Haptopus : Haptic VR Experience Using Suction Mechanism Embedded in Head-mounted Display

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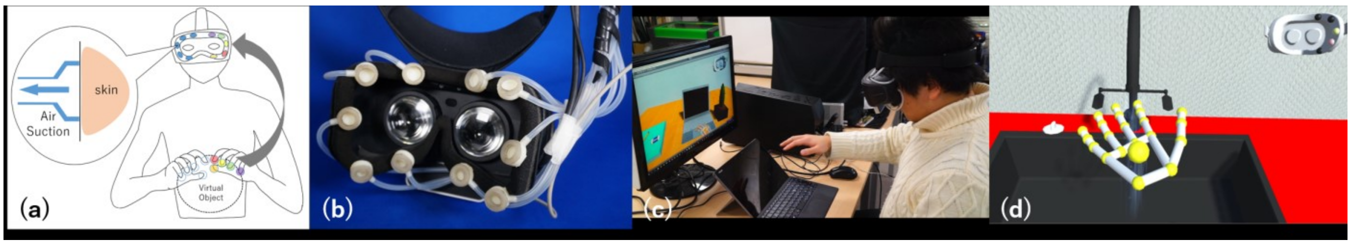

Figure 1: (a) Concept images of Haptopus, (b) Haptopus, (c) playing application, (d) user's view

ABSTRACT

Along with the spread of VR experiences using low-cost head-mounted displays (HMDs), many proposals have been made to improve the VR experience by providing tactile information to the fingertips. However, attaching a device to fingertips has issues such as difficulty in attaching and detaching and hindering free movement of fingers. To address these issues, many methods have been proposed to incorporate a haptic presentation mechanism in an HMD, but only for presenting passive tactile information of the face or whole body. To present the tactile sensation of the fingertips in a configuration that can be incorporated in an HMD, we developed a skin-suction mechanism called Haptopus to simulate the pressure applied to multiple fingers. Haptopus can express the sense of fingers touching virtual objects by presenting corresponding suction pressure around the eyes.

CCS CONCEPTS

• **Human-centered computing → Haptic devices;**

KEYWORDS

Haptopus, Suction stimulus, Haptics HMD, Virtual Reality

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1 INTRODUCTION

Low-cost head-mounted displays (HMDs) have recently become widespread and are used in a wide range of applications. With the spread of HMDs, many studies have been conducted to combine visual information with tactile information for a more immersive virtual reality (VR) space.

While there were several studies on wearable tactile prssentation (Pacchierotti, et al., 2017), current wearable-type devices have practical issues such as difficulty in attaching and detaching and mutual interference between devices when worn on multiple fingers.

To address these issues, methods have been proposed to present the tactile sense corresponding to fingers and hands in the VR space to the other parts of the body. Such tactile presentation to different sites is common in the study of prosthetic hands, and many attempts have been made to place transducers on arms and shoulders. For application to the VR space, for example, a study for presenting a sense of touch received by the hand to the soles of the feet has been conducted (Okano, et al., 2016).

We argue that one alternative body part of presenting finger tactile sensation is the face. If we can embed tactile display into an HMD, we do not need to wear additional haptic devices, solving the above issues. Many proposals to include a tactile-sense-presentation mechanism into an HMD have been made, e.g., vibration tactile sense, balloon compression, and temperature presentation. However, the vibrotactile sense needs to convert pressure sensation, which is important tactile information when handling objects, into vibration, which is somewhat annoying to be presented continuously. Balloon compression can present a sense of pressure, but when it is embedded in an HMD, the balloon pushes up the HMD and causes alignment issues. Temperature presentation can express environmental conditions, but its low spatial resolution hinders its use to express multi-fingers information (Oliveira, Brayda, & Nedel, 2017) (Kon, Nakamura, & Kajimoto, 2017) (Peiris, Peng, Chen, Chan, & Minamizawa, 2017).

Our idea is to use an air-suction mechanism instead of a balloon mechanism. It is known that air suction on the skin with a certain diameter generates the illusion of pressure. Using this illusion, the tactile-presentation mechanism can be much smaller than a balloon mechanism, and a multi-finger-type device can be built into an HMD. With this device, the user can perceive fingertip tactile information in the VR space as tactile information mapped on the face without needing to wear a separate fingertip device.

2 Haptopus

2.1 Suction Unit & Converting Suction into Pressure

We developed a mechanism called Haptopus that consists of a suction unit, which is shown in Figure 2. Suction is applied with an air-suction pump, and the air pressure is controlled using a solenoid valve. Although the skin mechanoreceptor responds to the magnitude of the strain energy, since the direction of the strain is difficult to perceive, it can be felt as being pressed with a certain diameter (Makino, Asamura, & Shinoda, 2004).

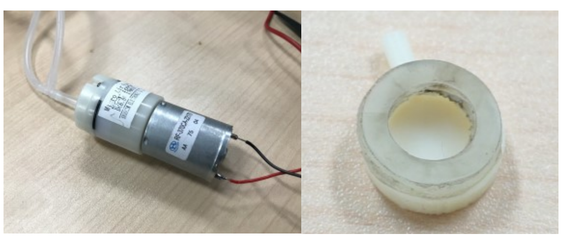

Figure 2: Suction unit & Suction port

2.2 Haptic Mapping of Transferring Touch Sense of Hand to Face

As shown in Figure 3, the tactile information of each fingertip is mapped to the face. This mapping is based on our preliminary experiment, which can be discriminated individually. The distance between each element is around 40 mm, and the inner diameter of the suction components is 8, 10, 12 mm, optimized for each location. The suction pressure was presented for 1 second and turned off for 1 seconds and the maximum suction pressure value was limited to -600 hPa so as not to leave a mark on the skin.

Figure 3: Haptic Mapping of Transferring Touch Sense of Hand to Face

3 DEMO EXPERIENCE

Haptopus can express the sense of fingers touching virtual objects by presenting corresponding suction pressure around the eyes (Figure 1). It can not only present a simple contact feeling but also pain sensation like a thorn or a needle by applying strong suction. It is also possible to express the softness of a contact object by controlling the presentation pressure in accordance with the user's motion. Furthermore, several stimulation points can correspond to multiple degrees-of-freedom of one finger, enabling expression of the force direction; thus, expression of the detailed characteristics of contact objects such as edges and irregularities (Figure 4).

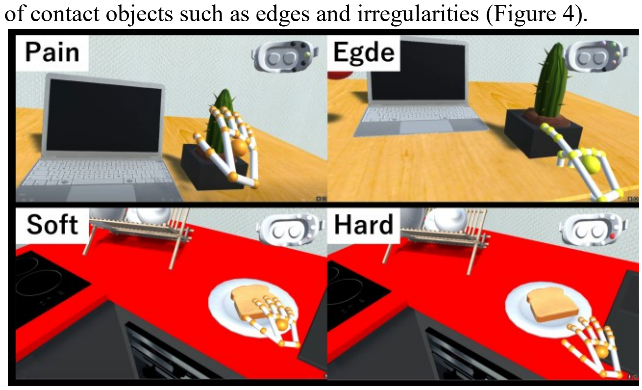

Figure 4 VR applications

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