Driving System of Diminished Haptics: Transformation of Real World Textures

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Abstract. In this study, we developed a portable driving system for Diminished Haptics that transforms the haptic textures of real materials by ultrasonic vibration based on a squeeze film effect. A real material is attached on the display area (a square area with 30-mm sides) and its haptic texture is reduced. However, the vibration amplitude is decreased due to a shift of resonance frequency when a user's finger contacts with the haptic display. Thus, a resonance frequency tracing system in the driving system plays an important role to maintain the vibration amplitude. In this paper, we focus on the details of the resonance frequency tracing system and the effect of the system is evaluated.

Keywords: Diminished haptics, Real-world texture, Texture transformation, Ultrasonic transducer driving, Resonance frequency tracing

1 Introduction

Representation of texture has attracted attention from manufacture in industries, researcher of ergonomics, neuroscientist, and so on. Thus, the expression of textures has become a popular research area [1]. The aim of this study is to transform the textures of real objects. There are two major methods to transform real textures. One is to physically modify the original texture and the other is to reduce or add the texture by actuation. In the real world, there are many types of haptic textures and it is possible to

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modify the textures by preprocessing, e.g., grinding, rapping and so on. In this study, we focus on the second method for easiness and variability.

Previous methods for haptic texture representation are divided in two categories. One is wearable devices to provide additional vibration to users' fingers [2]. The other is haptic displays that provide haptic feedback on their smooth surfaces. The technologies employed in the latter approach include ultrasonic vibration [3, 4] and electrostatic forces [5], which have been applied to trackpads [6], pointing devices [7], and augmented reality (AR) systems [8].

In this study, we present a new method for haptic representation by reducing original textures. This method is opposite to previous methods. We reduce the degrees of real haptic textures based on a squeeze film effect of ultrasonic vibration [9]. This method is named "Diminished Haptics" [10].

The squeeze film effect is applied by using an ultrasonic transducer. Some real material is mounted on the tip of the transducer. The vibration amplitude is decreased due to a shift of resonance frequency when the material is contacted by user's finger. Thus, Diminished Haptics requires a function that traces the resonance frequency to keep the amplitude (i.e. thickness of a squeeze film) as much as possible. The driving system for this purpose is described in this paper.

2 Structure and principle

The Diminished Haptics system consists of a vibration device (a transducer and a display surface) and a resonance frequency tracing system (a controller and a driver). The system overview is shown in Fig. 1 (Left). While the devices used in previous studies rendered some artificial textures, our device reduces the haptic textures on real objects. We use ultrasonic vibration to reduce the haptic textures based on the squeeze film effect. A haptic display surface on the vibration device is a square area with 30-mm sides. Real materials (e.g. sandpaper, wallpaper, etc.) are attached on the display surface. User touches the display surface with their bare fingers and feel haptic texture is reduced by squeeze film effect.

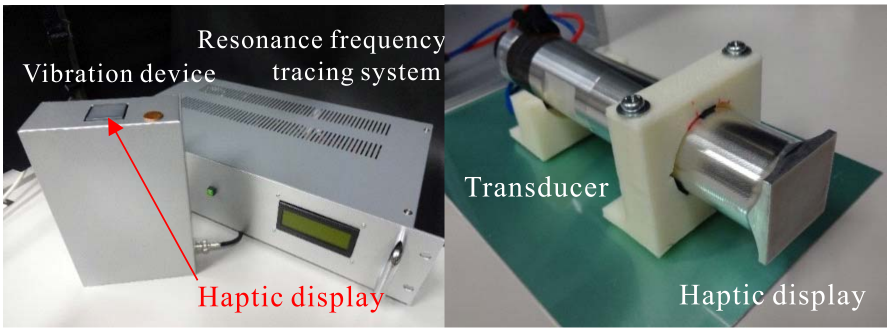

Fig. 1. (Left) Overview of Diminished Haptics system, (Right) Structure of vibration device

Figure 1 (Right) shows the transducer (28-kHz resonance frequency without load) inside the vibration device, which is a bolt-clamped Langevin-type transducer with a horn. At a vibration node, the transducer is fixed on a casing with a jig.

Users feel real textures without ultrasonic vibration. With ultrasonic vibration, thin air layers arise (squeeze film effect) and cover real materials. Users' fingers are slightly levitated and the height of the real haptic texture is virtually reduced. The height of levitation can be controlled to continuously reduce the textures. The displayed textures are inherently high resolution and felt without lateral movement of fingers differently from friction-control-based texture displays.

3 Resonance frequency tracing system

One of the issues of our method is that the resonance frequency of the bolt-clamped Langevin-type transducer is shifted when a finger contacts with the display surface. With a fixed-frequency driving signal, the vibration amplitude decreases due to this resonance frequency shift and cannot efficiently levitate fingers. Resonance frequency tracing is hence required to keep the amplitude.

This shift of the resonance frequency is evaluated by measuring frequency characteristics of admittance of the transducer in Fig. 2. This data was measured by an impedance analyzer. Due to the output limit of this analyzer, the measurement was conducted with a low voltage with which squeeze film effect is not arisen. While this condition is not equal to that in use, we can qualitatively evaluate the effect of finger contact. With finger, the shift and reduction of admittance is observed. Therefore, resonance frequency should be traced in order to keep effective vibration amplitude. In this study, we developed a resonance frequency tracing system based on current phase measurement.

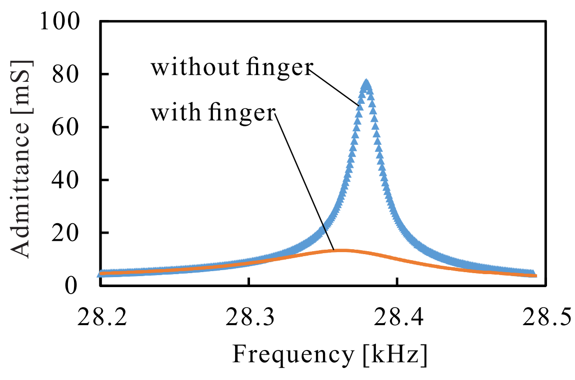

Fig. 2. Admittance of transducer with/without finger

A diagram of the resonance frequency tracing system is illustrated in Fig. 3. This system consists of a microcomputer, a direct digital synthesizer, an amplifier, a voltage and current detecting unit, and two wave forming circuits. These components are packaged in a portable casing. The phase difference at the resonance frequency is preliminarily measured and input into the tracing system as a target phase value. It traced the resonance frequency by monitoring the phase difference between the applied voltage and consumed current [11]. The detecting unit was inserted between the amplifier and the transducer to measure the phase difference. In the following experiments, this resonance frequency tracing system was used.

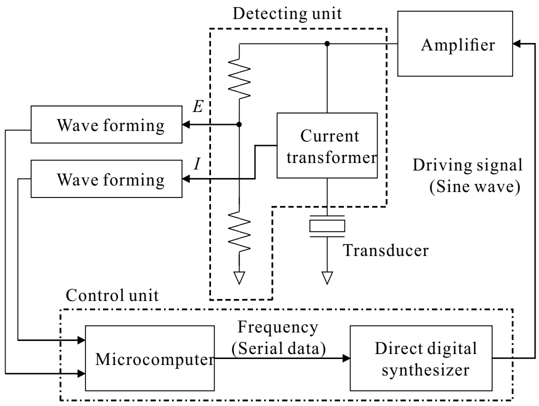

Fig. 3. Diagram of resonance frequency tracing system

4 Experimental result

To show the effectiveness of the resonance frequency tracing system, the vibration velocity of the display surface was measured by using laser Doppler vibrometer. The overview of the experiment and the measured velocity are shown in Fig. 4. Applied voltage was 19.1 $V_{0\text{-}p}$. Table 1 shows the measured vibration velocities with tracing on/off and with/without a finger. The decrease of vibration velocity is observed with tracing off and with a finger. The reduction of real textures is not effectively arisen with this decreased vibration. On the other hand, the decrease of vibration with tracing on is negligible. These results indicate that our resonance frequency tracing system is effective to keep the vibration velocity when a finger contacts with the display surface.

5 Conclusion and future works

In this study, we fabricated and evaluated a portable driving system for Diminished Haptics. A transducer induces the squeeze film effect on a display area (a square with 30-mm sides). Real materials (e.g. sandpaper, wallpaper, etc.) are attached on the display area and their haptic textures are reduced. To stabilize the degree of reduction of textures when a resonance frequency shift occurs due to placing a finger on the display surface, the system has a resonance frequency tracing system. We measured the vibration velocity to evaluate the effectiveness of the developed system and we confirmed that it operated successfully. In the next stage, we plan to extend this method to 3D objects.

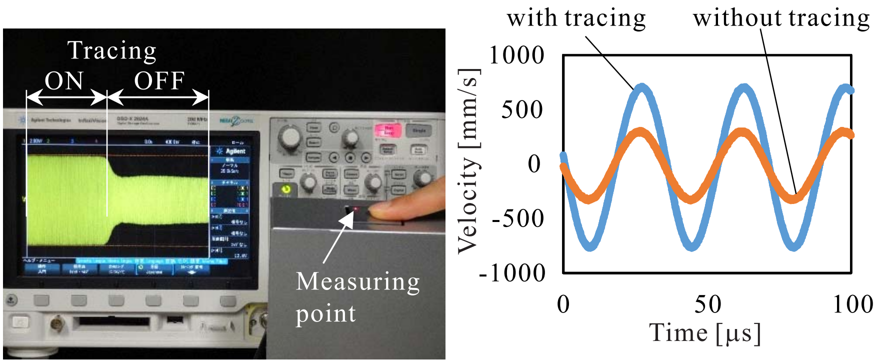

Fig. 4. (Left) Overview of experiment, (Right) Vibration velocity of display surface with and without resonance frequency tracing.

Table 1. Vibration velocity of on/off tracing and with/without finger

Tracing	Finger	Vibrationvelocity [mm/s]
OFF	Without	850
OFF	With	387
ON	With	818

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