Wearable Haptic Device that Presents the Haptics Sensation Corresponding to Three Fingers on the Forearm

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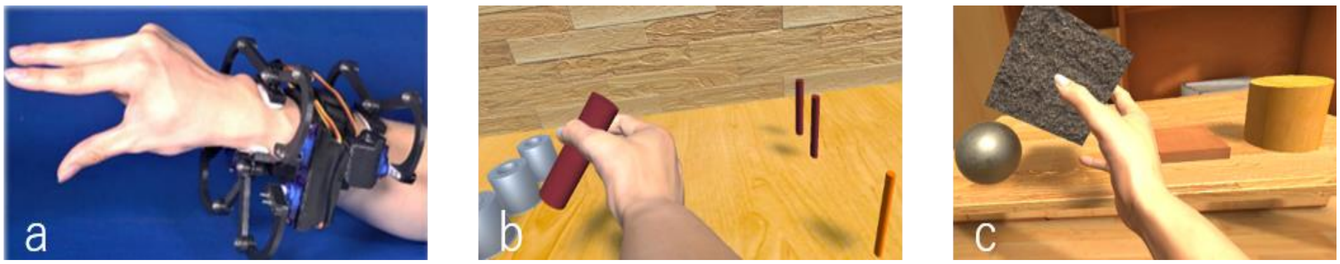

Figure 1: (a) Haptics Display (b, c) Touching and Grasping an objects

ABSTRACT

In this demo, as an attempt of a new haptic presentation method for objects in virtual reality (VR) environment, we developed a device that presents the haptic sensation of the fingertip on the forearm, not on the fingertip. This device adopts a five-bar linkage mechanism and it is possible to present the strength, direction of force. Compared with a fingertip mounted type displays, it is possible to address the issues of their weight and size which hinder the free movement of fingers. The experiences in the VR environment improved compared with without haptics cues situation regardless of without presenting haptics information directly to the fingertip. In this demo, we extended the method to three fingertips (thumb, index finger and middle finger) and three locations on the forearm using a five-bar linkage mechanism.

Author Keywords

Human-centered computing → Haptic devices

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces-Haptic I/O

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INTRODUCTION

Many studies have attempted to present tactile information in the virtual reality (VR) environment. The fingers are the main targets of haptics presentation in VR and many wearable tactile displays for the fingers, such as finger type and glove-type displays have been proposed [1][2]. However, the weight and size of these tactile displays typically hinder the free movement of the fingers, especially in a multi-fingers scenario. Therefore, we have proposed a method of presenting the haptic sensation of the fingertip to the forearm, including the direction of force, to address these issues [3]. In our previous report, we developed a device using a five-bar link mechanism that presents information on the force perceived by the fingertip, including the direction. The top side of the forearm was found as appropriate part corresponding to the index finger. In this paper, we present a follow-up study in which we extend the method to a three-fingers case. A minimum of three fingers is needed to firmly grip or manipulate an object, and therefore it can be adopted in numerous situations including teleoperation. The device weights about 190g and is made of ABS plastic injected by a 3D printer. It can be attached and detached using the Velcro tape. The device is connected to the PC through a microcontroller (NXP mbed 1768). LeapMotion was used for finger tracking.

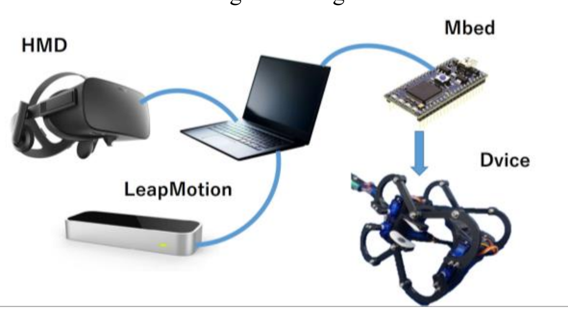

Figure 2: System Overview

SYSTEM DESIGN

The device adopts a five-bar linkage mechanism, which unlike its original structure, adopts an M-shaped structure. Tsetserukou proposed this as a link mechanism for presenting the sensation of force to the fingertip [4] or to the palm [5]. Based on these previous studies, we created a device that can be worn on the forearm. Two-DoF movement can be achieved by controlling two servomotors (Umemoto LLC Tower Pro SG 90 Digital · Micro Servo). The parts that present the haptic sensation can move up and down, left and right. Pressure sensation can be presented by the up and down movement and tangential friction sensation can be presented by the left and right movement. The maximum force in the downward and tangential directions is 6.0 N and 1.2 N, respectively.

The whole device is composed of two five-bar linkage mechanisms on the dorsal side of the forearm, separated by 100 mm, representing the index and middle fingers, and one five-bar linkage mechanism on the volar side of the forearm, representing the thumb. The separation is well above the two-point discrimination threshold of forearm skin, which is around 40 mm [6] (Figure 2).

We have reported that we chose four candidate locations for the haptic presentation of the index finger: the dorsal and volar side of the forearm close to the wrist, and the dorsal and volar side of the forearm on the elbow side. The results showed that the dorsal side of the forearm close to the wrist was the best location to present haptic sensation to the index finger [3]. Our current prototype is based on this result: the dorsal side of the forearm close to the wrist relates to the index finger, the dorsal side away from the wrist relates to the middle finger, and the volar side relates to the thumb.

Figure 3: Device Overview

USER EXPERIENCE

Following are the user experience of our demonstration. First, various objects are placed in VR space and users handle them by using our developed device. Demonstration related to handling task performance is performed. We prepare a classical peg-in-hall task, in which users grasp a peg and place it in the hole. We have confirmed in our experiment that our haptics device help performing this task with shorter time. Secondly, we considered the grasping and lifting of an object as a task involving multiple fingers and multiple directions of force. We have confirmed in our experiment that the realism was greatly improved when haptic sensation was presented by the device. The participants commented that "the feeling was close to the fingertips" and "I clearly felt a sense of grasping an object, not just cognition of touching or grasping an object, even if the touch was not on the fingertips." These comments suggest that realism can be improved by presenting a force applied to the fingertip on the forearm.

Figure 4: VR Applications Sample

CONCLUSION AND FUTUREWORKS

We proposed a method for presenting haptic information generated at the fingertip to the other parts of the body, in a three-finger scenario (thumb, index finger, middle finger). Specifically, we created a device that presents tangential and vertical forces applied to the index finger, thumb, and middle finger, and showed that the use of this device can lead to an improvement in the realism of the experience of gripping and lifting an object in a VR environment.

Because the device currently has only two DoF, we could only present the sensations of pressure (up and down direction) and tangential friction (right and left direction). We will improve the device by adding a third DoF to present various sensations, as well as applying it to a two-handed situation.

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