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Human-Robot Body Experience

 Springer

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Series Editors' Foreword

This is the eighteenth volume of *Springer Series on Touch and Haptic Systems*, which is published as a collaboration between **Springer** and the **EuroHaptics Society**.

Human-Robot Body Experience describes a set of human-in-the-loop experiments based on technologies in haptics, robotics, and virtual reality. It highlights the paramount importance of haptics in human-robot interactions. Overall, the results show a significantly stronger embodiment experience when haptic feedback is provided.

Robotic hand and leg illusions are discussed in depth in order to analyze haptic mechanisms. Several experiments that include interaction with vibrotactile and force feedback are also presented in terms of the light they shed on human-robot interconnection.

The book includes eight chapters grouped into four parts. The first part introduces the fundamentals of human-robot interaction. The second and third parts are focused on the upper and lower robot limbs, respectively, and the fourth part defines some guidelines on their design and future lines of research.

This volume reviews many important issues in human-robot interaction and paves the way for future research work as well as providing recommendations for the design of more effective human-robot interfaces.

Madrid, Spain
Ulm, Germany
Birmingham, UK
January 2021

Manuel Ferre
Marc O. Ernst
Alan Wing

Foreword

The body experience of users of assistive robots and other applications with an intensive mix of cognitive and physical human-robot interactions is a very challenging field of fundamental research with highly promising prospects for future technical applications, especially in haptics. Providing users with intuitive information, haptic feedback can enrich the control possibilities given to the user and thereby increase the usability of assistive systems, e.g., in teleoperation or prosthetics. With a very holistic approach, this monograph of Prof. Philipp Beckerle considers this fascinating research challenge from the perspectives of diverse disciplines in human and engineering sciences. In a very tangible fashion, Philipp brings together these perspectives outlining the enormous potential and impact of human-in-the-loop experiments for our understanding of human body experience and the design of haptic feedback devices and assistive controllers. This monograph will empower readers from different fields to understand the human-robot body experience, as Philipp coins it, in a very comprehensive way. The interpretation of the human-robot interaction that Philipp introduces in this book will certainly attract the interest of many researchers in our community.

Bridging between the disciplines, the first part of the book effectively provides readers with the necessary fundamentals, presents existing experimental designs, and their requirements. From this part, readers from different fields are wonderfully picked up and brought to a common understanding of the interrelations of human body experience and robotic assistance. In the second and third parts, Philipp's excellent monograph brings those fields together by suggesting and discussing human-in-the-loop experimental designs to probe human-robot body experience regarding the upper and lower limbs. The presented approaches and studies nicely outline the influence of haptics and control and how experience-related aspects could be considered in their design. Concluding the monograph, the fourth part discusses exciting technical solutions and provides a roadmap for future research on bidirectional human-machine interfaces and non-functional haptic feedback. Providing a very comprehensive picture of the scientific challenge and highlighting promising

future research directions, I expect this monograph to become a staple reference in this field.

Siena, Italy
February 2021

Domenico Prattichizzo

Preface

Robots and related assistive technologies are entering our daily lives and starting to share our professional and private workspaces. During tight interaction, the way of how we experience our bodies is influenced by interaction with robots and assistive devices, e.g., a prosthesis might feel to be part of the user's body. This monograph gives a broad overview of research of the body experience of human individuals who are directly interacting with robots and assistive devices. It presents results from the author's interdisciplinary research at the intersection of psychology, cognitive and computer science, neuroscience, and engineering. Going beyond disciplinary boundaries, human-in-the-loop experiments based on psychological paradigms are suggested to empirically evaluate how users experience devices and systematically analyze how body experience influences system, interface, and control design.

Personally, I would like to thank all collaborators, supporters, and students who put their hard work and dedication to the research condensed in this monograph. Special thanks go to the faculties of Electrical Engineering and Information Technology at TU Dortmund and Mechanical Engineering at TU Darmstadt as well as SIRS lab at the University of Siena for hosting and facilitating my research. Moreover, I highly appreciate the support provided by the IEEE Technical Committee on Haptics and acknowledge the support from the German Research Foundation (DFG) through the projects "Users Body Experience and Human-Machine Interfaces in (Assistive) Robotics" (no. BE 5729/3&11).

I am fully convinced that we will only be able to understand and shape human-robot body experience through intensive exchange and open discourse within and across disciplines. Numerous discussions with colleagues have shown me that despite recent insights, there is a long way ahead of us. Besides capturing the state of the art and providing concrete experimental approaches, this monograph discusses future directions to hopefully provide guidance to this endeavor.

Darmstadt, Germany
September 2020

Philipp Beckerle

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