Cross-Field Haptics: Push-Pull Haptics Combined with Magnetic and Electrostatic Fields

Satoshi Hashizume[*], Kazuki Takazawa, Amy Koike, Yoichi Ochiai
University of Tsukuba

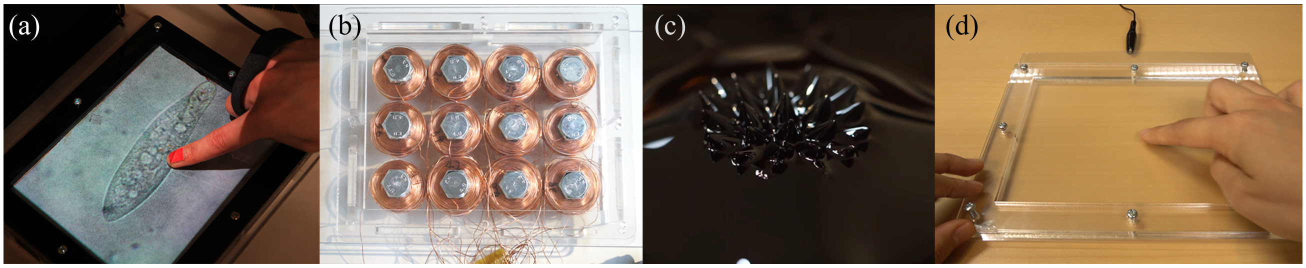

Figure 1: *(a) The user feels the paramecium caudatum sensation from the surface; (b) Electromagnet array layer; (c) Magnetic fluid layer; (d) Conductive electrode layer*

Keywords: haptic devices, cross-field, magnetorheological fluid, electrovibration

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

1 Introduction

The representation of texture is a major concern during fabrication and manufacturing in many industries. Thus, the approach for fabricating everyday objects and the digital expression of their textures before fabrication process has become a popular research area. Although it is easy to change the texture of objects in the digital world (i.e. just setting texture parameters), it is difficult to achieve this in the real world.

Tactile feedback allows displaying texture and affordance of contacts to users. In conventional studies, interaction using tactile feedback has been actively researched. Most haptic feedback systems currently being studied are categorized into two areas; wearable or non-wearable devices. Tactile feedback using wearable devices often uses force feedback devices, e.g., users wear the feedback devices on their arm or fingertips. Wearable devices can provide strong tactile feedback and tactile presentation for any condition. However, it is difficult to implement larger wearable devices to mount on the user. On the other hand, tactile feedback with non-wearable devices mainly utilizes environmental-type tactile displays such as magnetic field, electrostatic field and acoustic fields. Because the user does not necessarily wear the device, the user's load becomes a low-level load.

In present study, we aim to research new material interactions as environmental-type tactile display. We aim to develop a new tactile display to express various textures. The proposed system physically deforms and changes the physical force between the finger and the device. To achieve this, we combine magnetic and electrostatic fields. We utilize magnetorheological fluid (MRF) which is flexible liquid affected by the magnetic field, and electrovibration on a film that covers MRF to generate adsorption force from the electrostatic field to develop this device.

We compared tactile sensation for single field and multiple fields. Through verification, it was determined that haptics feedback using multiple fields provides a wide range of tactile sensations compared with that using a single field. By combining different types of force (e.g., pull and push) simultaneously, the proposed system can display various textures. To the best of our knowledge, this is early study that combines multi-field physical quantities to render haptic textures. The electrostatic and magnetic fields do not influence each other. Further, from the experiment, it was determined that the fields do not influence each other's tactile presentation.

2 Related Works

MRF is mainstream medium for tactile presentation used with magnetic field. MRF is a fluid that changes viscosity as per the given magnetic field. It is possible to express the softness of the object by changing the viscosity of the magnetic fluid and it is also possible to express bumpy through fluid vibrations. MudPad [Jansen et al. 2010] which use MRF, has a very low reaction time and can provide instant multi-point feedback for multitouch inputs. In this study, we employ MRF and magnetic field to render "push" haptic feedback.

Adding to MRF, we present haptic feedback using a technique called electrovibration [Mallinckrodt et al. 1953] as "pull" haptic feedback. Electrovibration creates a rubbery feeling when dragging a dry finger over a conductive surface covered with a thin insulating layer excited with a high voltage signal. TeslaTouch [Bau et al. 2010] uses electrovibration, which adds a signal to an electrode. Am interaction display and a touch display were developed using electrode without a power unit. REVEL [Bau et al. 2012] employs TeslaTouch for AR. Electrovibration can provide haptic feedback without using a complicated actuator and device. However, it is necessary to move a finger because tactile presentation is related to the electrostatic force generated between a finger and the surface. Therefore, it is impossible to provide one point haptic feedback such as button.

This study combines multiple haptics technologies as they help overcome each otherfs disadvantages and help improve interaction width. Cross-Field Aerial Haptics [Ochiai et al. 2016] draw tactile interface in the air by combining ultrasonic waves and laser plasmas. Cross-field haptics is not a widely studied in haptic areas. To explore haptic display areas, we decided to use the electrostatic and magnetic fields simultaneously. The magnetic field generates force

[*]e-mail:s1513110@u.tsukuba.ac.jp

SIGGRAPH '16, July 24-28, 2016, Anaheim, CA,
ISBN: 978-1-4503-4371-8/16/07
DOI: http://dx.doi.org/10.1145/2945078.2945108

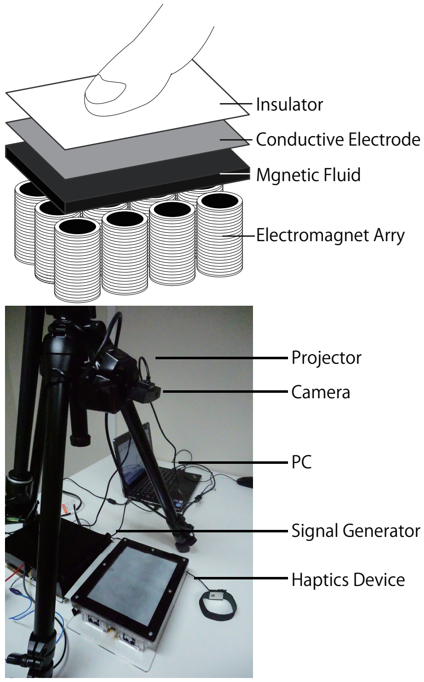

Figure 2: *System Overview*

to push up and down using MRF. The electrostatic field generates force go down in the right and left directions using electrovibration. The top, bottom, right and left directions can be produced by combining the power generated to pull with the power generated to push.

3 Implementation

The device consists of an electromagnet array layer, a magnetic fluid layer, and a conductive electrode layer (upper Figure 2). MRF is a liquid whose viscosity changes in response to a magnetic field. When no magnetic field is provided, the MRF acts as a Newtonian fluid such as water. However, in non-Newtonian fluids (Bingham fluids) such as butter, if a magnetic field is provided the viscosity is linearly controllable using a magnetic field. MRF is controled using an electromagnet. Further, to ensure that a groove of the magnetic field is not created on the screen, 12 coils (three vertical and four horizontal) are laid on the 12 mm$\times$17 mm screen. In this study we focused on the upward force of MRF. When viscosity changes, the force pushing up the finger by vibration created by switching the magnetic field in the electromagnet.

Electrostatic force part uses a conductive electrode. This part of system provides haptic feedback using electrostatics adhesion. Further, it also provides high-voltage electric vibration to the electrode. When a body is connected to GND and an electrode is struck, force is generated. Force is generated in the direction where a movement is resisted; therefore, the frictional force is generated. In this study, a transparent conductive film on the electrode, the insulation coating agent (Hayacoat), was applied as the insulating layer. The insulator is pitched by the electrode and the finger, and therefore, electric current does not flow into the human body. Even if it flows into the human body, it is restricted to 0.5 mA electric current, as there are constant current diodes of 0.5 mA on the GND side that is connected to the human body.

Arduino DUE and a personal computer are used for the control of a circuit (lower Figure 2). A finger that attached a marker is tracked with a camera, and the tracking position is used as input. A projector sends the image to a device based on the location of the tracked finger. An electronic signal is sent to the electromagnet and the electrode with a signal generator based on a tracked coordinate.

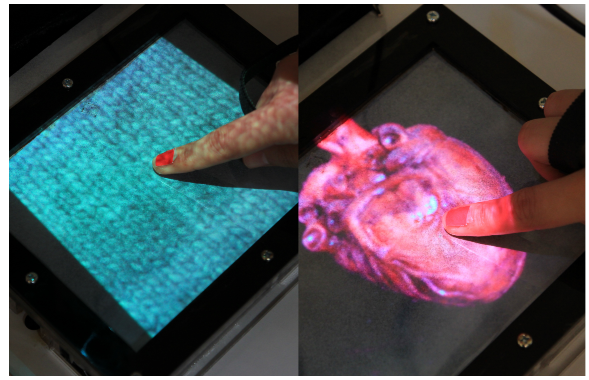

Figure 3: *Wool texture rendering (left) and reproduction of the heart motion (right)*

4 Application

Application to express various texture is possible (Figure 3 left). In order to do this, we change the frequency of the signal which add to electrode and electromagnet. TeslaTouch express texture using friction, our application express texture using the force of magnetic fluid in addition to friction.

Cross-field haptics can express the body tissue such as the heart and the liver (Figure 3 right). In the medical field such as the operations, accurate movement to match the state of the body tissue is essential. The exact behavior is performed easily if the body tissue can be expressed. To reproduce the organs, the texture of the surface, viscosity such as softness, and vibration such as pulsation is a need to express. Texture can expressed in electrovibration, the viscosity and vibration expressed using the MRF.

We understood that width of the sense of touch presentation spread from an experiment of cross-field haptics. The haptics feedback only for electrovibration can not provide tactile for a immobile finger, although this display can provide tactile for a immobile finger by combining electrovibration with MRF. However, there are some problems. Because of vibration by the MRF is big, friction feeling of electrovibration may be lost. It is necessary to regulate electricity to add to an electromagnet.

References

BAU, O., POUPYREV, I., ISRAR, A., AND HARRISON, C. 2010. Teslatouch: Electrovibration for touch surfaces. In *Proceedings of the 23Nd Annual ACM Symposium on User Interface Software and Technology*, ACM, New York, NY, USA, UIST '10, 283–292.

BAU, O., POUPYREV, I., LE GOC, M., GALLIOT, L., AND GLISSON, M. 2012. Revel: Tactile feedback technology for augmented reality. In *ACM SIGGRAPH 2012 Emerging Technologies*, ACM, New York, NY, USA, SIGGRAPH '12, 17:1–17:1.

JANSEN, Y., KARRER, T., AND BORCHERS, J. 2010. Mudpad: Tactile feedback and haptic texture overlay for touch surfaces. In *ACM International Conference on Interactive Tabletops and Surfaces*, ACM, New York, NY, USA, ITS '10, 11–14.

MALLINCKRODT, E., HUGHES, A. L., AND SLEATOR, W. 1953. Perception by the skin of electrically induced vibrations. *Science 118*, 3062, 277–278.

OCHIAI, Y., KUMAGAI, K., HOSHI, T., HASEGAWA, S., AND HAYASAKI, Y. 2016. Cross-field aerial haptics: Rendering haptic feedback in air with light and acoustic fields. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, USA, CHI '16, 3238–3247.