A Novel Interface to Present Emotional Tactile Sensation to a Palm using Air Pressure

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Abstract
We propose a new tactile interface to present various types of tactile sensation, especially a feeling of "softness". A user holds our interface, containing two speakers, with both hands while the speakers vibrate air between the speakers and palms. The user feels suctioning and pushing sensations to the palms due to the air pressure. By changing the frequency of vibration, the user experiences not only normal vibration but also "soft" feelings like that of liquid, spring-like objects, and living matter.

Keywords
Tactile, Air Pressure, Palm, Speaker, Handheld Device, Multimodal Information, Living Matter

ACM Classification Keywords
H5.2. Information interfaces and presentation: User Interfaces.

Introduction
Recently, the specifications of handheld devices have improved dramatically. As the treated information has become richer, we must consider a new type of user interface that can co-exist with existing interfaces, such as audio and visual interfaces, that is sufficiently intuitive to reduce the user's load.

A tactile interface is one such possibility. Many projects are trying to develop haptic/tactile sensations in handheld devices. Sekiguchi et al. proposed a haptic device to convey the sensation that "something is inside the box" using a solenoid or linear motor when a user shakes the device[1][2][3]. Poupyrev et al. developed TouchEngine[4], which presents a tactile sensation of a virtual button when a user pushes a display with his/her finger using thin piezoceramic film. Williamson et al. made a multimodal interface that recognizes shaking, tilting or a wobbling motion and conveys the presence of virtual balls by vibration and sound[5]. Yano et al. suggested a non-grounded haptic interface using the gyro effect[6]. Sakai et al. developed a haptic display using the time differential of angular momentum[7]. Amemiya et al. developed the Virtual Force Display[8] that presents a virtual force vector using periodic asymmetric acceleration.

Although these approaches succeeded in presenting haptic/tactile sensations, the quality of sensation is not high, and users can feel only a single or a few kinds of sensation. Therefore, in this paper, we focus on a richer expression of tactile sensation in handheld devices. Richer sensation will enable us to experience delicate feelings like emotional, familiar, subtle and tender sensations. In addition, our interface system is very simple, consisting of just two speakers.

Method

A strategy of temporally high and spatially low resolutions

In our basic strategy, a user holds the device with his/her hands and an elastic band around the circumference of the speaker cone seals the air between palm and cone (Figure 1). 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.

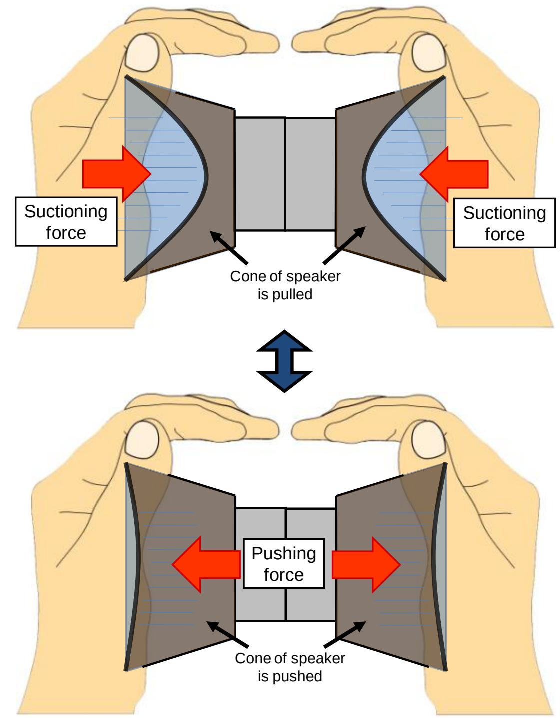

Figure 1. Negative and positive pressures conveyed with our device

Let us note the main difference between conventional tactile displays and our proposed display. There are two types of resolution in a tactile display. One is spatial, and the other is temporal. Conventional tactile displays seek to achieve higher spatial resolution, because their primary purpose is to display rich "literal" information, such as Braille. We call them, "temporally low, spatially high resolution" tactile displays. On the other hand, conventional "wearable" tactile displays use a different strategy. Due to the limitation of mounting space and the power source, they used one or a few vibration motors or solenoids. As a small mechanical device needs to utilize mechanical resonance for efficiency, the temporal bandwidth is notably narrow. We call them "temporally low, spatially low resolution" tactile displays.

Contrary to these previous tactile displays, our goal is to display "emotional", not "literal" information. Here, temporal bandwidth is much more important than spatial resolution. Our strategy is to present richer expression of tactile sensation by improving the temporal bandwidth, while keeping the spatial resolution low (Figure 2). As handheld devices already present figures, photographs, and video by visual display, they do not need to present shape by tactile sensation.

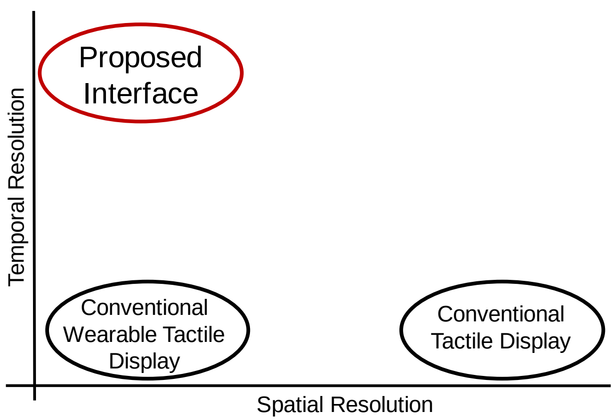

Figure 2. Performance of conventional tactile displays and the proposed interface

Method for producing the proposed interface
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. A previous device that used air pressure presented only low frequency tactile sensations[9]. 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. In our method, the speaker presents very soft and comfortable tactile feelings at 1-30Hz. 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 onto the palm, and the user feels only the pressure without any feeling of edges.

Implementation
The 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) (Figure 3). The handheld part has an outer shell made of ABS resin. The force sensor and

acceleration sensor are embedded in the shell (Figure 4). 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.

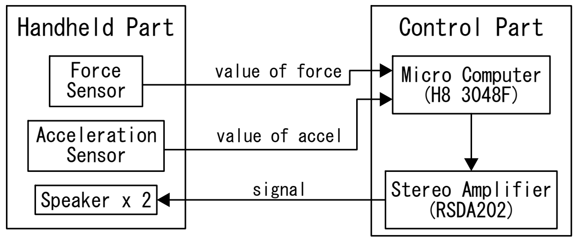

Figure 3. Overview of our system

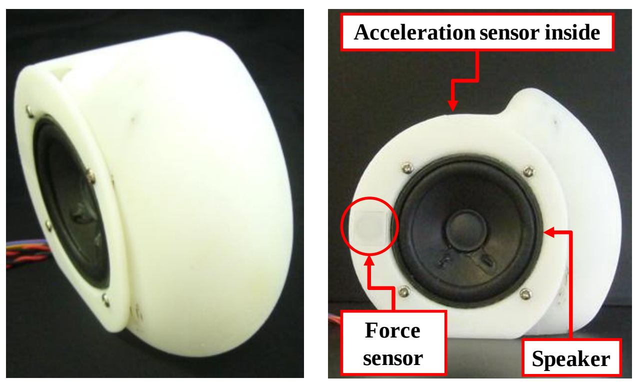

Figure 4. Handheld part

Experiment

First, we measured the pressure presented onto the palm from 1Hz to 500Hz to confirm the performance of our system. The amplitude for each frequency signal was constant.

From figure 5, we see the system can present about 1.4kPa or more to the palm at each frequency; 1.4kPa on the whole palm corresponds to about 400gf. Therefore, we confirmed our system has a very high temporal bandwidth.

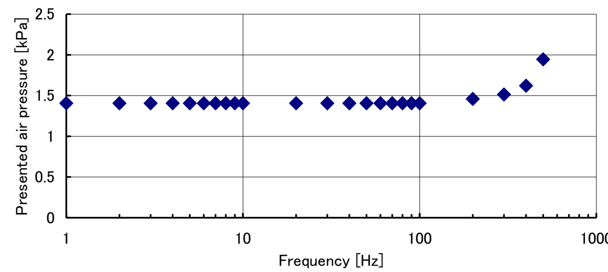

Figure 5. Relationship between frequency and presented air pressure

Next, we conducted an experiment to determine the relationship between frequency and tactile feeling. We also conducted two experiments using data from the force sensor and acceleration sensor.

Exp 1: Changing frequency

In this experiment, we used three categories of sinusoidal wave: low (1 to 3Hz), medium (3 to 30Hz) and high (30 to 300Hz). The phase difference of the two speakers was zero; when one speaker pushed or pulled the air, the other speaker pushed or pulled at the same moment.

Exp 2: Force feedback

In experiment 1, users felt the existence of some sort of living matter. Therefore, in the second experiment, we tried to emphasize that feeling using the force sensor attached to the surface of the device. The interaction was implemented according to the following scenario.

(1) When the user cradles the device in his/her palms, the speakers present a tactile sensation with stable frequency and amplitude to both palms.

(2) When the user strongly squeezes the sensor, the frequency becomes lower and erratic. The amplitude also changes erratically. This conveys the feeling of “suffering living matter”.

(3) When the user loosens his/her grip, the frequency and amplitude become faster and larger. This conveys the feeling of “tensed living matter”. Finally, the frequency and amplitude gradually return to their initial states (Figure 6).

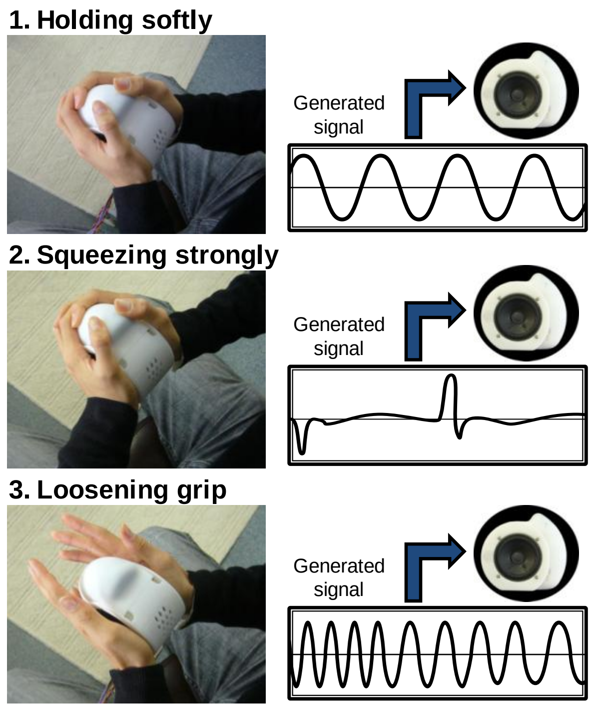

Figure 6. Feedback of force value

Exp 3: Acceleration feedback

The following experiment uses data from the acceleration sensor. When the user shakes the device, the two speakers are driven synchronously with the acceleration. For example, when the device is accelerated from left to right, the right speaker pushes air, while the left speaker pulls air (Figure 7). As a result, the user feels some sort of an “emphasized shake”. The feeling changes according to the time-delay between the acceleration and the speakers’ motion, yet it certainly implies dynamics, and the user can imagine liquid or small contents rattling around inside the device.

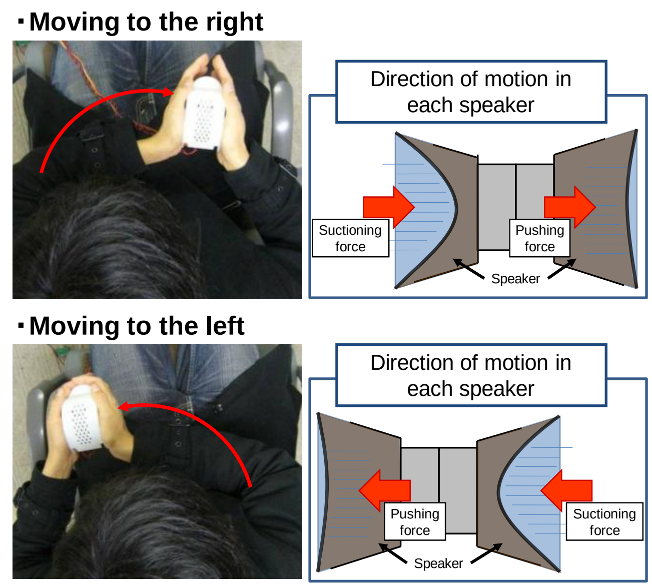

Figure 7. Feedback of acceleration value

Results and Discussion

About a hundred people took part in the three interface experiments. In experiment 1, for low (1 to 3Hz) and medium (3 to 30Hz) frequencies, most felt a soft tactile sensation to their palms and reported the sensation of a living thing in their hands. However the type of living matter that people imagined differed. At low frequency, most people imagined medium-sized living matter like a dog or cat. On the other hand, at medium frequencies, people imagined small living matter like a small bird or hamster. The reason for this difference is that the frequency of the throbbing of living matter quickens in proportion to the size of the body. As the primary goal of the device was to display not "literal information" but "emotional information" by tactile means, we can say we have achieved our goal. Note that as our system uses air pressure, no hard object contacts the skin, and there is no spatial edge. These features seem to play an important role in users imagining living matter. At high frequencies (30 to 300Hz), users reported feeling vibrations similar to those of a motor or solenoid.

In experiment 2, most people imagined a sensation of living matter stronger than that in experiment 1. In experiment 3, many people felt as if liquid was moving inside the device. Note this type of feeling of "physical dynamics" has been presented by haptic (force) displays previously, but in our system, we only stimulated tactile or skin sensations.

Conclusion

Our system can present very rich tactile sensation so that the user imagines some sort of real matter. This was achieved using temporally high and spatially low resolution tactile presentation.

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