An Emotional Tactile Interface Completing with Extremely High Temporal Bandwidth

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Abstract: We proposed and developed a novel interface to display high-quality tactile information by improving the temporal bandwidth extremely. The system is composed of two oppositely arranged speakers. A user holds the speakers in between his/her both hands while the speakers vibrate air between the speakers and the palms. The user feels suctioning and pushing sensations to the palms from the air pressure. Spatial distribution of the pressure is uniform and the user can feel pure force without any feeling of edges. As the speaker has a potential to present tactile sensation of very wide frequency range, we can present many types of high-quality tactile feeling, such as liquid, some small objects and living matter. Additionally, we implemented several interactions between the display and the user by using force sensor and acceleration sensor, which enabled us to experience emotional feeling.

Keywords: Tactile, Air Pressure, Palm, Speaker, High temporal bandwidth

1. INTRODUCTION

Currently, we can get quite high-quality visual and audio information without circumstance. On the other hand, high-quality haptic/tactile information is not obtained yet. Many projects are trying to develop haptic/tactile device for present “literal” information like Braille, but almost all people can get literal information from visual or audio. Therefore, we should think original and high-quality haptic/tactile contents that can only be accomplished by tactile perception.

Recently, some projects proposed “affective haptics”. Maclean et al. [2] investigated many type of haptic devices and haptic interaction design. They introduced the notion of “Haptic Affect” and “Emotional Communication”. Yohanan et al. [3] developed an affective haptic interface like a plushie, and found that participants registered a broader range of affect when active haptic renderings were applied as compared to when none were presented. Smith et al. [4] developed a methodology to measure the influence of design parameters on objective and subjective indicators of affect communication. They also demonstrated that affect can be communicated over a purely haptic link. Although these researches succeeded in defining a method of affect haptic design, expressiveness of devices were not so high because of using a conventional way of haptic presentation.

In this paper, we focus on a high-integrity tactile sensation for emotional communication. The high-integrity sensation will enable us to experience delicate feelings like emotional, subtle and tender sensations. We also developed high-integrity tactile display. Our interface system is very simple, consisting of just one or two speakers. Therefore, our system can be embedded in every device like a plushie, a PDA, a remote, a cell phone and so on. We first describe our strategy and method of presenting high-integrity tactile sensation. Next, we explain our prototype and show a performance of our prototype by experiment. Finally, we show some ideas using our system.
3. METHOD

In our basic method, a user holds the device with his/her hand and an elastic band around the circumference of the speaker cone seals the air between palm and cone (Fig. 2). If the cone of the speaker is pulled, the user feels suction, or negative pressure. If the cone is pushed, the user feels positive pressure. By controlling frequency and amplitude, our system can present temporally rich tactile sensations.

We used a speaker for our tactile device, because a speaker has great potential in presenting varied tactile information with changing frequency and amplitude. Our method uses air pressure that is fluctuated by the vibration of a speaker to indirectly stimulate the skin. Previous devices that used air pressure presented only low frequency tactile sensations [5]. In contrast, we tried to present tactile sensations of a very wide range of frequencies using a speaker, because the speaker can easily be actuated from very low (about 1Hz) frequency to very high (about 20kHz) frequency. For example, the speaker presents very soft and comfortable tactile feelings with a 1-30Hz sinusoidal wave in our method. Normal vibrations are felt at 30-1kHz. As the speaker can obviously present sound, the device is a simple and natural multimodal interface.

Using air pressure has another merit. In the case of a mechanical tactile display, solid moving pins contact and distort the skin. As the spatial distribution of the distortion is not uniform, users experience some sort of “shape”, which is unnecessary and cumbersome information. Conversely, when we use air pressure, we can present purely uniform pressure to the palm, and the user feels only the pressure without any feeling of edges.

4. IMPLEMENTATION

We made two types of prototypes. One has just one speaker and presents tactile sensation to one palm. The other one has two speakers and presents tactile sensation to both palms.

4.1 One speaker version

This prototype is composed of one speaker, a force sensor (Nitta Corporation, FlexiForce A201-1), an acceleration sensor (Kionix, Inc., KXM52-1050), Interface board (Interface Corporation, PCI-3523A), a stereo amplifier (Rasteme Systems Co., Ltd., RSDA202), and PC (Fig. 3). The handheld part has a speaker and sensors. A board which speaker and sensors are installed is three layer structure; acrylic board, silicone sheet and wooden board. Acrylic board is for operation finger. Silicone sheet is for the force sensor. The force sensor is embedded between a wooden board and a silicone sheet to adjust a sensitivity of force sensor. The speaker and the acceleration sensor are installed on a wooden board. In this version, the PC generates various signals. The generated signal is transmitted to the speaker via the stereo amplifier. Data from the force sensor and acceleration sensor are monitored by the PC. Thus we can change the frequency and amplitude of the wave by these values in real time. If we use a touch panel instead of the board, we can interact with a virtual object by visual and tactile sensations.

4.2 Two speaker version

This prototype is composed of two speakers, a force sensor (Nitta Corporation, FlexiForce A201-1), an acceleration sensor (Kionix, Inc., KXM52-1050), a microprocessor board (Renesas Technology Corp., H8 3048F), and a stereo amplifier (Rasteme Systems Co., Ltd., RSDA202) (Fig. 4).
The handheld part has an outer shell made of ABS resin. The force sensor and the acceleration sensor are embedded in the shell. In this system, the microprocessor generates a sinusoidal wave. The generated signal is transmitted to the speakers via the stereo amplifier. Data from the force sensor and acceleration sensor are monitored by the microprocessor. Thus we can change the frequency and amplitude of the wave by these values in real time.

4.3 Silicone membrane
We sealed the speaker cone with thin (1.0mm) and soft (degree of hardness is 5) silicone membrane so users with any hand size can use our system without air leakage (Fig. 5). This technique is also effective for presenting tactile sensation and texture at the same time. For example, when covering this system with a cloth that has unique texture, this membrane pushes or pulls the cloth with the air seal maintained. We can choose whether to use the membrane or use the palm directly for sealing depending on the situation.

![Fig. 5 Silicone membrane](image)

5. EXPERIMENT
We have measured the pressure presented to the palm using frequencies from 1Hz to 500Hz to confirm the performance of our system [1]. We confirmed the system can present about 1.4kPa (about 400gf) or more to the palm at each frequency (Fig. 6).

![Fig. 6 Relationship between frequency and presented air pressure](image)

Next, we conducted an experiment to replicate two types of waveforms using the feedback control. The aim of this experiment was to confirm response and repeatability of the pressure when it has feedback control. The control frequency was 2 kHz.

For a sinusoid wave, there was practically no phase lag and a measured value partially traced destination value in any frequency, has certain noise (Fig. 7). The reason of this problem is that a noise from the sensor propagated to a control signal.

![Fig. 7 Wave-forms of the destination and measured pressure value (1 Hz)](image)

In case of a rectangular wave, a delay in response of step change of pressure was 5ms or less, and a measured value partially traced destination value (Fig. 8). Currently, we couldn’t eliminate a rising oscillation and negative-going oscillation. We suppose that a main reason for the oscillation is a characteristic of the speaker. The speaker has very high response rate (up to 20kHz), but current control system is controlled by 2-3kHz. Therefore, current control system is too slow to fully manipulate the speaker. We will try to fix this problem by reforming control algorithm and using higher control loop.

In conclusion, we confirmed a high potential of speaker as a tactile device, and got a primary knowledge to control a speaker well through these experiments.

![Fig. 8 Wave-forms of the destination and measured pressure value (1Hz)](image)
7. APPLICATION

We have three main ideas as the effective application of our system.

7.1 Living matter

Our system can be applied to present the natural feeling of “living matter”. We have already developed this application, and several hundred people have experienced it.

We adopted a two speaker version of our system. This system reproduces the heart beat or breath of a small living being such as a cat, hamster, or bird. The base frequency is very low (3–5Hz), so a user can experience very soft and comfortable tactile sensations.

We also prepared three different sized devices (Fig. 9). The smallest is 57mm × 90mm × 70mm, the middle-sized is 60mm × 130mm × 109mm and largest is 100mm × 170mm × 110mm. The size and base frequency can be chosen according to the user’s preference.

Furthermore, we implemented interaction scenarios using a force sensor.

1. When the device is held softly, it presents a tactile sensation with stable low frequency.
2. When the device is squeezed strongly, the frequency and amplitude become lower and erratic, as if the living matter is suffering.
3. After squeezing, when the grip is loosened, the frequency and amplitude become faster and larger as if the living matter becomes breathless.

We demonstrated this application, and about two hundred people experienced it. Most of them felt a soft tactile sensation to their palms and reported a certain sensation of a living thing in their hands. This result suggests that our system could display “emotional information” by tactile means.

7.2 Handheld device

In this application, we aim to enhance the tactile sensation conveyed by a handheld device. Many previous works have presented tactile sensation to an operating hand [6]. In addition, almost all cell phones, gaming controllers, personal digital assistants and several other devices present tactile sensations to holding hand [7]-[12]. Unfortunately, they only use low-quality vibration. In contrast, our system can provide extremely high quality tactile information. For example, our system has the potential to present feelings of “physical dynamics” such as viscosity and elasticity. Note these physical sensations have been presented by haptic (force) displays previously, but in our system, we only stimulate tactile or skin sensations.

We tried to display a physical model by using one speaker version. In case of “emphasized shake”, the speaker presented push or suction force depending on the user’s shaking motion. As a result, the user felt as if liquid was moving inside the device. This result indicated that the system successfully reproduced physical sensations by tactile stimulation.
7.3 Tactile communication

Previous works have proposed tactile mutual communication. InTouch [13] is an interpersonal communication device using the force-feedback of three poles. A user can share the poles with a remote user by haptic sensation. ComTouch [14] transmits information on the pressing of a hand by vibration and augments remote voice communication with tactile sensation. Ozawa et al. [15] developed a 3D hand shaking system, in which a user wears a haptic glove type device and looks at a 3D display, and the user feels the haptic sensation of shaking hands with another user. The Robotic User Interface [16] enables a physical remote communication by swinging the arms or head of a robot. These works need either a complex display or a physical object intermediating for the two users. On the other hand, our system has the possibility of transmitting emotion most directly, because the intermediate layer is thin silicone membrane or air. In other words, our system conceivably realizes true “skin to skin” communication. Thus, we have considered using our system for tactile communication and have two methods for effective tactile communication. Our first prototype is to attach a speaker to a cell phone as in Fig. 13.

The first method is one-way communication using a touch panel. First, a device recognizes the user’s touching force pattern with a touch panel. The device then transmits this pattern and a partner’s device reproduces it (Fig. 15). VibeTonz [17] realized the transmission of some emotions by vibration. However, our system can present finer and more affective tactile information.

The other method is to “virtually hold hands”. Our device (including a force sensor, heart rate meter, acceleration sensor, etc.) reads the situation for each user. The data for the situation is sent to the partner’s device using a network in real time. Each device then renders the partner’s situation by tactile sensation. In addition, when attaching our device on a cell phone with Bluetooth, the user can talk while feeling the partner’s affection, warmth and affinity.

8. CONCLUSION

In this paper, we described our strategy for designing a new type of tactile interfaces and a method for achieving it. Furthermore, we implemented prototypes and confirmed their performance. Our system showed sufficient temporal high fidelity, which is necessary for the expression of affective touch. We can present very rich tactile sensations such that the user can imagine as if he or she is holding real matter. In our next stage, we will implement the effective applications for the device, which should show us new realm of tactile contents.

REFERENCES


