KUSUGURI: A Shared Tactile Interface for Bidirectional Tickling

Masahiro Furukawa
Keio University
Graduate School of Media Design
4-1-1 Hiyoshi Kohoku-ku Yokohama
Kanagawa 223-0061
+81-45-548-5688, JP
m.furukawa@tachilab.org

Hiroyuki Kajimoto
The University of Electro-Communications
1-5-1 Chofugaoka Chofu
Tokyo 182-8585
+81-42-443-5445, JP
kajimoto@hc.uec.ac.jp

Susumu Tachi
Keio University
Graduate School of Media Design
4-1-1 Hiyoshi Kohoku-ku Yokohama
Kanagawa 223-0061
+81-45-548-5688, JP
tachi@tachilab.org

ABSTRACT
Tickling, a nonverbal form of communication, can provide entertainment. Therefore, tickling is a desirable addition as content as a remote communication method. However, tickling is difficult to realize because it requires both body contact as well as bidirectionality. In this paper, we propose a method of "Shared Tactile Interface" which allows sharing of a body part with another user at a distance. The interface has three features: direct contact, transfer of the tickling sensation, and bidirectionality. The first allows users to view another person's finger as if it is directly contacting the user's own palm and moving on the user's palm. The second feature delivers a vibration to the user's palm which generates an illusion and perception of a tickling sensation. The third feature enables bidirectional tickling because one user can also tickle the other user's palm in the same manner. We built prototypes based on this design method, and evaluated the proposed method through two technical exhibitions. The users were able to tickle each other, which confirmed that the design method "Shared Tactile Interface" works as expected. However, we found issues especially regarding the reliability of the tickling sensation.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Haptic I/O, Screen design, Theory and methods*

General Terms
Design, Theory, Human Factor

Keywords
Tickling Sensation, Tactile Illusion, Haptic Communication, Tactile Communication, Tactile Interface

1. INTRODUCTION
Tickling has an important role in fostering a sense of trust [1]. In general, we can talk to each other with voice by telephone and we can also use gestures with video chat, even if we cannot meet person-to-person. On the other hand, it is still difficult to cultivate our relationships with physical contact at a distance. Tickling as an informal form of communication is not easy to realize across distances because tickling is based both on touching each other and on reciprocal touching.

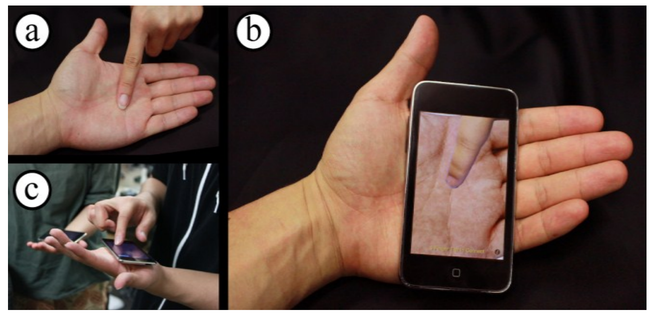

Figure 1. Concept of the "Shared Tactile Interface". (a) Being tickled directly, (b) Being tickled virtually with the Shared Tactile Interface, (c) Tickling each other with our proposed method

For tickling devices to be effective, both users need to use them to tickle each other. However, employing these devices requires a mechanism that tends to be quite large. In addition, tickling works as communication only when each person is able to touch the other; otherwise, it lacks context. In addition, one-sided tickling can harass another person.

In this paper, we propose a design method that we call a "Shared Tactile Interface." The device shown in Figure 1 (b) allows the user to share a part of the body in order to tickle a second person at a distance. To achieve this, we focus on the feature of tickling where a feeling of being tickled occurs when tickling is initiated by another, but not by oneself. This feature takes into account the use of a part of body not only in order to tickle another person, but also in order to be tickled. This method provides the users with the experience of tickling each other with handheld devices without losing general-purpose properties. In other words, our proposed method is expected to be simple but also will achieve scalability.

We found that the tickling as a form of nonverbal communication requires the following three conditions: the tickling sensation must be transferred; bidirectional contact is needed; and bidirectional tickling must be sensed. Of course, the user at the other end must feel the tickling sensation. Bidirectional contact between users is necessary for interactive tickling. No method has yet been proposed that fulfills these three conditions. The contributions of this paper are the following:

1. Provides a method that gives the illusion of tickling
2. Measures and transfers a tickling sensation
3. Provides a visual design method that gives the impression of users touching each other

2. RELATED WORK

The goal of this research is for two users to tickle each other across a long distance. Typically, a vibration motor is attached to a body [2][3] to achieve a sensation. Kume proposed the Foot interface, which has vibration motors on the underside of a slipper shaped device, and provides the sensation of movement of tickling insects moving under the slipper when the user steps down [2]. However, this sensation is not bidirectional. Tsetserukou et al. reported a wearable humanoid robot that included a tickling device called the "HaptiTickler", which allowed users to tickle each other [3]. This method, however, requires a virtual space and avatar in addition to the tickling device.

Methods that do not use vibration motors have also been proposed; for example, the tickling of crawling insects has been realized by random direct contact of small hard wires to the skin [4]. This method requires a large number of spatial actuators although its effect has a high degree of reality. Kitagawa determined that a sound recorded by an inner ear microphone in a dummy head when its ear is stroked with a paintbrush delivers a tickling sensation to a listener. However, applying this method for bidirectional tickling is difficult because it requires visual feedback for the listener during stroking.

Bidirectional haptic or tactile communication can be roughly divided into two methods: a way to deliver a force [6][7], and a way to deliver simulated gestures [8][9]. Scott has proposed the rolling tube, named "inTouch," which allows transfer of an active gesture as a torque, but also bidirectional perception of the gesture. However, in this case, the purpose is not for users to touch each other. Eichhorn has reported a handheld device that allows a user to stroke each other [8]. However, this device is not suitable for general purposes; it is designed only for this purpose. Hemmert has designed a mobile phone-shaped device that allows kissing and whispering. It is difficult to achieve this concept with a small handheld device because it needs to be driven by an outer actuator.

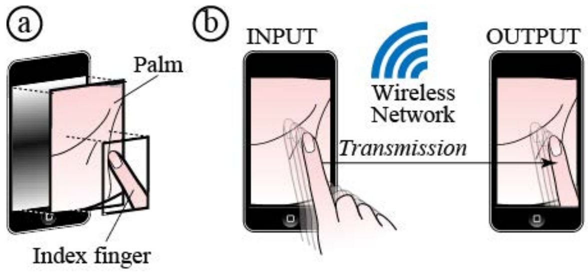

Figure 2. Visual Design of the Shared Tactile Interface (a) Two static images are placed on the display of a handheld device, (b) Only the finger movement, as a tickling gesture, is transmitted to the other side.

Pseudo-haptics are often used for haptic communication. Tsukada proposed a way to superimpose the movement of a cursor, which shows each user's gesture inputs on the faces and shoulders in each screen during a video chat [10]. Although the method allows the users to stroke each other, this method differs from our proposed method in two points: the physical body is not used to superimpose the gestures, and exchange of video streams is required.

Methods using a part of the user's body as a human-computer interface fall roughly into two classifications: input methods [11][12][13] and output methods [14]. Harrison et al. have proposed the "Skinput" method, which allows the user to tap buttons projected on the user's own forearm. This method appears to be difficult to apply for measuring a tickling gesture because it requires detection of a progressive wave propagating through skin and bone, although the method is sufficiently accurate for use as a tapping interface. Pranav has introduced an input method called "Sixth Sense" [12]. With this method, it is necessary to run a computer vision program and place an external camera to track the fingertip during the gesture. Nakatsuma et al. have proposed a wrist-watched shaped device, which can track the point where the finger taps the back of the hand [13]. It is difficult to use this method for tickling because the display is placed on the wrist, not on the palm. This means that the back of the hand, as the input surface, is shared with the display as the output surface. This method does have a feature that allows the user to feel where the touch occurs because the user touches the back of his/her own hand. Tamaki et al. introduced the concept of using the user's own hand, which is actuated by an electrical stimulation, as a display for hand gestures. This differs from the method proposed here as the hand is used only as a display.

3. SHARED TACTILE INTERFACE

In this paper, we propose a "Shared Tactile Interface," which is achieved by sharing a part of the user's body and which allows users to tickle each other from a distance. This method is based on three requirements: bidirectional contact, bidirectional tickling, and transfer of tickling.

3.1 Bidirectional Contact and Tickling

We focused on a specific characteristic of tickling: it is well known that the tickling sensation is not felt if one tickles oneself. Prediction of one's own behavior suppresses the perception brought about by the behavior [15]. In other words, tickling will only be sensed by a tickling action initiated by another person. This is the point that allows one user to tickle another even when sharing a palm.

Figure 1 (a) shows a scene during tickling. If the user tickles his/her own palm as in Figure 1 (a), the user feels no tickle sensation. We propose to use the user's own palm as if it was another's, in order to tickle, and to send this tickling gesture onto the other user's palm at the same time, as shown in Figure 1 (b). This figure shows that user on the other side is tickled by the appearance of the tickling gesture on his/her palm. As a result, he/her can feel the tickling sensation. Therefore, this strategy requires that the user makes the motion of tickling his/her own palm while imagining that his/her own palm is actually the palm of the other user. In addition, "bidirectional tickling" is achieved because the same effect occurs in the reverse direction. “Bidirectional contact,” which enables both users to contact to each other, is also achieved.

3.2 Transfer of the Tickling Sensation

Several methods can produce the tickling sensation. First, tickling sensations are commonly known to arise when something strokes the skin with a small force. For example, Blakemore used a tickling robot that had a rod with a soft form on the tip [15]. A tickling robot, however, is not practical for bidirectional tickling due to its size.

Second, the appearance of being tickled can be utilized because a tickling gesture alone can create a weird feeling. In other words, a sensation like tickling can be elicited even when no contact is made with the skin. This phenomenon is considered to arise because a moving visual cue is interpreted as the same as a somatic sense [16]. This finding seems to indicate a hypothesis that transfer of the tactile sense is not essential. Our results obtained in a previous study, however, do not support this hypothesis [17].

3.2.1 Illusion of a Tickling Sensation

We use illusion obtained from the integration of visual and tactile sensations in order to transfer the tickling sensation. To realize the illusion, the following three points are required: first, the tickling gesture must be made to appear as if it is occurring *on* the user’s own palm. Second, the item doing the tickling must move on the palm. Third, a slight vibration needs to occur at the same time as that movement.

First, as shown in Figure 2 (a), we place a static image, which we call the “palm image,” on a handheld-sized portable device. This gives the impression that the device is a part of the user’s own palm. The device itself is visually transparent as long as the position between the user’s palm and the device remains consistent.

The palm image does not need to be generated in real time, because it is so small that no large change will appear in the palm unless the palm is pushed with a large force. A large deformation could not be obtained visually from the image that was used in the previous study [17], which supports the possibility that the use of a static image for the palm image is feasible.

Second, we add another static image, which we call the “index finger image” shown in Figure 2 (a), onto the palm image so that the movement appears to occur on the palm. At this time, only the movement of the tickling gesture is transferred onto the palm image in the other device, as shown in Figure 2 (b). This gives the visual effect that the index finger is tickling the second user’s palm in the other device. The possibility also exists to shoot and show a real gesture of the index finger; for example, bending of the finger and scratching. This image however would require placement of an additional camera for capturing the actual gesture, and would also consume considerable bandwidth to maintain exchanges of the video stream. For this reason, we use the static image and make it follow the tickling gesture, based on the basic finding that the moving visual cue elicits a tickling sensation on its own [17].

Third, we provide a slight vibration that is synchronized with the visual movement of the tip of the index finger because our previous result [17] indicates that the vibration tends to reinforce the tickling sensation. The tickling force is very small, which we mentioned before. Of course, transmission of an actual stimulus is relatively simple. However, realization of the stimulus is not as easy, due to issues of measurement as described in subsection 3.2.2. Therefore, we employ a sinusoidal wave with a constant frequency and small amplitude as a simulated tactile stimulus and this is modified depending on the velocity of finger movement. The value of the constant frequency is 250Hz, which is known as the peak of Pacini corpuscle response [18].

One issue that determines the nature of the stimulus is how high a quality of tactile stimulation is necessary in a spatial domain. Ideally, the point where the user feels the sensation of being touched should move corresponding to the actual finger movement. However, previous research has not dealt with this type of movement because the vibration provided by the backside of a handheld device consists of a spatially flat vibration with a center that does not move around [17]. Therefore, contribution of movement of a tactile image to the tickling sensation has not yet been addressed.

We evaluated the contribution of moving of the tactile image using a method called the “Tactile Brush” [19]. Although this technique employs a device with a number of spatially placed vibrators, it is not appropriate for our method because the small size of the handheld device restricts the number of vibrators that can be placed on it. Therefore, we use a minimum of two vibrators to realize the movement of the tactile image, referred to as “Phantom Sensation,” which is perceived as a tactile sensation occurring between two vibrators [20].

3.2.2 Measurement of Tickling Gesture

Measurement of the tickling stimulus as a vibration propagating through the skin is difficult because the amplitude is small. This means that the required high-precision distance sensor, which costs additional space in a handheld device, will conflict with the design for realizing bidirectional contact and tickling.

Consequently we have focused on the movement of the tickling gesture, which can be readily measured by a capacitive sensor. Our method can use this type of sensor because it has two advantages: it is built sufficiently small that it can be embedded in a handheld device and it does not require a pushing force.

The consideration of the tickling stimulus as a finger movement can overwhelmingly cut down the amount of data that needs to be transferred. For example, if the stimulus is measured as a sound with a sampling rate of 44.1 kHz and resolution of amplitude at 16bit, it transfers as 706kbps uncompressed. On the other hand, if it is represented with two 16-bit integer values describing position on a two-dimensional surface and with a frame rate at 30fps, it can be expected to transfer as 0.96kbps, apart from transmitting the finger posture and the pushing force, which are ignored in this paper.

4. Implementation

We evaluated the Shared Tactile Interface through implementation. The Apple iPod Touch 3rd and 4th Generation were used as target handheld devices due to their embedded capacitive touch sensors.

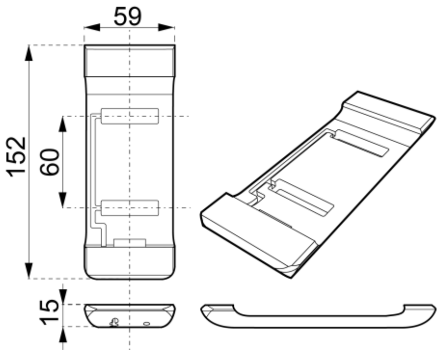

Figure 3. Schematic of the outer case that provides spatially distributed vibrations.

Figure 4. Vibrator attached to the outer case.

Figure 5. Device as seen from the user's viewpoint.

4.1 Bidirectional Contact

The palm image is taken of a male's palm, and the index finger image is taken of a female's index finger using an Eos Kiss X4 (Canon). The size and position of the palm image is modified to retain position consistency between the user's hand and the image displayed on the handheld device. Post editing is used to add a shadow to the index finger image to make the user feel as if the user's palm is being touched directly. Although these two images should appear as an actual image taken from the user's own palm and index finger, we have found that the tickling sensation is felt even if the image is the same male's palm. Therefore, both of these images are stored in each device in advance and are not changed.

The palm image gives the effect that the device display is part of the user's palm. The index finger therefore looks like it touches the palm directly when its image appears. The rendering refresh rate is maintained at 30fps.

The two devices are connected via a Bluetooth network, which is implemented in a GameKit framework in iOS5 SDK. Events of touch, movement, and release then trigger the sending of the data, which are expressed as text data including the contact position and three event states. The number of fingers is regulated to only one for simplification. Therefore, the data format is described as "x,y,m" with three integers; where "x,y" means the position and "m" means the three event states. Data are never sent and the index finger image never appears unless contact takes place.

Two responses occur when the data are received at the other side: First, transparency of the index finger image, and second, its position are controlled. Control of transparency is effected by having the index finger appear and disappear gradually at the time of touch and release. The index finger image remains to appear during the state 'move'. The position of the finger pad of the image corresponds to the received touch point.

Therefore, the exchange of data between the two equivalent devices accomplishes bidirectional contact and bidirectional tickling.

4.2 Transfer of the Tickling Sensation

Although vibration motors embedded in the handheld device are generally used to provide a vibration to the user, we do not employ these for the following reasons: this type of vibration motor uses a rotating decentering weight and cannot provide independent control of the intensity of vibration and frequency. In addition, rising time takes longer than for a piezoelectric and electromagnetic drive type. A vibration motor with a descending weight is not appropriate for nonverbal communication, as this requires a quick response and controllable frequency, although it is suitable for providing a symbolic vibration.

We employed piezoelectric and electromagnetic drive types. The piezoelectric drive embedded piezoelectric speaker inside the device [1] [21] is used, and the electromagnetic drive is implemented by enclosing it in an outer case attached to the device. We use an audio signal with a sinusoidal wave at 250Hz to provide proportional modification of the velocity of the index finger movement.

The prototype of the piezoelectric drive does not require any change of hardware. The center of the tactile image provided with the piezoelectric prototype does not move as there is only one actuator inside.

The two vibrators were used to produce the movement of the tactile image in only one dimension, although four vibrators seem to be necessary to provide the effect in two dimensions. The intensities of vibration of each vibrator, g_0 and g_1, are given by:

$$g_0 = \frac{h}{H}v, \quad g_1 = \frac{H-h}{H}v, (0 \le h \le H, 0 \le v)$$

where g_0 and g_1 indicate the gain of the audio signal, H is the available moving length in the screen, and v is the moving velocity of the finger. The vibrators are driven by two 1W Class D Audio Amplifiers TPA2001D1 at a gain of 12dB.

The vibrators are ForceReactor AF series L type from ALPS Electric Co., Ltd., and are placed on the backside top and

[1] We did not employ the inner speaker in the iPod Touch 4th generation because it was difficult to make the backside vibrate with an audio output due to different acoustic seal structures of the iPod Touch 4th generation and the iPhone. The iPod Touch series does not contain a vibration motor.

bottom of the screen at a distance of 60mm. These vibrators, which are attached with double-sided elastic tape 1mm thick, and the amplifier circuit, are built into this outer attachment as shown in Figures 3 and 4 on the left. The vibrators are covered with fabric tape as shown in Figure 4 on the right and attached 1mm higher than the surface of the backside. Figure 5 shows the appearance from the user's viewpoint.

The prototypes are listed in Table 1. "Prototype A," which has one vibrator attached to the backside, is used in the preliminary study. "Prototype B" has the piezoelectric speaker replaced with the electromagnetic one. "Prototype C" has two electromagnetic vibrators.

Table 1. Vibrator Specifications

Prototype	Vibrator Type	Number
A	Electromagnetic	1
B	Piezoelectric	1
C	Electromagnetic	2

Figure 6. User Test Using Prototype B at CEDEC2011.

Figure 7. User Test Using Prototype C at SIGGRAPH ASIA 2011.

5. User Study

We conducted a user study in order to evaluate the feasibility of the proposed method. The evaluation points were: (1) bidirectional contact, (2) bidirectional tickling (3) transfer of the tickling sensation. Evaluation was divided into three trial types; scenario 1 was the user being tickled; scenario 2 was the user tickling another user; and scenario 3 was two users tickling each other.

The exhibition style was a demonstration. We prepared a pair of prototypes that allowed visitors to have a free experience of the devices. Technical explanation was provided by a poster and a video. The presenter stood in front of the prototypes and also explained the technical aspects and instructed the visitors on use of the devices. In this paper, we describe the experience flow and the visitors' responses.

5.1 Experience Flow

Visitors were able to experience the devices after establishing a Bluetooth connection with each prototype.

At first, the presenter gave a brief summary: "This is a remote tickling technique." He passed the prototype, which was already displaying the palm image, instructed the visitor to place the device on the visitor's own left palm, and then asked visitor to position the prototype as precisely as possible. The presenter placed the other device on his own left palm. Only the palm image was displayed at this time. The distance between the visitor and presenter was approximately 50cm, and they could face and talk to each other.

Once the devices were positioned, the presenter stroked the prototype on his own palm with his right index finger. This triggered the appearance of the index finger image, which moved with the same motion as the presenter's actual finger, and provided the previously described vibration. We observed the visitor's responses at this time (scenario 1).

Next, the presenter explained that the visitor was also able to tickle and prompted the visitor to tickle the device on the visitor's palm. We also observed this as scenario 2.

After that, the presenter handed over the prototype to another visitor and left the two visitors to experience the devices as scenario 3.

5.2 Exhibition

The user study was conducted at two conferences. The first one was the CESA DEVELOPERS CONFERENCE (CEDEC) 2011, which is the largest Japanese domestic conference, held in Yokohama Japan on September 6th to 8th [22]. The attendees, which are almost all male, range in age from their 20s to 50s and most work as engineers or specialists in the technical field, with a few from academic fields and from the general public. The number of visitors to our exhibit was about 50. A part of this exhibition was recorded as about 1.3 hours of video in total. Only prototype B was used for this exhibition.

The second venue was the ACM SIGGRAPH ASIA 2011, which is an international conference on computer graphics and interactive techniques, held in Hong Kong on December 12th to 15th 2011 [23]. A technical demonstration was held for three days, form the 13th to 15th. Attendees were about 60% male, and included a large number of high school students due to tours by high schools, a number of engineers working on computer graphics and artists, specialists, and researchers. The number of visitors was about 600. A part of this exhibition was recorded as about 15 hours of video in total. Two pairs of prototype C, four devices in total, were used for this exhibition, although prototype B was used when necessary, for about 10% of the total demonstration time.

5.3 Results

The scenes of visitor experiences are shown in Figure 6 and 7. Figure 6 is an image taken at the first exhibition that used only prototype B, with the piezoelectric actuator. Figure 7 is an image is taken at the second exhibition with prototype B and C, with the electromagnetic type attached. The following results were obtained regardless of prototype B/C, unless otherwise noted.

5.3.1 Scenario I: Being tickled

Both prototypes were placed approximately correctly based on our observations, but matching the palm image to the visitor's palm was difficult in the case of a small hand. To feel the tickling sensation, the user needed to feel that the palm image in the screen was a part of the user's own body. The misunderstanding of direction for placement, which was sometimes observed in cases where the visitor tried to place the device on his/her own, caused that the device to be rotated 90 degrees. On the other hand, placement was always correct when the presenter asked the visitor to open his/her left palm and placed the device on the palm. Therefore, it was apparently not very easy to understand how the device should be rotated on the palm unless the user's looked carefully at the image.

We found the following responses to tickling provided by the presenter through observation of the use of the pair of devices, regardless of prototype B or C: About half of the visitors did not show any distinct change in their facial expression and nodded weakly in response to the presenter's explanation. On the other hand, the remaining half of the visitors' faces changed into smiles, frequently wide ones. The first set of visitors who did not present obvious facial expressions answered “No, I could not feel it” in response to an oral question “Do you feel a tickle?” asked casually by the presenter. They often continued to give comments such as “It's creepy,” or “I only felt a vibration.” On the other hand, most of the second group of visitors answered “Yes,” that they felt a tickling sensation. The effect, however, was not so ticklish as to be startling. Only about 1 % of the visitors, who were all female, seemed to wince in response.

Some of the visitors who felt the tickling sensation tried to tickle the device at the presenter's side in order to make sure of the sensation. In this case, it seems that they could not feel the tickling compared to the case where they were tickled by the presenter.

We gave visitors who tried the prototype C the opportunity to experience prototype B if they wished. About half of them usually commented that prototype C was better than prototype B, although they answered that they felt the tickling even when they evaluated the piezoelectric type prototype B.

Visitors who experienced prototype C voluntarily reported that they could feel as if the pointing finger was moving on their palm. Few visitors who tried prototype B reported this. Some visitors, who were academic people, experienced prototype C said “I felt a horizontal movement of the tactile image” although the number was few. Almost all visitors turned over the prototype C after their experience in order to see how it works.

After giving the presenter's question of “What do you feel?” the presenter often asked the visitors to close their eyes and then asked them what they felt when they were not watching their palm. The visitors who said that they had felt the tickling sensation when viewing their palms answered that they did not feel it when they could not see their palms.

Visitors who could not feel any vibration from the prototype B usually could feel the vibration from the prototype C because prototype C was able to produce a much higher intensity of vibration than prototype B. On the other hand, there were some visitors who could felt the tickling sensation from prototype B but commented that the vibration provided from prototype C was too strong to be called a tickling sensation.

5.3.2 Scenario II: Tickling Another

Almost all of the visitors were puzzled when told that they needed to consider their own palm as that of another person at the beginning of the experience. The visitor also needed to discover that the finger movement on the other's palm was synchronized with visitors' own as they looked directly at the other's, because no feedback was provided, such a visual change or vibration for the visitor who tickled the device on their own palm. The visitors in particular who started voluntarily to tickle the device on their own palms before given the brief summary, did not obtain any feedback from the device and did not comprehend completely until the presenter explained and tickled them to show what they should feel. Some visitors expressed displeasure about the lack of feedback in the case of one-side tickling. Once they found out that their own finger movement was sent to the other side, they radically changed their behavior; they tried to tap or to stroke the screen of the device randomly before understanding. After that they started to enjoy the tickling task, continued to do so, and tried to confirm whether they were able to tickle the other side by watching the screen at the other side.

Some visitors pointed out that the finger appearing on the other side was not the actual visitor's own finger.

Many visitors tried to tap the screen of the prototype. As mentioned before, because prototypes B and C are not designed to transfer taps, the index finger image only appeared for a quick moment and did not provide any vibration even if they tapped. The visitors seemed to figure out that they could not tap to each other after a while.

5.3.3 Scenario III: Tickling Each Other

The concept of being able to tickle each other appeared to be immediately understood after the demonstration. We found that many visitors began to smile regardless of age or gender.

Pairs of visitors continued to tickle each other. The high school students especially tended to be enthused about tickling in the second exhibition at SIGGRAPH ASIA 2011. Some female high school student groups attempted to write a letter on her own palm in order to send it to a friend. However, it seemed difficult to transfer letters without looking at their own palms.

On the other hand, some visitors who were typically engineers in their 30s and 40s did not change their facial expressions at all. These visitors commented that they could not feel tickling and likely remained in order to confirm the movement of the finger.

5.4 Discussion

The transfer of the tickling sensation and also the comment “creepy” indicates that the palm image on the device was considered as the user's own palm, because the movement of the finger seemed to produce the tickling sensation by a visual means, as described earlier.

Whether the visitors felt a tickling sensation depended on the large individual differences in sensitivity to tickling. The reason for this seemed to be the sensitivity to vibration because the intensity of the vibration was not modified for different individuals.

Too strong a vibration would not provide a tickling sensation but just a vibration. Therefore, the intensity should be modified carefully depending on the individual.

The feature of tickling, whereby a self-inflicted tickle stimulus does not create a tickling sensation was observed with the device. The visitors evidently were able to experience a tickling sensation. Therefore, the design method "Shared Tactile Interface" enabled users to tickle each other.

The finding, that the movement of the tactile image produced by the prototype C enabled the visitors to feel the tickling sensation more readily seems to indicate that this provides a better experience. In this case, however, the number of actuators needs to increase.

Above all, the results of the scenario 1 "Be tickled" showed that the bidirectional contact was made and the tickling sensation was transferred. Additionally, the result of the scenario 2 "Tickle another" and scenario 3 "Tickle each other" indicates that the bidirectional tickling was achieved. Therefore, these results suggest that the proposed method "Shared Tactile Interface" is feasible.

5.5 Limitations

The issue raised regarding that there was no feedback or an acknowledgement given to the initiating user whether the receiver at the other end tickled or not indicates that the current prototype is not properly fit to be used for remote communication. Therefore, the prototype seems to require additional means of communication, such as voice or visual (e.g. facial expressions). Furthermore, it is possible to replace the static images with dynamic ones which express active responses by showing the bending of the palm when being tickled.

On the other hand, some visitors requested to distribute the application software of the prototype without the outer case which encloses all the actuators. There could be some factors affecting the evaluation of the remote communication in our experimental setting since the actual distance between two users were not large enough to simulate a remote communication scenario. Even though users preferred and eager to use the proposed method, further evaluation of remote communication features would be desirable.

The vibration itself was not ticklish as we expected. It is, however, ideal to be used one providing tickling sensation without any illusions. Thus, such unpredictable stimulation which has been used by Tsetserukou et.al [3] is worth considering to be used instead.

The prototypes used the images prepared in advance without using pictures of visitors' palm and index fingers. Some visitors pointed out that they could not relate to the device's picture, in other words, this tends to affect visitors' identity. Therefore, exchanging of the images taken by the user will enable the users to preserve his/her identity.

The prototype could not transfer the tapping sensations due to focus given to the tickling gestures. The tapping, however, can be measured with an accelerometer and vibrator seems to be able to re-produce it properly.

6. CONCLUSION

In this paper, we proposed a "Shared Tactile Interface," which is achieved by sharing a part of the user's body and allows users to tickle each other from a distance. In order to exchange this nonverbal cue, the proposed method must fulfill three requirements: bidirectional contact, the bidirectional tickling, and transfer of the tickling sensation. The tickling sensation is defined as to feel as if tickling another user and to feel as if being tickled oneself.

We achieved the three features: bidirectional contact, bidirectional tickling, and transfer of the tickling sensation. The proposed method shows a part of the user's own body in order to measure the finger gesture and to show the movement of the index finger at the same time.

We conducted a user study in order to evaluate the feasibility of the proposed method through two exhibitions as technical demonstrations at conferences. The proposed method enabled us to transfer the tickling sensation between users. Therefore, we concluded that this result indicates the feasibility of a design method for a tactile interface that uses a part of the user's body.

It was difficult to produce a stable tickling sensation even if the tickling stimulus was provided stably. The reason for this seems to be the large individual differences in sensitivity to tickling and the fact that a vibration itself is not a tickle. In addition, the gestures such as tapping and tickling with multiple fingers, which were left out of consideration for implementing the prototypes used here, should be included in order to evaluate the proposed design more extensively. We will deal with these issues in our next steps.

7. ACKNOWLEDGMENTS

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