Improving Edge and Texture Rendering in Mid-Air Haptic Systems

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Introduction
Mid-air haptics attempts to realize Ishii's vision [3], in which tangible objects evolve into radical atoms that engage the users in the real physical world. In the research literature there has been some implementations like HaptoMime [7], HaptoClone [6], and UltraHaptics [1].

Current mid-air haptic systems use ultrasound energy to induce skin stretches which are perceived by the mechanoreceptors [5] in the hand as tactile input. This approach has limited edge and texture rendering capabilities. One of the challenges of mid-air haptics is rendering edges or corners of an object. This limitation can be attributed to the amount of energy that can be exerted by the ultrasound array on the hands. Another potential concern for this limitation could be the range of frequency that needs to be tailored for a better experience. Human hands have four different types of mechanoreceptors at varying density throughout the hand. Each type of mechanoreceptor has a frequency response characteristic unique to the type of the receptor.

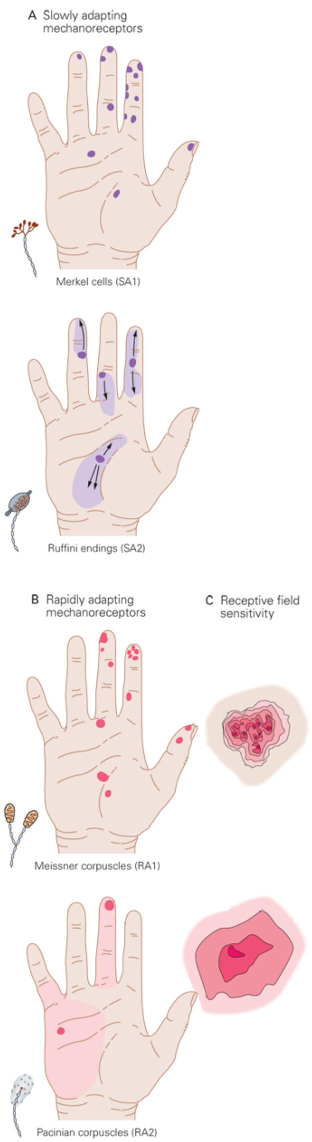

Figure 1: Distribution of different mechanoreceptors across the hand by Kandel (Chapter 23, Figure 4) [4]

Additionally it is important to note that the receptors also have a varying activation zones in the area in which the mechanoreceptors can be innervated.

Perception in Human Hand

Human hands have four different types of mechanoreceptors (a sensory receptor that responds to mechanical pressure or distortion), each with varying physiological qualities. They can be classified based on their response time to stimuli and receptive field size.

One potential way of improving edge detection is by tailoring mid air haptic systems to focus on Merkel cells [4]. Merkel cells, by their physiological propertie, respond to edges and small sharp borders.

Fine, micro-textures are captured by Fast-Adapting Pacinian receptors, whereas course textures (e.g. Braille) are captured by Fast-Adapting Meissner's receptors and Slowly-Adapting Merkel Cell receptors. Lastly, skin stretch is captured by Slowly-Adapting Ruffini Endings [8].

Workshop Discussion

By utilizing a deeper understanding of the physiological mechanisms of how a human hand understands and encodes different sensory input can we potentially:

- Improve the experience of haptic feedback devices
- Enable better edge and texture rendering rendering capabilities
- Pave way to exploring mid-air haptics in precision haptic rendering environments like medicine
- Encode rendering with specific amplitude and frequency for different regions of the hand

Such a system can be implemented exploring standing waves and how they actuate the skin at various positions,

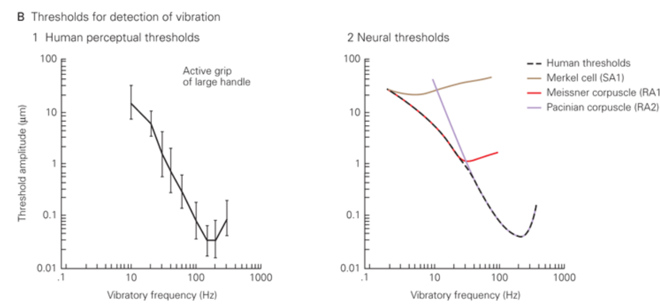

Figure 2: Frequency and amplitude response of different mechanoreceptors by Kandel (Chapter 23, Figure 8) [4]

at different frequencies and at different amplitudes to maximize the rendering accuracy of the haptic device. The ideal next steps after this discussion is to explore experimental verification of these ideas via *UltraHaptics* Touch Development Kit.

Potential Applications

Edge and texture rendering in haptic devices could be vital in many fields, including medical applications [2], such as training and remote surgeries. Such a haptic device can be useful in a **C**ave **A**utomatic **V**irtual **E**nvironment (CAVE).
In CAVE the navigational technique, *World In Miniature* [9] could be improved by introducing a portable haptic feedback system. This would enable the user to course correct their inputs with the accurate edge and texture render of the landscape.

About the Authors

Sandeep George is a PhD student with Dr. Sonny Chan and Dr. Lora Oehlberg. He has worked in the computer software industry for about a decade and has spent most of his career at Adobe Systems, including Adobe Research.

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