Lecture 01.05 Epistemology of measurement

epistemology

Epistemology is the study of knowledge and how it is acquired. Epistemology of measurement is the study of how knowledge is acquired through measurement. The model-based description of measurement, above, is closely associated with this study.

One of the most interesting aspects of this work is the way it both questions the validity of and offers an alternative to the intuitive realism about measurement that suggests that there is a real quantity independent of the measurement and that measurement error is the difference between that quantity and the estimate of the quantity.

01.05.1 Questioning realism

Here are four ways of questioning our intuitive realism.

01.05.1.1 The unknowable real

A first assault on realism is the following. The exact real value of a quantity cannot be known (at least for continuous scales). This is generally accepted. Therefore, the error between the measurement and the real value cannot be known. We are left to compare (inherently inaccurate) measurements with each other, using statistical techniques. Even if measurements are made with different techniques and averaged, we cannot know all these techniques don't share a common systematic error.

01.05.1.2 Circles are a thing

Another assault on realism can be made by emphasizing the fact that when measurements take place, some sort of idealizing model of the concrete situation is implicit. For instance, what would it mean to measure measure the temperature of an object without an idealized model of temperature making fluid volumes expand? Ok, instead, could we start from the theoretical model? What, then, would "temperature" mean? There is a circularity the confounds us at the bottom; however, this circularity is apparently *non-vicious* when considered from the historical point-of-view, which we will now consider.[8]

non-vicious circularity

[8]The conventionalists tried to take a "way out" of the circle by attempting to arbitrarily fix meaning with "coordinative definitions." The historical point-of-view questions the validity of this given the fact that definitions seem to require revision upon the development of sufficiently accurate measurements. That is, the definition of a quantity cannot remain

01.05.1.3 History teaching us a thing

Thomas Kuhn, among others, pointed out that the idea that the hypothesize→ measure → interpret → judge "scientific method" is rarely actual for significant scientific progress. Instead, we refine our measurements to the point that they expose a lack in our theory. The lack becomes the focus, and is measured with greater and greater precision. Finally, a new theory emerges that can explain the lack in the previous theory's explanatory power.

01.05.1.4 Bliss is ignorance

Finally, we call into question the very idea that a "real" value even makes sense without a certain amount of (useful) pretending. What does it mean to (say) measure the speed of light in a medium? We must, of course, assume (and try to control) certain aspects of the medium that we know are never *completely* the case, such as that it has uniform properties like density, temperature, and pressure. Moreover, we are assuming a completely static, repeatable measurement environment, while we all know perfectly well that one "cannot step twice into the same stream." (Tal, 2017)

These suggests a new understanding of the relationship between measurement and theory.

01.05.2 A new paradigm

These critiques of realism lead us to an emerging model-based paradigm in the epistemology of measurement. This view understands the limitations, circularity, and ideality of measurement, yet forges a new path forward. We might summarize this view as advocating something like the following attitude toward the epistemology of measurement (Tal, 2017):

accuracy The *accuracy* of a measurement has been defined as its nearness to the *unknowable* "real value." Now we define it to be its "agreement with values reasonably attributed to a quantity given available empirical data and background knowledge."

precision The *precision* of a measurement has been defined as the size of its clustering (e.g. standard deviation). Now we define it to be a type of *inaccuracy* from "uncontrolled variations" of indications.

static.

On a higher level, we develop models and measure and refine the models and measure some more. That is, *measurement refines theory* and *theory refines measurement*. Measurement processes inform theoretical models, through which measurement results are interpreted. The interpretation refines the model that inform the next generation of measurement processes. Etc.

Embrace the circle as it embraces you.