# Book Review

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*Autonomous Robots: From Biological Inspiration to Implementation and Control.* George A. Bekey. (2005, MIT Press.) Hardcover, 577 pages. ISBN 0262025787.

## 1 A Milestone in the History of Modern Robotics

While robotics research has achieved considerable success in the development of rapid, precise, and powerful machines, its contributions to our comprehensive understanding of biological systems are not negligible. As previously explained, for example, by Wiener, Ashby, and Braitenberg and, more recently, Arkin, Brooks, and Pfeifer [1–6], by applying "understanding by building" approaches, scientists and engineers have revealed a number of underlying mechanisms of animals' adaptive behavior that could not have been understood otherwise. This volume written by George Bekey is an additional milestone in the history of synthetic studies, with a special focus on the recent attempts by robotics scientists. The exploration of robotics research during the last few decades is particularly interesting because of the rapid technological growth in computational power, actuators, and sensing devices.

Because robotics research deals with complex real-world systems, it is often very difficult even for experts to achieve a comprehensive overview of the field. One of the most significant contributions of this volume is the way the author has structured the field of modern robotics, which consists of core active areas in the recent history of robotics research such as learning, locomotion, manipulation, and navigation. The main interests of robotics scientists are nicely reflected in this "bottom-up" structure, which gives a complete picture of this broad discipline and where it is heading. The contents are not limited to the well-established robotics technologies (e.g., robot manipulation and navigation techniques), but the author has allocated a considerable amount of the book to ongoing research issues such as legged locomotion, multiple robots, and humanoid robots, even though these have not achieved successful industrial applications yet. These up-to-date challenges illustrate that robotics research is still an exciting, growing discipline.

Each case study introduced in this book explains how robotics scientists created models of animals' adaptive behavior with concrete technological terms: It generally starts with the underlying mechanisms of animals' behavior, and then they are translated into engineering forms. It is particularly interesting that the processes of abstraction and translation from biological knowledge are essential to create artificial counterparts of biological systems. And as a result, these models could contribute not only to development of biologically inspired applications, but also to our further understanding of biological systems.

It seems to me that, by introducing these case studies throughout the book, the author implies an important aspect and contribution of robotics research: The use of robotic devices and technology provides a unique contribution as a scientific tool for our understanding of biological systems. Dealing with the physical systems is not an extension of the theoretical studies, but it raises a number

of additional interesting questions and problems. This point is nicely described, for example, in the comment on "machine learning versus robot learning":

> It should be noted that machine learning and robot learning are not synonymous. Machine learning takes place in a computer. For such learning to qualify as robot learning, the computer must have interactions with the world, since the robot itself is situated in the world. The robot receives information from the world using its sensors and acts upon it using its effectors or actuators. Many, but not all, approaches to machine learning have been applied in robotics. (p. 128)

## 2 Contents

The book consists of four main parts, viz., a general overview of the field of robotics; mechanisms and architectures of basic technologies; the case studies of robotics research on various animals' functions; and current trends and future work. The first few chapters set up the conceptual foundation of the entire book, namely, goals of robotics research, differences between animals and robots, various research directions, and finally an overview of the robot structures by explaining how basic technological elements are related with each other to yield a complete functional entity. The second part elaborates the mechanisms and architectures of the constituent elements: sensors, actuators, software and control architectures, and adaptive controllers with learning functions. It covers both low- and high-level hardware and software, and should thus be an ideal introduction for beginners who wish to start building robots. Then, in the next part, the highlight of this volume consists of an enormous number of case studies of robotics research (several hundred recent robotic systems are introduced). They are categorized into eight chapters, each of which explains specific topics such as locomotion, manipulation, grasping, multi-robot systems, humanoids, and navigation. Each chapter explains biological inspirations, theories, examples, and applications, and it is independently conclusive, so that readers can grasp the basic ideas of each topic area, depending on their interests. The last part of this volume deals with current research trends and future work. It introduces the potential influence of the current research trends in human-robot interaction, multi-robot systems, micro- and nano-robots, and reconfigurable robots.

## 3 What's Missing?

Although this volume covers nearly all aspects of robotics research and technologies, it might be unsatisfactory for those who are most interested in conceptual issues and fundamental breakthroughs. In my opinion, along with more comprehensive and detailed claims of the challenges, it would have made sense to discuss the potential dangers of robotics research that are pointed out at the end.

As discussed, in the fields of artificial life and artificial intelligence there are still a number of fundamental open problems that need to be solved in order to develop truly adaptive autonomous systems [6, 7]. And it is generally agreed that a large body of these problems is related to the physical system-environment interactions, where robotics research will play a significant role, in view of the fact that robots are by definition physical entities (i.e., embodied and situated, as the author mentions in the introduction). It should be discussed that we still do not have hardware technologies for autonomous systems that self-sufficiently deal with complex and dynamic environments over an extended period of time, and we still do not fully understand the theoretical framework of adaptive systems that autonomously generate rules and symbols from the physical dynamic interactions. For example, the notorious grounding and frame problems are only briefly mentioned in this book.

## 4 Summary

In general, the book will be very readable for those who have a general background in science or engineering. The many pictures and illustrations, together with a minimum of equations, will be

attractive for students who prefer introductory lessons to gain a structured set of essential concepts in the field. Moreover, the long list of references should be also useful for those who start careers in the field of robotics. The important theories and concepts are sufficiently introduced (from practical engineering knowledge to theoretical framework and concepts). In consequence, this book should be ideal for the students of robotics research, and the researchers in neighboring disciplines, including computer science, artificial life and intelligence, biology, psychology, and neuroscience.

## References

1. Wiener, N. (1965). *Cybernetics*. Cambridge, MA: MIT Press.
2. Ashby, W. R. (1956). *Introduction to cybernetics*. London: Chapman & Hall.
3. Braitenberg, V. (1986). *Vehicles: Experiments in synthetic psychology*. Cambridge, MA: MIT Press.
4. Arkin, R. (1998). *Behavior-based robotics*. Cambridge, MA: MIT Press.
5. Brooks, R. (1999). *Cambrian intelligence: The early history of the new AI*. Cambridge, MA: MIT Press.
6. Pfeifer, R., & Scheier, C. (1999). *Understanding intelligence*. Cambridge, MA: MIT Press.
7. Bedau, M. A., McCaskill, J. S., Packard, N. H., Rasmussen, S., Adami, C., Green, D. G., Ikegami, T., Kaneko, K., & Ray, T. S. (2000). Open problems in artificial life. *Artificial Life*, *6*(4), 363–376.