LaserStroke: Mid-air Tactile Experiences on Contours Using Indirect Laser Radiation

Hojin Lee
Pohang University of Science and Technology (POSTECH)
Pohang, South Korea
hojini33@postech.ac.kr

Hojun Cha
Pohang University of Science and Technology (POSTECH)
Pohang, South Korea
hersammc@postech.ac.kr

Junsuk Park
Pohang University of Science and Technology (POSTECH)
Pohang, South Korea
park64kr@postech.ac.kr

Seungmoon Choi
Pohang University of Science and Technology (POSTECH)
Pohang, South Korea
choism@postech.ac.kr

Hyung-Sik Kim
Konkuk University
Chungju, South Korea
hskim98@kku.ac.kr

Soon-Cheol Chung
Konkuk University
Chungju, South Korea
scchung@kku.ac.kr

ABSTRACT
This demonstration presents a novel form of mid-air tactile display, *LaserStroke*, that makes use of a laser irradiated on the elastic medium attached to the skin. LaserStroke extends a laser device with an orientation control platform and a magnetic tracker so that it can elicit tapping and stroking sensations to a user's palm from a distance. LaserStroke offers unique tactile experiences while a user freely moves his/her hand in midair.

Author Keywords
Laser; Haptics; Mid-air; Tactile display; Touch interaction.

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces - Haptic I/O

INTRODUCTION
Most haptic interfaces transfer the energy produced by actuators to the skin through solid channels. This requirement, however, may undermine the usability of haptic interfaces depending on applications. In such cases, mid-air haptic displays, e.g., those using air jets [6] and acoustic radiation via ultrasonic waves [2, 1], are promising alternatives transmitting stimulus energy through air. They also provide natural tactile sensations, but they share one fundamental problem that the energy travel distance is quite limited.

Recently, a new alternative has emerged seeking the possibility of using lasers for mid-air tactile stimulation [3, 4, 5]. A laser can travel a long distance with little energy attenuation, which is a clear advantage compared to air jets and

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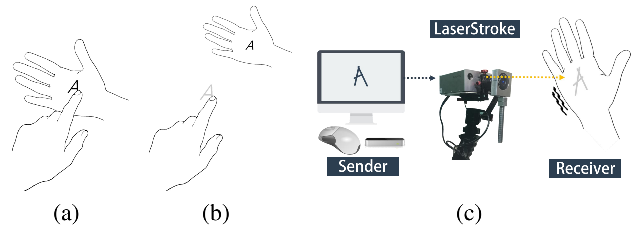

Figure 1. (a) Direct skin stroke. (b) LaserStroke: 2D skin stroke by a laser in free air. (c) System diagram.

ultrasound. Our research group first demonstrated that laser-induced thermoelastic effects can elicit a tactile sensation when a nanosecond laser is irradiated directly to the human skin [3]. However, we encountered large individual differences in the induced sensation, ranging from mechanical tap to pain, and it was due to the individual-dependent optomechanical properties of the skin. To address this problem, we suggested indirect laser radiation: a laser pulse is irradiated on the elastic medium attached to the skin [4]. This method can invoke a tapping-like tactile sensation with little individual variance. In parallel, Ochiai et al. presented a display utilizing a femtosecond laser to provide both visual holograms and tactile sensations focused in air [5].

In this demonstration, we present *LaserStroke*, a laser-based mid-air interactive tactile display system, extended from [4] in order to provide a sequence of moving tactile stimulations to the user's palm (Figure 1). In LaserStroke, a laser device is mounted on a motorized platform that controls the laser radiation orientation, and the user's hand is tracked by a magnetic tracker. By irradiating repeated laser shots to the user's palm, we can elicit a sensation of smooth stroke on the palm following a given contour in midair. Details are described in the rest of this paper.

HARDWARE COMPOSITION
Figure 2 shows an overview of LaserStroke. We use a Q-Switched Nd:YAG laser device (M-NANO, Montfort Laser GmbH), which has a wavelength of 1064 nm and a pulse

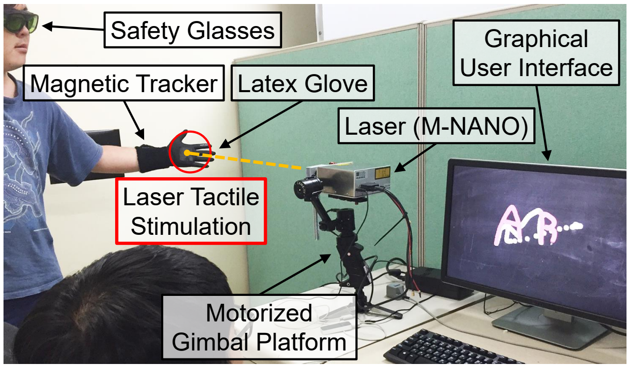

Figure 2. Implmented System.

Figure 3. Glove for 2D indirect laser radiation.

length of 8 ns. The spot size of laser pulse is approximately 5 mm, and the repetition rate of laser pulses is set to 30 Hz. The laser device is mounted on a commercial gimbal platform for cameras (CAME-Single, Came-TV), which supports rotational motion of the laser device in two degrees of freedom (yaw and pitch).

To provide mid-air tactile sensations, we adapt the indirect laser radiation method presented in [4] as follows. A user wears a black latex glove that fits the hand tightly (Figure 3). This is to ensure a sufficient strength of tactile stimulation and also block unexpected heat transfer. Both are evoked by the absorption of a laser irradiated on a light-absorbing elastic medium attached to the glove. As for the elastic medium, the palm of the glove (50 mm $\times$ 50 mm) is coated with a black rubber-coated polyvinyl chloride (PVC) tape. This material is chosen for its high light-absorption rate and elasticity, which are crucial to invoke a thermoelastic expansion of the medium sufficient for tactile perception. The user also wears a wrist band to which a wireless magnetic tracker (Liberty Latus, Polhemus) is fastened for position/orientation tracking of the hand. Laser shots are irradiated on the PVC-taped region on the glove for tactile rendering.

DEMONSTRATION SCENARIOS

Our demonstration will proceed in two interactive scenarios of free stroking and symbol messaging. Each interactive demo engages two users: a Receiver and a Sender. In both demos, the Receiver wears the glove and wrist band in one hand. In the free stroking demo, the Sender sits in a chair in front of a computer screen and draws a contour on the screen using a mouse or a Leap Motion controller (a commercial finger tracking device). In the symbol messaging demo, the Sender selects a symbol out of many symbols (shapes or alphabets), and then LaserStroke automatically generates a predefined trajectory for the selected symbol. For these trajectories, LaserStroke computes desired radiation points on the Receiver's palm to draw the trajectories and controls the laser device and mounting platform to irradiate laser shots, also based on the measured position/orientation of the hand by the magnetic tracker.

CONCLUSIONS

LaserStroke is an interactive mid-air tactile display system that tracks the user's hand and irradiates laser beams on the hand accordingly in order to elicit continuous tactile sensations while allowing free movement of the user's hand. Its use of laser gives advantages in terms of spatial resolution and energy travel distance compared to other alternatives. This demonstration presents two interactive scenarios using LaserStroke to validate the usefulness of laser-based mid-air tactile displays.

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