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Virtual Reality: Touch/Haptics

Haptic technology does for the sense of touch what computer graphics does for vision. Haptic technology allows creating computer-generated Haptic Virtual Objects (HVOs), which can be touched and manipulated with one's hands or body. HVOs provide a rich combination of cutaneous and kinesthetic stimulation through a bidirectional haptic (touch) information flow between HVOs and human users.

Many mechanical properties of everyday objects are experienced through touch. These properties include weight and shape of objects, object elasticity, object's surface texture (e.g., smooth or rough), etc. HVOs can have many of these real-object mechanical properties. Perhaps more importantly, HVOs can have mechanical properties that do not exist in nature. For example, HVOs can possess paradoxical, normally impossible combinations of mechanical properties. Persons touching such paradoxical HVOs can experience surprising perceptual effects. For example, persons actually touching a surface with a hole can haptically perceive instead a surface with a bump on it. Human haptic capabilities can be investigated in totally new ways with these and other HVOs. HVOs are also used in touch-enabled human-machine interface applications. For example, HVOs are used to create virtual internal organs that can be touched and manipulated by surgical trainees.

HVO creation

Generally, HVOs are created through force fields (or "force-feedback"), generated by computer-controlled mechanical systems called Haptic Interfaces (HIs). An HI delivers the force-feedback to a person's hands or body. This reproduces major aspects of what actually happens when touching real, everyday objects.

For example, in Fig. 1a, a person handles a stick to poke and deform a real (not an

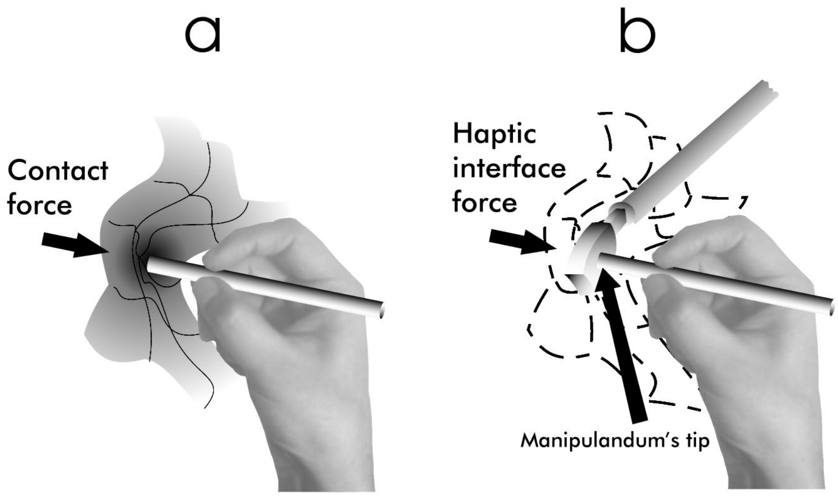

Figure 1. Reproducing a real-world interaction scenario (a) with a haptic virtual object (b)

HVO), flexible surface (e.g., a rubber sheet). Following the physics of this mechanical interaction, the surface exerts a force back into the stick. This contact force is transmitted to the person's hand. The person experiences this force as the surface's resistance to deformation. This interaction scenario can be reproduced with an HVO. For this, the person holds an HI's stick-like manipulandum (Fig. 1b). The rest of the HI mechanism is only partially shown (the bar connected to the manipulandum's tip, Fig. 1b). The person moves the manipulandum in an empty, delimited, three-dimensional space (the HI workspace). HVOs are created within this workspace. The person uses the manipulandum to "poke" an HVO (dashed surface, Fig. 1b). The HVO is not a physical object at all. It consists only of computer-controlled forces that are generated as follows.

As the person moves the manipulandum, HI's sensors measure the current position of the manipulandum's tip (Fig. 1b). A Control Computer (CC) monitors this position. When the person moves the manipulandum's tip into the workspace region occupied by the HVO, the CC detects this "collision" of the manipulandum's tip with the HVO. Then, the CC calculates a simulated contact force from a model (e.g., equations) of the real interaction's physics. Next, the CC activates the HI's actuators (e.g., electric motors) which, in combination with HI mechanics, produce an actual physical force that is applied into the manipulandum's tip (Fig 1b). This force physically realizes the simulated contact force. As when touching the real surface (Fig. 1a), the person feels HI forces through the manipulandum. As the person explores and even "deforms" the HVO, adequate HI forces sculpt, so to speak, the HVO. This software-controlled HVO creation process is called Haptic Rendering (HR). The CC executes HR events (collision detection, force calculation and generation when necessary) at a high rate (one kHz or more). In contrast, graphics rendering typically works at a rate of 30 Hz.

Different manipulandums can be used to interact with HVOs, e.g., tools resembling thimbles (for fingertip insertion), scissors (e.g., for surgical simulation), hand exoskeletons, etc. Multifinger HVO interaction is also possible. HVOs can be combined with visual, auditory and other display technologies for multimodal sensory stimulation.

HVOs as experimental stimuli in perception research and related areas

HVOs' mechanical properties can be selectively defined and changed through software. This is very difficult (or impossible) to achieve with real objects. Therefore, HVOs allow entirely new ways to investigate perception. For example, persons touching paradoxical HVOs can experience contact forces normally found when touching a surface with a bump, while actually touching a surface with a hole. As a result, persons haptically perceive a surface with a *bump*. Such situations reveal that contact forces can determine how object shape is haptically perceived, even when other sensory cues (e.g., the object's actual geometry) offer conflicting haptic information. The full potential of HVOs remains to be explored in fields such as haptic perception, multimodal and intermodal perception and integration, motor control and dexterous manipulation, functional brain imaging (e.g., for correlation of brain physiology with real-time HVO interaction), and in applications such as surgical simulators and touch-enabled Internet browsing.

For effective use of HVOs in experiments and more generally, it is essential to thoroughly understand i) the physics of the haptic interaction scenario of interest, ii) the capabilities and limitations of available haptic technology, iii) how the haptic interaction scenario and its physics can be implemented with haptic technology, iv) how this implementation may differ from the original scenario, and how this may influence human perception and performance, and v) how judicious experimental design and testing can deal with all these issues.

Gabriel Robles-De-La-Torre

See also **Cutaneous Perception; Haptics; Kinesthesis; Multimodal Interactions: Visual-Haptic; Vibratory Perception**.

Further readings

Basdogan C., Srinivasan M.A. (2002). Haptic Rendering in Virtual Environments. In: K.

Stanney (ed.), *Handbook of Virtual Environments*. London: Lawrence Erlbaum,117-134.

Hayward V., Astley O.R., Cruz-Hernandez M., Grant D., Robles-De-La-Torre G. (2004). Haptic Interfaces and Devices. *Sensor Review*, 24, 16-29. Click here to download

Robles-De-La-Torre G. & Hayward V. (2001). Force can overcome object geometry in the perception of shape through active touch. *Nature,* 412, 445-8. Click here to download

Robles-De-La-Torre G. (2006). The Importance of the Sense of Touch in Virtual and Real Environments. *IEEE Multimedia* 13, 24-30. Click here to download

Robles-De-La-Torre G. (2008). Principles of Haptic Perception in Virtual Environments. In: M. Grunwald (Ed.), *Human Haptic Perception: Basics and Applications.* Basel: Birkhäuser Verlag. Click here to download