Noncontact Cooling Sensation by Ultrasound-Driven Mist Vaporization with 3D Visual Feedback

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Abstract. Combining tactile sensation with a 3D image can improve the immersion of MR contents. We developed a system that presents a noncontact cold sensation with a 3D image. The cooling stimulus is generated by rapidly vaporizing mist using ultrasound. In the demonstration, visitors can experience the noncontact cold sensation with and without an ice image and compare them.

Keywords: cooling sensation, haptic display, midair haptics, focused ultrasound

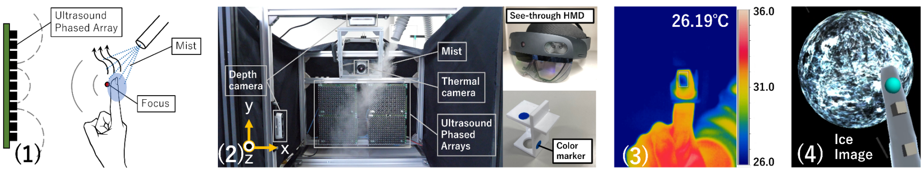

Fig. 1. (1)Presentation of cooling sensation by ultrasound-driven mist vaporization. (2)System configuration. (3)Thermal image indicating cooling. (4)User's point of view in a demonstration.

1 Introduction

Tactile stimulation can improve immersion in MR space. To avoid restricting the user's motion, noncontact tactile presentation by airborne ultrasound phased array (AUPA) has been proposed [1]. AUPA, a device with an array of ultrasonic transducers, forms a focus in the air by controlling the phase and amplitude of each transducer. At the focus, noncontact stimulation is provided to human skin.

AUPA can present not only mechanical tactile stimulus (i.e. pressure and vibration sensation) but also noncontact cooling sensation. The cooling sensation is presented by injecting a mist at the ultrasound focus and volatilizing it rapidly [4].

In this study, we add 3D visual feedback to the noncontact cooling sensation and demonstrate that the combination can realize a realistic tactile sensation of a cold object such as ice.

2 Noncontact Cooling Sensation with a 3D image

In the demonstration, participants can experience realistic cooling sensation feedback when touching the 3D images of ice and other objects (Fig.1-(4)).

Our system (Fig.1-(2)) consists of four AUPAs, a mist generator, two depth cameras (Intel RealSense D435), and a see-through head-mounted display (Microsoft HoloLens2). The AUPA has 249 ultrasound transducers driving at 40 kHz [2]. The system tracks the position of the user's fingertip to detect contact with the 3D image and present a cooling sensation. The position is measured using two cameras and two color markers at the finger. The side camera detects the z-y position of the marker at the side, and the top camera detects the x position of the marker at the top. When the fingertip contacts the 3D image, an ultrasound focus is formed on the fingertip to volatilize a mist and present a cooling sensation (Fig.1-(1)). By modulating the sound pressure at the focus, cooling sensation and vibrotactile stimulation can be presented simultaneously. We have preliminarily confirmed that this method can decrease the surface temperature of the fingertip by 1.8 degrees Celsius in 0.5 seconds (Fig.1-(3)).

3 Conclusion

We developed a system that presents a noncontact cold sensation with 3D visual feedback. In the future, we quantitatively evaluate the effect of adding visual feedback to the cooling sensation.

References

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