Tactile display combining electrical and mechanical stimulation

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Abstract. This paper reports a novel tactile display that combines a mechanical pin array with electrical stimulation. The former is suitable for the presentation of a constant pressure distribution, while the latter is suitable for the presentation of rapid movement. Both the mechanical pins and electrodes were placed at 3.0 mm intervals, to produce a 2.1 mm resolution combined tactile display.

Keywords: tactile displays · tangible interface · mechanical pin array · electrical stimulation

1 Introduction

Tactile displays can provide important information to people with vision impairments and can also be used to reproduce tactile sensation in virtual reality equipment. The tactile stimulation can be realized using many technologies, including static indentation, vibration, and control of friction.

However, implementation of a tactile display with design flexibility and high resolution presents difficulties in both fabrication and integration [1]. Current high resolution tactile displays can be classified into two types of display. The first type of display is based on mechanical energy (i.e., a pin array tactile display). In pin array tactile displays, the pins can be in one of two positions (up or down) or can vibrate in the vertical direction. The pins can be actuated using piezoelectricity [2], electromagnetic technologies (e.g., solenoids, voice coils) [3], or heat pump systems. However, the bandwidth is limited in most cases, and presentation is limited to static or low frequency indentation, or single resonant frequency vibrations. Fabrication of denser arrays is also both difficult and expensive.

The other type of high-resolution tactile display is the electro-tactile display [4], which has the advantages of low cost, low power consumption and simple structures. In addition, it can present vibrations of up to a few hundred Hz. However, the electro-tactile display also has certain drawbacks. If the distance between the pin electrodes is small, then higher voltages are required to deliver sufficient electrical current flow around the mechanoreceptors [5]. The sensation of static pressure can be presented using cathodic electrical stimulation [6], but sensations elicited by long term stimulation are not stable.

This paper introduces a novel tactile display (Fig. 1 (left)) that combines a mechanical pin array with electrical stimulation. The combined tactile display was realized by laying the electro-tactile display on top of the pin array display. This combination enables tactile presentation with high resolution, wide bandwidth, and relatively low cost.

2 Prototype Device

We used a KGS SC5 tactile module [7] for the pin-array tactile display and the electro-tactile display that we developed in our laboratory. The pin array display module comprises an 8×8 piezoelectric actuator array (pin diameter of 1.3 mm) with a spatial resolution of 3 mm. The electro-tactile display comprises 7×7 electrodes (electrode diameter of 2 mm) and the same spatial resolution as the pin-array tactile display. The electrode substrate is made from a thin film, and contains an 8×8 array of holes so that it can be laid directly over the pin array display. The total display size becomes 130 mm× 24 mm× 25 mm and the total number of stimulators becomes 113 (64+49) with spatial resolution of 2.1 mm (Fig. 1 (right)).

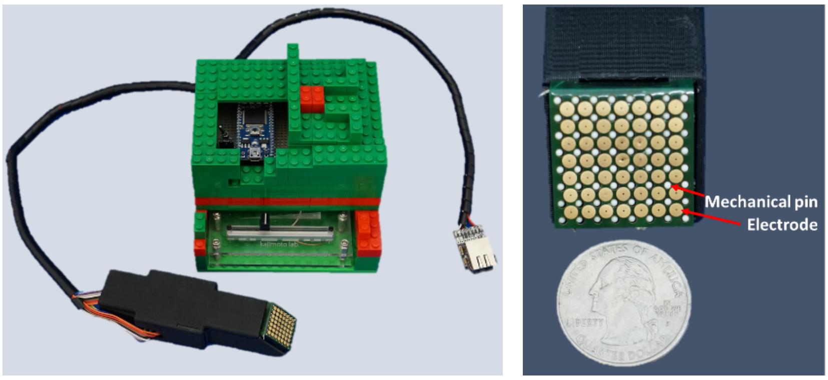

Fig. 1. Appearance of prototype device (Left: overall image; right: array of pins and electrodes)

We combined the two tactile displays, although they were controlled separately. Each controller board comprises a microcontroller (MBED LPC1768) that is connected to the local network via an Ethernet cable (Fig. 2). To present the required tactile patterns, we developed a tactile pattern generator web application (Fig. 3b) that sends different data to the two controller boards using WebSocket real-time communication.

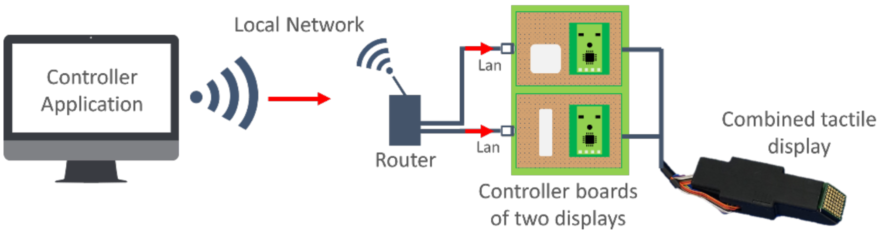

Fig. 2. System structure.

3 Application

As a first step, we created an application that presented random stimulation (Fig. 3a) with a 10 Hz refresh rate to determine whether or not the sensations from the two types of tactile stimulations differ. We recruited six participants from our laboratory, and found that almost all of them found the sensations to be similar.

We also developed two applications. The first is the tactile pattern generator (Fig. 3b) that we mentioned in the previous section. The other is a visual-to-tactile conversion application (Fig. 3c). Using the tactile pattern generator application, we can create and present many different tactile stimulation patterns that change in time order (e.g., writing characters on the finger).

In the visual-to-tactile conversion application, we used Canny edge detection to convert the visual information into tactile information. The tactile pattern follows the movement of a mouse pointer or touch coordinates in real time and the user can perceive the information of an image on the screen when their finger is touching the tactile display.

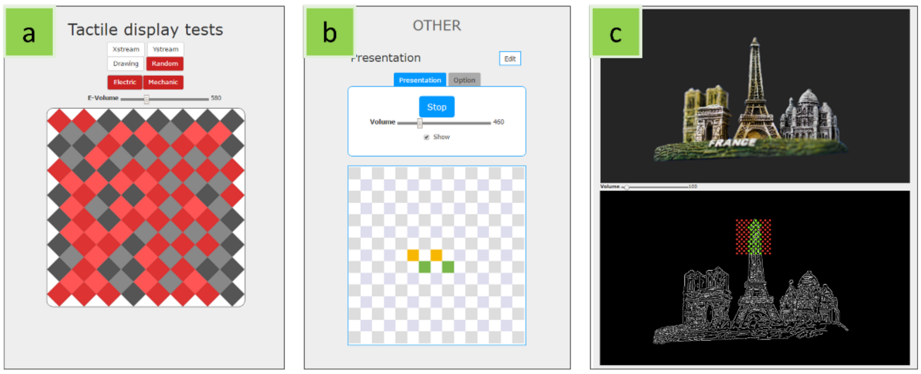

Fig. 3. Applications: a) random presentation, b) tactile pattern generator, and c) visual-to-tactile information converter.

4 Conclusion and Future Work

We have proposed a tactile display that combines electrical and mechanical stimulation for high resolution, high bandwidth, and relatively low cost tactile presentation. The two types of tactile presentation devices have the same pitch size of 3 mm, and the combination produced a 113 element, 2.1 mm resolution tactile display. We also developed a controller system and two applications to demonstrate our tactile display's high resolution capability, and its feasibility.

We initially found that the electrical and mechanical tactile stimulations were perceived to be similar. This is possibly because we have used a mechanical tactile display that has a relatively high bandwidth (0 to around 20 Hz).

However, our current prototype is relatively large, which is also because of the mechanical display part. As our next step, we intend to make the mechanical part thinner, which will inevitably reduce the bandwidth of the mechanical presentation. However, we believe we can compensate by assigning roles to the two stimulation channels, such that the electro-tactile display represents the surface texture and the pin-array display represents the shapes. We also intend to use the system in a virtual environment.

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