

# Evolutionary Robotics

## A Review

*Horatiu Voicu*

This book explores different ways of building autonomous agents by using evolutionary techniques. It presents experimental studies of evolving low-level and high-level functions in real and simulated robots. The main thesis of the book is that evolutionary robotics provides a viable alternative to classical techniques of designing autonomous robots. An important point emphasized throughout the book is that "evolutionary robotics, ... releases the designer from the burden of deciding how to break the desired behavior down into simple behaviors." The book is suited for both the educated reader with an interest in such matters and the professional reader, including researchers in artificial life, cognitive science, adaptive behavior and AI. Its style, scope, and depth make the reading worthwhile.

The text is divided into chapters covering the main themes of genetic and neural algorithms and applications of these methodologies to real or simulated robots. Each chapter ends with a summary that outlines the main points covered, with an emphasis on the main experimental results. At the end of the book, there are a number of useful notes, as well as an extensive bibliography, that cover more than 20 pages. Throughout the text, there are numerous pointers to other sources of reading. The book has been written in such a way that once the first three introductory chapters are read, it is possible for readers to continue at any point that is of particular interest or relevance to them. There appears to be no need to read

each chapter or section because each topic presents a different aspect of approaching evolutionary robotics. The book begins with a good introductory chapter that makes references to the topics described in the remainder of the book.

Part 1, comprising the first three chapters, introduces the nature and purpose of evolutionary robotics, including the basic ingredients that

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*Evolutionary Robotics*, Stefano Nolfi and Dario Floriano, Cambridge, Massachusetts, The MIT Press, 320 pages, \$50.00, ISBN 0-262-14070-5.

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compose it: evolutionary and neural algorithms.

In the first chapter, the authors emphasize the role of self-organization in using evolutionary techniques for designing autonomous systems. Unlike other techniques where the designer needs to decompose the desired behavior into simple basic behaviors, in evolutionary robotics, the designer has to provide only a fitness function that will lead the self-organizing process to the best solution.

Chapter 2 presents an introduction to the algorithms used later in designing autonomous robots capable of accomplishing simple and complex tasks.

Chapter 3 describes several techniques for evolving autonomous ro-

bots and presents advantages and limitations of different approaches. The KHEPERA robot family is introduced, and the problem of real versus simulated behavior is discussed.

Part 2, covering chapters 4 to 11 describes applications of the algorithms and techniques presented in the previous chapters. Chapter 4 deals with the evolution of simple navigation. It starts by showing that in the case of simple navigational tasks, robots display navigation strategies that are at least as good as the strategies implemented in hand-designed controllers. The chapter continues with visually guided robots that undergo incremental evolution. This approach involves presenting the robots' tasks of evermore increasing complexity. The results of this technique show that this approach could be applied potentially to study evolution of biological organisms. The chapter ends with an analysis of the impact on performance during the evolutionary process when the genotype is transferred to a different robot or evolved using a simulated robot.

Chapter 5 shows that by using a direct mapping from sensory information to motor control, combined with a set of environmental constraints, agents can exhibit complex behaviors (for example, alias avoidance, that is, avoiding places that have the same sensory image as other places). However, when the number of constraints is reduced, agents based solely on sensory-motor coordination fail to accomplish complex tasks.

Chapter 6 shows that evolutionary techniques are able to build neural networks that can construct their own internal representations of the environment without the help of a designer. This result is promising because it proves that evolutionary techniques can be utilized to solve problems that require more than reactive behavior. A good candidate for accomplishing this task is the modular architecture that builds systems that take into account the most relevant aspects from the perspective of the control system, not the designer.

Chapter 7 investigates how learning and evolution can interact to produce adaptive individuals. Unlike most of

the simulations presented to this point, in the ones presented in this chapter, the genotype does not encode directly the weights of the connections between neurons. It includes only the learning rule and the sign of the connections. Simulations show that learning individuals give a better performance than nonlearning individuals. These simulations also show that adaptive agents benefit both from the information stored in the genome and from the information provided by the environment. Therefore, the main focus of the evolutionary process is to build adaptive individuals that are able to cope with different types of environmental settings.

Chapter 8 focuses on competitive coevolution. In this approach, two or more individuals evolve in the same environment. One individual acts as a predator, and the other ones act as prey. The experimental results indicate that in some cases, competitive coevolution produces incremental evolution, but in others, it reaches a cycle from which it cannot escape. An additional set of experiments shows that when the evolutionary process can choose whether the agent has the ability to learn, predators immediately shift toward individuals with ontogenetic plasticity, but preys do not show the same effect. Competitive coevolution is interesting because it can produce incremental evolution without the help of the designer.

Chapter 9 examines the problem of mapping genotypes into phenotypes. Although this process might seem less important than other aspects of evolution (in some applications, this step is completely ignored), its role in the adaptability of the final result is considerable. A complete description of the mapping process should take into account a developmental stage in which the agent interacts directly with the environment. This chapter proposes several methods based on arbitrary assumptions that do not necessarily resemble the same processes found in nature. The exact outcome of these methods is not completely understood, and they require more research.

Chapter 10 presents several applications in which simulated and real

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robots with different hardware architectures learn to walk in different environmental settings. Although this work is promising, there are always more complex tasks that could be achieved.

The final chapter addresses the issue of evolvable hardware, which is a new approach to electronic and mechanical engineering. The evolutionary techniques could be implemented online for producing hardware by using reconfigurable hardware. One important question still to be answered is whether biological metaphors can be applied to direct hardware implementation because neurons and transistors have different environmental requirements.

Evolutionary techniques are one of the most advanced and relatively recent methods that humans use to copy how nature works. Although evolutionary theory was brought forward by Darwin almost a century and a half ago, the formalization and implementation of the theory had to await the technological developments of the 1950s. Like any other promising tool (for example, artificial neural networks), evolutionary techniques had their successes and downfalls in the last four decades. Because they have a strong dependency on computational power, these techniques could show a great potential in the medium-term future.

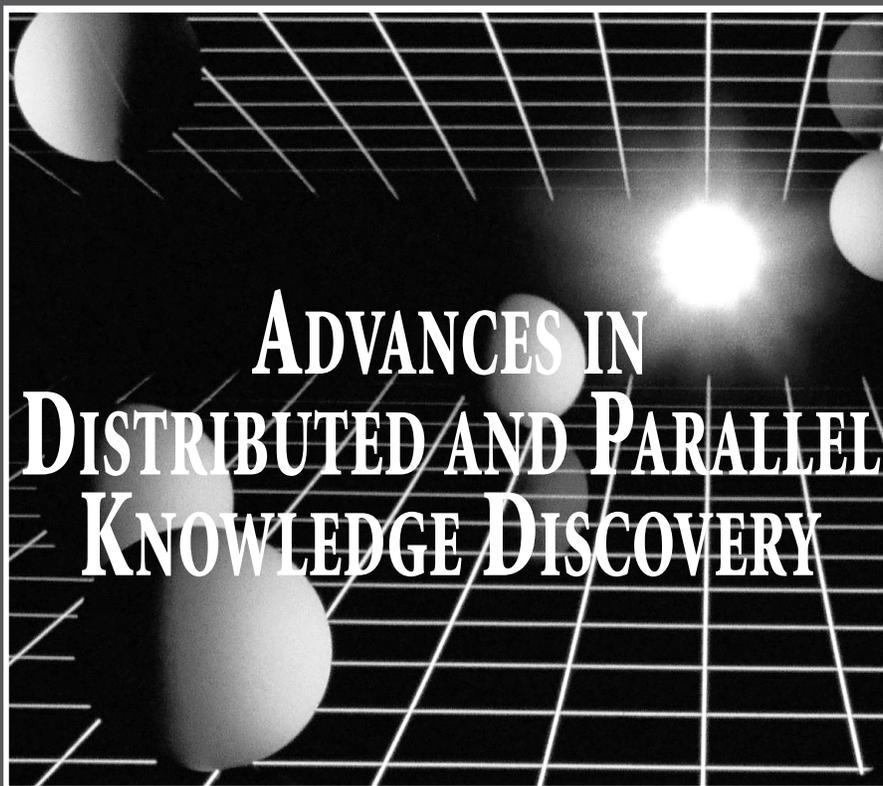
The book sets an agenda for major issues in evolutionary robotics to be researched in the immediate future. One important research trend is to include in the evolutionary techniques as many relevant details of the natural process of evolution as the current technology allows. For example, combining evolution and learning in

building autonomous systems and trying to implement how real genotypes are mapped into phenotypes are topics that have only recently been addressed.

Another trend is to include in a simplified version as many relevant details of the natural process of evolution as possible. Currently, many details of the natural evolutionary process are ignored in their artificial counterpart because of computational limitations. For example, building an autonomous system using evolutionary techniques involves many real-world trials that are time prohibitive. To obtain results in a timely fashion, researchers use simulations that replace the real-world autonomous system with a model.

In summary, the book is highly recommended for all involved in the field of evolutionary robotics. It will be an important reference for experimental and theoretical studies in evolutionary robotics for quite some time.

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Edited by Hillol Kargupta and Philip Chan

**K**nowledge discovery and data mining (KDD) deals with the problem of extracting interesting associations, classifiers, clusters, and other patterns from data. The emergence of network-based distributed computing environments has introduced an important new dimension to this problem—distributed sources of data. Distributed knowledge discovery (DKD) works with the merger of communication and computation by analyzing data in a distributed fashion. This technology is particularly useful for large heterogeneous distributed environments such as the Internet, intranets, mobile computing environments, and sensor networks. When the datasets are large, scaling up the speed of the KDD process is crucial. Parallel knowledge discovery (PKD) techniques addresses this problem by using high-performance multi-processor machines. This book presents introductions to DKD and PKD, extensive reviews of the field, and state-of-the-art techniques.

**PUBLISHED BY THE AAAI PRESS / COPUBLISHED BY THE MIT PRESS**  
Five Cambridge Center, Cambridge, Massachusetts 02142 USA  
<http://mitpress.edu/> • 617-625-8569 • 800-356-0343

ISBN 0-262-61155-4, 472 pp., illus., bibliography, index