Variation of Tactile Feelings of Focused Ultrasound: Modulation Frequency and Hand Movement

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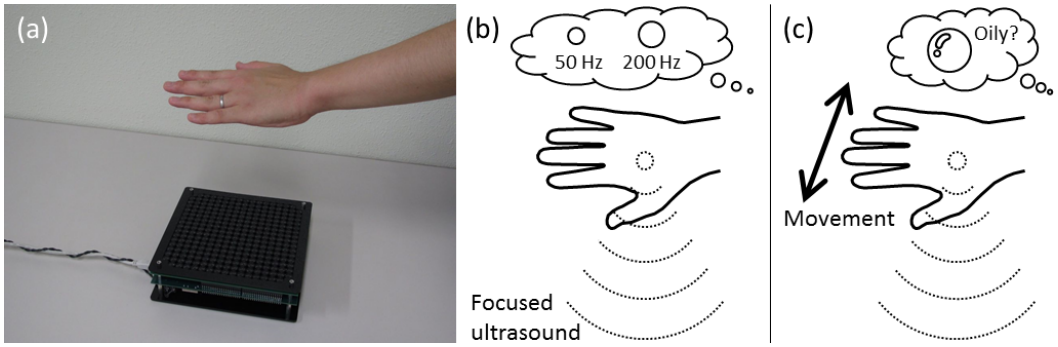

Figure 1: *(a) Ultrasound focusing device. (b) Frequency-dependent sensation. (c) Movement-excited sensation.*

1 Introduction

Ultrasound-based aerial haptic feedback has been studied these days [Hoshi et al. 2010; Carter et al. 2013; Hasegawa and Shinoda 2013]. Studies on this technology mostly focused on producing contact sensation in air and investigating the characteristics of human tactile sensation. There are a few reports on the quality or metaphor of the produced tactile feelings. For example, 100-Hz or 200-Hz modulated ultrasonic stimulation was expressed as "electrostimulation," "a stream of air," and "a small soft-haired blush" in [Hoshi et al. 2010]. Synthesizing realistic tactile feelings, such as recorded from real blanket, is still remaining a difficult technological issue because of controlling hundreds of ultrasonic transducers.

In this paper, two interesting phenomena are reported. One is frequency-dependent size sensation, and the other is movement-excited virtual sphere.

2 Airborne Ultrasound Tactile Display

The author uses an integrated compact ultrasonic device [Hoshi 2012]. This device consists of 285 ultrasonic transducers and outputs force of up to 16 mN. This force is caused by a high-intensity ultrasonic wave, which is generated by phased array focusing technique. Note that this force value is sufficient to produce vibrotactile stimulation but too weak to produce a continuous force.

3 Variation of Tactile Feelings

Through the demonstrations/exhibitions in the past years, the following two interesting effects were found.

(1) The diameter of the ultrasonic focal point is felt differently depending on the modulation frequency. Specifically, the focal point of 50-Hz vibrotactile stimulation is felt sharper (i.e., more localized) than that of 200 Hz. The boundary of the sensation is also blurred at 200 Hz modulation. This may be related to the frequency response and receptive area of mechanoreceptors [Vallbo and Johansson 1984], especially Meissner and Pacinian corpuscles.

(2) The continuous force produced by the current ultrasonic device, which is hard to feel on your hand due to its relatively weak output force (16 mN) and adaptation of nerves, can be got felt when you place your hand on the focal point and move your hand transversely. The onset of the stimulation is easy to feel and the hand movement produces a situation that you continuously put a new region of the skin on the focal point. The resultant sensation is like "an oily small ball" or "a waterjet at short range." This can be explained as pure normal force (i.e., no tangential force) applied on the skin.

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SA'15 Workshop on HMCD, November 02 – 06, 2015, Kobe, Japan.
ACM 978-1-4503-3932-2/15/11.
http://dx.doi.org/10.1145/2818384.2818398