

Preface

Haptic rendering is the process of computing and generating forces in response to user interactions with virtual objects. Six-degrees-of-freedom (6-DoF) haptic rendering simulates both forces and torques during physical interactions between a virtual tool moved by a human user via a haptic device and the objects in a virtual environment. Both the tool and the objects can possess complex shapes. Forces and torques exerted on the virtual tool are computed and displayed to the haptic device. In this book, we introduce the latest progress on 6-DoF haptic rendering for fine manipulation.

Fine manipulation is pervasive in the real environment, such as in surgical operation, mechanical assembly, inspection, and maintenance tasks. 6-DoF haptic simulation of fine manipulation is a difficult problem because of multi-region contacts, narrow space constraints, and requirements to preserve the appearance and tactile sensation of fine-features. Compared to the fields of computer graphics and speech synthesis, haptic rendering is still a young research field. High performance rendering methods are needed to simulate physical responses in various fine manipulation scenarios, such as the nonlinear behavior of human tissue during surgical process, or the contact forces from multi-region contacts involving fine geometric features during assembly of complex structures such as an airplane.

In this book, we introduce a systematic, constraint-based approach for 6-DoF haptic rendering that is particularly suitable for fine manipulation. We also introduce its application to virtual training for dental operations. We provide programs, 3D models, and videos for download. All these materials are available online from the book website <http://extras.springer.com/>.

The structure of this book is organized as follows. In Chap. 1, we provide a brief introduction to the history of haptic rendering and a literature survey on 6-DoF haptic rendering. We next introduce the concept of fine manipulation and associated computational challenges for haptic rendering. In Chap. 2, we introduce a configuration-based optimization approach based on modeling non-penetration constraints by sphere-trees, which can realize stable and responsive haptic rendering between rigid objects with 1kHz. In Chap. 3, we extend the approach to simulating fine geometric features, such as sharp edges. In Chap. 4, we extend the approach to

simulating deformable objects and hybrid contacts, which are characterized by simultaneous interactions between a tool with both rigid and deformable objects. In Chap. 5, we introduce a measurement-based approach for achieving objective and quantified evaluation of the fidelity of 6-DoF haptic rendering, which is not only applicable to the introduced approach in this book but also to other existing haptic rendering approaches. In order to provide an intuitive application and validation of the introduced haptic rendering approach, in Chap. 6, we describe the design of a dental simulator that validates the approach on 6-DoF haptic rendering and provides the functions and user evaluation results of the system. Finally, in Chap. 7, we summarize the book by discussing open challenges and possible research topics in this exciting field.

Target readers of the book include but are not limited to:

- Researchers and scholars in the field of haptics;
- Software developers and engineers for developing haptic applications, including virtual surgery, computer games, virtual product prototyping, upper limb rehabilitations, etc.;
- Researchers and developers in dental education and professional training;
- Graduate students in related majors, such as computer graphics, animation, virtual reality, and robotics.

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