HaptoMapping: Visuo-Haptic AR System using Projection-based Control of Wearable Haptic Devices

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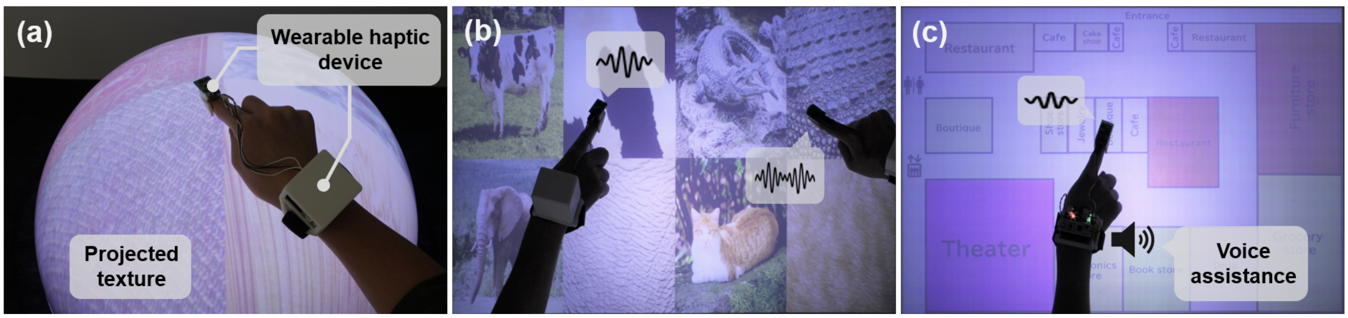

Figure 1: Application scenarios of HaptoMapping: (a) Texture design support system, (b) Visual and haptic dictionary of animals, (c) Interactive map enhanced with haptic (and audio) information for both sighted and visually impaired people.

ABSTRACT

Visuo-haptic augmented reality (AR) systems that present visual and haptic sensations in a spatially and temporally consistent manner have the potential to improve AR applications' performance. However, there are issues such as enclosing the user's view with a display, restricting the workspace to a limited amount of flat space, or changing the visual information presented in conventional systems. In this paper, we propose "HaptoMapping," a novel projection-based AR system, that can present consistent visuo-haptic sensations on a non-planar physical surface without installing any visual displays to users and by keeping the quality of visual information. We implemented a prototype of HaptoMapping consisting of a projection system and a wearable haptic device. Also, we introduce three application scenarios in daily scenes.

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1 INTRODUCTION

Visuo-haptic augmented reality (AR) systems that provide visual and tactile sensations to users can promote natural and efficient user interactions in AR applications. To ensure effective visuo-haptic AR experiences, we need to keep the spatial and temporal consistency of the visual and haptic sensations. Several systems have achieved to maintain the consistency [Bau et al. 2010; Harders et al. 2009], though, they had to enclose the user's view with a display or restrict the workspace to a limited amount of flat space. Another approach that solves the above problems is to combine a projection-based AR system and haptic devices controlled by the luminance of projected images [Rekimoto 2009; Uematsu et al. 2016]. However, potentially, the quality of projected images is significantly degraded because the luminance of the original image needs to be spatially modulated depending on the desired haptic information.

In this paper, we propose "HaptoMapping," a projection-based visuo-haptic AR system, that ensures the consistency by keeping the quality of visual information. We use pixel-level visible light communication (PVLC) [Kimura et al. 2008] that enables us to embed imperceptible information to projected images by fast flashings of binary images. It keeps the quality of projected images by compensating the luminance to be perceived as the desired one, and the embedded information varies with each pixel. It controls a wearable haptic device at a pixel level using the information. We can employ various surfaces for screens using the projection mapping technique. Also, multiple users can simultaneously experience it because no visual display needs to be inserted between the users and the surface, and it is easy to extend to multimodal by adding other sensory presentation devices such as audio speakers.

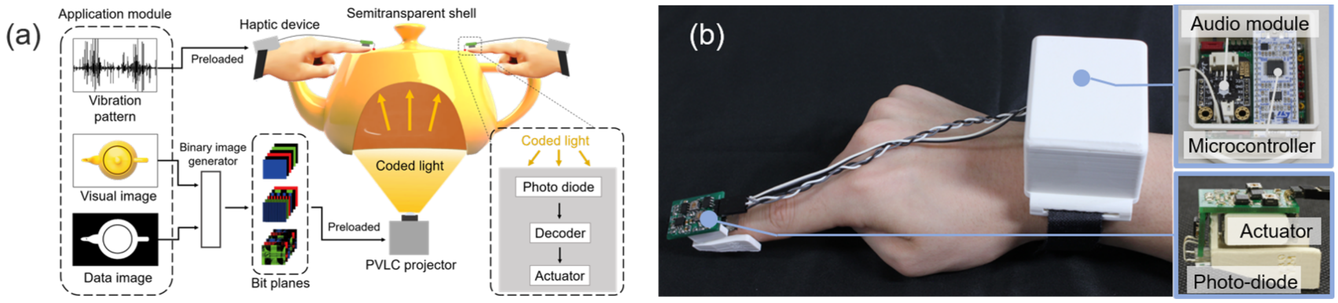

Figure 2: (a) Configuration of HaptoMapping , (b) The haptic device controlled by PVLC

2 METHODS AND IMPLEMENTATION

Fig. 2a shows the concept of HaptoMapping. We have developed a prototype of the system comprised of a projection system and wearable haptic devices.

As the projection system, we utilize PVLC for embedding haptic information into projected images using a DLP projector. The projector projects a series of binary images represinting data in a short time (8.5 ms). A photosensor on the device detects the series as signal information, while human perceive it as a color image. We employed a high-speed DLP projector development kit (DLP LightCrafter 4500, Texas Instruments) for PVLC. We embedded data on x and y coordinates and the haptic information's ID to each pixel. We have created a generator of the binary images that takes a visual image and a data image of which each pixel value represents the pixel's haptic data as inputs. It first generates a uniform binary image for synchronization. Then, it creates binary images whose each pixel value represents each bit of x, y coordinates, and the haptic data of the pixel. Finally, it adds binary images that compensate for the nonuniform luminance caused by data transmission (projection) to be perceived as the visual image.

We design our haptic device to present various haptic sensations depending on the user's position in the projected image. The prototype of the device is controlled by PVLC in Fig. 2b. It comprises a receiver with a photodiode (S2506-02, Hamamatsu Photonics), a controller module, a vibration actuator, and a Li-Po battery. The controller module has a microcontroller (Nucleo STM32F303K8, STMicroelectronics) and an audio module (DFR0534, DFRobot) to present vibration information stored in it as audio files. The microcontroller acquires the position of the device and haptic information by decoding the signals and send it to the audio module to drive the actuator. We used a linear resonant actuator (HAPTIC™ Reactor, ALPS ALPINE) as the vibration actuator.

3 APPLICATIONS

We introduce three application scenarios using HaptoMapping. Fig. 1a shows a realistic texture design support system onto a nonplanar surface. Users can use this system when seeking a desirable texture from a bunch of texture samples for a new product. This system helps the users to test textures on 3D surfaces and to find a suitable texture without scattering their workspaces by real texture samples. We utilized the LMT haptic texture database [Strese et al. 2014] for projected images and haptic information.

Fig. 1b shows a visual and haptic dictionary of animals. Users can not only see graphics of animals but also touch skins of them. Since each device independently receives the embedded information, multiple users can simultaneously experience this visuo-haptic AR application. Users can see animals' photos and touch their skins virtually, and therefore, they may learn how animals look like and how their textures are different.

Fig. 1c shows an interactive map enhanced with haptic (and audio) information for both sighted and visually impaired people. Visually impaired people can acquire information on the map: the shape of the aisle of a place (a mall) by vibration and types of stores by sounds while sighted people can do by seeing the map without perceiving the embedded information. Since it is easy to extend to multimodal by adding another sensory presentation device, we added an audio speaker to the user's wrist. When a user scans the surface, the actuator vibrates on the shop area, and the speaker tells what kind of shop it is. This system is reconfigurable in terms of visual, audio, and haptic information.

4 CONCLUSION

We introduced HaptoMapping, a visuo-haptic AR system that ensures the spatial and temporal consistency between the visual and haptic sensations and also showed three application scenarios in daily scenes. As future work, we will design a rendering method for haptic sensations corresponding to the user's movements.

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REFERENCES

Olivier Bau, Ivan Poupyrev, Ali Israr, and Chris Harrison. 2010. TeslaTouch: Electrovibration for touch surfaces. In *Proc. UIST '10*. 283–292.

Matthias Harders, Gérald Bianchi, Benjamin Knoerlein, and Gábor Székely. 2009. Calibration, registration, and synchronization for high precision augmented reality haptics. *IEEE TVCG* 15, 1 (jan 2009), 138–149.

Sho Kimura, Ryo Oguchi, Hideo Tanida, Yasuaki Kakehi, Keita Takahashi, and Takeshi Naemura. 2008. PVLC Projector: Image projection with imperceptible pixel-level metadata. In *Proc. ACM SIGGRAPH '08 Posters*. 135:1.

Jun Rekimoto. 2009. SenseableRays: Opto-haptic substitution for touch-enhanced interactive spaces. In *Proc. CHI EA '09*. 2519–2528.

Matti Strese, Jun-Yong Lee, Clemens Schuwerk, Qingfu Han, Hyoung-Gook Kim, and Eckehard Steinbach. 2014. A haptic texture database for tool-mediated texture recognition and classification. In *Proc. HAVE '14*. 118–123.

Haruya Uematsu, Daichi Ogawa, Ryuta Okazaki, Taku Hachisu, and Hiroyuki Kajimoto. 2016. HALUX: Projection-based interactive skin for digital sports. In *Proc. ACM SIGGRAPH '16 Emerging Technologies*. 10:1–10:2.