Preface

Robotic technologies provide new solutions for rehabilitation and support for disabled and elderly people. For all kinds of robot-assisted rehabilitation therapies, the human–robot interface is important for robots to work in harmony with the structure and movement of the human body. In the past decades, biomechanists have developed complex human limb models that combine neural signals with kinematic and kinetic data to study human control strategies. The ability to accurately predict the movement intention and quickly determine the corresponding training strategy is important to improve the effectiveness of robot-assisted medical treatment.

Biomechatronics is an applied interdisciplinary science that effectively integrates mechanical elements, electronics, and parts of biological organisms. Biomechatronics is a rapidly growing field as it provides the basic fundamentals for developing new medical devices and technologies. However, only very few institutions currently offer undergraduate and postgraduate programs in the field. With the rapid development of the medical device industry, there is an increasing demand for graduates with the required multidisciplinary knowledge in medical devices and technologies. This book presents new insights into the emerging technologies and developments that are being, or will be used in medical biomechatronics. This book provides biomedical engineering students and professionals with the fundamental biomechatronics engineering knowledge to analyze and design new biomechatronic devices.

This book demonstrates the recent research work carried out at the Medical and Rehabilitation Research Centre in the University of Auckland. The focus of this book is on the novel applications of biomechatronics for providing better clinical, medical, and rehabilitation services for patients and medical professionals. Each chapter describes in detail the design of biomechatronic systems, the methods and control systems used, and their implementation and testing, to show how the systems fulfil specific medical needs. This will be useful for researchers, academics, and graduates that are new to the field of biomechatronic engineering. This book will also be appealing to researchers or clinicians in the medical field, who are not engineers, as the book introduces the fundamental engineering technologies that aim to improve medical practices.

The aim of this book was to provide a snapshot of our recent research contributions to the field of advanced biomechatronics. Chapter 1 gives an overview of biomechatronics with a focus on interfaces and robots. It briefly introduces the history and background of biological interfaces, discusses the current issues involved in biomechatronics, and outlines the motivation of the work in this book.

Chapter 2 presents the historical background of advanced biomechatronics for medical rehabilitation. This chapter provides an overview of neural interfaces, interaction control, and rehabilitation. It considers different types of interfaces including the brain–computer interface (BCI), neural interfaces, and electromyography (EMG)-based physiological interfaces. Subsequently, studies related to biosignals processing and computational modelling of human–robot interface are also examined.

Chapter 3 introduces steady-state visual evoked potential (SSVEP)-based BCIs and an effective SSVEP signal processing method. This chapter presents an in-depth study that was performed to accurately distinguish the target frequency components from weak and noisy SSVEP using a minimum number of recording electrodes. Based on the findings of the SSVEP signal study, a new signal processing method based on adjacent narrow band filter (ANBF) was introduced together with the concept of a 12-class SSVEP-based BCI. The effectiveness of the BCI was proven through experimental data from multiple subjects.

Chapter 4 introduces a SSVEP-based BCI for lower limb rehabilitation, in which the movement of robotic exoskeleton is continuously controlled by the user's intent. Three new and different training protocols, specifically for rehabilitation exercise, are presented. They were tested with the ANBF method introduced in Chap. 3. This chapter shows the promise of future brain-controlled rehabilitation devices. Patient participation was proven one of the most important factors for rehabilitating the neural system after an injury or a stroke.

The design of a hybrid electroencephalography (EEG)-based BCI for controlling a video game using EEG rhythms and SSVEPs is presented in Chap. 5. As interfaces between brain and computers, EEG-based BCIs are also useful tools for assistance. This chapter presents the research presented in prior chapters applied to a sophisticated gaming situation that involves training and more complex commands. These control commands were used to control the actions of characters in a video game. The system was developed on a standard computer and tested with five healthy participants.

Chapter 6 details an EMG-driven elbow physiological model for interfacing with the upper limb. This chapter presents the elbow physiological model, which consists of a musculotendon dynamic model, a musculoskeletal geometry model, and a kinematics model. This chapter also presents an interface that calculates each muscle's force with the musculotendon model, the joint torque with the musculoskeletal geometry model, and the joint angle and the angular velocity with the kinematics model. This chapter describes the method of surface EMG (sEMG) signal processing, which extracts the muscle activation signal with the linear envelope and nonlinear dynamics techniques.

An exoskeleton control method based on the neural interface is discussed in Chap. 7. This chapter presents an upper limb exoskeleton to assist elbow movement. The upper limb exoskeleton uses sEMG and wrist force measurements to analyze the movement intent of its wearer. Two types of human–robot interaction approaches were used. This chapter also describes an interface based on human sEMG and a physiological musculoskeletal model for upper limb movements.

In Chap. 8, a patient-specific muscle force estimation model (PMFE) is proposed. Muscle forces are calculated by the PMFE based on a patient's custom musculoskeletal model. These forces serve as control inputs to control an exoskeleton's antagonistic air muscles. The PMFE is an anatomy-based inverse dynamic–static optimization model that aims to fulfill the requirements for controlling a human-inspired rehabilitation robot. At the core of the PMFE is a two-dimensional (2D) computer-generated musculoskeletal model that computes anatomical parameters and time-variable moment arms.

Chapter 9 further details the patient-specific EMG-driven neuromuscular model (PENm). In this chapter, real-time calculation of the PENm is made possible by a minimum set of patient-specific parameters, which are based on the results of a sensitivity analysis and a dynamic calculation optimization algorithm. The PENm can predict accurate joint moments in real time based on only two EMG channels from one extensor and one flexor muscle and the minimum parameter set.

Chapter 10 summarizes the main outcomes, conclusions, and contributions of this research. This chapter also discusses future directions that can be explored to extend or advance these contributions. This may be used to guide coming research or act as a reference for institutions developing new biomechatronic systems. An index is also offered to aid the search of terms used in this book.

I would like to express my deep appreciation to those who have contributed to this book. The authors are also grateful to Dr. Xing Song, Allan Veale, Ran Tao, and Ye Ma for their assistance in the book's compilation. It is our sincere hope that readers will find this book useful in their study and research.

Auckland, New Zealand
August 2016

Shane Xie

http://www.springer.com/978-3-319-52883-0

Biomechatronics in Medical Rehabilitation
Biomodelling, Interface, and Control
Xie, S.; Meng, W. (Eds.)
2017, XVIII, 203 p. 107 illus., 93 illus. in color.,
Hardcover
ISBN: 978-3-319-52883-0