Natural Information and Computation: A Proposal Based on Interaction and Decision Making

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Abstract

Based on the concept that the structure of nature is informational and the dynamics (changes of state) is computational, we analyze the mechanisms of interaction and decision making that are present in natural systems as information and computation respectively.

Some contemporary views about nature assume information and computation as the key to understand and explain the basic structure of physical reality. These views have different approaches, because they come from different knowledge areas such as Physics, Chemistry, Biology, Computer Science and Philosophy. Among them is the latest infocomputacionalism, which treats reality as a hierarchy of levels, starting with a basic level of proto-information (elementary physical phenomena) as the material of the universe, and building a number of higher levels of organization through computational processes (Dodig Crnkovic 2011). Fundamentally, this view treats the structure of the universe as informational and the dynamics (changes of state) as computation (Dodig Crnkovic 2011).

Although the info-computacionalism characterizes the structure of nature as informational and the dynamics as computational, it does not clearly define what is information and computation in natural systems. Aiming to detail the concepts presented by info-computacionalism, this paper presents a proposal of how to observe the informational and computational behavior in natural systems by analyzing the mechanisms of interaction and decision making that are present in these systems.

Information and Computation in Natural Systems

Natural systems are open systems communicating with the environment whose behavior is emergent and complex, i.e., the global behaviors presented by natural systems are the result of the simultaneous interactions of local elements (de Castro et al. 2011). The interaction between agents (or elements) of a natural system generates a type of information not previously stored, but associated with an action. This type of information is named *referential information* and represents the causal links that exist between disjoint domains of a system (Kampis and Csányi 1991). The concept of referential information implies that the dynamics of a system is not determined by an informational internal set (stored information), but by interactions with other domains of the system that generate changes in the stored information, triggering causal processes. Thus, information in natural systems is a composition of two aspects: *referential information* that represents the interactions between different parts of a system and *non-referential information* that is knowledge-based and passive of encoding (Kampis and Csányi 1991).

Basically, it is possible to imagine natural systems (regardless of it being atomic, molecular or biological) as a set of agents that interact with each other and the environment. In this model an agent may suffer an action from another agent or from the environment. If this action suffered by the agent causing an interference in its internal configuration (*self*), it is characterized as a relationship between the agent and the entity which generated the action. The decision making, carried out by the agent in relation to the action suffered is characterized in this model as computation. The increase in complexity in the relationships and in decision making performed by the agents represents a *semantic jump*.

Didactically, a semantic jump may be positive or negative. The former indicates an increase in the complexity of interactions and computations performed by the agents, while the latter indicates a reduction in the complexity of these events. In other words, the semantic jumps are responsible for the transition between the various levels of abstraction that constitute a natural system. The semantic jumps are so named because each level of abstraction creates a new interpretative framework (different from previous) about the phenomena occurring in the system, i.e., at each level of abstraction there is a different semantics in relation to the structure and dynamics of the system.

For example, a bacterial colony performs computations (decision making) in a distributed manner, where each bacterium is an autonomous system that can store, process and interpret information. Thus, computations in a bacterial colony occur at two levels of abstraction: the macro level, formed by the network of chemical communication between bacteria inside the colony; and the micro level, formed by intracellular communication networks in each cell (Xavier, Omar, and de Castro 2011). Depending on the level of abstraction we are watching the meaning of each entity is different. At a more basic level each colony can be understood as a system, at a higher level as an agent, and the each semantic jump will represent a new set of entities and phenomena that are implemented using the structures and dynamics of the lower layers.

It is possible to realize that the information in nature, in its most basic form, is denoted by causal links (interactions) between its elements and that the natural computations are represented by decision making performed by these entities in relation to the stimuli received. The study of the mechanisms of interaction, decision making and transitions (semantic jumps) between levels of abstraction in natural systems, such as in bacterial systems and molecular ones, can bring a new light into the understanding about nature and computing, besides making possible the development of new bio-inspired systems for complex problem solving.

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