

Solving the puzzle of a theory of complex systems, a logical approach

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Carlos Eduardo Maldonado

Recibido: 30/07/2019 · Aceptado: 05/11/2019 · Publicado: 23/12/2019

Resumen

Todavía no existe una teoría de los sistemas complejos. Cuando se estableció por primera vez, los investigadores del Instituto de Santa Fe (SFI) acuñaron una expresión y formularon un programa de investigación, ambos estrechamente entrelazados. El concepto era sobre las nuevas ciencias de la complejidad, y el programa consistió en encontrar las leyes que hacen posibles los sistemas complejos. La identificación de esas leyes coincidió con la elaboración de una teoría de los sistemas complejos. Al final, resultó que el programa nunca se logró hasta hoy y que la pregunta se superpone a las ciencias sociales y humanas. Este artículo busca resolver el problema desde un punto de vista lógico.

Abstract

There is not a theory of complex systems, as yet. When it was first set out, the researchers at the Santa Fe Institute (SFI) coined an expression and formulated a research program, both closely intertwined. The concept was about the new sciences of complexity, and the program consisted in finding the laws that make complex systems possible. The identification of those laws was one and the same problem with coming up with a theory of complex systems. As it turned out, the program was never achieved until today. At the end, the question is overlapped unto the social and human sciences. This paper seeks to solve the problem from a logical standpoint.

Palabras clave

ciencias de la complejidad | lógicas no clásicas | filosofía | epistemología | metateoría

Keywords

sciences of complexity | non-classical logics | philosophy | epistemology, meta-theory

1. Introduction

The expression “the sciences of complexity” was coined within the very framework in which the Santa Fe Institute was settled down. From the very beginning a research program was formulated, thus: a theory of complex systems is to be found that grounds the very sciences of complexity. Such a theory was supposed to be simple, very much in analogy to the GUT in physics (Weinberg 1992). It must be said here from the outset that such a purpose could never be achieved given the very assumption that it was presumed that a/the theory of complexity. As a consequence the sciences of complexity exist and are being truly developed without albeit having ever reached, achieved or developed such a thing as a theory

of complex systems.

The theory was conceived very much in terms of (a philosophy of) physics, namely as a unified or a fundamental theory. In 1987 a seminar was organized aimed at entirely formulating a research program, namely reaching a fundamental theory of complex systems. Such a theory, it was argued, was to be presumably conceived as a simple theory at the basis of the increasingly growing field of complex science. Several years afterwards, in 1994 the same seminar was reorganized –or re-edited– with an astonishing surprise: in spite of counting with some of the best minds in the field, the program could not be attained by then. As a consequence, the tone was lowered and the program suffered a displacement to secondary places. Eventually nobody, i.e. no researcher or scholar from or at the SFI spoke any longer about having or reaching or pointing out to a general or transversal or unified theory of complex systems. Ultimately, the only and last voice to pronounce the issue was M. Mitchell in 2009.

This story has been told a number of times (Mitchell, Goodwin, Gell-Mann) either recounting the origins of the SFI, or also formulating the program about the search for a theory of complexity. Several prestigious authors even once openly engaged in that search (Kauffman 1995, Holland 1995, Maldonado 2009). Others pointed out to the very same problem from a different standpoint (Bak 1996, Horgan 2012).

The situation is really appealing and thrilling. The sciences of complexity are an overly increasing field. The number of prestigious journals completely devoted to the issue is large and increasing, mainly in English. Several prestigious editing houses have created series or collections that pivot around the sciences of complexity. The number of international congresses, seminars and academic events are continuously organized around the world in which most of the scholars and researchers actively participate. Moreover, different Ph.D. programs and Master programs are being organized and developed in some of the most important universities around the world, and the number increase year by year. Truly robust networks are being created that engage young and older scholars, scientists and researchers around some the key problems that define the sciences of complexity. The most important universities around the world have an institute or a center devoted to the field and issue. Without any doubt there is positively advance in punctual aspects of complexity science.

Yet, no theory has been reached, attained or developed, so far. The situation is very much alike in biology and medicine, where there is no general theory of life, i.e. the living systems, or of health either. We have science without theory.

This paper aims at solving such a situation. I claim that a theory of complex systems is possible and tenable, indeed. My take is grounded on logics in general, on the non-classical logics in particular and most conspicuously on metatheory, a subject that arises from the non-classical logics. Four arguments are brought that open up definitely the road for a theory of complex systems, thus: first a critique of a general unified theory is brought up. This argument argues that the search for a general unified theory of complexity is indeed a reductionist enterprise, therefore condemned to failure. The first section can be considered as *pars destruens*. The remaining sections are the *pars construens*.

The second argument opens up the door for solving the puzzle. It is concentrated on metatheory and a model of theories is introduced that allows reaching a theory of complex systems. The third argument consists bringing together the model formulated in a dynamic way. The idea of a theory net is introduced and justified. Finally the focus is placed on the human and social sciences, clearly the most complex science ever. The discussion is placed on the understanding of the human complexity. At the end some conclusions are drawn.

2. The dream about a general unified theory of complex systems: a failed dream

The search for a theory for the sciences of complexity was conceived from the outset as a physical if not a physicalist endeavor. As it is well known mainstream physics can be viewed as the enterprise that seeks the unification of the four physical forces – gravitation, the weak force, the strong atomic force, and electromagnetism. From a broader more philosophical perspective, the knowledge of reality can

be stated as the unification program between the theory of relativity and quantum physics. Consequently, physics is that science defined by a clear-cut heuristics, namely reaching a grand unified theory. Such a theory has also been named as a theory of everything (ToE) (Barrow 2007).

The first scientific revolution, namely classical science was possible thanks to the achievements by I. Newton that led to the formal set of classical mechanics. The rationale was that very simple laws –three, to be sure– laid at the basis of the explanation of the entire universe, from the fall of an apple on one's own head, to the relation between the Earth and the moon, or the orbit of the Earth around the sun. The beauty of the theory consisted in its simplicity and elegance –no question about this.

The origins of the sciences of complexity laid on physics, chemistry, biology, and mathematics mainly, simply because those were the most prestigious sciences mostly well-funded, and with important scientists around it. However, according to H. Pagels (1989), the sciences of complexity were possible thanks to the development of computation, but, at the same time helped foster computation, as well. As it can be clearly seen, the so-called hard sciences laid out the foundations for the sciences of complexity. These were sciences bearing very fundamental tools, rods, methodologies, and techniques–much more than a sheer epistemology or a discourse.

The imprint of physics over all the other sciences cannot be hidden. It is indeed physics that speaks loudly and firmly about reality as being grounded on laws; additionally, such laws are essentially simple and yield a mathematical model; ultimately, a good explanation is one founded on law-like behaviors. Biology and chemistry follow physics unto this road (Nowak 2006).

The physical or physicalist approach was never questioned among the array of researchers working in or around the SFI. Even some biologists did follow along the path even if tacitly reckoning the importance of a general elementary theory for life (Solé and Goodwin 2000). A contrary and much more free undertaken is the one carried out by Mitchell (2003).

The point is that the new sciences of complexity were supposed to be possible on the basis of a fantastic achievement, namely reaching a unified theory of complex systems which were said to be simple, and laid at the bottom of nature and society. Mathematicians and biologists, physicists and even economists went into the search for such a theory. The outcome was to be poor and empty. And yet, the surprise big: there is a group of sciences (in plural) made up therefore by several other disciplines which also entailed methods and approaches that worked and work and still make significant contributions to the understanding of the world –but which do not possess a theory, as yet.

The sciences are well known. According to one account, the sciences are chaos, catastrophe theory, thermodynamics of non-equilibrium systems, the science of complex networks, fractals, artificial life, and non-classical logics. The disciplines that comprise the sciences of complexity are, among others, self-organization, swarm intelligence, turbulence and fluctuations. The approaches include first-order and second-order transitions, self-organized criticality, and non-linearity. Among the rods and tools, we find agent-based modeling and simulation, metaheuristics, P versus NP problems, and several others. The landscape has been thoroughly studied and exposed (Maldonado 2016).

All in all, the field of complexity studies becomes stronger, deeper and larger day by day. But we/they lack a theory in the terms that it was conceived of after the SFI was settled down.

This paper argues that one way to solve a problem consists in displacing the focus of the issue researchers are concerned with. Thus, it is here suggested that the focus can be shifted to logics – a field that has never been proposed or carefully considered about, ever –so far.

Being as it may be, one thing is certain: the dream of a general unified theory is a dream has already been dreamt. We cannot pursue that track any longer; moreover, that path should not be pursued, at all.

3. Metatheory: opening the scope of a theory

The study of theories, namely types of theories and their robustness or capabilities used to be part of the philosophy of science in general, but it belongs nowadays to metatheory. Metatheory, as it is well known, emerges within the field of logics in general, and particularly within the framework of non-classical logics (Peña 1993).

We can distinguish four main theories in science in general, thus:

- Complete theory (CT). All scientific theories of classical science belong to this kind, from Galileo to Einstein, from Newton to Maxwell, from Vesalius to Pasteur or Koch, for instance. In other words, these are theories that are conclusive and pretend to be exhaustive vis-à-vis the domain it is concerned with. It is exactly against this type of theories that K. Gödel develops his theorem about incompleteness.
- Incomplete Theory (IT). The discovery that there are and there should be incomplete theories is due to Gödel's development of logics debating the Hilbertian program. Complete theories are tautologies, whence inconsistent. As a consequence from Gödel on the claim that incomplete theories are desirable cannot be avoided or superseded. A consistent theory is to be, it appears, incomplete (Gödel 1992, Nagel and Newman 1958).
- Paraconsistent Theory (PT). A paraconsistent theory is the one that accepts contradictions under the proviso that the contradiction is not trivial. Non-triviality hence arises as the rationale for paraconsistent theories. The best example about a paraconsistent theory is quantum physics: matter or light behaves sometimes as a particle, and sometimes as a wave. Both particles and waves are contradictory behaviors. Still, they do make sense, as it has been proved in quantum theory.
- Underdetermined theory (UT). An undetermined theory is the one in which we have the general picture of the phenomenon, but we ignore the particular features or traits of the system we are concerned with. Biology offers good examples about underdetermined theory (Kaufmman 2000), and it is more than reasonable to think that a theory of complex systems is an underdetermined theory. The rest of this paper is devoted to understanding this idea.

In order to better understand the logical classification of theories, it is important to take into account that in general theories are distinguished syntactically and semantically. As it is well known, such a distinction originates from Carnaps' characterization of logical systems according to the rules of formation or the rules of transformation (Van Fraassen 1987).

From a logical standpoint a theory is a set of well-formulated formulas –wff–, generated according to rules of formation provided that the set of wff is closed in relation with certain rules of inference. A more formal explanation of the types of theories just mentioned is the following: A complete theory (CT) is basically an axiomatic theory, and it has an enumerable number –that can be finite or infinite– of axioms such that after a given number of steps it is possible to establish whether a wff is an axiom of the set of statements, or not.

A theory is inconsistent (IT) in contrast to a consistent theory if and only if it never has a set of theorems such that one is the negation of the other. More formally said, an (IT) is such that there are a rule of inference of statements that allows always to replace in any formula called, say, r , an occurrence of p in r for an occurrence of q ; then it can be said that p and p are can be replaced in the given set of statements.

A theory is paraconsistent (PT, if and only if it is no superconsistent; in other words, a theory is superconsistent if and only if any rigorous extension of a set of statements that is inconsistent in regards to any functor of negation of the set of statements is a deliquescent theory. A deliquescent theory is the one in which the wff is a theorem of that theory (Peña 1993).

An underdetermined theory (UT) is a theory in which the general traits of the system that is considered are rather well known, but we do not have a good knowledge of the details, as yet. Probably the first time an (UT) is introduced is with Kaffman, (2000), even though he refers himself back to

Wittgensteins' Tractatus.

The typology of the theories sketched above can be formalized in the following equation (this equation is largely exposed and treated in Maldonado 2019):

<https://gazeta-antropologia.es/solving-the-puzzle-of-a-theory-of-complex-systems-a-logical-approach/maldonado/>

The equation is to be read as follows: a PT is a theory whose explanatory power is already exhausted. In other terms, it is a theory we can make things with, but with which no further explanations can be achieved. A good example of such a theory or explanation is Pythagoras's equation. We can build rooms and buildings based upon it, but we cannot make it say more than what it has already said in history. The brackets on the left of the equation mean that the space of comprehension or understating is closed. On the contrary, the brackets remain open as we move to the right side. Consequently, the space of possibilities is larger the more we read the equation to from left to right. Ultimately, underdetermined theories remain as the ones that are more open –since they were the most recent to be discovered or formulated somehow.

The argument here is that we are not compelled to work or think about complete theories. These are exactly the type of theories that have already been dreamt already. That is the kind of knowledge that used to pontificate in the sense that they claimed that “this is the way things are, and no more; period”.

Over against the idea of complete theories the logical study of theories shows that other types of theories are possible that make much more sense from the standpoint of logical explanations. These are indeed IT, PT, and UT. A new perspective emerges here; we turn to the third argument.

4. The idea of a theory-net

Taking up just provisionally a concept from N. Cartwright (2005), we can safely say that complexity is about coping with a “dappled world”. As it happens, a dappled world is a world marked by uncertainty, fluctuations, turbulence, self-organization, emergence, non-linearity, far-from-equilibrium systems or also dissipative structures, fractality, multi-scale approaches, strange attractors, catastrophes, randomness, and many other features and characteristics of increasingly complex systems.

As it is well known, complexity science does not work with a particular definition of complexity; rather, it works with characteristics or properties of non-linear complex systems (Bar-Yam 1992). The very idea of understanding and explaining complexity at large by the properties of complex behaviors means that we do not have a complete and clear-cut idea of nature and the world. Instead, we have a dappled world, a world traced by the progressive achievements of research –which is an open-ended endeavor.

I would like to suggest that the idea of a general theory of the world belongs to the past – more exactly to the first scientific revolution; in other words, it belongs to classical science. A general all-encompassing theory seems not to be necessary or sufficient, any longer. We can and most probably should think about a theory-net. Such a possibility has been extremely rarely considered. We have a rather large and solid array of models, theories and explanations around us. J. Hands (2017) provides a set of criteria for accepting the validity –he speaks of the reasonableness– of a theory. These are: the beauty of a theory, the parsimony, its internal consistency, and the external consistency with other scientific tenets.

Beauty has several times, although still rarely, been accepted as demarcation criteria for what a good theory is. Mathematics stands out –particularly via symmetry– as the rationale for beauty. There is however not a rigorous reflection upon it, as yet. The parsimony refers to a principle of economy, usually known as Ockham's razor. Even in complexity science at large Ockham's razor prevails, indeed. The consistency of a theory points out to the fact that there should not be (trivial!) contradictions within the set of arguments of a given model. The accordance with evidence means that the theory in

question makes predictions or retrodictions that can be independently tested.

By and large, the most interesting criteria here is the call for acknowledging that a certain theory may or can have an external consistency with other scientific theories, models, approaches, languages and methodologies. Hands recalls for consilience, a concept originally coined by E. O. Wilson (1998). A “conjecture conforms with solidly verified knowledge in other scientific disciplines to form a common basis for explanation” (Hands 2017: 95).

This, it is strongly believed here, is the safest way to solve the puzzle about a theory of complex systems, namely a, say, UT is soundly secured if it exists in a constellation of other solidly verified arguments, explanations and understandings of it is at stake.

Accordingly, a theory of complex systems is to be thought thereafter as a the accordance among a set of theories and models that support each other and help provide a solid view of nature and reality. If reasonable, then the call for “a” or “the” theory of –here, complex systems– becomes really archaic. From classical science and classical philosophy of science the discussion about a good theory has improved, it appears.

As it can be inferred, a sound complex approach of a theory of complex systems entails taken up seriously one of the most important characteristics of complexity, namely plurality or diversity; negatively said, non-reductionism. Hence, the third argument here claims that a theory net is possible and necessary. Such a theory net is made up by ITs, PTs, and UTs. The very idea of a hierarchy of theories is to be rejected or left aside in the framework of complex studies. Properly understood, the very idea of complexity is incompatible with the belief in hierarchies. Rather, the emphasis is placed on cooperation, networks, mutualism, adaptation, co-evolution, interdependency, and the like.

The very idea of a theory-net has never being proposed within the community of scholars or researchers on complexity at large. One reason is that there are very few –truly very few –working on the question that serves as basis for this paper. But the main reason is because not many people are fully aware about the very possibility of explaining the world in terms of a theory-net. Many complexologists, it seems, are classical in spite of themselves, apparently.

5. But what about anthropology? The challenge of the social and human sciences

A very interesting shift has been produced within the community of complexologists all over the world. More explicitly than tacitly there has been the acknowledgement that social systems in general are the most complex ones possible, and more particularly, human social systems are by far the most complex, ever.

Complexity science arose studying physical systems, and from there they progressed to living systems. Very soon after that shift the awareness that living systems are much more complex in any sense that physical systems emerged. Afterwards, more recently, the awareness that the human systems are the most complex systems imaginable was a common asset in the community of scholars and researchers working on complex systems. A number of works and discoveries led to such a conclusion. Nowadays there is barely any good scientist working on complex systems who does not work on social human systems – whether he or she originally was educated or formed in physics, mathematics, biology, computational science or chemistry, for instance. Spearhead research in complexity science means working on the social and human sciences –systems, or behaviors.

Most probably the first book on complexity and anthropology is Helmreich (2000); the first book on complexity and sociology is B. Castellani (2009). In Spanish the first book on complexity and anthropology were Adams 2001 and Pérez-Taylor 2015, and Solana 2001 about the complex anthropology of Edgar Morin. Two different books that offer either a state-of-the-art regarding complexity and social science or a synthesis between both of them, are correspondingly: Byrne and Callaghan 2014 and Maldonado 2016.

According to an already classical diagnostic, R. Merton once declared (1968) that all theories belonging to the social and human sciences are just “middle-range theories” –over against grand theories. The argument even if biased has never been debated on behalf of social scientists that work on complexity. A good conjecture is that the best theory in the framework of the social sciences is the triad made up by choice theory (origin: economics) –game theory (origin: mathematics), and collective action theory (origin: political studies). As it is well known, this triad constitutes a solid unity, and knows of particular developments such as evolutionary game theory, and several others.

In Merton’s own take, there is implicitly the belief that there are a hierarchy of theories, and that a grand theory is very much in the tenure of the physical sciences (Pentland 2015).

Being as it might be, the most complex systems in the fourth argument here is that given that social human systems are by far the most complex in any concern, a corresponding theory is to be set out. A twofold possibility then arises, thus: it can be either an underdetermined theory, or also a theory-net compounded by IT(s), PT(s) and UT(s).

In other words, a truly complex system, no matter what, cannot be reduced to a single theory, whichever its nature. The phantom of reductionism must be rejected by all means. It is my contention that social and human scientists can take the lead about discussing and developing a theory of complex systems. Non-classical logics in general and metatheory in particular offer good chances for such an enterprise, but it is also possible that the gate towards a theory-net be also open as a most plausible road (Weingartner 2010). In any case, a theory of complex systems cannot be taken as a complete theory in any regard. Darwin’s own theory provide a great hint here, namely the theory of evolution is an incomplete theory (simply) because the subjects the theory is concerned with – living systems – are incomplete themselves. It is important to remember that the goal of a logical system in general consists in providing a syntactic characterization of semantic notions; it is however the goal of metatheory to evaluate such endeavors.

The social and human sciences have recently known about developments that manifestly surpass classical approaches. One of these achievements is the development of big history (Christian 2004, Stokes 2012), in which there is a truly cross-disciplinary approach to both the social and human sciences and to biology, geology, and geography, to name but just some other sciences. More radically, when talking and thinking about complex approach we are discussing much more and quite a different matter than just inter or multi-disciplinarity. This is the crux about a theory of complex system in the framework of the social and human sciences.

To be more specific, a real thinker and researcher do not just think or work in terms of boxes. The English-speaking expression is very lucky and appropriate here: thinking out of the box. This means just thinking without boundaries, or feuds. Voilà a most challenging idea.

Crossing or integrating biology, ecology, the social and human sciences, mathematics, logics, physics and most probably also computational science can help provide the rationale for a theory of complex systems. After all, complexity is about getting the big picture of society, the world, and the universe. A good theory cannot be made up by fragmentary and weak pictures. The big picture –this is what is after all at stake. The sciences of complexity are nothing else than about getting the big picture –which is not to be taken as a sort of “holistic” or systemic view. Noise –whether white, pink or black, as it is often said in engineering is to be discarded by all means, here.

I would like to strongly stress it, thus: the original call about the need for a general unified simple theory of complex systems was formulated and framed within physics and physics-like science. Now, provided that there is a generalized consciousness that the social systems are by far the most complex systems, such a theory of complex systems is not feasible without firmly and frankly facing the entire corpus of the human and social sciences, under one proviso, namely that these groups of sciences be already percolated by rigorous concepts, tools, rods, and metaheuristics of complexity science at large.

In case normal normal social sciences still are under the possession of middle-range theories social and human complex sciences have already overcome such a state of mind and transformed their own semantic, logical, and methodological status. It would be a long text apart to support this claim; it sufficed to an updated state-of-the-art regarding the relationships between complexity science and the social and human sciences (Byrne and Callaghan 2014, Maldonado 2016). In any case, the truth is that the human and social sciences may strongly contribute to bringing out, reaching, achieving or developing such a theory (UT) –a theory-net, or consilience. The puzzle has indeed been solved, as it is indeed the case.

6. Conclusions

As it can be seen from the bibliography mentioned above, around the years 1990s there is a great enthusiasm about the possibility of getting a general unified theory of complexity. Between, say the second of the 1990s, until today there is barely any bibliography about the issue except for Mitchell (2009). Silence pervades a most fundamental research program –a sign of defeat.

This paper argues that a theory of complex systems is possible under the proviso that it is not to be taken as a general and unified one –like it happens in physics. We can and should think about theories and models outside physics (Maldonado 2017). The suggestion here is nurtured from logics – non-classical logics, and metatheory.

Good science is about good explanations and understanding. However, a good explanation consists in good theories and good models –something that is easier said than done (Maldonado 2017). In the history of spearhead science as it is being developed out there, very few scientists discuss and develop models, for most scientists, scholars and researchers are just engaged in discussing about authors, schools, and techniques. Even fewer scientists do develop theories –for it is extremely hard; it is the outcome, generally speaking, of one's own life-time. At the very top of the mountain, still fewer scientists are capable of reaching or developing a science.

To be sure, no body encounters anything within the realm in which he or she has been working for a while. On the contrary, most discoveries and inventions: a) happen randomly –it is the importance of serendipity or the aha! moment (Roberts 1989), or else, also, b) any discovery is made in the surroundings (or neighborhood) of the field or terrain in which a scientist has been working. The condition sine qua non consists in any case in the capability to be open to the surroundings and to randomness. Science very rarely happens in terms of the setting of goals, objectives, and the like. As one W. von Braun said: "I do research when I do not know where I am heading to with what I am doing".

The dream dreamt by the founders and early academic staff of the SFI is not trivial or crazy, at all. The failure consisted in the tacit or explicit assumptions for reaching a general unified theory of complex systems. The crux of this paper is that the assumptions and the very focus are to be changed –whence the contributions from non-classical logics and metatheory.

Good science does not just explain society and the world nowadays. It does so thanks to developing good models and good theory. And sometimes, but developing also brand new sciences and disciplines. This, it is claimed here, is the real and final challenge and bet for scientists, philosophers and researchers.

It is just a bet –but a sound and sincere one.

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Autores

Carlos Eduardo Maldonado

Full Professor, School of Medicine, Universidad El Bosque (Bogotá, Colombia)

maldonadocarlos@unbosque.edu.co

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