HALUX: Projection-based Interactive Skin for Digital Sports

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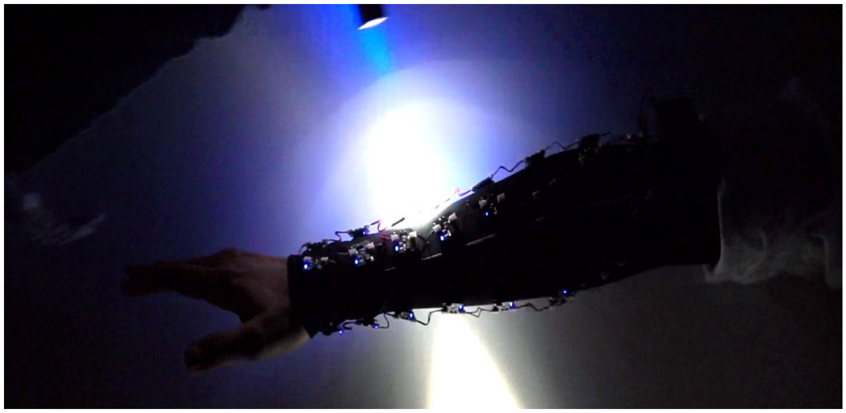

Figure 1: *HALUX let users feel projected light thus enables accurate and high-speed vibrotactile feedback.*

Abstract

Entertainment contents employing users' whole-body action is now becoming popular, along with the prevalence of low-cost whole-body motion capture systems. To add haptic modality to this context, latency becomes a critical issue because it leads to spatial disparity between the assumed contact location and tactile stimulation position. To cope with this issue, we propose to project drive signal in advance so as to eliminate latency derived from communication. We do not explicitly control each vibrator, but we project "position-dependent, vibration strength distribution" image. Furthermore, the system becomes highly scalable, enabling simultaneous drive of hundreds of units attached to the body.

Keywords: digital sports, display based computing, haptic interaction, projection, virtual reality

Concepts: • **Human-centered computing ~ Interaction devices;** *Haptic devices;*

1 Introduction

With the spread of the whole-body motion capture devices for video games, audiovisual entertainment contents using the whole-body action as an input is now becoming popular. To further realize immersive experience, the whole body haptic sensation is considered important, and many studies placed numerous vibrotactile actuators on large body area. A vest type tactile display was developed to present the information of tactile sensation onto the whole-body [Lemmens2009] [KOR-FX 2014]. A chair was also frequently used to embed vibrators [Karam2010] [Israr2011]. Sato et al. [2008] developed arm-worn tactile display to present insects-crawling experience on the arm. Recently the whole-body vibrotactile interaction was demonstrated in the game *Rez Infinite* for PlayStation VR. *Skinterface* [2015] is another example to achieve immersive tactile interaction in VR space.

In terms of interactivity, they commonly have a significant issue of latency when the user's motion is fast, such as in the case of digital sports. Latency may occur due to the slow response of vibrator or wireless communication delay. For example, commonly available vibrator using eccentric rotating mass (ERM) and Bluetooth communication both have around 100 ms delay. If we assume 200 ms delay between user's action and vibrotactile presentation, and body velocity of 5m/s (for comparison, baseball pitcher's hand reaches to around 30m/s), this latency causes positional disparity of up to 1 m (Figure 2), which greatly degrades the feedback quality.

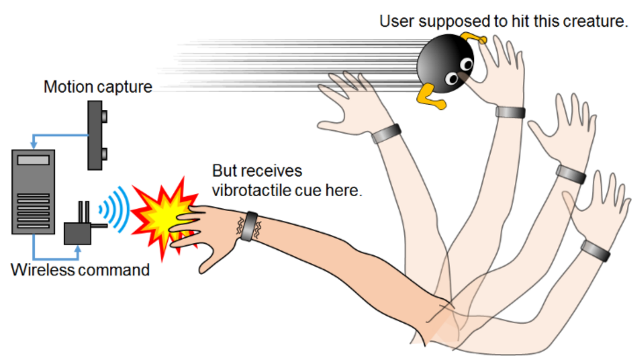

Figure 2 *Latency causes large tactile displacement.*

Our idea is to use a projector to drive vibrators (Figure 3). A high-response voice coil actuator and an optical sensor are attached on the user's body to respond to the projected pattern. We do not explicitly control each vibrator one by one, but we project "position-dependent, vibration strength distribution" image in advance. With this, the latency derived from communication is

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eliminated. Furthermore, the system is highly scalable, enabling simultaneous drive of thousands of units attached to the body.

Sugimoto et al. [2005] have developed a control method of robots using projected light and achieved high response and accurate positioning, called Display-based Computing (DBC). Hiraki et al. [2016] and Rekimoto et al. [2009] also used DLP projector as input device. Our method can be regarded as an application of the DBC to the whole body haptic feedback.

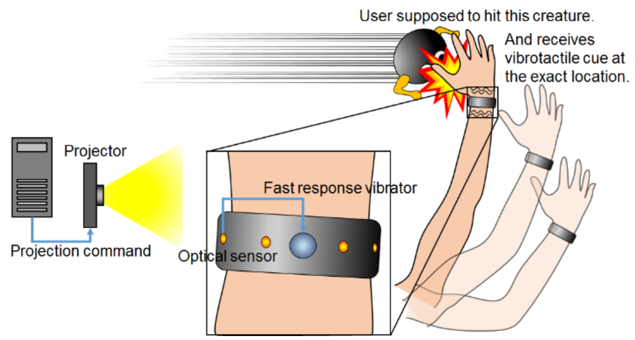

Figure 3 *Projection of vibration strength distribution.*

2 Hardware

Figure 4 shows a sensor-vibrator unit and example layout on one arm. The unit comprises a linear resonant actuator (LRA) (LD14-002, Nidec Copal Corporation), a photo-transistor (PT19-21C, Everlight Electronics CO., Ltd.), an oscillation circuit for LRA, and a LED. LRA was selected for its fast response (less than 20ms). The resonance frequency of oscillation circuit for LRA control is set to 150Hz, and its amplitude is modulated by the photo-transistor. By mounting large number of the units on the whole-body (e.g. 32 units per one arm), users can not only feel the existence of virtual objects, but its size, shape, and direction of motion.

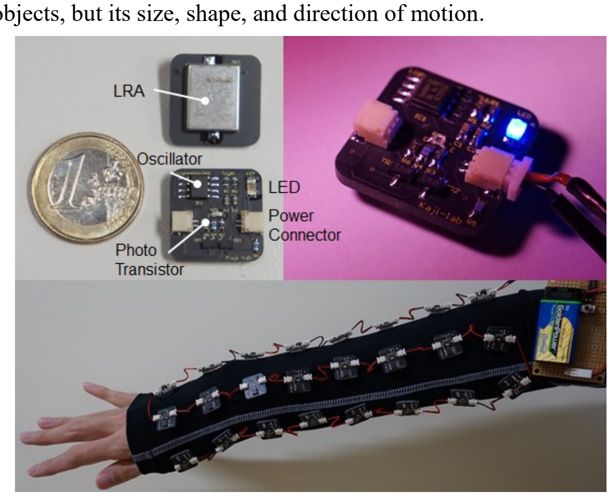

Figure 4 *Sensor-vibrator unit and example layout.*

3 Demo Experience

In the mid-1970s, Myron Kruger presented a first Augmented Reality installation named Videoplace [Kruger1985]. Videoplace used a camera to capture the user's body and a projector to present it with digital creatures on screen, enabling users to fully interact with the digital world.

Our demonstration, named HALUX (HAptic-LUminance eXchange), inherits this setup with addition of the whole-body haptic feedback (Figure 1, Figure 5). The system comprises a motion capture sensor (Kinect v2, Microsoft Corp.), a projector, a head mounted display (Oculus Rift DK2, Oculus VR, LLC), and more than 100 sensor-vibrator units for arms, abdomen and legs. The HMD is used to realize full immersive visual experience as well as to blindfold users from projected lights, but setup without HMD is also possible. The motion capture sensor is used to grasp user's posture and project vibration strength distribution before the user's motion.

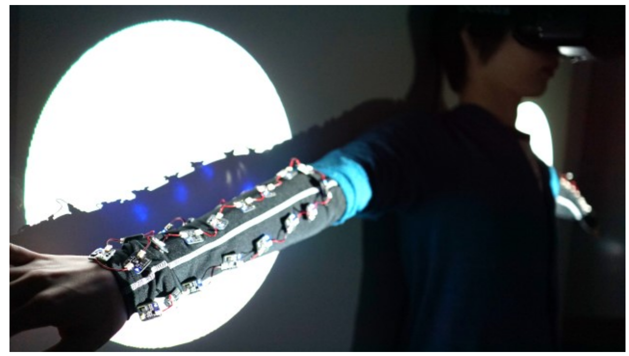

Figure 5 *Demo overview.*

Acknowledgement

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