

Is Ultimate Reality Beyond Categorization as Analog or Digital?

Todd L. Duncan
(duncan@scienceintegration.org)

Abstract

This essay explores a simple but subtle idea. What if “analog” and “digital” are labels that apply to the quantitative formal systems we use to help describe our experience with reality, but ultimate reality transcends complete characterization by any particular formal system, and therefore also transcends these labels? This idea provides a natural context for reconciling the applicability of both discrete and continuous descriptions of nature in different situations.

All of our knowledge of the universe comes from experience in one form or another. This could be the simple, local observations made while sitting under a tree in the park, feeling the warm sunlight on our face and hearing the chirping of birds and the rustle of wind through the leaves above us, noticing the intensity of colors in the leaves. Or the experience of starlight hitting our eyes from a much greater distance. Or even more remote from our immediate surroundings, such as the echoes of the hot, dense beginning of our universe visible as the Cosmic Microwave Background Radiation, mediated by radio telescopes and displayed in false color to bring that experience to our eyes. Or the perhaps even more subtle experience of our own internal awareness, thoughts, and feelings.

We organize our experience into patterns, and have found over history that we can create quantitative formal systems to describe these patterns as events in space and time, obeying certain laws of physics which compress the patterns and can be formulated within the language of the relevant formal system. This is perhaps the essence of what physics is, a perspective nicely described by Sean Carroll [1]. As Carroll points out, the usual and obviously very fruitful approach in physics is to “model the world as a formal system, which is both unambiguous and complete as a description of reality.” Carroll adds emphasis to this common view, with the statement, “Once we figure out the correct formal structure, patterns, boundary conditions, and interpretation, we have obtained a complete description of reality.”

The first important point to make about this description of what physics does is that the analog or digital labels apply to the *formal system*, not directly to “reality” (whatever that may be). A formal system for example can be built on real numbers with continuous values as in classical mechanics, or a different formal system can be built on discrete mathematics as in many versions of modern quantum theory. Number systems can be labeled as continuous or discrete. These labels apply to reality itself only to the extent that reality in some sense is a number system.

The second point is the often unexamined assumption, at the core of this way of looking at physics, that there *is* a single correct formal system that captures everything there is to say about reality. Of course we have not yet arrived at that one complete formal system, but it is assumed to exist. Thus deciding whether that formal system is at root analog or digital would be

synonymous with whether nature itself is continuous or discrete.

But isn't the view that reality *is* a formal system almost obviously false, at least in the following sense: A formal system is a model. Where does the model “live,” in such a reality? The formal system is incomplete as a description of the real universe at least in the sense that it does not include the *capacity* to make models within its formal system. A.J. Leggett [2] raises the essence of this point with the question, “In the last analysis, can a satisfactory description of the physical world fail to take account of the fact that it is itself formulated by and for human beings?” Edward Harrison expands on a similar theme by highlighting “the distinction between Universe and universes. The Universe by definition is everything and includes us experiencing and thinking about it. The universes are the models of the Universe that we construct to explain our observations and experiences.” [3] In this case, analog and digital descriptions of nature can be viewed as “masks” that we fit over the Universe, each capturing some aspects but also omitting some aspects. They may *both* be true in some sense, if we accept that there is no single formal system that is a perfect mask for nature, so that a digital mask and an analog mask may both be relevant in different situations.

There is much to be explored within this framework. Perhaps most obviously, What exactly does it mean to say that there is more to the universe than can be captured by a formal system? As physicists we are so used to working within formal systems that it's hard to even gain the perspective to make sense of the question. A starting point is to ponder some of the “really big questions” similar to those John Wheeler was fond of bringing to our attention, such as “What makes ‘meaning’?” and “How come existence?” [4] These kinds of questions stretch our thinking into the ultimate mysteries where formal systems are most likely to be inadequate.

For example, suppose our investigation ultimately reveals that at the most basic level, there are discrete building blocks out of which matter is composed, and that space and time are pixelated - there are smallest length and time scales beyond which no further resolution is possible. (These might be closely related conclusions since it appears that “matter” itself is patterns of fields in space and time.) This would be the more modern version of saying that the universe is composed of atoms, rather than a continuous substance.

Would this mean the analog versus digital question would be settled, in favor of digital? Not if we continue asking deeper questions. What is the substrate within which this description of space and time is encoded? Where is the fact of spacetime being pixelated “stored” to make sure that it consistently keeps the correct pixel size? How do the “atoms” get instructions about the laws they must obey? Even if things are made of discrete building blocks, still we need instructions, telling the “atoms” that they must obey those laws. Where do those instructions live? It seems that these instructions can't live within the structure of spacetime or the “matter” itself, because the very existence of these things requires instructions to define their properties. The instructions must be information of some sort, which brings to mind Landauer's [5] insight that “information is physical” - in order to protect the second law of thermodynamics, information must be fundamentally connected to the physical form in which it is stored. But in that case, where can the information live that creates the physical form in which information can be stored? An apparent paradox that points to a deep insight lurking here somewhere. A useful reflection on related issues is offered by Steve Talbott [6].

Once we recognize that we need more than the “atoms,” to describe reality fully, then we can actually dispense with the need for the atoms to be the real, fundamental building blocks, at all. Why not focus on whatever it is that provides the instructions which create these “atoms” as a successful formal system model? And once we reach that point, our seemingly air-tight conclusion that reality is digital comes into question, because we are focused on a deeper reality beyond the one we had concluded was digital.

The aim here has merely been to raise these issues as food for thought. To really understand how to answer the question of whether nature is fundamentally discrete or continuous, we need to get to the heart of what it means to have a model superimposed on reality. As Kenneth Craik warned, we must guard against letting our “perception of reality become as narrow as [our] theory.” [7] And most importantly, we need to understand whether reality is such that *any* formal system model can ever completely capture it. It’s well-known that this is a tricky issue. Although Gödel’s Theorem is not directly relevant to this context, it *does* serve as a reminder that sufficiently rich formal systems are inherently incomplete. In fact the very act of formalizing is what *creates* the incompleteness. The two go hand in hand. As Douglas Hofstadter points out, “Once a system is well-defined or boxed, it becomes vulnerable.” [8] Perhaps by boxing nature into analog or digital categories, we create a different form of incompleteness in our description of nature.

References

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