Ultrasound-Driven Fingertip-Mounted Passive Haptic Device Using a Simple Lever Mechanism

Tao Morisaki[1*], Masahiro Fujiwara[1], Yasutoshi Makino[1], Hiroyuki Shinoda[1]

[1]Graduate School of Frontier Sciences, The University of Tokyo, Japan
author morisaki@hapis.k.u-tokyo.ac.jp

Abstract. A lightweight and powerful tactile display is required for a natural tactile experience. In this study, we demonstrate a fingertip-mounted passive haptic device remotely driven by airborne focused ultrasound. This plastic passive device is lightweight (6.2 g) and presents strong haptic stimuli of 0.39 N. The device amplifies an input acoustic radiation force (0.02 N) using a lever mechanism and presents the amplified force (0.39 N) to the finger pad in 46 ms.

Keywords: passive haptic actuator, ultrasound, lever mechanism

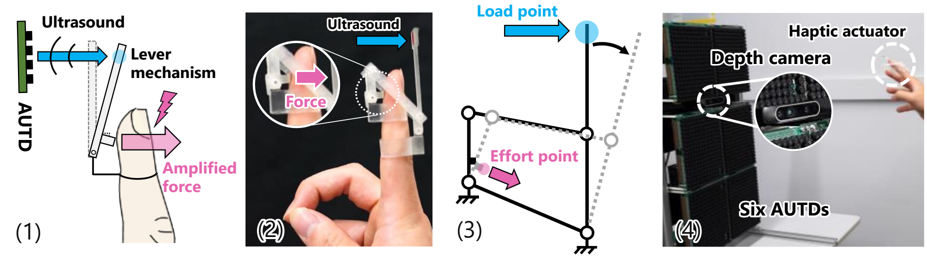

Fig. 1 1) Concept of ultrasound-driven passive haptic device using a simple lever mechanism. 2) Developed finger-mounted passive haptic device. The device amplifies applied ultrasound radiation force 19.8 times and presents the amplified force (haptic stimulus) to the finger pad. The amplified force was up to 0.39 N in this setup. 3) Schematic of the finger-mounted device. 4) Driving system of the device.

1 Introduction

Haptics is applied for many applications such as immersive VR. For a natural tactile experience, a haptic device that does not restrict the user's movement is needed.

This study proposes a fingertip-mounted passive haptic device driven by airborne focused ultrasound (Fig. 1). This device is lightweight (6.2 g) and does not require complex wiring even when multiple devices are used. The device presents strong haptic stimuli (0.39 N) to the finger pad in 46 ms by amplifying an input acoustic radiation force (0.02 N) which is a weak noncontact force generated at ultrasound focus. The amplification is realized by a lever mechanism. This device has a large workspace and fast presentation time compared to conventional passive devices [2, 4].

The amplification of ultrasound radiation force using a lever, shown in Fig. 1-(1), is effective for developing such a high-speed and powerful passive actuator. Since the radiation force is presented at the sound velocity, even if the force is amplified by a lever, the presentation speed of the amplified force is still fast.

2 Fingertip-Mounted Passive Haptic Device

The developed passive haptic device for a fingertip is shown in Fig. 1-(2) and (3) and the driving system is shown in Fig. 1-(4). The plastic haptic device weighs 6.2 g and was developed using a lever-crank mechanism. By applying ultrasound radiation force to the edge of the lever, the device is driven and presents the amplified force (haptic stimulus) to the finger pad. The amplification factor was 19.8 times. The driving system consists of six airborne ultrasound tactile displays (AUTDs) generating focused ultrasound [1, 3, 5] and a depth camera (RealSense D345, Intel). The depth camera measures the edge position of the lever, and the AUTDs focused ultrasound on the edge and drive this haptic device in real-time (60 fps).

In this demo, participants can experience a strong haptic stimulus up to 0.39 N presented by the passive haptic device. This device also can present a low-frequency vibration (5–10 Hz) by modulating applied radiation force.

3 Conclusion

In this study, we proposed a fingertip-mounted passive tactile device driven by airborne ultrasound. The device is lightweight and can present strong constant force (0.39 N) and low-frequency vibration. In the future, we will develop various forms of an ultrasound-driven passive actuator, such as an accessory type.

References

1. Carter, T., Seah, S.A., Long, B., Drinkwater, B., Subramanian, S.: Ultrahaptics: multi-point mid-air haptic feedback for touch surfaces. In: Proceedings of the 26th annual ACM symposium on User interface software and technology. pp. 505–514. ACM (2013)
2. Hiraki, T., Nakahara, K., Narumi, K., Niiyama, R., Kida, N., Takamura, N., Okamoto, H., Kawahara, Y.: Laser pouch motors: Selective and wireless activation of soft actuators by laser-powered liquid-to-gas phase change. IEEE Robotics and Automation Letters 5 (3), 4180–4187 (2020)
3. Hoshi, T., Takahashi, M., Iwamoto, T., Shinoda, H.: Noncontact tactile display based on radiation pressure of airborne ultrasound. IEEE Transactions on Haptics 3 (3), 155–165 (2010)
4. Lu, X., Yan, Y., Qi, B., Qian, H., Sun, J., Quigley, A.: Contactless haptic display through magnetic field control. IEEE Transactions on Haptics (2022)
5. Suzuki, S., Inoue, S., Fujiwara, M., Makino, Y., Shinoda, H.: Autd3: Scalable airborne ultrasound tactile display. IEEE Transactions on Haptics 14 (4), 740–749 (2021)