# Ecosystems Computing:
## Introduction to Biogeographic Computation

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## ABSTRACT

*The main issue to be presented in this paper is based on the premise that Nature computes, that is, processes information. This is the fundamental of Natural Computing. Biogeographic Computation will be presented as a Natural Computing approach aimed at investigating ecosystems computing. The first step towards formalizing Biogeographic Computation will be given by defining a metamodel, a framework capable of generating models that compute through the elements of an ecosystem. It will also be discussed how this computing can be realized in current computers.*

*Keywords:* *Biogeographic Computation, Biogeography, Ecosystem Computing, Ecosystems, Natural Computing*

## 1. INTRODUCTION: THE NATURAL COMPUTING OF BIOGEOGRAPHY

By the 1940s, Computer Science was engaged in the study of automatic computing. One decade later came the study of information processing, followed by the study of phenomena surrounding computers, what can be automated, and then formal computation. In the new millennium, Computer Science has given attention to the investigation of information processing, both in Nature and the artificial (Denning, 2008).

DOI: 10.4018/jncr.2011100104

Some researchers understand computing as a natural science, for information processes have been perceived in the essence of various phenomena in several fields of science. In the book *The Invisible Future* (Denning, 2001), David Baltimore says "Biology is nowadays an information science." However, if computing is concerned with the study of information processing, what would be the computing of nature? That is, in what sense nature processes information? A consistent definition is given by Lloyd (2002): "all physical system registers information and, by evolving in time, operating in its context, changes information, transforms information or, if you prefer, processes information." Information here is a measure of order, organization, a universal measure applicable to any structure, any system (Lloyd, 2006). Understanding nature as an information processor gives us a new concept to the terminology computing, and that is exactly the fundamental basics of Natural Computing (de Castro, 2006, 2007). Several researchers, in many sciences, have already studied nature in such context:

- *Immune systems* (Cohen, 2009; Hart et al., 2007; de Castro & Timmis, 2002);
- *Ecosystems* (Gavrilets & Losos, 2009; de Aguiar et al., 2009; Gavrilets & Vose, 2005);
- *Bees* (Maia & de Castro, 2012; Lihoreau et al., 2010);
- *Ants* (Vittori et al., 2006; Pratt et al., 2002; Dorigo et al., 1996);
- *Genes* (Kauffman, 1993; Holland, 1992);
- *Bacteria* (Xavier et al., 2011, Mehta et al., 2009);
- *Basic laws of nature* (Dowek, 2012);
- *All universe* (Lloyd, 2006);
- *Among many others* (Schwenk et al., 2009; de Castro, 2007, 2006; Denning, 2007; Brent & Buck, 2006).

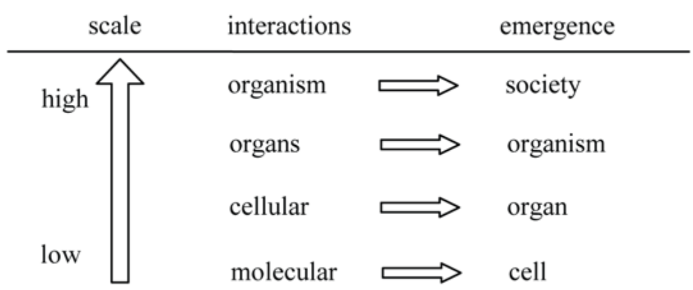
Just as with biogeography, the object of study here are ecosystems: individuals, species and environment. Starting with the premise that nature processes information, the main goal of this paper is to introduce a new research field aimed at investigating ecosystem computing, based on the knowledge of Biogeography and Natural Computing as sciences.

Ecosystems are highly complex and dynamic environments composed of a high number of interdependent variables defined in space and time (Provata et al., 2008; Harel, 2003; Milne, 1998; Kauffman, 1993; Jorgensen et al., 1992). They are usually studied by understanding their component parts, as the studies involving the dynamics of solar systems (Cohen, 2000), in which forces, such as gravity, are used to explain the emergence of its behaviors.

The composition of ecosystems obeys physical and chemical laws, but there is no set of fundamental laws that explain how they work (Cohen & Harel, 2007). The application of reductionist methods for the understanding of how living systems work is widely used, but shows clear limitations when the goal is to extract universal laws to explain these systems (Cohen, 2007; Fleck, 1979). It is possible to identify a scale of emergence going from simple molecules to a complex organism. Biogeography emphasizes the emergence of societies of living organisms (individuals and species), representing the highest level of Figure 1.

By analyzing this scenario from an information processing perspective and taking into account the fundamentals of Natural Computing, it is possible to note that the basic elements of an ecosystem compute and, thus, conclude

*Figure 1. Emergence of behaviors and objects in different scales (based on the paper "Explaining a complex living system: Dynamics, multi-scaling and emergence," by Cohen, 2007)*



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