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BOOK REVIEW

# Dario Floreano and Claudio Mattiussi (eds): Bio-inspired artificial intelligence: theories, methods, and technologies

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Traditionally artificial intelligence has been focused on attempting to replicate the cognitive abilities of the human brain. Alternative approaches to artificial intelligence take inspiration from a wider range of biological processes such as evolution, networks of neurons and learning. In recent decades there has been an explosion of new artificial intelligence methods inspired by even more biological processes, such as the immune system, colonies of ants, physical embodiment, development, coevolution, self-organization, and behavioral autonomy, to mention just a few.

"Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies", by Dario Floreano and Claudio Mattiussi, is a systematic and comprehensive introduction to the emerging field that groups all these methods: biologically inspired artificial intelligence. As a result, it discusses biological and artificial systems that operate at a wide range of time and space scales, but manages to move fluently from slow evolutionary time, to life-time learning, to real time adaptation. On the space scale, it goes from individual cells and neurons, to multicellular organisms, and all the way to societies. I found this book notable for at least two reasons. First, it provides a coherent intellectual framework to organize all these computational developments by grounding them in their biological nature and in the pervasiveness of evolution throughout biology. Second, it provides a clear, well-written, comprehensive, and authoritative account of these developments in an educational format well suited for a classroom. The authors manage to do all of that in only 659 pages, a great accomplishment considering the scope and depth of this book.

The book is organized in seven chapters: evolutionary systems, cellular systems, neural systems, developmental systems, immune systems, behavioral systems and collective systems. The chapters are not independent but meant to be read in order

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with later chapters heavily using information from the previous ones. For instance, the behavioral systems chapter relies on the previous chapters about evolutionary, cellular, developmental and neural systems. Each chapter starts with an historical account of the relevant biological theories, followed by a description of how these biological principles are translated into scientific methods and technologies. Each chapter provides many detailed examples that illustrate the application of these methods to real world problems, and finishes with a well-commented section on suggested readings.

Chapter 1, evolutionary systems, lays the foundations. It starts by pointing out that "nothing in biology makes sense except in the light of evolution"[1], which sets a unifying theme for the book. It provides a good overview of evolutionary theory and genetics before progressing to an overview of evolutionary computation. It provides several examples on evolutionary electronics, such as antenna design and circuit design via evolution.

Chapters 2 through 5 are inspired by the structure and function of cells in multicellular organisms. Chapter 2, cellular systems, starts by defining the basic ingredients of cellular systems, and progresses to cellular automata and its variations: non-homogeneous, asynchronous, probabilistic, and particle. Next, it discusses cellular computers, artificial life and complex systems. Chapter 3, neural systems, starts with an overview of biological nervous systems and continues with and introduction to artificial neural networks including neuron models and architectures. It provides an overview of supervised, unsupervised and reinforcement learning in neural networks. It concludes with an overview of evolution of neural networks, neural hardware, and hybrid neural systems, in which actual cultures of biological neurons—so called "wetware"—are combined with electronic hardware on a chip. Chapter 4, developmental systems, after a very short biological background on development, jumps directly to a good overview of L-systems. Next, we are presented with the interplay between evolution and development from the biological point of view. Chapter 4 concludes with an introduction to artificial evolutionary developmental systems. Chapter 5, immune systems, starts with a detailed explanation of how biological immune systems work. Next it progresses to algorithms and applications, including shape space, negative selection, and clonal selection. It ends with the discussion of three examples, ARTIS, LISYS, and immunotronics.

Chapters 6 and 7 are inspired by individual and group behavior of multicellular organisms. Chapter 6, behavioral systems, starts with two historical sections about the role of behavior in cognitive sciences and in artificial intelligence. Next, it provides an introduction to behavioral-based robotics, bio-inspired robots and to the use of robots as biological models. Then, it provides a discussion on the interplay between evolution and neural development in the context of behavioral systems. It ends by touching on the coevolution of body and control, self-reproduction, and the so called reality gap: issues that could arise when transferring behaviors evolved in simulated robots into real robots. Chapter 7, collective systems, starts with an overview of biological self-organization. It introduces particle swarm optimization, ant colony optimization, and swarm robotics. Next, it explores the evolutionary view of collective systems. It gives an overview of coevolutionary dynamics in

biology, followed by a discussion on cooperative and competitive evolutionary algorithms. It ends with a note on the evolution of communication.

In the preface, the authors state their hope for their book to be instructive and useful for a wide audience. Their hope is well founded. I think this book is well suited for various audiences. First, the text is ideal for a graduate level course; in fact, the authors based this book on a course they taught for almost ten years at the Swiss Federal Institute of Technology. As a supplement to the book, the authors provide an online teacher's kit with slides and exercises. This book is also a very complete reference and catalog of biologically inspired methods well suited for researchers, graduate students and engineers in the field of computer science. Finally, save for few technical sections, the vast majority of the book is very accessible, engaging to read and easy to follow. It is definitely a good introduction for anybody interested in biologically inspired artificial intelligence.

In summary, Floreano and Mattiussi deliver a great book that I highly recommend.

## References

1. T. Dobzhansky, Nothing in biology makes sense except in the light of evolution. Am. Biol. Teach. **35**, 125–129 (1973)