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Editorial

Haptics and VR: Technology and Applications

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1. Introduction

Although the most recently developed virtual reality systems convey photorealistic visual information and 3D audio information to users, it is not easy to create immersive and realistic sensations for users to perceive the real world. Haptic technology provides realistic and immersive sensations to users by adding extra dimensions to the virtual environment, as if they manipulate objects in a real environment. It is necessary to consider a hardware module (such as a haptic device and/or haptic actuator) and a software module (haptic rendering method) to create a realistic touch sensation in a virtual environment. Haptic rendering is a method that computes resistive force, vibrational feedback, or motion feedback according to the mechanical or surface properties of a target object and the amount of user interaction. A haptic device containing haptic actuators is an interface that provides computed haptic information to users. This issue presents the latest haptic research on relevant topics, particularly psychological studies on human touch, haptic simulation using a haptic model and rendering, haptic actuators/devices, and haptic applications.

2. Toward Immersive Haptic Interaction

This issue not only addresses devices and methods to create a realistic touch sensation in a virtual environment, but also psychological studies and haptic applications. When a user interacts with a target object, visual and tactile matching of the perceived object is very important. Yamaguchi et al. conducted a psychological study to investigate the degree of matching required in visual and tactile sensations when tactile sensations of the image and the real object are presented simultaneously [1]. They prepared line-grating textures with different spatial frequencies and found a permissible range for the discrepancy between tactile and visual perception in the case of a one-dimensional grating. Kaneko and Kajimoto developed and verified a measurement system for determining skin displacement on textured surfaces [2]. The developed system spatially measured the skin shear and vibration of the contact area to reproduce the texture sensation. Therefore, the data obtained from the measurement system are a design parameter for developing tactile devices and rendering methods. This also includes haptic actuators/devices that create touch information and convey it to the users. Tactile information is a key factor for enhancing interactions with virtual objects that are displayed on a screen in consumer electronic devices. Mason et al. suggested a vibrotactile actuation mechanism for creating a variety of haptic sensations in large touchscreen display devices [3]. They investigated the influence of the electrode configuration in an actuation mechanism on maximizing vibrotactile information, and presented an electrostatic resonant actuator (ERA) with a moving mass and dual electrodes. These results show that the dual-electrode configuration can significantly increase the vibration intensity compared with the conventional ERA. This demonstrates the promising potential of the proposed actuator for generating vibrotactile feedback in large touch displays. Xing et al. presented a tactile device by arranging a piezoelectric actuator array to generate a rich haptic sensation, and established a mathematical model to express its force vibration response [4]. Furthermore, they investigated the vibrotactile performance of the proposed tactile device.

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This issue investigates the effect of vibrational stimulation created by vibrotactile actuators on the ability of humans to perceive virtual objects, human manipulation performance in dynamic tasks, learning/enhancing motion skills, the subjects' reported workload, etc. Toda et al. constructed a measurement system consisting of a vibration motor, motor driver, microcontroller, and force sensor to examine whether applied vibration on the big toenail influences the center of mass movement during walking [5]. Vibrotactile stimulation of the big toenail did not influence the amplitude of the center of the mass movement, but changed the walking speed, stance time, and center of mass movement in the lateral direction at baseline.

Kinesthetic sensation and tactile feeling are important factors when a user manipulates and operates an object. Jeong et al. proposed the design of kinesthetic devices for haptically simulating a mock circulatory system and showed that the design overcomes conventional cardiovascular simulators [6]. The design of the haptic devices began to describe the human blood pressure waveform and then establish a simple mathematical model of the cardiovascular system. Subsequently, they showed that the proposed design could be used for the palpation of the human cardiovascular system. Hassan et al. presented a pneumatically controlled haptic mouse that created kinesthetic pressure and vibrotactile sensations [7]. The presented haptic mouse was composed of a stretchable layer to generate a variety of haptic sensations (such as pressure, vibration, and impulse) and a non-stretchable layer to maintain its shape. Moreover, they addressed haptic rendering methods to compute realistic haptic sensations. Heo et al. suggested a tiny rotary haptic actuator using magnetorheological fluids that could easily be inserted into small handheld devices [8]. To create large torque feedback in small-sized devices, they used two operation modes of MR fluids and optimized the design of a tiny rotary haptic actuator.

The concept of visuo-haptic mixed reality (VHMR) with an encountered-type haptic display (ETHD) has been proposed [9]. They presented an unbound real-life tool to enable users to touch and manipulate real and virtual objects in a mixed environment. Three processes (tool tracking, haptic rendering, and visual rendering) were designed to evaluate the concept of VHMR. Through evaluation, they found that the visual and haptic information were well synchronized. Escobar-Castillejos et al. suggested a visuo-haptic framework that combined game engines and haptic devices [10]. An experiment was conducted to show that the proposed framework enhanced a user's ability to interact with virtual objects and provide better visualization. Semin et al. investigated the masking effect of haptic stimuli under two different types of vibrations (mechanical vibration and electrovibration), and suggested a haptic rendering method to remove the mutual masking effect [11]. Through the users' test, the proposed rendering method was proven to not only compensate for the mutual masking effect, but also render a variety of haptic stimulus intensities. Escobar-Castillejos et al. surveyed and organized medical guidance and surgical systems using haptic feedback [12]. In particular, they examined the technology, haptic feedback, learning methods, data collection, and storage of these systems. Bok et al. developed a tactile sensor that enabled robots and electronic devices to understand and distinguish the surface texture of a target object [13]. Based on the developed tactile sensor, they designed and fabricated a robot fingertip module to realize human mechanoreceptors.

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