

Preface

The term “haptics” unlike the terms “optics” and “acoustics” is not so well known to the majority of people, at least not in the meaning used in the scientific community. The words “haptics” and “haptic” refer to everything concerning the sense of touch. “Haptics” is everything and everything is “haptic,” because it not only describes pure mechanical interaction, but also includes thermal- and pain-(nociception) perception. The sense of touch makes it possible for humans and other living beings to perceive the “borders of their physical being,” i.e., to identify where their own body begins and where it ends. While vision and hearing will make us aware of our greater surroundings, the sense of touch covers our immediate vicinity: In the heat of a basketball match a light touch on our back immediately makes us aware of an attacking player we do not see. We notice the intensity of contact, the direction of the movement by a shear on our skin, or a breeze moving our body hairs—all without catching a glimpse of the opponent.

“Haptic systems” are divided into two classes.¹ There are *time-invariant systems* (the keys of my keyboard), which generate a more or less unchanging haptic effect whether being pressed today or in a year’s time. Structures like surfaces, e.g., the wooden surface of my table, are also part of this group. These haptically interesting surfaces are often named “haptic textures.” Furthermore, there are *active, reconfigurable systems*, which change their haptic properties partly or totally depending on a preselection—e.g., from a menu, or based on an interaction with real or virtual environments.

¹ In engineering there are three terms that are often used but do not have definite meaning: System, Device, and Component. Systems are—depending on the task of the designer—either a device or a component. A motor is a component of a car, but for the developer of the motor it is a device, which is assembled from components (spark-plug, cocks, knocking-sensor). It can be helpful when reading a technological text to replace each term with the word “thing.” Although this suggestion is not completely serious, it surprisingly increases the comprehensibility of technical texts.

The focus of this book is on the technological design criteria for active, reconfigurable systems, providing a haptic coupling of user and object in a mainly mechanical understanding. Thermal and nociceptive perceptions are mentioned according to their significance but are not thoroughly discussed. This is also the case with regard to passive haptic systems. For active haptic systems, research and industry developed a large number of different universal haptic systems that can be used for different purposes. Because of the large variability of these devices, they sometimes fall short of requirements for certain applications or are—in short, just too expensive. We therefore believe that there is a need for a structured approach to the design of *task-specific haptic systems* on the one hand and a necessity to know about the different approaches for the components and structures of haptic systems on the other hand.

The fact that you have bought this book suggests that you are interested in haptics and its application in human–machine interaction. You might have already tried to sketch a technical system meant to provide a haptic human–machine interaction. Maybe, you are just planning a project as part of your studies or as a commercial product aimed at improving a certain manual control or introducing a new control concept. Maybe, you are a member of the increasing group of surgeons actively using haptics in medical technology and training to improve patients’ safety and trying to apply the current progresses to other interventions.

Despite of, or even because of, this great variety of projects in industry and research working with haptic systems, the common understanding of “haptics” and the terms directly referring to it, like “kinaesthetic” and “tactile,” is by no means as unambiguous and indisputable as it should be. In this book, we intend to offer a help to act more safely in the area of designing haptic devices. We consider this book as a starting point for engineers and students new to haptics and the design of haptic interfaces as well as a reference work for more experienced professionals. To make the book more usable and practical in this sense, we added recommendations for further insight into most chapters.

It begins with a presentation of the different areas that can benefit from the integration of haptics, including communication, interaction with virtual environments, and the most challenging applications in telepresence and teleoperation. Next, as a basis for the design of such systems, haptics is discussed as an interaction modality. This includes several concepts of haptic perception and haptic interaction and the most relevant results from psychophysical studies that can and have to be applied during the design process of a task-specific haptic system. Please note that this book has been written by and is addressed to engineers from several disciplines. This means that especially psychophysical content is sometimes simplified and shortened in favor of a fundamental basic insight into these topics for engineers working on a haptic device. Next, the role of the user as a (mechanical) part of the haptic system is discussed in detail, since this modeling has a large impact on system properties like stability and perceived haptic quality.

Part I of the book concludes with an extension of the commonly known development models of mechatronic systems to the special design of haptic systems. This chapter lays special focus on the integration of perception properties and ergonomic aspects in this process. The authors believe that the systematic consideration of perception properties and features of the sensory apparatus based on the intended interaction can reduce critical requirements on haptic systems, such as lowering the efforts and costs of development as well as leading to systems with higher perceived quality.

In Part II of the book, an overview of technological solutions, like the designs of actuators, kinematics, or complete systems including software and rendering solutions and the interfaces to simulation and virtual reality systems, is given. This is done with two aspects in mind. First, the reader should be able to find the most important and widely used solutions for recurring problems like actuation or sensing including the necessary technical basis for own designs and developments. Second, we wanted to give an overview of the large number of different principles used in haptic systems that are maybe a good solution for a new task-specific haptic system—or a noteworthy experience of which solution not to try.

The first idea for this book was born in 2003. Originally intended as an addition to the dissertation of Thorsten A. Kern, it was soon thought of as filling a gap: The regrettably small number of comprehensive recapitulating publications on haptics available for, e.g., a technically interested person, confronted with the task of designing a haptic device for the first time. In 2004, inspite of a considerable number of conference proceedings, journals, and Ph.D. theses, no document was available giving a summary of the major findings of this challenging subject.

The support of several colleagues, especially Prof. Dr.-Ing. Dr. med. Ronald Blechschmidt-Trapp and Dr.-Ing. Christoph Doerrer, helped to make the idea of this book clearer in the following years—and showed that this book would have to be much more extensive than originally expected. With the encouragement of Prof. Dr.-Ing. habil. Roland Werthschützky, the first edition was edited by Thorsten A. Kern during a post-doc time. It was funded by the Deutsche Forschungsgemeinschaft (DFG, grant KE1456/1-1) with special regard to the consolidation of the design methodology for haptic devices. Due to this funding the financial basis of this task was guaranteed. The structure of the topic made clear that the book would be considerably improved by contributions from specialists in several areas. In 2008, the German version *Entwicklung Haptischer Geräte* and in 2009 the English version *Engineering Haptic Devices* were published by Springer. Both books sold about 500 copies in total up till now.

In 2010, the idea of a second edition of the book was born. With the change of Dr. Kern from university to industrial employer, the attention also shifted from mainly kinaesthetic to tactile devices. This made severe gaps in the first edition eminent. In parallel, science made great progress in understanding the individual tactile modalities, blurring the borders between different old concepts of the same perception, offering now an opportunity to find an engineering approach to more than the pure vibrotactile perception. It took however until the year 2013 for the work on the second edition to start. In that year, Christian Hatzfeld finished his

dissertation dealing with the perception of vibrotactile forces. Also, encouraged by Prof. Dr.-Ing. habil. Roland Werthschützky, he took the lead in editing this second edition. In addition to the first edition, this work was also funded by the DFG (grant HA7164/1-1), pointing out the importance of an adapted design approach for haptic systems.

With the cooperation of Springer and the series editors, the second edition of this book was integrated in the *Springer Series on Touch and Haptic Systems*, as we felt that the design of task-specific haptic interfaces would be complemented well by other works in this series. We wish to thank all the authors who contributed to this book as well as all colleagues, students, and scientists from the haptics community who supported us with fruitful discussions, examples, and permissions to include them in this book. On behalf of many, we would like to point out Lukas Braisz, who was a great support in preparing the figures, especially in the new chapters of the second edition. Special thanks go to our mentor and advisor Prof. Dr.-Ing. habil. Roland Werthschützky, who encouraged and supported the work on both editions of this book.

Since a book is a quite static format compared to the dynamic progress of haptics in general, we set up an accompanying homepage with regular updates on the books topics at <http://www.hapticdevices.eu>. We hope that this work will alleviate the work of students and engineers new to the exciting and challenging development of haptic systems and serve as a useful resource for all developers.

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Engineering Haptic Devices

A Beginner's Guide

Hatzfeld, C.; Kern, T.A. (Eds.)

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