Yoshiyuki Sankai · Kenji Suzuki
Yasuhisa Hasegawa *Editors*

Cybernics

Fusion of human, machine and information systems

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Preface

"Cybernics: Fusion of Human, Machine, and Information Systems," selected as the Global Center of Excellence program in Japan from 2007 to 2011, is a new domain of science that centers on cybernetics, mechatronics, and informatics; it integrates humans and robots functionally, organically, and socially with information technology. It is a fused and complex interdisciplinary area in which robotics, brain science and neuroscience, information technology, ergonomics, human society, Kansei engineering, physiology, sociological sciences, and even ethics are deeply intertwined.

This program aims to develop not only pioneering researchers who are able to lead the way with technological innovations, but also experts who support the field of cybernics through analysis of or teaching about the sociological issues associated with the introduction of cybernics-related technologies into society. This program therefore offers unique disciplines, such as Cybernics Tutorial Studies, Cybernics Project Research and Cybernics Internship Program as well as standard course subjects. This volume is edited based on the course materials of the cybernics educational program. We have digested the lectures in this book for self-learning of the interdisciplinary knowledge.

Cybernics Tutorial Studies are implemented with the emphasis on nurturing the ability of students to develop the ability to think from multiple perspectives. The learning format utilizes instructors from many different fields, which is a critical part in developing this field that is marked by alliances among medicine, engineering, and the humanities. The course is taught in a practical tutorial format that is designed to discuss specific issues in small groups and reach a conclusion within the space of 1 h. The format is designed as an engineering-type tutorial. It is based on a combination of tutorial formats widely used in medical fields and is the fruit of interviews with British researchers who are pioneers in this methodology. The focus in these tutorials is on developing the ability of students to adopt a multifaceted approach to solving practical issues in the composite field of human–machine–information systems. Unlike courses that consist mainly of lectures by instructors, students here actively examine case studies. Instructors from

various disciplines in medicine, engineering, and the humanities teach these small classes, and they discuss with the students special topics related to unresolved and unexplored fields. The results of these discussions are announced as a research presentation.

In addition, project-type research programs—called Cybernics Project Research—are undertaken by students as research leaders. Together with other graduate and undergraduate students, a student research leader proposes and executes a project that drives the research. This involves a series of processes, including proposals for research plans, interviews, conducting research, interim evaluations, compiling reports on results, and post-completion evaluations. During this process, student research leaders proceed with their project research and receive both internal and external evaluations, which help cultivate their leadership and management capabilities.

Through the Cybernics Internship Program, students gain valuable experience in research and development with companies that have academic alliances. As well, they garner experience in such areas as running clinical trials and dealing with medical organizations, both in Japan and overseas. As a result, students acquire the ability to understand the importance of safety-risk assessment as they recognize and implement the high research standards that can be used for clinical trial standards, and they discover how to solve problems within real-life situations.

Cybernics Standard Course subjects were established to provide basic knowledge and techniques in advanced interdisciplinary academic fields through various innovative lectures. The knowledge acquired becomes a basis for discussions in the Cybernics Tutorial Studies and helps the students advance their own research efforts. This academic field covers a broad range of disciplines and is categorized into three groups: cybernoid research, next-generation interface management, and technologies for next-generation systems. Students make their own course notes in this area in a target-oriented fashion by compiling information from a variety of different lectures in different fields.

The interdisciplinary knowledge acquired in this way will help promote human resources with abilities in diverse academic fields: individuals will be able to approach problems from multifaceted perspectives, thereby contributing to innovative research through a synthesis of leading areas of interdisciplinary research. With robotics as their standard, students thus educated will be able to rise to the challenge facing future generations through this novel synergy of science and the humanities.

With the growing profusion of next-generation robotics systems, robotics scholars have become aware of the ethical, philosophical, social, and cultural implications in adopting robot technology into social fields. Thus, we have published a book entitled *Cybernics Technical Reports: Special Issue on Roboethics* (University of Tsukuba, 2011), based on the results of two international workshops on roboethics organized as part of the cybernics program. For further information on the fascinating topic of roboethics, readers are advised to consult that book.

Owing to its extremely low birthrate and the rapid aging of its population, Japan is facing a difficult future. We hope that the cybernics program will continue to contribute a great deal to the education of researchers who will aim to solve the problems of the future by advancing interdisciplinary research based on the fusion of human, machine, and information systems.

Finally, on behalf of the editors of these lecture notes, we gratefully acknowledge the assistance of Ms. Ayumi Shiibayashi in managing this publication.

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Part I
Overview of Cybernics

Chapter 1
Cybernics: Fusion of Human, Machine and Information Systems

Yoshiyuki Sankai

Abstract Cybernics is a frontier science centered on cybernetics, mechatronics, and informatics, and it aims toward an integration of humans with robotics by means of information technology A pioneering development in Cybernics is the exoskeletal robot suit HAL (Hybrid Assistive Limbs), which is able to enhance and reinforce human limb motions by detecting weak bioelectrical signals. The development of HAL is particularly important in light of the rapidly aging population in both Japan and other advanced countries. In promoting HAL as a new piece of medical equipment, the manufacturer faced considerable obstacles from administrative bodies. Japan clearly needs a world-class permit-approval process for nascent technology that can serve as an international certification standard. Education also needs to be addressed, and for this reason the Cybernics Program was established. The program aims to create and establish technology for the functional, organic, and sociological integration of human, machine, and information systems.

Keywords Cybernics • HAL • International standardization • Human resource development • Cybernetics • Mechatronics • Informatics

1.1 Introduction

Japan's extremely low birth rate and the rapid aging of its population will present the country with considerable societal problems in the future. These social challenges will have to be addressed through sophisticated interdisciplinary advances in the fusion of human, machine and information systems, and this fusion will in turn

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forge a new level of coexistence and interdependence between technology and humankind. However, as innovative areas of science and technology are developed that can better meet the future needs of individuals and society, having to deal with real-life subjects and handle complex interdisciplinary problems will inevitably demand a new approach to multidisciplinary issues. In this regard, the conventional vertical divides of academia act as a hindrance.

It is against this background that we at the University of Tsukuba have developed the new research field of Cybernics. This novel domain of frontier science centers on cybernetics, mechatronics, and informatics, and it aims toward an integration of humans with robotics technology in a functional, organic, and social manner by means of information technology (IT). Cybernics constitutes a complex interdisciplinary area, in which robotics, brain science and neuroscience, IT, ergonomics, Kansei engineering, physiology, social sciences, and ethics are deeply intertwined. And in this revolutionary field, the exoskeletal robot suit HAL (Hybrid Assistive Limbs) is a pioneering achievement. HAL is able to enhance and reinforce the limb motions of the human body by detecting weak bioelectrical signals traveling through the body from the brain, which generates the nervous impulses that control the musculoskeletal system (Figs. 1.1 and 1.2).

This chapter will begin with an overview of Cybernics. Several perspectives relating to the development of innovative technology will then be presented, with the focus being on HAL. Based on these considerations, a proposal will be made that a center of excellence be established in research and education that will amount to an alliance of people and society, cutting-edge technologies, legal systems, ethics, and management systems to explore the future challenges facing humankind. The details of organizing a program toward this end will be presented before the conclusions to this chapter are given.

1.2 Cybernics

Cybernics is a new domain of science and technology, uniting people, machines, and information systems to create research and development (R&D) environments that extend from basic concepts to practical applications within a social context. It aims to explore technologies that sustain people and society. The core disciplines of Cybernics are cybernetics, mechatronics, and informatics; however, it also embraces such various fields of science and technology as those listed below in addition to nonscientific areas, for example, social science, law, and business administration:

- Cranial nerve science
- Behavioral sicience
- Robotics
- IT