G Model
ECOCOM 646 No. of Pages 7

ARTICLE IN PRESS

Ecological Complexity xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Ecological Complexity

journal homepage: www.elsevier.com/locate/ecocom

Original Research Article

Something about science: Mulling over impredicative systems

Roberto Poli

Department of Sociology and Social Research, University of Trento, Italy

ARTICLE INFO

Article history:
Received 30 December 2016
Received in revised form 14 May 2017
Accepted 23 May 2017
Available online xxx

Keywords:
Impredicative system
Self-reference
Anticipatory system
CLEF
Modeling relation

ABSTRACT

The science of the twenty-first century won't be less creative and surprising than the science of the twentieth. Both complexity and chaos show the unavoidability of uncertainty - whether it is embedded in feedback cycles and emergence or in the infinite precision of initial conditions. A subtler transformation is ongoing, however: a transformation at a deeper level than the move from linear to non-linear models and much less visible than it. Both linear and non-linear techniques are forms of predicative modeling. The underlying unproven assumption is that the vast majority of systems are predicative, and only marginal, borderline systems are impredicative. Yet the transformation to which I am alluding directs attention to the opposite possibility: the unquestioned belief in the predicativity of most systems may prove to be illusory. As a matter of fact, many disciplines, including sociology, anthropology, and biology, exhibit varieties of self-reference, which is the primary source of impredicativity. The idea that most systems are indeed impredicative opens new avenues for science. Moreover, it may help in addressing some of the most egregious failures of contemporary science. The possibilities to deepen and extend science as well as to address daunting obstacles of present science are serious enough reasons for thorough investigation of the difference between predicative and impredicative science.

1. Introduction

Science changes.[1] Since the dawn of modern science, science has grown, dramatically improving its methods and developing new theoretical frames. I see no reason to believe that the science of the twenty-first century will be less creative and surprising than the science of the twentieth.

As far as recent decades are concerned, the most pervasive developments of science are related to complexity theory – however defined. As a first approximation, a complex system is a system with many interacting parts, and complexity derives from feedback cycles among the system's parts, as well as from the subsequent collective emergence of new properties and behaviors. Chaos theory adds a different component to this picture: an unavoidable degree of uncertainty due to the necessary but impossible condition of measuring the system's initial conditions with infinite precision.

At first glance, twentieth-century science may be described as characterized by the move from a science primarily based on linear models to a science progressively based on non-linear ones. Both complexity and chaos show the unavoidability of uncertainty – whether it is embedded in feedback cycles and emergence or in the infinite precision of initial conditions. This focus on modeling techniques subsumes a variety of subtler differences. Linear models assume that even grossly simplified representations of real phenomena are nevertheless proxies helpful for the dominant 'command and control' attitude. Complexity, on the other hand, shows that uncertainty is unavoidable and that the command and control attitude is not viable.

A subtler transformation is ongoing, however: a transformation at a deeper level than the move from linear to non-linear models and much less visible. This transformation, if successful, may impact on the very idea of science in a vastly more important way than the move from linear to non-linear modeling techniques.

In fact, both linear and non-linear modeling techniques are forms of predicative modeling, which do not take into account any form of self-reference, the hallmark of impredicativity (discussed more fully below). Despite the prevalence of impredicative over predicative systems (and models and definitions) this is usually considered of marginal interest, the underlying unproven assumption being that the vast majority of systems are predicative, and only marginal, borderline systems are impredicative. Yet the transformation to which I am alluding directs attention to the opposite possibility: the unquestioned belief in the predicativity of

E-mail address: roberto.poli@unitn.it (R. Poli).

[1] This chapter has been written after Ch. 11 of my *Introduction to Anticipation Studies* (Poli, 2017b) and my introduction to the forthcoming *Handbook of Anticipation* (Poli, 2017a).

http://dx.doi.org/10.1016/j.ecocom.2017.05.002
1476-945X/

most systems may prove to be illusory – a kind of self-inflicted groupthink. As a matter of fact, many disciplines, including sociology, anthropology, and biology, exhibit varieties of self-reference, the primary source of impredicativity (Bartlett, 1987, p. 6).

The idea that most systems are indeed impredicative opens new avenues for science. Moreover, it may help in addressing some of the most egregious failures of contemporary science. The possibilities to deepen and extend science as well as to address daunting obstacles of present science are serious enough reasons for thorough investigation of the difference between predicative and impredicative science.

2. A first glance at impredicativity

In logic, the definition of an object is impredicative if it directly or indirectly refers to the object itself. This self-referential nature of impredicativity is the feature that has raised most doubts concerning impredicativity. Sometimes, impredicativity gives rise to paradoxes (the most notable of them is Russell's paradox of sets that do not contain themselves as elements), although impredicativities are usually harmless and are regularly used in mathematics. The reduction of mathematics to its predicative fraction (i.e. to recursive functions or algorithms) corresponds to a major curtailment of its capacity. While Feferman (1998, 2005) has shown that a large part of classical mathematics can be reconstructed without using impredicative definitions, there is a great deal of mathematics that goes beyond the limits of the mechanical rote repetition of a set of rules.

Furthermore, many natural systems do indeed show forms of impredicativity, that is, the presence of self-referential cycles in their constitution. Organisms generate the parts of which they are made; minds produce the psychological processes on which they are based; societies produce the roles or patterns of actions that constitute them. If it is true that biological, psychological and social systems are indeed impredicative, we have room for finding common ground among otherwise widely isolated disciplines.

The presence of the closure manifested by impredicativity is always flanked by twin forms of openness. An organism self-produces its own parts but needs food and usually other enabling (and constraining) environmental supports; a mind self-generates its psychological processes but needs a supporting organism and usually a brain; a society self-produces its roles but needs people to perform them. Every system requires admissible environments (possibly in the form of other more encompassing systems). But once the supporting or enabling (as well as constraining) capacity of the environment has been provided, the impredicative cycle characterizing the system proceeds in its own way.

We shall say that impredicative systems are open to material causation (such as food for organisms). The nature of the closure defining impredicative systems raises complex issues. For the time being, let us suppose that the impredicative cycle includes efficient causes. For reasons that will become apparent in due course, I shall call 'hierarchical' a cycle including efficient causes (Louie and Poli, 2011).

The main distinction within impredicative or self-referential systems is between incomplete and complete forms of self-reference. Logical forms of self-reference (such as the well-known Epimenides paradox) are typically incomplete because they need an external interpreter able to make sense of expressions like 'this', 'sentence' and 'falsity'. These cases of self-reference do not refer to themselves alone; they also and necessarily refer to something else, namely an external interpreter. On the other hand, complete self-reference pertains to systems whose terms are all defined within the system. For details see Lofgren (1968), for whom complete self-reference is independent from set theory and can therefore be added as a new primitive.[2]

Unsurprisingly, many properties of impredicative systems are still unknown, and suitable research programs must be developed. Specifically, we know very little about nested or tangled impredicative systems, such as the organism—mind—society encapsulation (Gnoli and Poli, 2004; Poli, 2017b). On the other hand, some results are nevertheless available.

Since the internal cycle defining an impredicative system can be taken as an implicit model of the system itself, the next step is to distinguish between those systems that are able to use that model as opposed to those systems that are not. I shall call the systems of the first type 'anticipatory'. The class of impredicative systems can then be divided into the subclasses of anticipatory and non-anticipatory systems.

In their turn, anticipatory systems can be distinguished between the systems in which all their efficient causes are closed within hierarchical cycles and those in which only some of the efficient causes are closed within hierarchical cycles. The former systems will be called CLEF (closed to efficient causation). A major issue is what systems are CLEF? (that is, impredicative, anticipatory and CLEF). According to Robert Rosen, living systems are CLEF. I claim that also psychological and social systems are CLEF, which implies that either (1) further *formal* distinctions should be found among these three classes of systems, or (2) their difference depends on the realization, that is, implementation in different material systems (which amounts to saying that matter matters, at least derivatively), or (3) further conditions of both types (formal and material) are needed.

What these cases have in common is an idea of system different from the idea of the system characterizing artifacts or mechanisms. To build, say, a house, one starts from a whole series of materials (bricks, concrete, tiles, doors, windows, etc.) and assembles them appropriately. Organisms and society are not 'built' in this way. Since their beginnings, they have always been systems (or wholes) and they generate within themselves all the relational and functional structures that they need.

The techniques developed by predicative science, what we have called the linear and non-linear modeling techniques, can be used for impredicative science as well, provided that one clearly acknowledges that these techniques provide partial, fragmented models of aspects of the encompassing impredicative system. Even so, they can be of great help. At the same time, it is fair to say that predicative modeling techniques can also be deeply dangerous if they are believed to capture the nature or intrinsic complexity of an impredicative system.

The important lesson to be learned is that impredicative science does not dismiss the capacities and the results of predicative science. On the other hand, impredicative science is more general than predicative science: it shows that predicative science deals with specific cases. In other words, an impredicative system can always be modelled predicatively by severing some of its temporal, spatial or functional connections.

Predicative systems can simulate any system behavior. Given any system behavior, provided that it can be described sufficiently accurately, there is a predicative system which exhibits precisely this behavior (Rosen, 2012, p. 10). The manner in which the behavior is naturally generated is utterly immaterial. What matters is only the simulation. The underlying reason is that any function can be approximated arbitrarily closely by functions canonically

[2] Apart from the pioneering efforts of Rosen, and usually without his idea that impredicativity is the next paradigmatic frontier of science, the issue of impredicativity has received some attention. See a. o. Aczel (1988), Barwise and Etchemendy (1987), Kampis (1995), Varela (1974).

Please cite this article in press as: R. Poli, Something about science: Mulling over impredicative systems, Ecol. Complex. (2017), http://dx.doi.org/10.1016/j.ecocom.2017.05.002