Haptic Simulation, Perception and Manipulation of Deformable Objects

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Abstract

This tutorial addresses haptic simulation, perception and manipulation of complex deformable objects in virtual environments (VE). We first introduce HAPTEX, a research project dealing with haptic simulation and perception of textiles in VEs. Then, we present state-of-the-art techniques concerning haptic simulation and rendering, ranging from physically based modelling to control issues of tactile arrays and force-feedback devices. In the section on cloth simulation for haptic systems we describe techniques for simulating textiles adapted to the specific context of haptic applications. The section concerning tactile aspects of virtual objects shows how arrays of contactors on the skin can be used to provide appropriate spatiotemporal patterns of mechanical excitation to the underlying mechanoreceptors. Finally, the last section addresses the problem of developing suitable force feedback technologies for the realistic haptic rendering of the physical interaction with deformable objects, addressing the design of novel force feedback systems, innovative concepts for curvature simulation and control algorithms for accuracy improvement.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Virtual Reality

1. Introduction

Research on multimodal simulation in virtual environments faces the challenge of reproducing the aspect and behaviour of real objects. The simulation should be as realistic as possible and take place within a virtual reality (VR) system which provides the user with multiple interfacing modes (such as vision, audio, and interaction devices). Multimodality typically addresses the stimulation of different channels of perception. In this context, some perceptual channels have been more exploited than others. The achievement of a high degree of **visual** realism is increasingly becoming more popular in the entertainment industry, where video games are offering an always improved experience to the user. This is particularly supported by the establishment of dedicated Graphics Processing Units (GPUs) included in high-end graphics cards featuring programmable shaders. Also 3D spatialised **sound** has become common in the last years, and audio surround facilities in CAVE systems and even in home theatres are widely used. The ability to **touch** virtual objects, however, has not been fully exploited so far. The integration of realistic force-feedback and tactile stimulation within virtual reality applications is far less satisfying than audio-visual integration, and still at the beginning.

This tutorial deals with the reproduction of the sense of touch within virtual reality environments. In this context, we will present how to simulate, perceive and manipulate complex deformable objects such as virtual textiles both from the visual and the haptic viewpoint.

1.1 Reproducing the sense of touch

The discipline dealing with technology interfacing the user via the sense of touch is called **haptics**. A main obstacle to the widespread adoption of haptic devices within ordinary VR systems is currently represented by the unavailability of efficient-and-affordable haptic devices. But there are also other factors which preclude the application development in this domain, such as the high complexity and computational costs linked to haptic simulation.

In order to be performed accurately, multimodal simulation addressing vision and touch involves a high load on the computer's processing units. It is therefore important to find the best trade-off between the simulation's realism (in terms of visual and physical accuracy) and performance (in terms of response latency). To optimize the resource management, the visual and the haptic sensory channels can be processed in separate layers, since they have different requirements in terms of update rates or relevant physical properties to be simulated. However, this practice requires a robust and stable coupling between the two modalities [AH98]. The synchronization between layers must occur in real time, because delays or asynchronous behaviour can strongly affect the believability of the user experience.

1.2 Rendering complex deformable objects

The research concerning new ways of rendering virtual objects both visually and haptically in a fast and stable way represents a particular challenge when dealing with

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