Tactile Presentation Device Using Sound Wave Vibration

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Abstract

Imparting vibration to the contact surface of an object is a method of presenting a tactile sensation of the object surface. However, it is difficult to temporally and spatially present wide-band vibrations through the direct vibration generation of a general actuator. In this study, we focus on sound waves, and propose a method to present tactile sensations by generating vibrations via irradiating sound waves of various frequencies and amplitudes on a plate. In experiments using a parametric speaker as an acoustic device, the vibration of the plate during sound wave irradiation was measured; it was confirmed that different tactile sensations could be obtained by changing the frequency and amplitude of the irradiated sound wave.

Index Terms: Human-centered computing—Human computer interaction（HCI）—Interaction devices—Haptic devices

1 Introduction

Currently, with the development of VR technology, and the spread of touch panels in society, various devices that attempt tactile presentation have been proposed and developed. In particular, many research studies attempt to present tactile sensations.

Tactile sensations are generally presented using actuators or electricity. When actuaters are used, a vibration stimulus is given to the skin by vibrating the surface that contacts the skin or tracing with the vibrator, presenting a feeling of roughness or friction. The shape of an object can be conveyed by arranging actuators in an array and moving them up and down [1, 4]. On the other hand, an electrical method, exists directly acts on nerves connected to each receptor through electric stimulation via electrodes placed on the skin surface. Alternatively, conductor panel surface and the human body can be charged, and a sense of friction is generated by the attraction of the static electricity acting between them [2, 3].

To present several kinds of tactile sensations using a single device, it is important to allow broadband and spatially free vibration and to allow the simple adjustment of the stimulus intensity. However, it is difficult to present a wide-band vibration temporally and spatially through the direct vibration generated by a general actuator. Methods using electricity are advantageous because they have no mechanical mechanisms and have a high degree of spatial freedom; however it is difficult to adjust the stimulus intensity. -In this study, we focus on sound waves with various amplitudes in a wide frequency band and propose a tactile sensation presentation method using sound waves for vibration generation.

2 Proposed Method

In this study, first, a sound wave is irradiated toward the plate to generate vibrations on the plate. Subsequently, the tactile sensation is presented by the user tracing the plate on which the vibration was generated. Various vibrations are generated on the plate by changing the frequency, sound pressure, and irradiation position of the irradiated sound wave, which presents different tactile sensations.

Sound waves have a wide range of frequencies and sound pressure so they can be changed in a wide range. In addition, because the vibration source can be adjusted by changing the irradiation position with respect to the plate, different vibrations can be presented to the plate under similar frequency and amplitude conditions and spatial freedom can be ensured.

Sufficient sound waves must reach the plate to vibrate it. However, sound waves in the low frequency band have low directivity and diffuses, so they do not reach the plate sufficiently. In this study, a parametric speaker that can provide high directivity to low frequency sound waves is used as an acoustic device.

3 Prototype Device

Figure 1 shows the device configuration. The plate is vibrated by irradiating sound waves from the parametric speaker. When the vibrated plate is traced with a finger, a tactile sensation is presented by the application of a vibration stimulus to the skin.

Figure 2 is a prototype device. The sound equipment used was a parametric speaker experimental kit manufactured by Tristate. The waveform generation software was WaveGene. An aluminum plate of with dimensions of 110 mm × 80 mm and a thickness of 0.5 mm was used. In the figure, a PVC plate is used to make the device configuration easier to see. The distance between the parametric speaker and plate was 8 mm. This prototype device does not consider changes in the irradiation position of the sound wave.

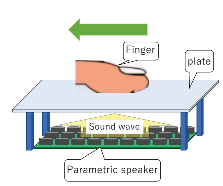

Figure 1: Device configuration

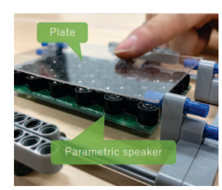

Figure 2: Prototype device

4 Measurement of Plate Vibration

The frequency of the output sound wave and the actual vibration frequency of the plate may differ even when the vibration is generated by irradiating a sound wave to the plate. Therefore, the vibration of the plate was measured to investigate the kind of plate vibration actually presented. Because the changes to be measured are small, and a sensor directly attached to the plate may have a large effect on the vibration, a non-contact measurement is the most suitable. Therefore, measurement was performed using laser light. A JPM-1-3 (A4) APC module that emitted a green laser light manufactured by LightVision Technologies Inc. was used. The laser beam was applied to the surface of the plate while irradiating the sound waves and the reflected light was projected onto the screen and photographed. The reflected light was captured at a resolution of 1024 × 1024 at 1000 fps using a high-speed camera (FASTCAM Mini AX50) manufactured by the Photron Corporation. Figures 3

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and 4 show the reflected light projected on the screen and part of the image taken by the above camera. The shooting was performed via the company's camera control software PFV (Photron FASTCAM Viewer) and the video shot with the software was decomposed into images for each frame. The reflected light in each frame image was tracked, and a fast Fourier transform was performed to determine the plate's vibration frequency peak. This was measured five times for each sound wave, and the average was calculated. Figures 5 and 6 are the displacements of the reflected light with irradiating sound waves of 40 Hz・0 dB and 220 Hz・− 20 dB frequencies, respectively. It can be concluded that the output sound wave and the vibration frequency of the plate are similar.

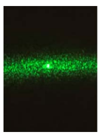

Figure 3: Reflected light

Figure 4: Reflected light captured

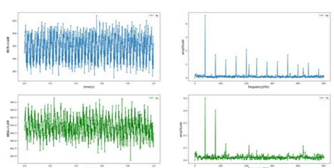

Figure 5: 40 Hz・0 dB

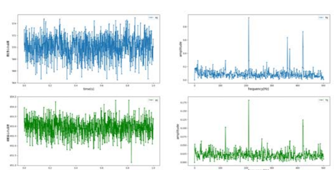

Figure 6: 220 Hz・− 20 dB

5 Survey of Tactile Sensations Presented

The influence of the plate is large even when sound waves with different frequencies and sound pressures are applied to the plate; as a result, the vibration becomes the same and there is a possibility that there is no difference in the tactile sensation. Therefore, we conducted an experiment to examine the tactile sensation presented by the prototype device. The experiment participants were six males in their twenties. The aluminum plate was irradiated with 10 different sine waves of different frequencies and sound pressures every 30 seconds and traced. The difference in the tactile sensation between the state where the sound wave was not irradiated and the state where the sound wave was irradiated, and how they felt it were illustrated under each condition. The tracing location on the plate was not specifiedy. In addition, the pushing load and tracing speed during tracing were arbitrary and the difference in the feeling due to the change was illustrated as well. The frequency and sound pressure of the irradiated sound wave were selected based on previous studies and preliminary experiments. In this experiment, the irradiation position of the sound wave was not changed and audiovisual interruption was not performed.

From the experiments, it was confirmed that several types of tactile sensations could be presented by changing the frequency and sound pressure of the radiated sound waves. When irradiating sound waves in the low frequency band or sound waves with high sound pressure, there are opinions that ”it is quite coarse” and ”large irregularities”, and when the frequency is increased, there is an opinion that it is ”fine grainy”. Others commented that the hardness had increased. In addition, there were opinions that ”friction increased” when any of the sound waves was irradiated. Moreover, the common opinion is that it is strange to feel both the smoothness of the aluminum plate which is the material of the plate, and the roughness due to stimulation. Regarding the pushing load, there were many opinions that it was easier to feel a change in the tactile sensation when tracing the surface lightly without pushing too much. Regarding the tracing speed, there were many opinions that a slightly faster tracing would make the change in tactile sensation easier to understand, and a slower tracing would increase the vibration sensation. However, there is an opinion that there is no difference between the case where the sound wave is irradiated and the case where the sound wave is not irradiated and that there is a strong sense of vibration. The relationship between the frequency and sound pressure of the sound wave and the tactile sensation was not seen in this experiment as well. In this experiment, because the audio-visual sense of the participants was not blocked, it is considered that the appearance and image of aluminum, the material of the plate, the output sound and the sound of the plate vibration were also affected.

6 Conclusion

In this study, we proposed a tactile sensation presentation method using vibration caused by sound waves. The experimental results showed that the frequency of the output sound wave and the vibration frequency of the plate were the same. It was also found that different tactile sensations could be presented by changing the frequency and sound pressure of the radiated sound waves. In the experiment, an aluminum plate was used for the contact surface; however, it is necessary to verify the vibration and tactile sensation of the contact surface when the material of the contact surface is changed in the future. In addition, the vibration distribution of the plate is measured to examine the more effective presentation location on the plate. Moreover, an evaluation scale is created based on the results of previous research studies and the experiment in this study, and an evaluation experiments of the presentation device is performed with audio-visual shut-off.

Acknowledgments

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