·Editorial·

Haptic feedback for virtual reality

Dangxiao Wang[1,2]

1. *State Key Laboratory of Virtual Reality Technology and Systems, Beihang University, Beijing* 100083*, China*

2. *Beijing Advanced Innovation Center for Biomedical Engineering, Beihang University, Beijing* 100083*, China*

hapticwang@buaa.edu.cn

Touch is an important channel for human beings to communicate with the external world and plays a crucial role in human interaction with nature. Information such as softness, friction, texture and warmth, or more complicated human emotional communication can only be perceived by the act of touching. Despite its importance, it is striking that haptic feeback in human-machine interaction is still in its infancy. For example, a human user can enjoy realistic visual or auditory experiences facilitated by a computer through devices such as a head-mounted display or a stereo headset. However, haptic experiences that the user can obtain is extremely limited during such interactions.

Haptic interaction technology enables users to touch virtual objects and experience tactile sensations, including contact force, softness, texture, weight, vibration, and temperature. These sensations can significantly enhance users' interactive experience of virtual-reality systems. Haptic interaction technology can be applied in many fields, such as surgical simulation/training, virtual assembly and maintenance of complex mechanical equipment such as aircraft engines, interactive entertainment experiences such as movies and computer games.

In view of the promising prospects of haptic interaction technology, Institute of Electrical and Electronics Engineers (IEEE) established the Technical Committee on Haptics (TCH) in 2006 and IEEE Transactions on Haptics (ToH) in 2008. Several international conferences have been held, including IEEE World Haptics Conference (WHC), IEEE Haptics Symposium, EuroHaptics, and AsiaHaptics.

The topic of this issue is haptic feedback for virtual reality, which aims to further promote academic exchanges regarding haptic feedback. We have selected nine papers (three review papers and six specialized papers) that provide the latest updates on the development of haptic interaction technology in five areas: psychophysics, haptic feedback devices, force sensors, vibrotactile feedback, and haptic feedback for visually impaired people.

Understanding on psychophysics can provide fundamental biological guidelines for developing effective haptic feedback devices. Lei et al. summarized how the tactile stimuli was exploited to compose tactile cues and as tactile apparent motion to interface with other sensory stimuli (visual and auditory stimuli) to examine the underlying perceptual organization in a multisensory context. In another study, Takahashi et al. characterized the proprioceptive sensation induced by Tendon Electrical Stimulation (TES), and constructed a multimodal presentation system to investigate whether TES contributed to the reproduction of haptics cooperating with other modalities. They found that TES appears to be an effective component of multimodal force sense presentation systems.

Haptic devices provide a physical interface between human users and virtual environments. The review paper from Wang et al. surveys the paradigm shift of haptic devices in the past 30 years, which is classified into three stages, including desktop haptics, surface haptics, and wearable haptics. The driving forces, key technologies and typical applications in each stage are reviewed. In another paper, Yan et al. summarizes the typical devices of electrostatic tactile representation, tactile rendering model-driven and data-driven algorithm, driving signal loading method, tactile representation effect evaluation method and so on. Electrostatic tactile display may greatly enhance the immersion of bare finger interaction with a touch screen.

Multi-dimensional force sensors are necessary to capture users' manipulation behavior. Song et al. surveyed multi-dimensional force sensors based on different measurement principles, such as resistive, capacitive, piezoelectric, are briefly introduced. The mechanical structures of the elastic body of multi-dimensional force sensors and the calibration process are reviewed.

Vibrotactile feedback is a low cost and widely used modality of haptic display. Song et al. developed a virtual reality system for manipulation of the liquid bridge in space station, which can support typical tasks including bridge pulling, and clearance process etc. Experimental results validate that by combining multi-finger recognition, vibrotactile feedback and immersive display, the proposed system is able to achieve the goal of natural interaction for space telescience experiment. Zeng et al. studied the effects of eye-mounted vibrotactile feedback on VR immersion. Several vibrators are mounted around the human eye area and they can produce different vibration waveforms and frequencies. Their results provide references to the modeling of eye tactile feedback in improving the VR immersion.

Haptic feedback for visually impaired people is an important application field. By summarizing interaction patterns of blind people and analyzing the information flow during multisensory interaction, Jiao and Xu proposed a multichannel haptic / acoustic model and experimentally analyzed blind users' cognitive ability when provided with haptic / acoustic information inputs. Wu et al. proposed a tactile generation approach that can enable the blind to recognize text in digital images. They presented a Gauss difference algorithm based on tangential flow of edges, which can extract the contour of text precisely, and obtain the smooth contour of text with remarkable edge features.

Dangxiao Wang
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