

Reality as simplicity ^{*}

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ABSTRACT

We discuss some fundamental aspects of information theory and its relationship to physics and neuroscience. The aim is to identify some questions and point out the relevance of the concept of Kolmogorov complexity in their eventual resolution. The discussion is based on two premises: 1) all human experience is generated in the brain, 2) all the brain has access to is information. Taken together these imply that concepts such as “reality”, the “universe” and even “physics” are derived mental constructs based on information, i.e., algorithmic models. It is argued that the concept of Kolmogorov complexity can play a fundamental role in this union, and that in some sense, reality arises from simplicity. A consequence of these ideas is that neuroscience and physics have to merge at a fundamental level for mutual advancement.

Keywords

Complexity theory, physics, presence, neuroscience

1. THE BRAIN AND REALITY

Consider a universe and a brain in it. If we think of this brain as a modeling tool exchanging information with the rest of the universe it is part of (the “environment”), then it follows that all questions about ‘reality’ should be framed in an information theoretic framework with neuroscience at the center. For all practically purposes, this brain can only state that *there is information*. For example, one of the building blocks of physics is the concept of state. Yet information is the currency the brain uses to give states an identity and infer things about them. From a wider physical perspective, the result of a brain’s interaction with its environment is a change in both their states, and this is mediated by information. Information theory provides the conceptual framework for understanding the relation of brains with the universe.

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Some of the brain-environment information exchange is mediated by “controlled information membranes” (senses and effectors), but some it is not and can be dangerous. In an eventual physical-informational theory yet to be developed (*It from bit*), one would say that the information conveyed by a bullet as it traverses a brain will change its state sufficiently to destroy its function.

Given these premises, we can ask how brains infer what is “out there”. In our quest for survival, we build models (algorithms) with the aim of predicting the future (i.e., future sensorial streams). Thus, the first important observation is that “reality” is a construct of our brains—a model. Reality is the algorithm brains build to sustain existence (and dodge information bullets). Examples of the models built by brains and that are successful at compressing information include: space, time, the dimension of space [4], mass, energy, atoms, quarks, tigers, people.... But not all models are born equal. Simpler models are statistically more likely (in some sense) [5], and easier to use. Brains are therefore “compression machines”. Compression is formalized by the notion of Kolmogorov complexity (KC^1), a mathematical concept which provides the cornerstone to study how the brain’s compressing algorithms are created. We recall its definition: the Kolmogorov complexity of a data set is the length of the shortest program capable of generating it. An alternative related mathematical formalization based on the concept of *inference machine* has recently been proposed [6] (and we note in passing that an important ingredient for the associated results is that the inference machine is itself part of the universe it is trying to infer). What we argue here is that what we call reality is represented by the simplest programs our brains can find to model the experience of interacting with its environment. This may explain the power of mathematics. Mathematics provides the tools for meta-compression: mathematics is the discipline per excellence that draws conclusions logically implied by a set of axioms. Where mathematics is successful in compressing, a modeling landscape is reduced to a finite set of axioms together with the equations for “logico-dynamics”. Today we know that any such system will leave gaps (Gödel, Turing)—how the axioms are chosen is very important.

2. IN SEARCH FOR THE BOUNDARY

¹Kolmogorov complexity is also known as ‘algorithmic information’, ‘algorithmic entropy’, ‘Kolmogorov-Chaitin complexity’, ‘descriptive complexity’, ‘shortest program length’, ‘algorithmic randomness’.

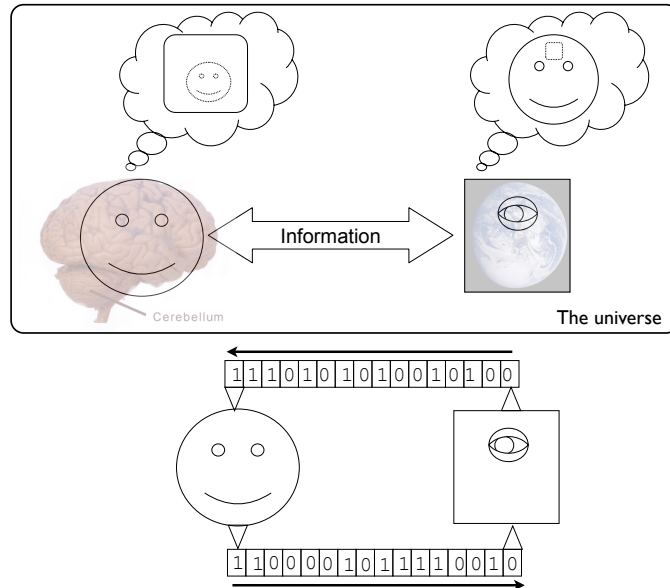


Figure 1: The brain creates the model of reality through information exchange (in and out) with the “outside”. In this case we show the full universe divided into a brain interacting with the rest of the universe by bi-directional information exchange, using sensors and actuators. The interaction can be described by the symmetric coupling of two Turing machines.

A simple model for a universe computing its future is a closed system of billiard balls. A subset of billiard balls can be arbitrarily identified as the Turing state register and the rest as the tape, with newtonian mechanics as the transition function. Similarly, the universe evolves and in some sense computes its future [3]—and brains are part of it. But what defines the boundary between ‘me’ and the ‘rest of the universe’? From a fundamental physical viewpoint, there is no such boundary. A complete theory should be able account for this divide. Is there a guiding principle to separate “inference machines” from the rest of the universe? What, if anything, does Kolmogorov complexity have to do with it? A possible approach to this question may be through the description of the brain-universe relationship by two coupled Turing machines. The concept of a coupled (“beyond-Turing”) Turing machine has been described before [2]. A coupled Turing machine is one which can accept external inputs while operating, and which may also possess output channels. What we are proposing here is a specific symmetric construct involving two such machines: one in which the output of one is the input of the other—see Figure 1.

It would appear that computation is a dynamical phenomenon that requires recursion and therefore time. Yet time may not be a fundamental physical concept after all. It may itself be thought of as a derived concept—another model (the “great simplifier” [1]). Note that our billiard ball “universe-computer” can be described in a timeless way by its constants of motion (or, more directly, by the Hamiltonian and the initial conditions). Can we construct a new information theory that does not rely on the concept of repetition, recursivity and hence time? It should be clear that computation does not add anything to the information of the

initial state: everything is already in the program plus data which is available at time zero. Both *time* and *computation* (hence computers) are probably themselves models.

Finally, these ideas can be used naturally in the context of the field called *Presence*. In *Presence*, the technological goal is to place a brain in a controlled, convincing and interactive information bath. Following the logic laid out in this essay, we can state that in order to achieve ‘more’ *Presence*, simplicity in the underlying environment model is a key aspect. We state this as the KC hypothesis and as a VR design principle: *given alternate models (interpretations) for a given mediated experience, a brain will select the KC-simplest one it can construct. Furthermore, the simpler the model, the more real the experience will feel.*

3. REFERENCES

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