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Title

Truth in Complex Adaptive Systems models should be based on proof by constructive verification

Abstract

It is argued that the truth status of emergent properties of complex adaptive systems models should be based on the epistemology of intuitionistic logic and on the ontology of proof by constructive verification.

Chaitin's construction of the universal diophantine equation (1987, 1990), raises issues which bear directly on the ontology of complex adaptive systems models. This point revolves around the question of what constitutes a valid proof. What constitutes a valid proof also determines what we accept as being true for, as Snapper (1988, p.54) points out '*...we prove that something is true*'. What constitutes a valid proof is in turn, dependent on the logic system subscribed to. For classical mathematics and conventional science this is the classical logic laid down by the Greeks. Classical logic is founded on the three laws of Aristotelian logic: the law of identity, the law of non-contradiction and the law of the excluded middle. These are axioms of classical logic. Of these ontological propositions, the 'law of the excluded middle' is not accepted by mathematical intuitionists. The argument here, is that it should not be accepted by complex adaptive systems modellers either.

The law of the excluded middle states that any declarative sentence - that is any grammatically correct sentence in a formal or natural language which makes an assertion about a fact – has to be either true or false. It has to be either true or false because it either does, or does not, correspond to the fact about which it is making an assertion. This correspondence is wholly independent of any verification of the proposition of the declarative sentence, or of the individual making the declaration. As Snapper notes, classical or Platonic truth is 'verification free' (1988 p.55). Subscribing to the law of the excluded middle imposes a Platonic character to truth. That is, the truth or falsity of the sentence exists independently of time and

independently of any observer. In the Platonic notion of truth, a sentence is true if it *corresponds* to the fact about which it is making the assertion. This is therefore also known as the correspondence theory of truth.

Mathematical intuitionists, such as Brouwer, Heyting and Dummett, do not subscribe to the law of the excluded middle (Benacerraf and Putnam 1983). If, ontologically, one rejects the law of the excluded middle, then it is impossible to say anything about the truth or falsity of a declarative sentence before its truth or falsity has been verified in some epistemologically acceptable manner. Just as classical mathematics is based on an epistemology of classical logic, intuitionistic mathematics is based on its own system of intuitionistic logic formalized by Heyting (Heyting 1966). In intuitionistic mathematics, intuitionistic logic defines what constitutes a valid proof, i.e. it defines its epistemology. Again a valid proof defines something as being true. In this case, the truth status of a sentence is conditional on the testing of the assertion that sentence makes using the epistemology of intuitionistic logic. Prior to a properly constructed verification of that sentence's assertion, the sentence has no truth value ascribed to it. It is neither true nor false but simply of indeterminate truth status. The ontology of intuitionistic truth is that of 'truth by *constructive verification*'. It is a pragmatic theory of truth and is based on the work of the philosophical pragmatists William James, Charles Peirce and John Dewey (Snapper 1988).

It is not the intention of this paper to recount the arguments for and against rejection of the law of the excluded middle, these are presented in the collective works of the mathematical intuitionists and represented in edited volumes on the philosophy of mathematics such as Benacerraf and Putnam (1983) and Hart (1996). The relevant issue is, given what we know of the character of complex adaptive systems and the means at our disposal to study such systems, whether the truth status of complex adaptive systems models should be based on constructive verification or be verification free. This issue in part depends on the complex adaptive systems ontological rejection of the reductionism of uni-directional causality.

The reductionism of uni-directional causality is a descriptor of the ontological position that all properties of a system observable at one hierarchical level, are explicable through analysis of the system's components at a lower hierarchical level. Conventional science assumes that things can always be completely explained by looking at their components.

Morowitz (1996) argues that an important aspect of the property of emergence in complex adaptive systems is that it is fundamentally anti-reductionist. In complex adaptive systems displaying emergent properties, the rules governing the behaviour of elements at one hierarchical level are frequently explained by (emergent) properties only observable at a higher hierarchical level. CAS epistemologists such as Morowitz (1996) and Rosen (1991) argue that this, while scientifically unconventional, is still a perfectly valid form of science. As Morowitz (1996 p.196) points out

Under this mode of operation the successful theories may generate emergent properties not directly derivable from or perhaps even imagined from the simple constructs but by running the program. The emergence is one of the desirable features of complexity theory.

In complex adaptive systems it is argued that it is possible to explain the existence and behaviour of elements of a system in terms of the function that system itself serves with larger systems. Here causation can operate in both directions (smaller \leftrightarrow larger \leftrightarrow smaller) across all hierarchical levels of system scale.

If we accept that identification of emergent properties of classes of systems is *apriori* impossible from an analysis of their component parts, then the existence of such properties can only be demonstrated through adoption of an epistemology which accepts as 'true' those system properties which can be constructively demonstrated to exist. That is, emergent properties of complex systems can only be said to exist if we can construct systems that display those emergent properties. Because, as Morowitz notes, such properties frequently cannot even be imagined, it is not possible to postulate their existence through the formulation of declarative sentences within the language of the formal systems of complex adaptive systems models. Because it is not possible to formulate appropriate declarative sentences which proclaim the existence of such emergent properties, it is not possible to ascribe truth value to them on the basis of their correspondence with 'facts' which, likewise, cannot be imagined.

Indeed it is even questionable as to whether such qualitatively different system properties operating at higher hierarchical levels can be expressed within the limited vocabulary of the formal systems of CAS models. This is because emergent properties are robust statistical aggregates of what are frequently transcomputational sets of the combinatorics of deterministic relations between elements of the system at lower hierarchical levels. For this reason, the detection of emergent properties through the analysis of individual deterministic relations is not possible.

If, as argued, emergent properties cannot be expressed through the declarative sentences of the formal system of the CAS model, then their truth-value could never be established through the use of classical logic. For these reasons, it seems unreasonable, to ascribe truth value to *a priori* unimaginable and qualitatively different properties of systems that are to some extent both structured and limited by: a) our choice of system observables, and; b) our choice of natural and formal languages. Thus, it is argued that the truth status of emergent properties of complex adaptive systems models should be based on intuitionistic logic and on proof by constructive verification.

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