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Critical review

A response to simplifying complexity ☆

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Abstract

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1. Complexifying simplicity

In a recent issue of Geoforum, Steven Manson (2001) presented a timely review of Complexity Theory in order to orient the unversed reader in a framework of Complexity Theory's key concepts. Manson begins with an overview of the evolution of research in Complexity Theory, appreciating its antecedents and asking a number of thought provoking questions. This is followed by a discussion that pulls together much of the disjointed literature in establishing a typology of approaches to Complexity Theory, including an examination of their advantages and disadvantages.

In meeting the aims of his review of Complexity Theory, Manson has covered a substantial amount of literature, much of which is difficult to commensurate and sometimes even contradictory. He effectively cuts through its often effusive nature, uncovering some of the embedded constructs and recognizing its links to the past and its future potential. However this author considers that Manson's presentation of complexity did not make clear a number of fundamental concepts in his article. These points are to be taken up here through a discussion of an alternative view in the context of Complexity Theory: the first is a discussion of Manson's usage of "types of complexity theory", the second involves a re-evaluation of the differences between these "types", and the third addresses the differences between Complexity Theory and Chaos Theory.

The second and third points of discussion are common misconceptions (in general and geographic literature) that arise from the assimilation of ideas without careful consideration of their context. This is a common problem resulting from geography's borrowing tendencies (Agnew and Duncan, 1981). All of these points are essential to the conceptual framework that orients and directs the reader and researcher. An alternative framework is then considered in Section 5.

2. Theories of "Complexity" versus complexity theories

There are many different forms of research efforts in complexity over many different disciplines producing many different measures and definitions of *complexity* that all fall under the rather broad umbrella of Complexity Theory (for a fairly comprehensive bibliography see http://aldebaran.cpm.aca.mmu.ac.uk/~bruce/combib/). Manson (2001, p. 405) states 'that there is no one identifiable complexity theory', however that depends on the conception of theory. At the basic level of theoretical construction, such as world-view (Moore, 1997), complexity theorists concur that the whole is greater than the sum of its parts. This aphorism appears to be the glue that binds the somewhat fragmentary nature of complexity research. Instead of considering algorithmic, deterministic, and aggregate complexity as separate types of Complexity Theory they can be thought of as different measures or definitions of the complexity of a system. Thus there are different theories of the definition of complexity rather than different types of Complexity Theory.

3. Complexity versus complicated

Manson (2001, p. 406) recognizes that 'there are separate kinds of complexity that have different and

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sometimes conflicting assumptions and conclusions'. Beyond this recognition it is important to ask what are the underlying constructs that make these "types", or rather definitions of complexity, incommensurable. The key to understanding most of the differences between the varying definitions or measures of complexity is the definition of the term *complexity* itself.

The difficulty with the term *complexity* is that it suffers a semantic hangover from its well-accepted dictionary definition; 'only a decade ago, "complex" simply meant made of many interrelated parts' (Koch and Laurent, 1999, p. 96), synonymous with complicated. However, there is now much more to *complexity* than its dictionary definition (Mikulecky, 1999). Many authors have failed to note the difference between *complicated* and the new interpretation of *complex* taken in Complexity Theory.

A system is *complicated* if it can be given a complete and accurate description in terms of its individual constituents, no matter how many, such as a computer or the process of programming a VCR (Cilliers, 1998); 'complication is a quantitative escalation of that which is theoretically reducible' (Chapman, 1985, p. 370). A system is said to be *complex* when the whole cannot be fully understood by analyzing its components (Cilliers, 1998). Many techniques under the banner of Complexity Theory have little or nothing to do with complexity as such, where the word *complexity* is used to describe complicated or difficult systems, typically with many parts (Edmonds, 1999). Chapman (1985, p. 370) asserts that if the world can be explained in a reductionist manner 'then "complexity" is not qualitatively different from "simplicity" but merely quantitatively different'.

Manson (2001, p. 406) states that 'all three kinds of complexity are concerned with how the nature of a system may be characterized with reference to its constituent parts in a non-reductionist manner'. However, neither algorithmic nor deterministic complexity, as Manson defines them, are complex in the sense described above. Manson discusses two forms of algorithmic complexity: the first is more commonly described as computational complexity and the second as algorithmic information theory. Neither formulation of complexity is concerned with how the system may be characterized by its parts in a non-reductionist manner. Both translate complexity as complicated.

Manson's unfortunate usage of *deterministic complexity* as a classification of a group of types adds to the confusion. Within the literature deterministic complexity typically refers to those Manson has placed under the rubric *algorithmic complexity*. What are commonly referred to as deterministic measures of complexity, are those that require the accounting of every bit in an object (Gell-Mann and Crutchfield, 2001).

What Manson terms *aggregate complexity* comes nearer the mark of complexity that both Manson and this author consider apposite in terms of Complexity Theory. However, Manson's discussion of aggregate complexity is a description of the structure and behavior of complex systems rather than a *type* of complexity. Manson's explanation of change and evolution in Subsection 4.1.6 is also somewhat confusing. The *dissipative* form of transition *is* a form of self-organized response by the system to perturbation. Self-organized criticality, rather than 'the ability of complex systems to balance between randomness and stasis' (Manson, 2001, p. 410), is that balance (commonly termed the edge of chaos) between chaos, which is not equivalent to randomness, and order. Furthermore, self-organized criticality is not a "type of transition" but a type of system organization.

4. Chaos Theory versus Complexity Theory

Because there is no framework or definition for Complexity Theory, or for that matter Chaos Theory, confusion between Complexity Theory and Chaos Theory or the concepts of complexity and chaos is another key difficulty overlooked by many authors. Because Chaos Theory is in some respects a precursor of Complexity Theory, much of the terminology has remained unchanged despite changes in meaning. Manson recognizes that 'deterministic complexity is [a]... marred concept' (2001, p. 408), but does not expand as to why it is problematic. The differences between Chaos Theory and Complexity Theory are not discussed.

Chaos Theory deals with simple, deterministic, nonlinear, dynamic, *closed* systems. They are extremely sensitive to initial conditions resulting in an unpredictable chaotic response to any minute initial difference or perturbation. Complexity Theory focuses on complex, non-linear, *open* systems. Complex systems respond to perturbation by self-organizing into emergent forms that cannot be predicted from an understanding of its parts.

Mikulecky (1995) notes that the evidence for the validity of chaotic dynamics for biological processes involve simple *isolated* systems. Chaos is found in the idealizations or models of real systems, but it is not evident in the systems themselves. Lorenz's renowned weather system was an open but isolated system, a product of abstract computation that lies outside of the embedded nature of real world systems, incorporating a set of rules that did not change; 'global weather is not a simple chaotic system' (Bak, 1997, p. 159). Manson references Zimmer (1999) to state that 'fewer systems than anticipated are in fact deterministically chaotic' (2001, p. 408). However on closer reading of Zimmer (1999), and with the difference between Complexity Theory and Chaos Theory in mind, it is evident that chaos has only been found in models, not *natural* systems. In Chaos Theory disorder arises from simple ordered states, in Complexity Theory large scale order arises from complex apparent disorder at the local scale.

5. The importance of structure

Thus, much misunderstanding arises from the confusion or inappropriate use of the terms of Complexity Theory and Chaos Theory. This may sound like mere semantics, but the importance of using appropriate terms cannot be emphasized enough, as they form the basis of communication. A well-defined set of terms provides a framework within which research can be placed and discussed.

Beyond confusion with complication and Chaos Theory, this authors other comments have been directed at the organization of the concepts of complexity in Manson's paper. The appropriate frameworks are very important to developing a correct interpretation of Complexity Theory. Frameworks form the next level of theoretical construction (Moore, 1997) above the world-view at which Complexity Theory seems to be stalling.

An alternative categorization of the varying types of complexity found across numerous disciplines rallying under Complexity's banner involves a careful analysis of their underlying definitions or measures of *complexity* per se. This author considers that the types of complexity may be divided into seven (not mutually exclusive) groups, covering most of the main variations found in the literature and which are briefly considered here.

1. *Deterministic complexity.* This type of complexity is based on information theory and is measured as the algorithmic content of a string of bits, defined as 'the length of the shortest program that will cause a standard universal computer to print out the string of bits and then halt' (Gell-Mann, 1995, p. 16). This category also includes computational complexity, a measure based on processing time. Thus complexity is equated with randomness.
2. *Statistical complexity*. Statistical measures of complexity attempt to measure the degree of structure or pattern present in a complex system, circumventing the problem of statistical complexity where randomness equals maximal complexity. The boundary conditions of extreme order and disorder are satisfied by vanishing at these limits (Feldman and Crutchfield, 1997).
3. *Phase transition*. Maximal complexity is defined as the mid-point between order and chaos, the edge of chaos (Kauffman, 1995).
4. *Chaos derivatives*. The measures of complexity developed under Chaos Theory are typically based upon the Lyapunov exponent or the Fractal dimension. The former 'defines in precise mathematical terms a system's sensitivity to initial conditions' (Jensen, 1987, p. 177); the latter defines complexity through a measure of the irregularity of an object.
5. *Connectivity*. Complexity is measured by the degree of connectivity within the system, where the greater the number of connections or interactions the higher the complexity (Kauffman, 1995).
6. *System variability*. Complexity is defined whereby an increase in system variability (e.g., spatial variability or between scale variability) results in an increase in the complexity of the system.
7. *Relative and subjective complexity*. These types of complexity hold that it is a consequence of human perception and is therefore relative to the observer; 'the complexity of an object is in the eyes of the observer' (Klir and Folger, 1988, p. 193).

Manson's foray into describing the structure and behavior of complex systems can also be reformulated. The classification applied here is specifically oriented to geographic applications. As with the earlier framework, the divisions imposed are not mutually exclusive, they are used as a heuristic device to enhance understanding. Mapping complexity produces four classes: complex system structure, landscape, behavior, and organization. Complex system structure defines the complex system as composed of *elements* and relations or *connections*. Complex system landscape defines the *state space* of the complex system within which *attractors* are found and the importance of *scale* is recognized. Complex system behavior is defined by self-organization and can be divided into *elemental behavior*, or element ↔ element interaction, *system ↔ environment* behavior, and the *complex whole behavior* that emerges from the two former types of behavior. Complex system organization is described as a continuum, the opposing extremes of which are defined as *order* and *chaos.* Between these two end points lies the *edge of chaos*.

6. Concluding comments

If a repetition of geography's history of misapplied or poorly understood concepts mined from other fields is to be avoided and the potential of complexity to be clearly understood, it is imperative that these concepts or theories are critically defined in the terms of their origins. The dangers of accepting a single account of Complexity Theory without a thorough understanding of its original other disciplinary context will result in an inability to communicate effectively to those applying "complexity theory" in other disciplines and may well lead to spurious research.

This returns the discussion to Manson's insightful, yet unanswered, question: 'What value does Complexity Theory hold for geographic research?' (2001, p. 405), a question that supports the call for research from the US National Research Council (1997). To effectively evaluate Complexity Theory's value for geographic research, and as a basis for future research and development, requires appropriate frameworks.

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References

Agnew, J.A., Duncan, J.S., 1981. The transfer of ideas into Anglo-American human geography. Progress in Human Geography 5 (1), 42–57.

Bak, P., 1997. How Nature Works: the Science of Self-Organized Criticality. Oxford University Press, Oxford.

Chapman, G.P., 1985. The Epistemology of Complexity and Some Reflections on the Symposium. The Science and Praxis of Complexity, Montpellier, The United Nations University.

Cilliers, P., 1998. Complexity and Postmodernism: Understanding Complex Systems. Routledge, London.

Edmonds, B., 1999. What is complexity? – The philisophy of complexity per se with application to some examples in evolution. In: Heylighen, F., Aerts, D. (Eds.), The Evolution of Complexity. Kluwer, Dordrecht. Available from <http://www.cpm.mmu.ac.uk/~bruce/evolcomp>.

Feldman, D.P., Crutchfield, J.P., 1997. Measures of statistical complexity: Why? Phys. Lett. A 238, 244–252.

Gell-Mann, M., 1995. What is complexity? Complexity 1 (1), 16–19. Available from <http://www.santafe.edu/sfi/People/mgm/complexity.html>.

Gell-Mann, M., Crutchfield, J., 2001. Computation in Physical and Biological Systems: Measures of Complexity. Santa Fe Institute. Available from <http://www.santafe.edu/sfi/research/focus/compPhysics/projects/measuringComplexity.html>.

Jensen, R.V., 1987. Classical chaos. American Scientist 75 (March–April), 168–181.

Kauffman, S., 1995. At Home in the Universe: the Search for the Laws of Self-Organization and Complexity. Oxford University Press, New York.

Klir, G.J., Folger, T.A., 1988. Fuzzy Sets, Uncertainty, and Information. Prentice Hall, New Jersey.

Koch, C., Laurent, G., 1999. Complexity and the nervous system. Science 284 (5411), 96–98.

Manson, S.M., 2001. Simplifying complexity: a review of complexity theory. Geoforum 32, 405–414.

Mikulecky, D.C., 1995. Life, complexity and the edge of chaos: cognitive aspects of communication between cells and other components of living systems. Biotheoretica Acta November 27. Available from http://views.vcu.edu/~mikuleck/rev.htm (submitted).

Mikulecky, D.C., 1999. Definition of Complexity (and linked pages). 2001. Available from http://views.vcu.edu/~mikuleck/ONCOMPLEXITY.html.

Moore, G.T., 1997. Toward environment-behavior theories of the middle range: their structure and relation to normative design theories. In: Moore, G.T., Marans, R.W. (Eds.), Advances in Environment and Design, vol. 4. Plenum, New York, pp. 1–40.

National Research Council, 1997. Rediscovering Geography: New Relevance for Science and Society. National Academy Press, Washington, DC.

Zimmer, C., 1999. Life after chaos. Science 284 (5411), 83–86.