Tactile Element with Double-sided Inkjet Printing to Generate Electrostatic Forces and Electrostimuli

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ABSTRACT

We propose a tactile element that can generate both an electrostatic force and an electrostimulus, and can be used to provide tactile feedback on a wide area of human skin such as the palm of the hand. Touching the flat surface through the our proposed tactile element allow the user to feel both uneven and rough textures. In addition, the element can be fabricated using double-sided inkjet printing with conductive ink. Use of a flexible substrate, such as a PET film or paper, allows the user to design a free-formed tactile element. In this demonstration, we describe the implementation of the proposed stimuli element and show examples of applications.

Author Keywords

Tactile Display; electrostatic force; electro stimulus; conductive ink; inkjet printer; flexible device.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces Input Devices and Strategies.

INTRODUCTION

In recent years, a large number of studies have been conducted about haptic displays, which can provide tactile sensation to the user. Haptic displays for virtual reality (VR) applications have especially received a great deal of attention.Various tactile sensations for human hands have been considered such as frictional haptics (ultrasonic [6], tension control with wire [2], or electrostatic tactile [3]) and vibration haptics (mechanical vibration [9] or electrical stimulus [5]).

Humans perceive tactile feedback from the four types mechanoreceptors in the skin. These cells are distributed throughout the skin and, in order to provide a realistic experience, it is necessary to present multiple stimuli to a large area of skin [1].

Figure 1. Printed tactile devices: (a) VR glove, (b) adding tactile feedback to a binarized image, and (c) tangible user interface with tactile feedback.

Several groups have developed tactile displays for multiple stimuli. Yem et al. proposed a “FinGAR”[10] that can provide selective stimulation of four modes on the finger tips with a combination of mechanical vibrations and electrical stimuli. They conducted a study to evaluate the ability of their device to reproduce sensations of four tactile feedbacks. Pyo et al. developed a surface display that can generate both electrovibrations and mechanical vibrations [8].

Previous studies considered to generate haptics feedback to a specific part of the human skin such as finger tips [8, 10]. In contrast to these studies, we aimed to generate multiple stimuli to a large area of skin. In order to present haptics feedback not only to the finger tips but also to a large area of human skin such as palm of the hand, it is necessary to arrange multiple stimuli elements. However, there are limitations on the number of stimuli elements having a size of several centimeters that can be arranged due to spatial restrictions. There is also a possibility that these arrangements hinder the natural behavior of the human hand. Thus, in order to realize multiple stimuli to the human body, which includes not only the finger tips but also the palm of the hand, we need;

- small and thin stimulus elements in order to avoid spatial limitations.
- tactile feedback using multiple stimuli to provide more realistic haptics.
- flexibility and high degree of freedom for the shape of the elements.

In this paper, we consider a tactile display that meets these requirements (Figure 1) and we focus on electrostatic forces [7] and electrical stimuli [11]. Both stimuli can be realized by applying voltage to electrodes. In addition, in order to realize a tactile display that can generate both electrostatic forces and electrical stimuli, we fabricated a miniature tactile element using double-sided inkjet printing with conductive ink. Thus, our method allows the user to realize smaller, lighter, thinner, and more flexible tactile elements compared with previous vibration tactile elements. Using a flexible substrate such as a polyethylene terephthalate (PET) film or paper allows the user to design free-formed tactile elements and a variety of tactile devices using 2D CAD software. We have confirmed that both uneven and rough textures can be added on the flat surface presenting multiple stimuli, i.e., electrostatic forces and electrical stimuli [4]. In this demonstration, we describe the implementation of the proposed printed stimuli element and we show two types of applications; a wearable type and a stationary type, to show the potential of flexible substrate.

PROPOSED METHOD

The proposed tactile display is shown in Figure 2 and consists of electrode patterns printed on both sides of a thin PET film with conductive ink (NBSIJ-MU01, Mitsubishi Paper Mill). The electrode patterns are connected to a micro-controller (mbed LPC 1768, ARM Ltd) and a voltage of almost 500 V is applied to the electrodes (MHV 12-1.0K2000P, Bellnix Co., Ltd). The surface of the tactile display can present a vertical vibration stimulus to humans as a result of an electrical stimulus applied to the tactile display. In addition, the back of the tactile display can a present a frictional stimulus to humans as a result of an electrostatic force applied on the tactile display.

On the surface of the tactile display, electrodes with a 3 mm diameter are arranged with a separation of 2 mm. The right (red) electrode is connected to high voltage and the left (blue) electrode is connected to ground. By applying voltage to the electrodes, potential differences occur inside the contacting skin, and mechanoreceptors are stimulated. As a result, users perceive a vibration stimulus.

On the back of the tactile display, an electrostatic tactile display is formed with an electrode and an insulator layer. When the tactile display, which is connected to high voltage, contacts a conductive material, the electrostatic tactile display becomes positively charged and the material becomes negatively charged. Therefore, the electrostatic tactile display is attracted toward the material and both the normal force and the frictional force to the tactile display are increased.

By controlling the intensity and frequency of the applied voltage to each tactile display, multiple tactile sensations such as tactile sensations of real objects are presented to the users.

APPLICATION

We propose using the tactile display in a sheet-based VR glove, as shown in Figure 1a. The VR glove has flexibility and is attached along the skin. The VR glove can easily be designed with 2D CAD software, which allows users to design and prototype VR gloves that fit their own hands. Tactile sensation of a physical object can be changed with the combination of electrostimuli and frictional stimuli. For example, we developed a system that can alter the tactile sensation of a conductive cube with an AR marker. The system displays the altered object to the users with a display or head-mounted

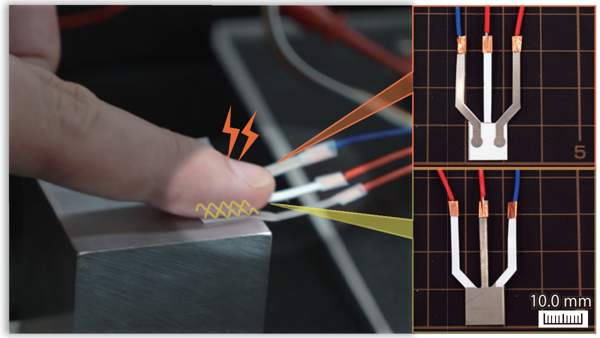

Figure 2. Inkjet-printed tactile display (left) with an electrical stimulus electrode on one side (upper right) and an electrostatic force electrode on the other side (bottom right).

display (HMD) and presents the altered tactile sensation with the VR glove. The users can experience the altered object with both visual and tactile information.

Figure 1b shows another application of the VR glove for a binarized image that is printed on a paper with conductive ink. The user can perceive the tactile stimuli only on the printed part through the VR glove. Specifically, tactile sensation can be added on the paper with the conductive ink. By providing tactile sensation to the printed image, users can experience not only visual information but also tactile information.

The proposed concept can easily change the design of tactile devices that are unique to sheet substrates such as PET or paper. We developed a physical slider interface with tactile feedback (Figure 1c). The interface consists of a base part that is fixed on the touch panel display using a dual sided tape and a thumb part that is slid on the base part. The surface of the Base part is printed with an electrode pattern using conductive ink and is connected to the ground. Each side of the thumb part has an electrode pattern to generate electrostatic forces and electrical stimuli. The thumb part also has a conductive pattern in order to generate a touch input on the touch panel display, and it can be moved along with the user's slide movement. This slider interface allows the user to feel a "snap feedback". The interface provides a continuous input without an applied voltage and an intermittent input with an applied voltage. Our method can realize a tactile feedback when switching between continuous and discrete inputs.

CONCLUSION

In this study, we proposed the concept of a miniature tactile display for multiple tactile stimuli. The proposed tactile display consisted of electrode patterns for electrostatic forces and electrical stimuli. The patterns were printed on a flexible sheet substrate. We also showed the potential of the proposed display for tactile applications. We believe that the proposed tactile display can be arrayed on a substrate. In future work, we will evaluate the characteristics of the proposed tactile display and optimize the design of the tactile display and the signal to the electrode. In addition, we will develop a tactile display array to provide tactile stimuli to large areas.

REFERENCES

1. Lynette A. Jones and Susan J. Lederman. 2006. Human Hand Function. 1st ed. USA: Oxford University Press.
2. Takafumi Aoki, Hironori Mitake, Danial Keoki, Shoichi Hasegawa and Makoto Sato. 2009. Wearable Haptic Device to Present Contact Sensation Based on Cutaneous Sensation Using Thin Wire. In *Proceedings of the International Conference on Advances in Computer Entertainment Technology (ACE'09)*, pp.115–122. https://doi.org/10.1145/1690388.1690408
3. Olivier Bau, Ivan Poupyrev, Ali Israr and Chris Harrison. 2010. TeslaTouch: Electrovibration for Touch Surfaces. In *Proceedings of the 23rd annual ACM symposium on User Interface Software and Technology (UIST'10)*, pp.283–292. https://doi.org/10.1145/1866029.1866074
4. Takuma Hirotsu, Syoki Kitaguchi, Kunihiro Kato, Homei Miyashita, Hiroyuki Kajimoto and Hiroki Ishizuka. 2017. Paper-Based Tactile Display for Multiple Tactile Stimulation. *IEEE World Haptics 2017 Demonstrations*.
5. Hiroyuki Kajimoto. 2012. Design of Cylindrical Whole-Hand Haptic Interface Using Electrocutaneous Display. In *Proceedings of the International Conference on Human Haptic Sensing and Touch Enabled Computer Applications (EuroHaptics'12)*, https://doi.org/10.1007/978-3-642-31404-9_12, pp.67–72.
6. Laura Winfield, John Glassmire and J. Edward Colgate. 2007. T-PaD: Tactile Pattern Display through Variable Friction Reduction. In *Proceedings of EuroHaptics Conference, 2007 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems. World Haptics 2007. Second Joint*, pp.421–426. . https://doi.org/10.1109/WHC.2007.105
7. Edward Mallinckrodt, A. L. Hughes and William Sleator. 1953. Perception by the Skin of Electrically Induced Vibrations. *Journal of Science* , Vol. 118, Issue 3062, pp. 277-278. https://doi.org/10.1126/science.118.3062.277
8. Dongbum Pyo, Semin Ryu, Seung-Chan Kim and Dong-Soo Kwon. 2014. A New Surface Display for 3D Haptic Rendering. In *Proceedings of the International Conference on Human Haptic Sensing and Touch Enabled Computer Applications (EuroHaptics'14)*, pp.487–495. https://doi.org/10.1007/978-3-662-44193-0_61
9. Qi Wang, V. Hayward. 2006. Compact, Portable, Modular, High-performance, Distributed Tactile Transducer Device Based on Lateral Skin Deformation. In *Proceedings of Haptic Interfaces for Virtual Environment and Teleoperator Systems*, pp.67–72. https://doi.org/10.1109/HAPTIC.2006.1627091
10. Vibol Yem and Hiroyuki Kajimoto. 2017. Wearable Tactile Device using Mechanical and Electrical Stimulation for Fingertip Interaction with Virtual World. In *Proceedings of IEEE Conference on Virtual Reality and 3D User Interfaces (IEEE VR'17)*. https://doi.org/10.1109/VR.2017.7892236
11. Andrew Y. J. Szeto, John Lyman and Ronald E. Prior. 1979. Electrocutaneous Pulse Rate and Pulse Width Psychometric Functions for Sensory Communications. *Journal of the Human Factors and Ergonomics Society*, Vol 21, Issue 2, pp.241–249. https://doi.org/10.1177/001872087902100212