A preliminary vocabulary of complexity

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Abstract

In 20th century, advances in physics (*relativity*, *quantum mechanics*, *chaos* and *complex systems*) led to the development of the "paradigm of complexity". In this paradigm, scientists realized that the study of modern phenomena could not be classified in any single discipline, thus requiring an interdisciplinary approach. However, although complexity is one of the most promising areas in contemporary science, it is still a fragmented body of knowledge, being composed of a plethora of methods, concepts and principles from a multitude of disciplines. To tackle this conceptual gap, this work proposes a preliminary vocabulary of complexity.

Keyworks

complexity, complexity science, complex systems, vocabulary

1. Introduction

In 20th century, advances in physics (*relativity*, *quantum mechanics*, *chaos* and *complex systems*) led to the development of the "paradigm of complexity" [1, p. 20]. In this paradigm, scientists realized that the study of modern phenomena could not be classified in any single discipline, thus requiring an interdisciplinary approach [1, 2]. However, although complexity is one of the most promising areas in contemporary science, it is still a fragmented body of knowledge, being composed of a plethora of methods, concepts and principles from a multitude of disciplines [1]. To tackle this conceptual gap, this work proposes a preliminary vocabulary of complexity.

2. Research Method

Given its interdisciplinary nature, I chose four books from different disciplines as the starting points to gather this vocabulary. The first book [1] is a guided tour in the area of complexity, covering the full history of the topic. The second one [3] describes how philosophy addresses the topic of complexity, by elaborating hypothesis about the subject, while the third [4] and fourth ones [2] are scientific books, respectively from mathematics/simulation and physics.

3. Findings

Advances in complexity science are still cutting-edge research in many fields, and therefore, there is no general consensus about the necessary and sufficient properties of complex systems. Below, I include only the consensual terms:

Definition 1 (Sciences of Complexity). The Sciences of Complexity consists of an interdisciplinary field of study whose goal is to understand how simple, independent entities without a central controller dynamically interact to generate a coherent whole that strives to achieve collective goals, generate patterns, exchange information, adapt and learn.

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At the heart of the sciences of complexity, there is the concept of complex systems, together with a number of properties:

Definition 2 (Complex Systems). A complex system is a tuple $C_s =< E, I >$, where C_s, E, I are, respectively, a complex system, a set of elements within C_s and a set of interactions on E.

- **Elements.** A complex system is composed of *many elements*, being them the prerequisite for interactions to occur. These elements depend on the studied field (e.g., atoms in quantum systems, cells in biology, ants and bees in biology, people and companies in economics, etc.). The macroscopic order that emerges is only possible when these large number of parts are present, allowing the complex systems to display their self-organizing properties [3, 2].

- **Interactions.** Interactions are exchanges of energy, matter, or information, whose interaction mechanisms can be collisions, forces or communication [3]. They are at the heart of complex systems: without them, the system would be just an aggregation of independent particles, with no possibility of displaying self-organizing properties.

- **Self-organization.** The distinguishing feature of complex systems is their dynamic behavior. This behavior falls between organized simplicity (simple, deterministic) and disorganized complexity (complex, random). They dynamically "self-organize", creating order out of disorder, contrary to the natural tendency of systems to follow the 2nd law of thermodynamics (entropy) of total disorder [1]. To understand and characterize how self-organization happens is the core of the discipline of complex systems [4]. What represents "order" and "disorder" varies significantly, some scientists argue that information processing features may be useful to measure order/disorder [1], while others include notions such as symmetry, organization, periodicity, determinism [3] or the formation of patterns [5].

- **Information-processing.** The way how complex systems handle information is the feature that explains how they operate [3, 1]. Literature explains that natural complex systems *compute information* in order to adapt to its environment and learn [3, 1]. The meaning of what precisely constitutes *information* and what the complex system does with this information still remains largely unanswered by the community [1]. The hypothesis is that the individual elements locally interact, giving rise to local systems states. Local states lead to the emergence of a global state of the system. Thus, *computation* is the result of decentralized interactions.

4. Conclusion

This work has presented a preliminary vocabulary of complexity. This vocabulary only considers the consensual terms found in literature. As a future work, I intend to investigate other terms, such as emergence, entropy, equifinality, etc. Further, I intend to extend a foundational ontology with this novel vocabulary in order to improve semantic clarity of these terms.

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