This book provides an overview of many different but interrelated ongoing studies of biomedical engineering for healthcare. Biomedical engineering is the application of engineering principles and design concepts to medicine and biology, which combines the design and problem solving skills of engineering with medical and biological sciences to improve healthcare diagnosis, monitoring, and therapy. Biomedical engineering is usually defined as a basic research-oriented activity closely related to technology and neuroscience. Health care (or healthcare) is the diagnosis, treatment, and prevention of disease, illness, injury, and other physical and mental impairments in humans. It is clear that the biomedical technology and healthcare of the future will have a tremendous impact on the quality of human life, especially for patients and persons with disabilities. The potential of this specialty is difficult to imagine.

Biomedical engineering is now a vitally important interdisciplinary field. Biomedical engineers are involved in virtually all aspects of developing new medical technology. They are involved in the design, development, and utilization of materials, devices, and techniques for clinical research and use; and they serve as members of the healthcare delivery team in providing new solutions for difficult healthcare problems.

To learn more about the human brain, researchers combined cognitive neuroscience with biomedical engineering for healthcare together. Using non-invasive magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), electromyograms (EMG), computed tomography (CT), magnetoencephalography (MEG), and event-related potentials (ERPs), changes in the default mode network (DMN) state have been found and linked to the diagnosis of dementia. The majority of neuroimaging studies that have contributed to the understanding of the pathophysiology and the clinical course of dementia have utilized structural magnetic resonance imaging (MRI) and positron emission tomography (PET). In addition, by observing behavioral cognition, abnormal results could highlight related mental illnesses. Thus, the early diagnosis of mental illnesses could be achieved by using several cognitive neuroscience methods, such as those mentioned above, and this is of importance since the data could provide useful information for healthcare before the onset or during the early stages of the illness.

The purpose of this book is to bring together researchers and practitioners, including engineers, medical doctors, health professionals, and neuroscience/informatics/computer scientists, who are interested in both theoretical advances and the applications of information systems, artificial intelligence, signal processing, electronics, and other engineering tools in biomedical areas related to cognitive neuroscience and medicine. We consider the following activities of cognitive neuroscience and biomedical technology:
Section 1: Biomedical Technologies for Healthcare

- Biomechatronics and healthcare.
- Biomedical image processing.
- Technology in rehabilitation.
- Biomedical robotics for healthcare.
- Sustainable materials and techniques in healthcare.

Section 2: Brain-Machine Interfaces for Healthcare

- Information technology and healthcare.
- Complex bioinformatics and healthcare.
- Systems biology and healthcare.
- Brain-machine interface and rehabilitation.
- Communication technology in healthcare.

Section 1 of this book is concerned with biomedical technologies for healthcare. This section broadly considers biomechatronics and healthcare, biomedical image processing, technology in rehabilitation, biomedical robotics for healthcare, and sustainable materials and techniques in healthcare, and focuses on many research fields in biomedical engineering. For example, a recently proposed optical method for non-invasive in vivo blood glucose level (BGL) measurement named “pulse glucometry” is introduced, which can be utilized in the measurement of other blood constituents (Mitsuhiro Ogawa, Takehiro Yamakoshi, Kenta Matsumura, Kosuke Motoi, and Ken-ichi Yamakoshi, Chapter 3). Some researchers have also investigated the possibility of developing a myoelectric elbow prosthesis powered by an ultrasonic motor, which could be effectively controlled by an EMG (electromyogram) control system (Yorihiko Yano, Chapter 2). In Chapter 5 (Hongen Liao) a particular application of biomedical information processing and visualization techniques for minimally invasive diagnosis and therapy in neurosurgery is demonstrated, which might be useful for saving lives. Combining images with different characteristics enables a deeper understanding of the objects under observation, which provides useful information for diagnosis and treatment. Therefore Chapter 6 (Tadanori Fukami and Jin Wu) reviews some representative imaging modalities (include MRI, CT, and PET) that are commonly used as diagnostic tools and discusses the use and efficacy of image fusion techniques for clinical use. Furthermore, in designing a walk assist robot to help patients with lower limb disabilities researchers have found that the robot can help patients in standing and performing walking rehabilitation training (Zhang Lixun, Bai Dapeng, and Yi lei, Chapter 13). Safety is one of the most important concerns for systems in which humans and machines coexist. Thus, human-friendly devices have been introduced, which have been applied to several types of robots and mechatronic devices for healthcare, lift support, and the evaluation of human functioning (Takehito Kikuchi, Chapter 10). To create a smarter robot which can improve people’s lives, it is very important to improve the robot’s perception of the external world. As such the robotic vision system is a key focus of attention. Kazuhiro Shimonomura (Chapter 20) describes a binocular robotic vision system that was designed to emulate the neural images of cortical cells under vergence eye movements. This system is useful for predicting the neural images of complex cells and for evaluating the functional roles of cortical cells in real situations. Researchers also review how surface modification is performed using calcium phosphate coatings for metallic biomaterials and then describe the fabrication processes and
performance of calcium phosphate coatings (Takayuki Narushima and Kyosuke Ueda, Chapter 24). In summary, whatever the biomedical method or technological study, researchers are working to improve people’s lives, with particular focus on patients and disabled people.

Section 2 focuses on brain-machine interfaces for healthcare. This section broadly considers information technology and healthcare, complex bioinformatics and healthcare, systems biology and healthcare, brain-machine interfaces and rehabilitation, and communication technology in healthcare. Brain–computer interface (BCI), sometimes called brain–machine interface (BMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. It is meaningful that BCI, or BMI, has since focused primarily on neuroprosthetic applications that aim at restoring damaged hearing, sight and movement.

Chapter 36 (Masayuki Hirta, Takufumi Yanagisawa, Kojiro Matsushita, Hisato Sugata, Yukiyasu Kamitani, Takafumi Suzuki, Hiroshi Yokoi, Tetsu Goto, Morris Shayne, Yoichi Saioh, Haruhiko Kishima, Mitsuo Kawato, and Toshiki Yoshimine) describes the integrative approach that researchers have used to develop a BMI system with brain surface electrodes for real-time robotic arm control in severely disabled people, such as amyotrophic lateral sclerosis patients. This integrative BMI approach includes effective brain signal recording, accurate neural decoding, robust robotic control, a wireless and fully implantable device, and a noninvasive evaluation of surgical indications. Researchers also summarize the techniques of computational fluid dynamics used in blood flow simulations of anatomically realistic artery models reconstructed from medical images acquired by CT or MRI (Yuji Shimogonya, Takuji Ishikawa, Takami Yamaguchi, Hiroshige Kumamaru, and Kazuhiro Itoh, Chapter 28). Furthermore, an ongoing project to administer music therapy sessions for patients with neurodegenerative diseases over 4 years has been summarized. It has been found that music therapy helped maintain or improve the QOL (quality of life) level of neurodegenerative disease patients, which would otherwise deteriorate with the progression of symptoms, that nurses were engaged in the building of a healing environment as “healers”, and that the patients found more hope in everyday life (Chiyoko Inomato and Shin’ichi Nitta, Chapter 25).

A fusion physiological sensing system and its applicability for daily healthcare monitoring has also been reported, which could contribute to the fields of personal healthcare, medical care, and rehabilitation through their fusion of information and communications technology (Kosuke Motoi, Mitsuhiro Ogawa, Takehiro Yamakoshi, and Ken-ichi Yamakoshi, Chapter 31). Chapter 35 (Yuichi Sakumura, Naoyuki Inagaki) explains how to obtain a simple quantitative model from the complex processes of neuronal polarization. Some researchers have developed a database system of dermatological images accessible to both doctors and patients, which have been implemented on a smartphone for quick and easy access during medical examinations and a tablet terminal for patients to use while waiting in the clinic. Using the tablet terminal, the doctor and patient may check for an improvement in symptoms together (Takeshi Toda, PaoMin Chen, Shinya Ozaki, Kazunobu Fujita, and Naoko Ideguchi, Chapter 38). Seiichiro Katsuma (Chapter 37) reports a novel method for preserving and reproducing human motion based on haptic technology, which may be important for the future of human support in our society.

As you will see, the two sections are not independent of one another. Instead, they take different perspectives to provide an overview of cognitive neuroscience and biomedical technologies for healthcare and the topics covered are often related. Readers should choose any of the research fields according to their interests. We hope this book will help you to learn more about biomedical engineering and healthcare, and be of benefit to your own research.

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