Haptic Rendering—Touch-Enabled Interfaces

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Since the inception of VR environments, human–computer interaction has focused predominantly on visual display. But sometimes vision is insufficient or unavailable. People use tactile and force feedback to identify objects and to explore the environment around them. This sensory cue is also used in manipulating objects. Therefore, an ideal man–machine interface for understanding virtual environments and visualizing complex information should enable the user to feel and orient objects and to manipulate data using touch-enabled interfaces.

In this special issue, we will examine the sense of touch as a communication medium in addition to graphical display. Specifically, we will look at different approaches to the design of touch-enabled interfaces for various applications, including scientific visualization, model design and editing, virtual prototyping, touch-enabled 3D widget design, and 3D painting and drawing, in addition to the development of rendering algorithms and haptic devices. These recent advances indicate that touch-enabled interfaces can provide a faster and more natural way of interacting with virtual environments and complex data sets in different applications.

In the first article, Lawrence et al. provide an overview of their work on the use of haptic interfaces for scientific visualization. Although visualization technology has advanced at a remarkable pace, it's often difficult and time consuming to understand the results displayed. The process of selecting a useful data subset can be frustrating when it comes to 3D volumetric data. The difficulty is further magnified when the data is multidimensional or multispecies. This article discusses the synergistic visual and haptic rendering modes for three types of data: scalar, vector, and tensor fields. It further describes when the haptic rendering modes are most beneficial and a number of lessons learned.

Sampled geometry has been gaining much attention in computer graphics and visual computing. Compared to traditional primitives such as triangle meshes, point-set surfaces have shown some unique rendering efficiency and freedom from connectivity constraints. This representation is especially suitable for large-scale, scanned models. However, areas using point-sampled geometry that have not been adequately addressed are interactive shape modeling and physically based editing of point clouds. In contrast, implicit modeling provides a powerful physically based modeling capability, but cannot handle arbitrary topology and complex geometry. The next article by Guo and Qin introduces a point-based representation that is also suitable for physics-based sculpting and interactive model deformation using a 3D haptic interface. The point-sampled surface is continuously reconstructed using global blending of locally defined trivariate B-spline implicit functions. The resulting system also allows the user to perform interactive 3D painting using a haptic stylus to further enhance the appearance of point-set surfaces.

In the design of 3D artifacts such as mechanical parts and architectural buildings, drawing is often an indispensable communication tool for exchanging ideas among designers, engineers, and end users. With the introduction of VR technology, it's now possible to design, discuss, and mark up a virtual artifact in a 3D VR environment using haptic interfaces to manipulate the object directly and annotate the 3D surfaces by drawing. However, 3D drawing is more challenging than 2D drawing due to various perception and proprioception factors. The third article, by Shon and McMains, describes experiments to evaluate the speed and accuracy of haptic interfaces for 3D drawing and studies the effect of changing some haptic characteristics.

The fourth article, by Komerska and Ware, suggests a set of new techniques called *haptic state-surface interactions*. Using haptic devices, various interaction states and state transitions are implemented through forces, rather than through menu selections. This approach parallels some real-world activities such as pressing hard to destroy (delete) objects and embodying haptic metaphors for common operations, thus making 3D interaction more fluid and natural. The authors also conducted experiments to evaluate the proposed techniques and enhanced the techniques based on the experimental feedback.

The next article by Luo and Xiao presents a physically accurate haptic-rendering algorithm, taking into

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account dynamic effects. Haptic force and moment rendering with physical accuracy is critical for applications requiring manipulation of virtual objects, such as virtual prototyping, virtual assembly, and teleoperation. The contact force and moment applied to the manipulated virtual object depends not only on the contact states, but also on the dynamic effects caused by the motion and the history of prior contact states, especially in the presence of friction. This article presents an efficient method, taking into account friction, gravity, and dynamic effects in haptic rendering.

Concluding this issue is the article by Borro et al. describing the design of a large haptic device for virtual prototyping, intended for aircraft engine maintainability. One of the most important aspects about maintainability is man and tool accessibility analysis to determine assembly or disassembly sequences and timing. With the rapid advancement in virtual prototyping technology, virtual mock-ups can now reduce the use of physical mock-ups, thereby shortening the design and development cycle. Borro et al. demonstrate that through a haptic device they can track hand movements and provide force feedback within the large geometric models describing aircraft engines. This capability enhances the sense of real manipulation and reduces development cost. The article describes not only the design of the large haptic device used in the maintainability studies, but also the interface description and experiences gathered from industry on using haptic interfaces for virtual prototyping applications.

In examining some of the recent developments of haptic interfaces for various applications, we believe that, although it is still in its early stages, computational haptics has already enriched human–computer interaction via the sense of touch. ■

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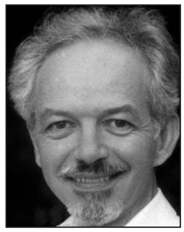

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