A New Interactive Haptic Device for Getting Physical Contact Feeling of Virtual Objects

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ABSTRACT

The emergence of new and inexpensive virtual reality (VR) technology has made it relatively familiar to most users. We can create virtual 3D objects and paint on them in a VR spaces. Many of the VR controllers used for such operations provide haptic feedbacks by vibration when the user touches the virtual objects. In the real world, we can perceive not only the touch sensation but also the reaction force when touching and stroking the object's surface. However, it is impossible to provide a reaction force only with the vibration feedback. That is, there is a sensory gap between the VR space and the real world. The gap makes it difficult to work in the VR space in a manner similar to that in the real world. In this study, we focused on providing the reaction force from the virtual object to the user, and proposed a device that could provide the force feedback to the user's arm without connecting the device to large equipment.

Keywords: Haptic devices, virtual reality, force feedback.

Index Terms: Human-centered computing —Human computer interaction (HCI)—Interaction devices —Haptic devices; Human-centered computing — Human computer interaction (HCI) — Interaction paradigms —Virtual reality

1 INTRODUCTION

We can create virtual 3D objects and paint on them in a virtual reality (VR) space. For such an operation, we can use VR controllers that are provided by HTC, Oculus, and other vendors. When the users touch the virtual object, the controllers can provide a vibration feedback. However, it is impossible to provide a reaction force like giving the feeling of touching the real object only with vibration feedback. Therefore, the user`s hands easily penetrate the virtual object and it is difficult for the user to recognize the shape of the touched object. That is, there is a sense gap between the VR space and the real world. The gap makes it difficult to work in the VR space in a manner similar to that in the real world.

PHANToM [1] provides a force feedback to the virtual object [2] with a pen-type device that is controlled by a robot arm. However, the user`s working space is limited only to the movable space of the robot arm. To solve this limitation, Kamuro et al. [3] proposed a haptic device that provides the reaction force feedback (contact feeling with virtual objects' surface) to the user's fingertip by the movement of the device's handle when the user touches or traces the surface of the virtual object. However, with this device, the contact feeling is given to only the fingertips but notthe arm. Therefore we propose a device that can provide a contact feeling to the user`s arm without connecting the device to large equipment (Fig. 1).

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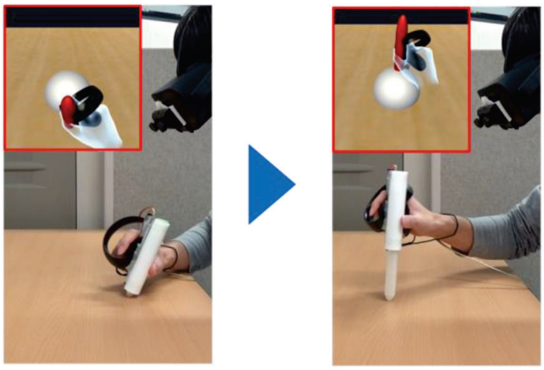

Figure 1: Reaction force provided by the proposed device via the tip extension and contraction mechanism.

2 PROPOSED METHOD

In the proposed method, the force feedback from virtual objects is provided by a contact between the device and the actual object in the real world. The device we propose has the mechanism to extend and contract its tip. When the user traces this device on a real table, its length varies according to the distance between the device and the virtual object on the table [4]. Specifically, when the user touches the virtual object with the device in the VR space, the length of the device is extended or contracted so that the user can obtain the force feedback from the contact point between the tip of the physical device and the real object (such as a table) in the real world (Fig. 1). The length of this device is determined by the distance from the contact point of the virtual device and the virtual object in the VR space to the physical surface in the real world (Fig. 2). The real-world reaction force realized with this method can be perceived as a reaction force in the VR space. This reaction force can always make the users recognize the surface of the virtual objects. Consequently, it is possible to fill the gap between the real world and the VR space.

3 IMPLEMENTATION

3.1 System Configuration

Figure 3 shows the device that we developed based on the proposed method. The system monitors the position and

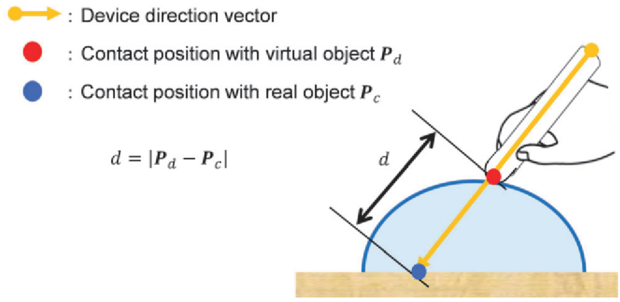

Figure 2: Calculation of the device distance.

orientation of the device in VR space, which are tracked by using Oculus Touch. The extension and contraction mechanism of the device consisted of an actuator with a knob (Alps Inc., Motor N fader RS60N11M9A0E) and the covered pen-shaped tip. The pen-shaped tip and its cover were fabricated with a 3D printer. The movable range of the knob is 10 cm, the position can be changed in 1024 steps, and its speed of motion can be changed in 256 steps. It has a fixing force up to 100 N and push-pull force up to 50 N. An Arduino board controls the movement of the knob through the actuator. We realized the extension and contraction of the device by attaching the tip to the knob and moving it back and forth.
We used a PC (Windows 10 Pro, CPU Intel Core i5-8400, 16 GB RAM, GPU NVIDIA GeForce GTX1080 Ti/11 GB GDDR5X) for device control and VR space rendering, and a head-mounted display (Oculus Rift CV1) for the VR space presentation, and Unity 5.6.2f1 (64-bit) for the development environment. The presentation of the VR space and the control of the device were executed at 90 fps.

3.2 Extension and Contraction Control Model of the Device Tip

The tip of the physical device is extended and contracted to provide force feedback of virtual objects, because it is necessary to keep the tip position of the virtual device on the surface of the virtual object. Furthermore, when the user traces virtual objects downward, the device has to be not only contracted but also fixed so that it does not penetrate virtual objects. The user can recognize the shape of a virtual object by moving the device along the surface of the virtual object with this control.

However, the user feels a stronger force feedback than necessary when the device continuously performs between holding strongly (the tip is fixed and pushing back (the tip is moving). Because of that, even while the user is tracing a smooth virtual object, the user feels like tracing a rough shape. In order to realize smooth tracing, the speed of motion of the tip v has to be changed smoothly according to the extension and contraction distance d. This means that if d is large, the system increases the device's speed of motion, and contracts the device quickly. On the contrary, if d is small, the system decreases the speed of motion. The speed of motion v in the current frame is calculated by using equation (1) and (2).

$$v = \alpha \cdot v_{\text{MAX}} + (1 - \alpha) \cdot v_{\text{MIN}} \tag{1}$$

$$\alpha = \frac{d}{l_{\text{MAX}}} \tag{2}$$

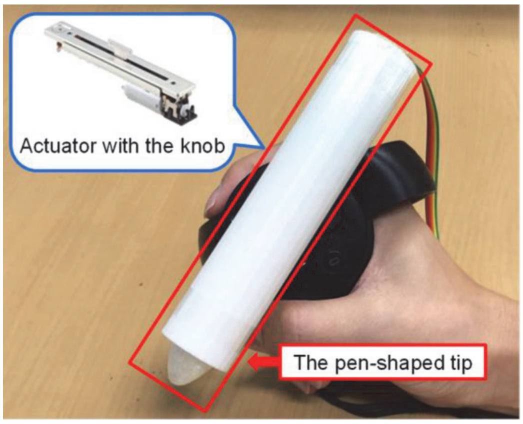

Figure 3: Device having an extension and contraction mechanism.

where v_{MAX} is the maximum speed of motion, v_{MIN} is the minimum speed of motion, l_{MAX} is the maximum length of the device, and d is the extension and contraction distance.

4 Demonstration

In our demonstration, participants wear Oculus Rift and touch virtual objects in the VR space with our device (Fig. 1). The virtual objects are a sphere, a cube, and their combinations, and are located on a virtual table. The virtual hand with the device is displayed in the position of the hand holding the device. By touching and stroking the virtual object with the device, the contact feeling from the virtual object is provided. The users note their experiences with both the proposed method and the vibration feedback used in the VR controller and compare them.

5 Conclusion

In this study, we proposed a method of providing force feedback between a virtual object and a device. In our method, the length of the device is extended or contracted so that the user can obtain the force feedback from the contact point between the tip of the physical device and the real object in the real world. We also developed a device with a mechanism to extend and contract its tip depending on the user's manipulation. When the user creates virtual objects and paints on them in VR space, they can obtain the contact feeling with a sensation of reality from the device. It is possible to fill the gap between the real world and the VR space.

In future work, we will provide more realistic touch sensations such as the textures and hardness of virtual objects by using vibration [5] or controlling the reaction force.

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