Chapter 3
Biological Information and Natural Computation

Gordana Dodig Crnkovic
Mälardalen University, Sweden

ABSTRACT

The dynamics of natural systems, and particularly organic systems, specialized in self-organization and complexity management, presents a vast source of ideas for new approaches to computing, such as natural computing and its special case organic computing. Based on paninformationalism (understanding of all physical structures as informational) and pancomputationalism or natural computationalism (understanding of the dynamics of physical structures as computation) a new approach of info-computational naturalism emerges as a result of their synthesis. This includes naturalistic view of mind and hence naturalized epistemology based on evolution from inanimate to biological systems through the increase in complexity of informational structures by natural computation. Learning on the info-computational level about structures and processes in nature and especially those in intelligent and autonomous biological agents enables the development of advanced autonomous adaptive intelligent artifacts and makes possible connection (both theoretical and practical) between organic and inorganic systems.

INTRODUCTION

Information has become a conceptual tool above others and it is found everywhere across research disciplines and in everyday use. Physics may be founded on informational grounds, and so other sciences involving physical objects (*paninformational stance, informational structural realism,*

Floridi). *Pancomputationalism (natural computationalism)* at the same time views the physical universe as a computational system. According to *pancomputationalists* (Zuse (1967), Fredkin (2009), Wolfram (2002), Chaitin (2007), Lloyd (2006) and others) the dynamics of the universe is a computational process; universe on the fundamental level may be conceived of as a computer which from the current state, following physical laws computes its own next state. The computa-

tion that pancomputationalism presupposes is *natural computation*, defined by MacLennan as "computation occurring in nature or inspired by that in nature", where the structure of the universe may be assumed as both discrete and continuous at different levels of abstraction. Our present day computing machinery is a proper subset of natural computing.

Combining informational structures as the fabric of the universe and natural computation as its dynamics leads to the idea of *info-computationalism (info-computationalist naturalism),* the framework which builds on two fundamental concepts: information as a structure and computation as its dynamics.

As both physical structures and processes can be expressed in terms of info-computationalism, a new means arise of smoothly connecting two traditionally disparate spheres: bodies and their minds, and so naturalizing epistemology. The unified framework presents the epistemological feed-back loop between theoretical model–simulation–experimental tests–data analysis–theory. It opens the possibility to integrate the human as natural being with the rest of the physical world into the common framework by integrating current knowledge from neurosciences, biology, physics, complexity etc.

For complex systems such as biological ones, both the analysis of experiments and theory is increasingly done by computer simulations. Life itself on a fundamental level may be viewed as a process of computation, where hardware at the same time is the software (such as DNA). Our studying of life as information processes leads to production of simulations able to mimic relevant characteristics and behaviors of living biological systems: dynamic and recursive behavior, morphogenetic patterns, emergency phenomena etc. A good example of computer simulation aimed at reverse-engineering of the brain is a Blue Brain project which will be described later on.

This paper will highlight current developments and trends within the field of natural computing in the framework of info-computational naturalism.

Interesting to observe is epistemic productiveness of natural computing as it leads to a significantly bidirectional research (Rozenberg & Kari, 2008); while natural sciences are rapidly absorbing ideas of information processing, field of computing concurrently assimilates ideas from natural sciences. There is thus an interesting synergy gain in the relating of human designed computing with the computing going on in nature.

FUNDAMENTAL QUESTIONS

Promises of info-computational programme rely on learning from nature using predictability of its physical processes and structures as a means to improve our understanding of computation and its counterpart information.

The following questions are of interest:

- Learning from natural computation, is non-algorithmic computation possible?
- Is there a universal model (for which the TM model is a special case) underlying all Natural computation?
- What can be learned about intelligence, cognition and our epistemological and ontological premises within info-computational naturalism?
- What computational problems can our understanding of natural self-organization and management of complexity help to solve?
- If our brains and nervous systems are info-computational networks, what can we say about mind?
- How to develop artifactually intelligent autonomous systems based on insights from organic computing?

Those questions are best approached on the inter-disciplinary/trans-disciplinary ground as a study of the foundational issues of computing and

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