representation theorem
“makes the theory of finite weak orderings a theory of measurement, because of its numerical representation” (Suppes, 2002)

With the mindset that “the theory of measurement is difficult enough without bringing in the theory of making measurements” (Kyburg, 1984)
RTM **is too abstract** for being a theory of an empirical process

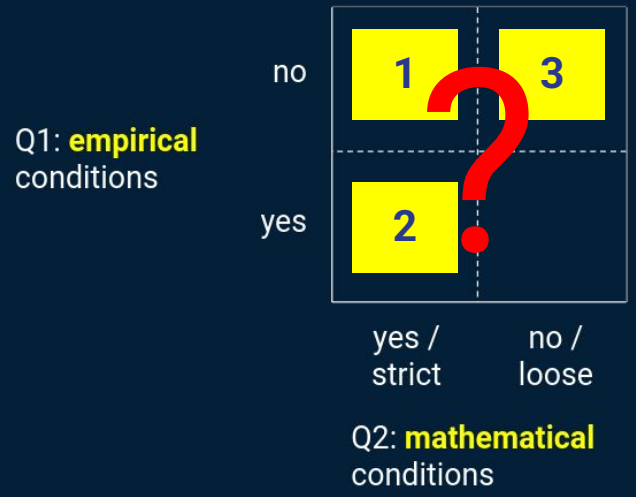
<measurement> as consistent representation:
the source of the special efficacy of measurement
is plausibly more than just
consistency in representation



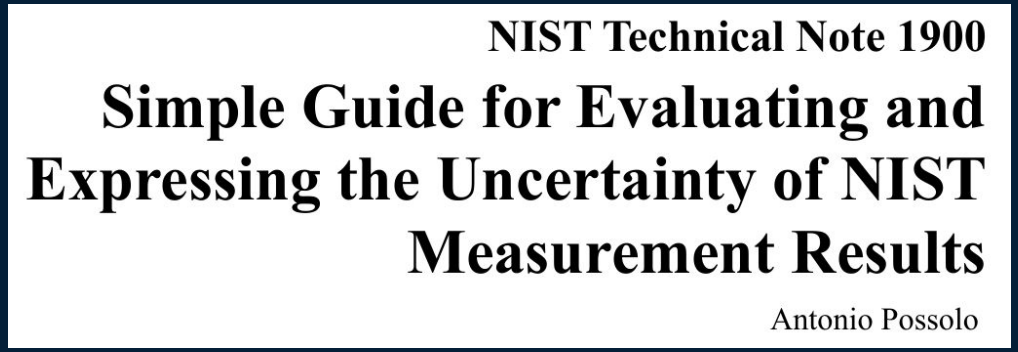
… and then?

The source of the special efficacy of measurement is hardly
1. the concept of divisibility
2. a specific kind of physicalism
3. consistency in representation

In our big data, dataist, virtual, digital, … context, how should measurement science develop a suitable concept of measurement?



An authoritative position



NIST Technical Note 1900

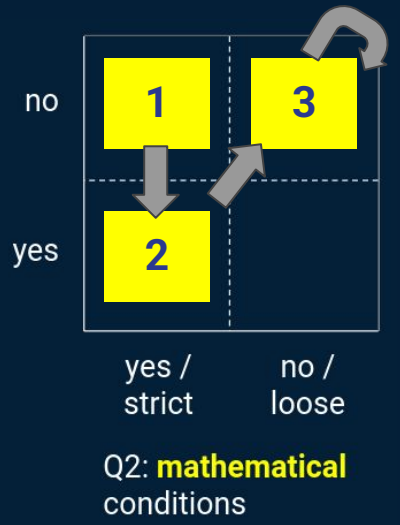
Simple Guide for Evaluating and Expressing the Uncertainty of NIST Measurement Results

Antonio Possolo

Measurement is an experimental or computational process that, by comparison with a standard, produces an estimate of the true value of a property of a material or virtual object or collection of objects, or of a process, event, or series of events, together with an evaluation of the uncertainty associated with that estimate, and intended for use in support of decision-making.

According to this position,
computations of documented quality are measurements

Documenting quality is not only a (possibly) necessary condition
for a property evaluation to be a measurement, but **is also sufficient**



This is an upgraded version of Option 3:
“**uncertaintism**” on top of (or in place of) representationalism

Three examples

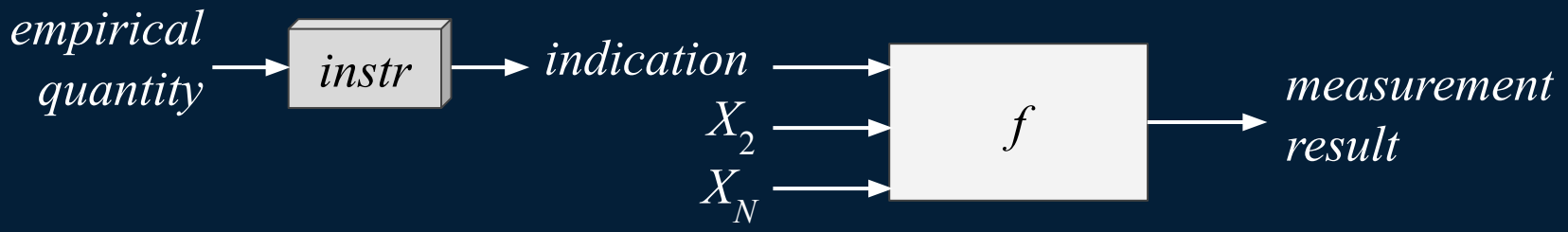
α A teacher asks: what acceleration does a force of 1.23(1) N produce on a body of mass 2.345(2) kg? Thanks to Newton's law and by propagating uncertainty, students obtain a value of acceleration and a related standard uncertainty.

β Someone compares in her mind the length of Harry Potter's magic wand and the length of a rod, that she remembers to be 1 metre. Since she is an uncertainty-savvy person, she reports 0.3(1) m as the result of the comparison.

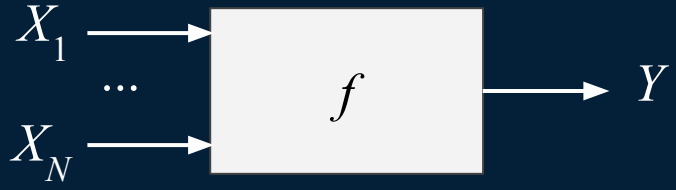
γ The avatar of a player must acquire the information about the length of some objects in her digital world, and being uncertainty-savvy she includes some uncertainty in her results and the related decision-making process.

All fulfill the conditions of the previous definition:
would you say that these are examples of measurement?

4. Another option

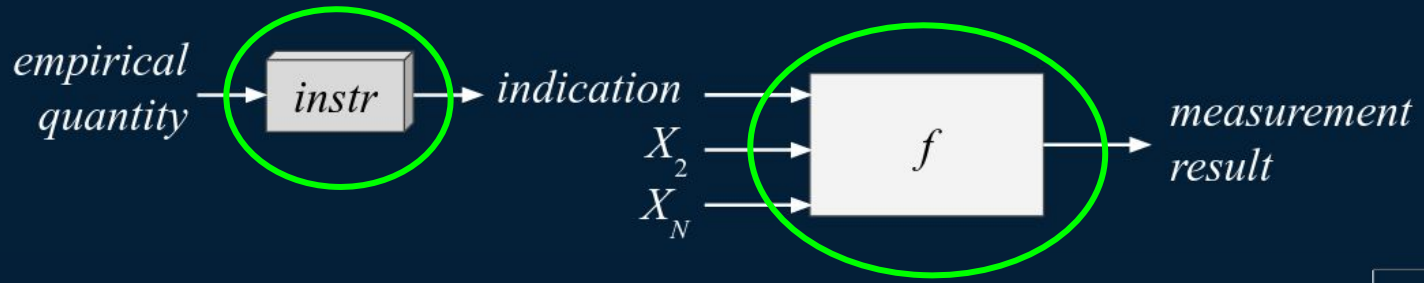


This is measurement

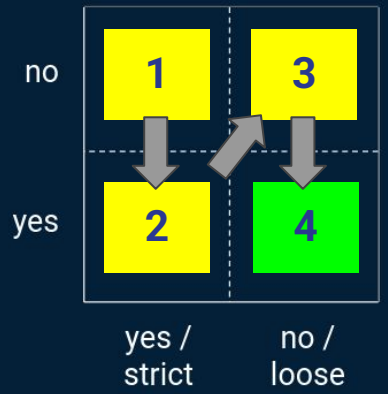


This is *not* measurement

Our question was:
“what is the source of the efficacy of measurement as a privileged source of knowledge?”



Measurement is effective...
because it is effective ***both***...
in **acquiring information from the empirical world**
and in **interpreting it by means of models**

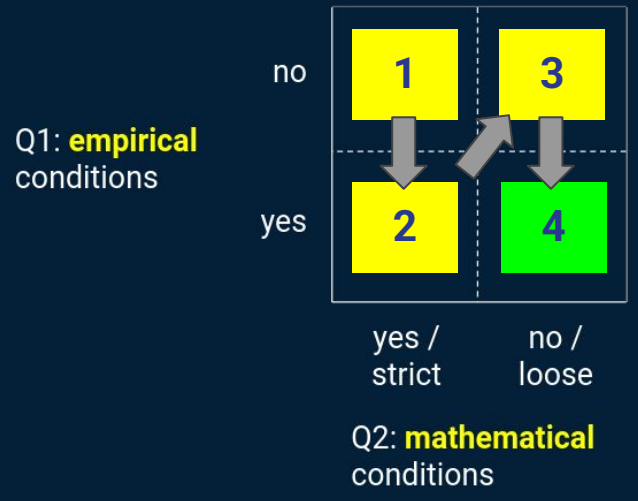


This standpoint promotes
a **model-dependent, critical realism**

My opinion: stick to something similar to the definition of <measurement> as in the International Vocabulary of Metrology:

> “process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity”

and improve it



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Thank you for your kind attention

Luca Mari

lmari@liuc.it
https://lmari.github.io