Chapter 16
The Grand Challenges in Natural Computing Research:
The Quest for a New Science

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ABSTRACT

An important premise of Natural Computing is that some form of computation goes on in Nature, and that computing capability has to be understood, modeled, abstracted, and used for different objectives and in different contexts. Therefore, it is necessary to propose a new language capable of describing and allowing the comprehension of natural systems as a union of computing phenomena, bringing an information processing perspective to Nature. To develop this new language and convert Natural Computing into a new science it is imperative to overcome three specific Grand Challenges in Natural Computing Research: Transforming Natural Computing into a Transdisciplinary Discipline, Unveiling and Harnessing Information Processing in Natural Systems, Engineering Natural Computing Systems.

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1. COMPUTING: YESTERDAY, TODAY, AND TOMORROW

The history of *computing* is much longer than the history of the *Computer Science* discipline. Whilst computing is related with the representation of numbers and can be traced back to even earlier than mathematical concepts, Computer Science, as we understand it today, is more related with the computer hardware, software and technology. Since Computer Science appeared formally in the 1940s it has been alternating its focus of attention (Denning, 2008):

- **1940s:** Study of automatic computing;
- **1950s:** Study of information processing;
- **1960s:** Study of phenomena surrounding computers;
- **1970s:** Study of what can be automated;
- **1980s:** Study of computation;
- **2000s:** Study of information processes, both natural and artificial.

From the early days of computer science, by the 1940s, researchers have been interested in tracing parallels and designing computational models and abstractions of natural phenomena. A pioneer example in this direction was the work performed by McCulloch and Pitts (1943), in which they proposed a logical model of how neurons process information. With the advent of computers, this type of research became even broader and deeper. New, interdisciplinary areas of investigation emerged based on efforts combining a natural science, e.g., Biology, Physics and Chemistry, with Computing. Examples include the Artificial Neural Networks, Evolutionary Algorithms, Artificial Immune Systems, and many others.

Not so long ago these research fields existed by themselves in a disconnected fashion, but by the early to mid 2000, the first volume of the pioneer Natural Computing journal was released (Rozenberg, 2002) and the first textbook of the field was published (de Castro, 2006). With these initiatives, the field became more consistent and gained the status of discipline (de Castro, 2007; Kari & Rozenberg, 2008; Johnson, 2009; Rozenberg et al., 2012).

Computing promoted a revolution in all sciences and in our way of life. Its capability of automatically and quickly processing information gave birth to various solutions and discoveries, from genome sequencing to weather forecasting. Computing is now ubiquitous and the way we interact with computers is changing rapidly as well. People relate, check-in to places, talk, share data, etc., all via networked computers. Even the interface is changing, computers no longer need to have a physical keyboard and a mouse, they can be used to synthesize natural phenomena, to design algorithms for solving complex problems, and many other functions. It is now time to raise an important question:

1.1. What is the Future of Computing?

An exploration of such question in any science, beyond computing, gives rise to what can be called the Grand Challenges. The advancement of all areas, including computing, requires a deep thinking about its current status and what are the main challenges to be transposed, so that major breakthroughs can be achieved. Over the World, Grand Challenges have been discussed in areas such as Global Health (e.g., The Grand Challenges in Global Health – http://www.grandchallenges.org), but have received a lot of attention in Computer Science (e.g., the USA CRA Conference on Grand Research Challenges in Computer Science and Engineering – http://www.cra.org; the UK Grand Challenges in Computing Research – http://www.ukcrc.org.uk; and the Brazilian Grand Challenges in Computer Science – http://www.sbc.org.br).