Sonovortex: Rendering Multi-Resolution Aerial Haptics by Aerodynamic Vortex and Focused Ultrasound

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CCS CONCEPTS

•**Human-centered computing →Haptic devices;**

KEYWORDS

haptics, air vortex, focused ultrasound

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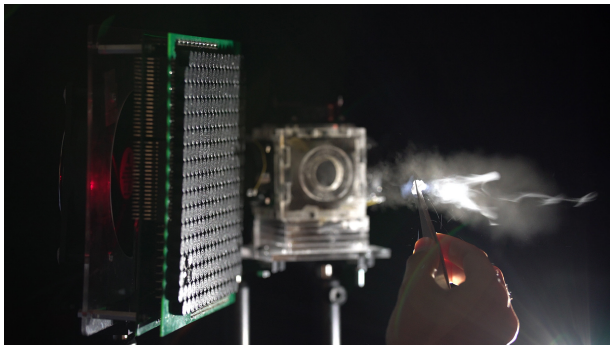

Figure 1: The Sonovortex device.

1 INTRODUCTION

Aerial haptic feedback is a popular topic in research fields on real-world-oriented interaction, augmented reality (AR), and virtual reality (VR). Various methods such as magnetic force, ultrasound, and air vortices have been proposed for this purpose.

Aerial haptic display has several advantages: it projects a force from a distance without physical contact or wearable devices, and it has high programmability. In other words, it can be set and rearranged at an arbitrary position in a 3D space because it does not require physical actuators.

In the this study, we seek to research new aerial interactions. We aim to develop a new aerial haptics system to express a wide range of feedback. The proposed system (Figure 1) combines aerodynamic and acoustic fields. We use the aerodynamic vortex [Sodhi et al. 2013]from the aerodynamic field, and the focused ultrasound [Hoshi et al. 2010] from the acoustic field to develop this device.

2 RELATED WORK

Ultrasonic technology possible to provide tactile sensations in mid-air without encumbering the user with an actuator when using ultrasound [Hoshi et al. 2010]. The position of the focal point can be changed using a phased array transducer as it is a representation of tactile behavior. Rendering volumetric haptic shapes is also possible by using focused ultrasound. MidAir [Monnai et al. 2014] reflects a virtual image in the air and provides tactile feedback using an ultrasonic speaker according to the virtual image and finger location. The imperfection of this method is that the foucused ultrasound force is very weak and only limited focal points can be generated.

An air jet was chosen intuitively to produce contactless haptic feedback with low accuracy. In [Suzuki and Kobayashi 2005], virtual objects were represented by air jets from an array of nozzles. Vortex rings have also been applied as a non-contact haptic feedback system. Air vortices have been used to provide impact in midair [Sodhi et al. 2013] These previous approaches mainly used vortex rings to add multi-modal sensation to a conventional display. However both of these methods have low fidelity due to the non-focusing stimulating area.

This study combines multiple haptics technologies as they help overcome each other's disadvantages and improve interaction width. Cross-Field Aerial Haptics [Ochiai et al. 2016] draw tactile interface in the air by combining ultrasonic waves and laser plasmas. Cross-Field Haptics [Hashizume et al. 2017] is touch type haptics device that combined magnetic and electrostatic field.

3 IMPLEMENTATION

Our system is shown in Figure 2. An air vortex is a ring of air that typically has a toroidal shape and is capable of traveling at high speeds over large distances. Vortex rings can be formed by pushing air with a piston through a circular aperture, or hole. How well the vortex is formed depends on the volume of air pushed, the velocity of the piston, and the diameter of the aperture.

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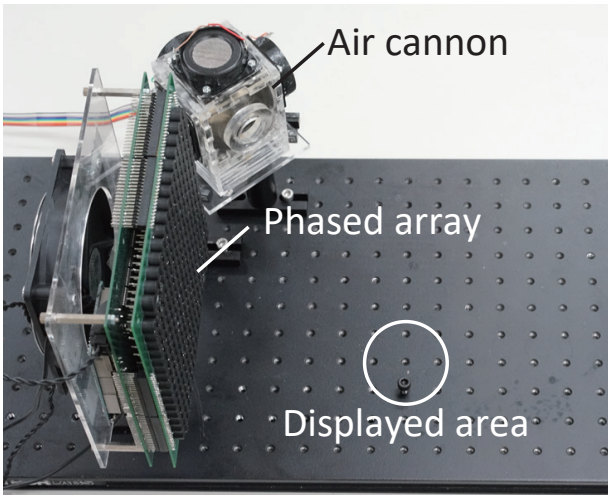

Figure 2: Aerodynamic and ultrasound system.

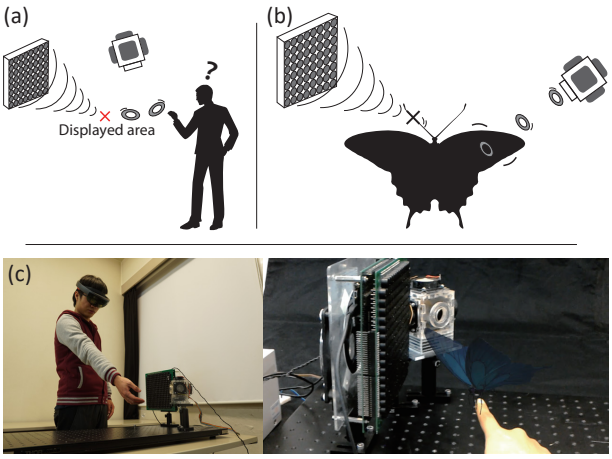

Figure 3: Application image.

The ultrasonic haptics is based on acoustic radiation pressure, which is not vibrational and presses the skin surface. This can be applied on the skin for a long time but this pressure is relatively weak (10-20 mN). The sensation is similar to a laminar air flow within a narrow area.

It's different in time to have tactile presentation of the aerodynamic vortex and the focused ultrasound. The focused ultrasound advances in the air by the speed of sound. Therefore, the focused ultrasound can express almost simultaneously tactile presentation with the generation of signal. The speed and the delay of the Aerodynamic vortex is larger than the focused ultrasound. The average speed of aerodynamic vortex device that we used has been shown to be $7.2m/s$. We applied a delay of 30mms in the focused ultrasound in order to make the aerodynamic vortex and the focused ultrasound reach the user at the same time.

4 APPLICATION

4.1 Locating haptic presentation area

Sonovortex can present high resolution haptic and low resolution haptic at the same time. In addition, by using an air cannon, haptic presentation can be presented to a wide range that ultrasonic waves can not provide tactile sense. Since the scope of haptic presentation of ultrasound is narrow, it is hard to understand where tactile presentation is occurring. However, if we show the route to the presentation range of the ultrasonic tactile with the air cannon (Figure 3(a)), we can easily reach the place where the ultrasonic tactile sense is presented. Guiding a disability parson to a tactile presentation area is possible.

4.2 Tangible display

Air cannon, which is low resolution haptic presentation method, can move larger things than ultrasonic waves. Therefore, it is possible to display expressions in which relatively large objects such as leaves and feathers are moved with an air cannon, and fine items such as petals and Antennae are moved by ultrasonic waves (Figure 3(b)).

4.3 VR and MR

Sonovortex can be used for VR and MR. In conventional aerial haptic technology, only a single resolution could be presented. Sonovortex can present multiple resolution haptic simultaneously(Figure 3(c)) . Therefore, reproducing tactile sensations such as fine shape and large motion is possible. In the case of butterflies, fine shapes such as antennae and feet are represented by ultrasound. Large movements such as butterfliy's wing movements are expressed with an air cannon. Besides, we can also express the movement of leaves of plants and the shape of branches.

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