FinGAR: Combination of Electrical and Mechanical Stimulation for High-Fidelity Tactile Presentation

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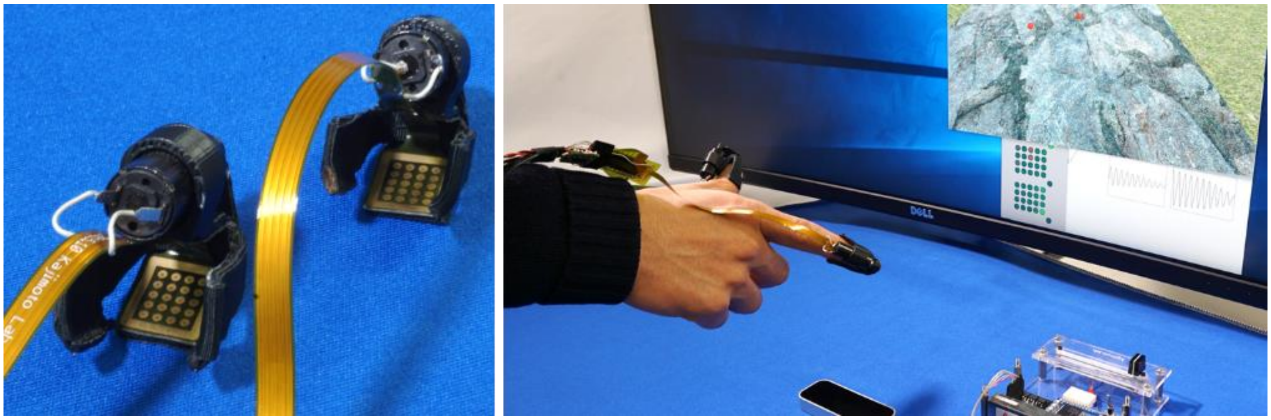

Figure 1 *FinGAR (left) and overview of the System (right). A thumb and an index fingers (represented by two red balls) are touching stone in virtual world, and obtain tactile sensation by electrical and mechanical stimulation.*

Abstract

It is known that our touch sensation is a result of activities of four types of mechanoreceptors, each of which responds to different types of skin deformation; pressure, low frequency vibration, high frequency vibration, and shear stretch. If we could selectively activate these receptors, we could combine and present any types of tactile sensation. This approach has been studied but not fully achieved. In our study, we developed FinGAR (Finger Glove for Augmented Reality), in which we combined electrical and mechanical stimulation to selectively stimulate these four channels and thus to achieve high-fidelity tactile sensation. The electrical stimulation with array of electrodes presents pressure and low frequency vibration with high spatial resolution, while the mechanical stimulation with DC motor presents high frequency vibration and shear deformation of the whole finger. Furthermore, FinGAR is lightweight, simple in mechanism, easy to wear, and does not disturb the natural movement of the finger, all of which are necessary for general-purpose virtual reality system.

Keywords: FinGAR, electro-tactile, mechanical tactile, mechanoreceptors

Concepts: • **Hardware ~ Tactile and hand-based interface;** *Haptic devices;*

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1 Introduction

Recent advances in low cost head mounted displays promoted prevalence of virtual reality applications. On the other hand, it also spotlighted importance of haptics sensation. We can play in a realistic virtual world, so we naturally want to touch it.

There are numerous studies to reproduce tactile sensation by deforming skin, such as employing mechanical pin matrix, vibrator, ultrasound, or electrostatic force. Each succeeded in reproducing some sort of tactile feeling, but relatively in a small range. In principle, we might be able to reproduce any tactile sensation if we could drive the skin with sufficient spatial (up to 1.5 mm at fingertip) and temporal (0 to 1 kHz) resolution, but as the skin has large mass and damper, it is still quite difficult to develop such versatile micro machine for tactile display.

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We propose to combine electrical and mechanical stimulation for high-fidelity tactile display. Our system, named FinGAR (Finger Glove for Augmented Reality), employed electrical stimulation to present pressure and low-frequency vibration, and mechanical stimulation to present high-frequency vibration and skin deformation. This combination enables selective stimulation with relatively a simple mechanical design.

2 Related Work

It is known that tactile information is provided by four types of mechanoreceptors in the skin [Jones2006]. They are Merkel cells for pressure, Meissner's corpuscles for low frequency vibration, Pacinian corpuscles for high frequency vibration, and Ruffini's endings for shear deformation (Figure 2). If we could reproduce each of these receptors' activity, we could reconstruct tactile sensation, just like primary colors in vision (RGB) are based on the physiological fact that there are three types of cone cells in retina.

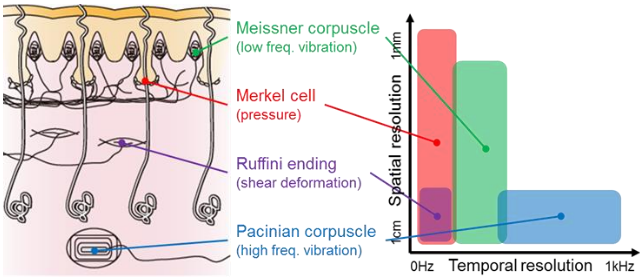

Figure 2 *Four types of mechanoreceptors in the skin and their spatiotemporal characteristics.*

This approach has been taken in some studies. Asamura et al. [1998] has controlled depth of vibration attenuation to selectively stimulate Meissner's corpuscles and Pacinian corpuscles. Kajimoto et al. [1999] has found that selective presentation of pressure feeling and low-frequency vibration by electrical stimulation is possible, by changing polarity of current. They also suggested that Merkel cells and Meissner's corpuscles are selectively activated by each polarity. However, selective stimulation of all four channels was not yet achieved.

3 System

Figure 3 shows the design and overview of FinGAR. The fixed part (glove) is made of ABS 3D printer. It sandwiches the fingertip from both sides. The total weight is 13 g.

A Maxon DC motor (118386) is mounted on the nail side to drive an arm that contacts finger-pad and stretch the skin. While Minamizawa et al. [2007] have constructed fingertip shear-deformation system using DC motor, we have found that the DC motor also serves as a high fidelity vibration unit [Yem2016]. With this setup, information of shear deformation (Ruffini endings) and high frequency vibration (Pacinian corpuscles) can be replayed.

An electrodes-film is attached at the end of the mechanical arm. It is composed of 4×5 array of electrodes with 2mm center interval, surrounded by a ground electrode. The electrical stimulation achieves high resolution replay of low frequency vibration (Meissner's corpuscles) and pressure (Merkel's cells) by changing the polarity of the electrodes.

As a result, combination of mechanical and electrical stimulation achieves four channel stimulation with sufficient spatial and temporal resolution for each channel (Figure 4).

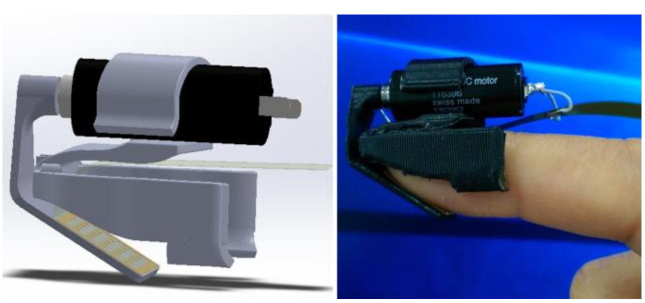

Figure 3 *The design of FinGAR and overview of wearing the device on an index finger.*

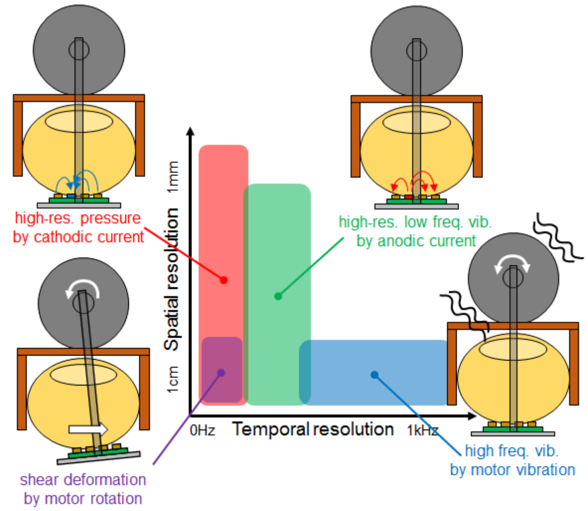

Figure 4 *Role of each stimulation mode.*

We designed the following algorithm for the reconstruction of realistic tactile feeling, by considering movement of the finger and the roughness of the contact object. When the finger is standstill on the object, we apply cathodic current to elicit pressure sensation on the fingertip. In contrast, if the finger starts moving, we apply anodic current to elicit spatially flowing vibration sensation (i.e. texture feeling). We simultaneously control the DC motor to provide sensation of skin stretch (occurs due to the friction between the skin and the shape) and high frequency of the whole finger's vibration.

4 Demo Experience

Our virtual reality setup comprises FinGARs for thumb and index finger, and a finger motion capture device (LeapMotion). We prepare virtual objects with several kinds of textures and shapes as shown in Figure 1(right). After adjustment of volumes, participants can freely touch the objects, and compare the sensation with real objects.

Acknowledgements

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