Textured Surfaces for Ultrasound Haptic Displays

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ABSTRACT

We demonstrate a technique for rendering textured haptic surfaces in mid-air, using an ultrasound haptic display. Our technique renders tessellated 3D 'haptic' shapes with different waveform properties, creating surfaces with distinct perceptions.

CCS CONCEPTS

•Human-centered computing → Haptic devices;

KEYWORDS

Haptic Rendering; Mid-Air Haptics; Ultrasound Haptics.

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1 INTRODUCTION

Non-contact haptic displays can enhance mid-air gesture interaction, by allowing users to 'feel' the controls they interact with and by allowing non-visual feedback to be presented directly to the hand. Many technologies have been developed to enable non-contact haptics in recent years, but ultrasound haptics [1, 4], in particular, has received a lot of attention because of the high resolution of its output.

In the next section, we present a brief overview of the ways this technology can be used to produce haptic sensations on the hand. These sensations utilise only a small part of the haptic sense, typically creating the perception of smooth and continuous vibration against the hand. Many rich areas of haptic perception are unexplored, e.g., the perception of different textures. In this work, we demonstrate a technique that creates haptic surfaces, with textured properties such as "roughness". This could enable richer non-contact haptics for mid-air interactions: for example, allowing realistic textured objects for VR/AR, or mid-air buttons with distinct tactile properties.

2 RELATED WORK

Ultrasound haptics [1, 4] is an emerging technology that allows users to experience tactile sensations in mid-air, with no need to hold or contact a device. Focused ultrasound from arrays of transducers (e.g., Figure 1, left) creates areas of acoustic radiation pressure, which are reflected by the skin [1]. By modulating the sound at a frequency from the range of haptic sensitivity (e.g., 200 Hz [1]), the sound is perceived as vibration. This has been likened to the feeling of a "gentle breeze" focused upon the skin [7].

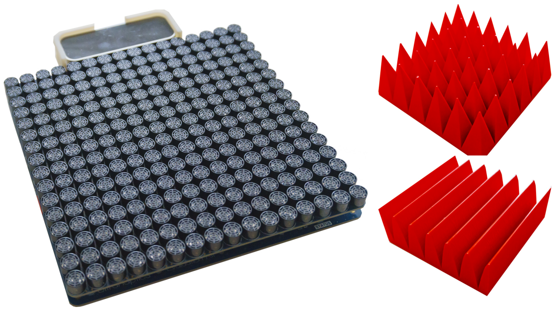

Figure 1: An Ultrahaptics device (left) and two 3D printed examples of haptic surfaces (right).

Early research prototypes allowed a single point of haptic stimulus above the ultrasound array [4]. Although limited, this had practical applications in HCI: a single point of feedback could be presented to a finger during mid-air pointing interactions [2, 8]. A single point could also be repositioned to create richer tactile sensations: for example, creating the illusion of continuous motion on the hand [9]. Later research allowed several distinct points of stimulus [1], creating potential for new types of haptic experience.

Ultrasound haptics is not limited to distinct 'focal points' of feedback. Long *et al.* [6] described a haptic rendering technique for volumetric shapes. They controlled the acoustic field to create the illusion of mid-air shapes (e.g., cones and cubes), by rendering the outline of the 2D cross-section of the shape as the hand intersects it; e.g., the circular cross-section of a sphere as the hand moves through it. Korres *et al.* [5] rendered haptic shapes by rapidly moving a single point of stimulus to create a "point cloud"; rapid movement created the perception of all points being presented simultaneously. Inoue *et al.* [3] generated an acoustic field from multiple surrounding arrays, allowing haptic stimuli without the need for frequency modulation (as in [1, 4], etc).

In this paper, we describe a haptic rendering technique that can be used to create textured surfaces using ultrasound haptics, allowing sensations like "roughness". This allows new haptic experiences and creates new opportunities for mid-air interfaces.

3 RENDERING HAPTIC SURFACES

We define a haptic surface as a tessellation of 3D shapes in a plane; e.g., a 6x6 plane of pyramids in Figure 2 or a 1x7 plane of tetrahedrons in Figure 1, bottom right. When tessellation is used to create a surface, the shape, height, and shape width can be varied. This changes the structure of the plane and gives three parameters for a haptic surface:

- TESSELLATION SHAPE (e.g., pyramid, tetrahedron)

- TESSELLATION HEIGHT (e.g., 1–10cm)
- TESSELLATION WIDTH (e.g., 1–10cm)

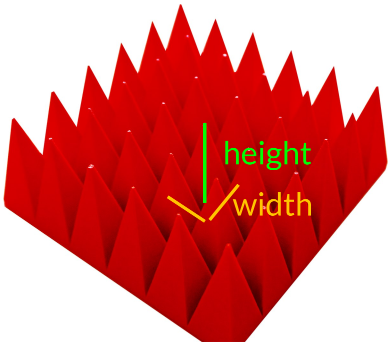

Figure 2: An example surface made from tessellated pyramids. The SHAPE, HEIGHT and shape WIDTH affect the structure of the haptic surface.

We render the haptic surface in mid-air using ultrasound haptics. When a user's hand intersects the surface, we get the points of intersection and present haptic feedback at those locations only (Figure 3, left). We do this by continuously moving a single point of ultrasound haptic feedback (e.g., to the six locations in Figure 3). This creates the illusion of simultaneous presentation across the whole hand [5].

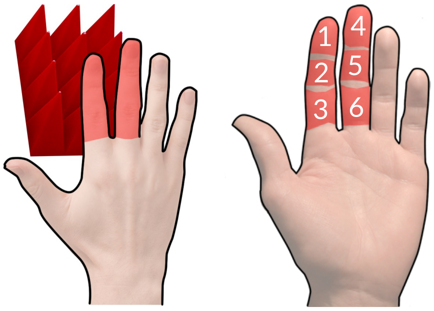

Figure 3: Areas of the hand intersecting the surface are stimulated (left). Rapid sequential presentation of feedback across the highlighted locations creates the illusion of simultaneous presentation (right).

There are several parameters of this rendering method that can be changed to create the perception that the hand is touching something with a distinct texture. The intensity and modulation frequency of the single point of haptic feedback can be changed (e.g., reducing intensity or increasing modulation frequency). We enhance this by varying the intensity using different waveforms (e.g., a flat or sine wave). We also vary the frequency at which the point of feedback traverses the hand. This works best from 5–40 Hz, e.g., each part of the hand is stimulated by the point of feedback up to 40 times per second. This gives another four parameters that affect the presentation of a haptic surface:

- INTENSITY (0%–100%)
- WAVEFORM (flat, sine, square, sawtooth, triangle)
- MODULATION FREQUENCY (e.g., 200 Hz [1], 175 Hz [2])
- HAND TRAVERSAL FREQUENCY (5–40 Hz)

The seven parameters identified here can be manipulated to create haptic surfaces with different perceptual properties. Research is ongoing to better understand how these can be used to create distinct textured surfaces.

4 DEMONSTRATION

Our demonstration will allow attendees to experience a variety of mid-air textured haptic surfaces, presented using an Ultrahaptics[1] device and rendered using our technique. We will also use 3D-printed physical visualisations of each surface (Figure 1, right), to show attendees what they are experiencing and to demonstrate the types of surface this technique can render.

5 ACKNOWLEDGEMENTS

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[1] Ultrahaptics: https://www.ultrahaptics.com/