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Demonstration of Force Rendering via Electrical Stimulation of Fingernail and Finger Pad

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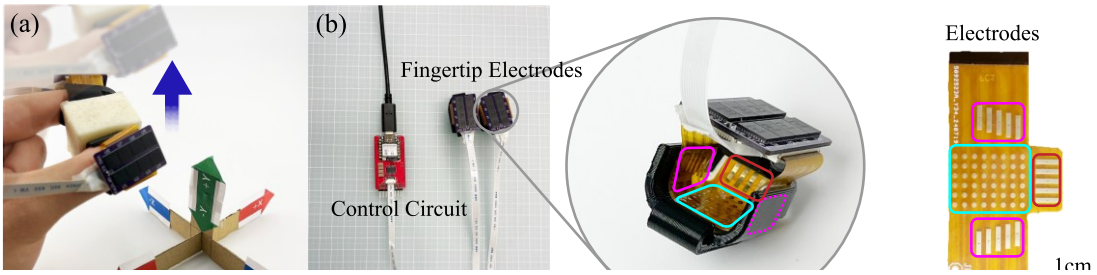

Fig. 1. (a) Illustration of the system concept and experimental setup. Directional force sensations are rendered through electro-tactile stimulation. (b) Two-finger electro-tactile display, with an enlarged view of the electrodes. The electrodes at the end of the finger are circled in red, and those on the side of the finger are circled in purple. The electrodes on the flat part of the finger pad are circled in light blue.

***Abstract*—Previous neurophysiological findings have indicated that mechanical strain near the fingernail plays a critical role in generating force sensations at the fingertip. Building upon this insight, this study introduces a novel technique for delivering multi-directional force feedback by distributing electro-tactile stimulation across the entire fingertip, including its lateral surfaces.**

Keywords—Electro-tactile Display, Force Perception, Wearable Devices

I. Introduction

In recent years, there has been growing interest in high-precision haptic technologies for applications such as entertainment, medical rehabilitation, and remote operations. Wearable haptic devices are particularly promising in VR/AR environments due to their portability and ability to function with body movement. While various systems have been proposed [1], most rely on mechanical actuators, which make them large, especially for force feedback applications.

Electrical stimulation offers a lightweight alternative, as it requires only electrodes attached to the skin. Prior studies have used this method to present cutaneous sensations via fingertip electrode arrays and force sensations via muscle or tendon stimulation on the forearm [2]. However, achieving a sense of touch, encompassing both skin and force sensations, requires electrodes in two distinct locations—the fingertips and the forearm—complicating the device's wearability.

In this study, we propose a compact electro-tactile method for presenting multi-degree-of-freedom force sensations by stimulating both the finger pad and the lateral side around the nail. Since this region also deforms during contact, and mechanoreceptors near the nail respond to force direction [3], our approach leverages these properties to provide directional cues without relying on bulky mechanical actuators.

II. Demonstration Overview

In this demonstration, participants will wear an electrical stimulation device, as shown in Fig. 1a, and hold a block. The device delivers electrical stimulation to induce a sensation of force, enabling participants to experience the effectiveness of the proposed method. The devices used are shown in Fig. 1b. Force sensations can be presented in six directions (+X, -X, +Y, -Y, +Z, -Z), all of which will be demonstrated during the demo. Additionally, the intensity of the electrical stimulation will be adjusted to accommodate individual differences, with calibration performed beforehand to ensure appropriate force presentation.

References

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