Presenting Sliding Sensation by Electro-Tactile Stimulation

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Abstract. This paper reports a preliminary trial on generating an illusory sliding-force sensation using electrical stimulation. Considering that the asymmetric vibration generates an illusory force, we have designed an electrical stimulation pattern by simulating the activity of skin receptors.

Keywords: Electrical stimulation, Force sensation, Sliding illusion

1 Introduction

Wearable-type haptic displays are attractive because they are lightweight and small sized; however, they have difficulty presenting external force as compared to desktop-type tactile displays. Therefore, many methods have been proposed to generate force sensation using illusory phenomena by skin sensation. A typical technique involves using asymmetric vibration [1-3]. When a weight is vibrated to be driven quickly forward and slowly in the reverse direction, the illusion of being pulled is generated on the hand grasping the transducer. However, this technique involves a strong vibration sensation that propagates over the entire hand.

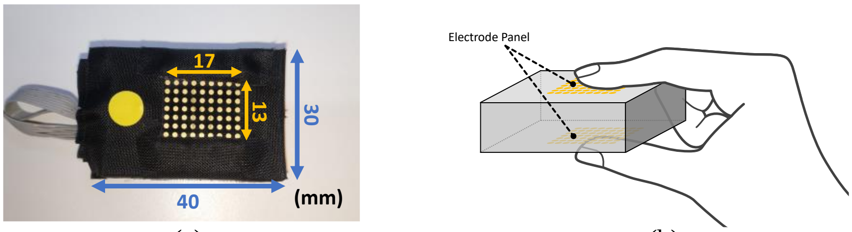
We have proposed a method to solve this problem by using a device that generates an illusory-force sensation through electrical stimulation [4]. The proposed method successfully generates an illusory-force in a direction normal to the skin surface. This paper is our next attempt to generate illusory-force sensation in the tangential direction.

2 Method

2.1 Electrical stimulation device

Electrical stimulation was performed using the electrical stimulator developed by Kajimoto [5]. This stimulator is divided into a control unit that determines the current and stimulation pattern, and an electrode unit comprising electrodes and switching circuits. The control unit is connected to a PC through a USB connection.

In the electrode unit (Fig. 1(a)), electrodes are attached to the top and bottom of a small box (4 cm × 3 cm × 1 cm, Fig. 1(b)). Sixty-three (7 × 9) circular electrodes (1.4 mm in diameter) are placed on one electrode board at 2 mm center-to-center intervals. The weight of the complete grasping part is 17 g.



(a) (b)

Fig. 1. (a) Electrode unit. (b) Structure of the grasping part.

2.2 Stimulus pattern

Fig. 2 shows the stimulus pattern, designed based on findings of Kaneko et al. [6]. They reported that asymmetrical vibration of the weights causes temporal bias in the skin deformation of the finger pad. Specifically, when an illusory-force sensation is generated from the base to the tip of the finger, a large skin tension is generated at the base of the finger with a large compression generated at the fingertip.

We focused on the activity of Meissner corpuscles and Merkel cells to apply this phenomenon to electrical stimulation. Meissner corpuscles are more sensitive to skin compression than tension during the beginning of slip [7], whereas Merkel cells are active in both tension and compression. As for electrical stimulation, anodic stimulation tends to generate Meissner-related sensation (vibration), and cathodic stimulation tends to generate Merkel-related sensation (pressure) [8].

Therefore, we hypothesized that the illusory sliding force is generated by cathodic stimulation to the area with strong tension and combined anodic and cathodic stimulation to the area with strong compression.

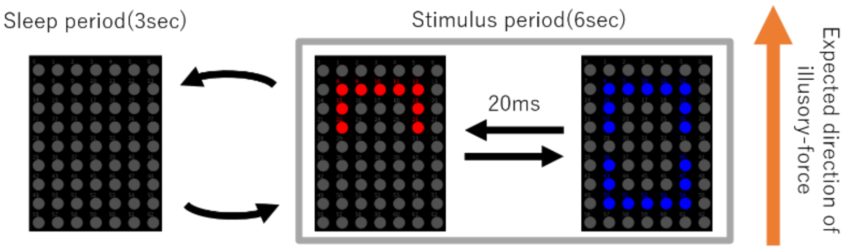


Fig. 2. Stimulus pattern. The same pattern is stimulated on both sides. Red dots represent anodic stimulation points, whereas blue dots represent cathodic stimulation points, respectively. Only one electrode is stimulated at a time; it takes 200 us to stimulate one electrode. As this speed is imperceptible, we feel as if the patterns are stimulated simultaneously. The maximum current for electrical stimulation is 6 mA.

In our preliminary trial conducted within authors, five out of six participants felt the illusory force. Out of these five, three felt the illusory sliding-force sensation while the remaining two felt the illusory sensation normal or oblique to the skin surface, possibly due to the difference in sensitivity between the thumb and index finger. The activity of deep mechanoreceptors such as Ruffini endings and Pacini corpuscles may be necessary for the generation of the illusory-sliding-force sensation.

3 Conclusion

This study attempted to generate the illusory sliding-force sensation using electrical stimulation. The stimulus pattern was designed based on the previous measurement of skin under asymmetric vibration—an existing method for generating illusory-force sensation. Our preliminary trial conducted within authors showed that three out of six felt illusory-sliding-force sensation.

However, our proposed stimulation pattern generates limited sensation compared to the illusory-force sensation by asymmetric vibration. Therefore, we will continue studying the stimulus patterns generating more distinct illusory-sliding-force sensations.

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