Biologically Inspired Intelligent Robots

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Yoseph Bar-Cohen
Cynthia Breazeal

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Contents

Preface

With today's technology, one can graphically animate the appearance and behavior of biological creatures. However, in past years, engineering such biomimetic (those that mimic biology) intelligent creatures as realistic robots was hampered by physical and technological constraints and shortcomings. Creating robots that can make bodily and facial expressions of joy and excitement, or hop and land safely without risking damage to the mechanism, as illustrated on the cover, are extremely complex to engineer though such functions are very easy for humans and animals to accomplish. Advances in biologically inspired technologies, such as artificial intelligence, artificial muscles, and others, are making the possibility of engineering robots that look and behave like humans a closer reality.

Generally, there is an extensive effort to develop robots that are minimally distinguishable from biological systems. However, it is important to point out that often researchers take the kernel of insight from biological systems to build capable robots that are unlike any existing organism. Researchers are also seeking to integrate several biological concepts from different organisms, creating robots that are not replicates of entire biological creatures. These robots consist of combined parts, concepts, algorithms, or methods that are relevant as solutions to various problems.

Making biologically inspired intelligent robots requires an understanding of biological models as well as advancements in analytical modeling, graphic simulation, and the physical implementation of the related technology. The research and engineering areas that are involved with the development of biologically inspired intelligent robots are multidisciplinary, which include materials, actuators, sensors, structures, functionality, control, intelligence, and autonomy. While the engineering challenges are very interesting to tackle, there are also fundamental issues that need to be addressed. Some of these issues include self-defense, controlled termination, and many others. There is already an extensive heritage of making robots and toys that look and operate similar to biological creatures, and models for such robots are greatly inspired by science fiction and the entertainment industry (movies, toys, animatronics, etc.). These models have created perceptions and expectations that are far beyond the reach of current engineering capabilities, which are constrained by the laws of physics and the current state of the art.

In recent years, the field of biomimetics has blossomed, where numerous advances have been made in related fields, including machine intelligence, materials science, biological science, the understanding of life's wondrous mechanisms, and its sibling, integrative biology. These advancements have allowed scientists and engineers to reverse engineer many animals' functions and system characteristics, and to technologically implement these capabilities. The related interdisciplinary work has resulted in mechanisms that can recognize facial expressions, understand speech, and move in robust bipedal gaits that are similar to humans. Additionally, advances in polymer sciences led to the development of artificial muscles that possess functional characteristics remarkably similar to biological muscles. The accelerating pace of change in these fields seems to make evident that the emergence of machines as our peers is imminent. However, this topic brings with it enormous implications including, but not limited to, questions regarding the nature of evolution and its role in technological progression.

This book primarily focuses on current developments in the field and its related disciplines as well as the technical challenges and trends in biomimetic robots—that is, the emulation of life using machines in the form of robotics. It reviews the various aspects of biologically inspired intelligent robots ranging from the biological model, graphic simulation, the physical implementation, examples of applications, and the vision for the future of the field. The biological model is described in Chapter 2, whereas Chapter 3 reviews biomimetics as a model for graphic animation and animated movies. Chapter 4 describes human and machine interfaces and the ability to "feel" virtual or remote environments in the form of haptic interfaces and telepresence. Chapter 5 covers the topic of cyborg technology, describing artificial limbs and prosthetics. The topics of physical construction, functions, control and psychology of robots are covered in Chapters 6 through 9. A review of current applications that mimic living creatures is described in Chapter 10, and in Chapter 11 the current challenges and the vision for the future of the field are reviewed. Efforts were made in the final chapter of this book to present a series of grand challenges to the science and engineering community, and to create a baseline for the current limitation of the technology. It is the Editors' hope that these challenges will be addressed and cost-effective robots will become our daily assistants, playing critical roles in our life just as the personal computer and other information technology tools have.

Yoseph Bar-Cohen, JPL
Cynthia Breazeal, MIT

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The Editors would like to acknowledge and express their deepest appreciation to the following individuals who took the time to review various chapters of the book and particularly those who were not chapter coauthors of this book. These individuals contributed significantly with their comments, constructive critiques, and recommendations that were very helpful in making this book of greater value to the readers:

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Please note that the color images throughout the book were selected in order to provide the reader with a realistic perspective of current biomimetic robot technology. This selection was not made to indicate that other images are less important; the selection was made for the ease of the printing process.