Book Review: *Human Robotics: Neuromechanics and Motor Control*

Etienne Burdet, David W. Franklin, and Theodore Milner
MIT Press, 2013.
Reviewed by Herman van der Kooij and Edwin van Asseldonk

OVER the last 10 years, we have taught a course that starts with the physiology of human muscles, sensory receptors, and the nervous system. After which, we introduce dynamical models of human motion and balance control, sensory integration, and motor learning. Till now, our lecture material was a colorful collection of journal (review) articles, chapters from various books, and written lecture notes. The disadvantages of using these different sources are that mathematical notations are not consistent, the information content of review articles is very dense, and many articles have to be read to get a complete overview of the experiments done and the models derived. The appearance of the book *Human Robotics: Neuromechanics and Motor Control* by Etienne Burdet, David W. Franklin, and Theodore E. Milner, published by MIT Press in 2013, fulfills our need to have one book that can be used in teaching the broad topic of human motor control. From this year, we will use this book in our classes.

The outline of *Human Robotics: Neuromechanics and Motor Control* follows more or less the structure of our classes. Chapters 2 and 3 provide a concise and clear overview of the physiology of the nervous system, peripheral sensory systems, and mechanics of the muscle-tendon complex. Here, the role of muscles as a source of impedance in addition to force is highlighted. In Chapters 4 and 5, fundamental concepts for single- and multi-joint systems are introduced such as direct and inverse kinematics, mechanical impedance, and kinematic and kinetic transformations from one coordinate system to another (e.g., from muscle to end-effector coordinates). The role of mechanical impedance (i.e., the resistance to movement) in motor control, and how impedance can be modulated by antagonistic co-activation, neural feedback, and limb configuration is explained in detail. These fundamental concepts are defined using mathematical notations commonly used in the robotic community. Numerous examples illustrate how these concepts are relevant in human motor control. Chapter 6 introduces different techniques used to control multi-joint dynamical systems, such as feedforward and feedback control, non-linear adaptive control, and neural networks. This chapter relies more on complex formulae than the other chapters. It also introduces advanced concepts from control theory that are probably difficult for readers who do not have a thorough understanding of modern control theory already. Chapters 7 and 8 deal with how humans adapt their reaching movements to stable and unstable force fields, which has been one of the authors' key research areas over the last decade. From their experimental data and models and those of others the interplay between feedforward and feedback control and the accompanying modulation of impedance during adaptation is nicely illustrated. Chapters 9 and 10 introduce optimal control and estimation theories as a framework to estimate the state of the body and plan and control human movements. The last chapter presents some applications of how the knowledge gained from the previous chapters can be applied to neuro-rehabilitation and robotic control.

The book contains many clear illustrations that make it easier to understand and remember the main elementary properties of sensory and muscle dynamics, experimental findings on motor control and learning, and theoretical concepts and models. The book does not cover the whole range of motor control, but focuses on upper limb functioning. This is not surprising since the authors are authorities in this field. Neuromechanics and control of whole body balance and gait could be a valuable extension for future editions of *Human Robotics: Neuromechanics and Motor Control*, especially in light of its relevance for rehabilitation and humanoid robotics. The different chapters have some overlap, and it is noticeable that the chapters have been written by different authors. The book does not contain exercises, which could be a valuable future addition, especially given that the book's primary target is undergraduate students. However, there is a website associated with the book that contains many useful models that can be used in assignments.

In summary, this book is a unique resource for students with a background in human movement sciences, kinesiology, or neurosciences, who want to learn more about theoretical concepts and models borrowed from systems and control theory that help to understand and predict human motor control. We also recommend this book for students with a background in systems and control theory or robotics, who want to know more about neuromechanics and human motor control.

Herman van der Kooij and Edwin van Asseldonk, *Reviewers*

- *H. van der Kooij is with Biomechanical Engineering, University of Twente, Enschede, and Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands.*
- *E. van Asseldonk is with Biomechanical Engineering, University of Twente, Enschede.*

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