Chapter 15
Conclusion

Like any other design process, the design of haptic systems is largely influenced by the optimization of a technical system based on the balancing of a plurality of decisions on separate components, which, as a rule, influence each other. In the beginning, the requirements of the customer, respectively, of the project have to be defined. The methods presented in Chap. 5 are intended to systematically identify the most important aspects of these requirements. However, the engineer should be conscious of the fact that for the design of a sense-related interface, less precise and definite terms are available than he may be used to. Additionally, the knowledge on the part of the customer may result in considerable confusion, as especially haptic terms, e.g. resolution or dynamics, may be used in the wrong context or understood in a wrong way. A better definition of the requirements without major misunderstandings is achieved by, e.g. giving the customer aids, "shows-and-tells" of haptics. It is necessary for the customer and the engineer to come to a common understanding based on references known to both. It seems promising to describe the interactions the user should be able to do with the task-specific haptic system very thoroughly, since they have a large impact on the design of the system and the requirements derived from the capabilities of the haptic sense. For this reason, an understanding of the specialties of haptic perception and interaction on the part of the engineer is necessary. It should not be limited to the technical characteristics described in Chaps. 2 and 3, but also include some knowledge about the "soft," i.e., psychological and social aspects of haptics as described in Sect. 1.1.

Based on the requirements discussed above, the technical design process may begin. An adapted version of the commonly known *V-model* is given in Chap. 4 to do this. This approach tries to integrate all of the above-mentioned aspects in a structured way. One of the very first decisions is the choice of the haptic system's structure (Chap. 6. Although this decision is at the very beginning of the design process, a rough sketch of the favored structure of the device to be developed is necessarily to be made. This demands a considerable knowledge of all the branches

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of haptic device design, which later will be needed again during the actual design phase.

Besides the already mentioned decision on the general structure, the basis of the design of kinaesthetic and tactile systems is its kinematic structure (Chap. 8). After the considerations made for kinematics, concerning the transmission and gearing proportions, the working volume, and the resolution to be achieved, suitable actuators are chosen or even designed. In Chap. 9, the basis for this is provided by comparing the different actuation principles. Examples of their realizations, even of unusual solutions for haptic applications, provide a useful collection for any engineer to combine kinematic requirements of maximum forces and translations with impedances and resolutions.

As closed-loop admittance controlled systems with kinaesthetic and tactile applications are gaining in importance, force sensors have to be considered as another component of haptic devices. In Sect. 10.1, this technology is introduced, providing the tools, as well as conveying the chances and also the challenges connected with their application. A frequent application of haptic devices is to be found in the human–machine interface of simulators, be it for games ranging from action to adventure games, or for more serious applications for training surgeons or in the military, respectively, in industrial design. In addition to the output of haptic information, an input of user movements is required. The measurement principles typically used are discussed in Sect. 10.2.

The design steps presented so far will enable the haptic device to provide a tactile or kinaesthetic output to the user, often measuring a reaction too. In particular, with today's computer technology, the data will be almost always interfaced with a standard PC. The requirements derived from this interface are subject to a presentation of standard interface technology given in Chap. 11, whereby the interfaces' performances are compared with each other.

Due to the rather frequent application of haptic devices in simulators, an interface with a simulation engine is required. An insight into the requirements and challenges of suitable haptic algorithms is helpful for the hardware engineer to improve the communication with software engineers and the interfacing with their VR environments. An appropriate introduction is given in Chap. 12.

The cross section given in this book is meant to improve and further speedup the design of haptic devices and to avoid the most critical errors typically made during the design process. The research in the area of haptic devices is making impressive progress. Every few months adapted control engineering concepts appear; the usage of haptic perception for the design is subject to current research. Actuators are being continuously improved; even new principles with haptically interesting properties regularly appear on the market. Closed-loop controlled systems become more and more interesting, due to the slowly increasing availability of highly dynamic high-resolution force sensors. This dynamics of a still young discipline commits developing engineers to monitor the current research attentively. For this purpose, finally, a list enumerating teams active in the haptic area has been compiled in Appendix B.