Contactless Touch Interface Supporting Blind Touch Interaction by Aerial Tactile Stimulation

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ABSTRACT

This paper proposes a contactless touch interface which supports blind touch interaction by the use of tactile stimulation. In the system users can interact with a touch screen without actual touch on it and get tactile feedback for the action. The components of this system are a special screen (Visuo-Acoustic Screen), a visual projector, an airborne ultrasound phased array for giving tactile stimulation by noncontact way and a pair of IR sensors for the finger detection. In this paper, we enable noncontact blind touch interaction by adding tactile feedback variation for notifying the finger location. We show the strategy for the blind touch and evaluate the efficacy.

Keywords: contactless touch interface, blind touch interaction, Airborne Ultrasound Tactile Display.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O; H.5.2 [Information Interfaces and Presentation]: User Interfaces —Input devices and strategies

1 INTRODUCTION

In this paper, we propose a contactless touch interface which enables blind touch interaction. This device is similar to usual touch screens but users can interact with it before the screen surface. There are two important distances, 15mm and 45mm, before the optical screen. At 15mm before the screen surface, users can feel tactile feedback for clicking in mouse operation or touching in usual touch panel operation. In addition, they can get tactile information of the buttons at 45mm before the surface, which enables blind touch operation. One of the suitable applications of this system is the usage in a medical operation room. Users, doctors in this case, want to operate touch panels with their dirty hands where blind touch is desirable for keeping their eyes on the patients.

The proposed device is categorized in noncontact interfaces regardless of presenting tactile feedback or not [1-6], where the surrounding systems response to users' motion. The noncontact nature is preferable for avoiding hygienic problems in public spaces as hospitals and restaurants. (In Japan, many sushi restaurants have touch panels for receiving orders at each table.) In addition, they enable 3D interaction by using free space before the display. A common problem of such noncontact interfaces is that they lack the tactile feedback. To solve this problem we have proposed contactless touch screen system having tactile feedback [7, 8]. We remotely stimulate the user's finger by ultrasound radiation pressure [9] over the screen. With this stimulation, the user can feel as if he/she pushes virtual buttons in front of the screen without actual touch. Another example of contactless interfaces with ultrasound tactile feedback is seen in Hoshi's work [10]. In Hoshi's device, the distance of user's hand and display is 600mm and the visual display is PC monitor. In the above previous studies, tactile sensation provided effective supplementary information, but guiding information for blind touch was not displayed.

This paper proposes a tactile supporting mechanism to enable blind touch interaction. We give tactile stimulation while searching buttons for notifying the button positions and the distance between the finger and the visual display.

A blind touch system provides a universal interface for healthy and visually impaired people [11-13]. In addition, our system is also useful for healthy people since it lessens the visual load. Such an interface is also suitable to automobile applications.

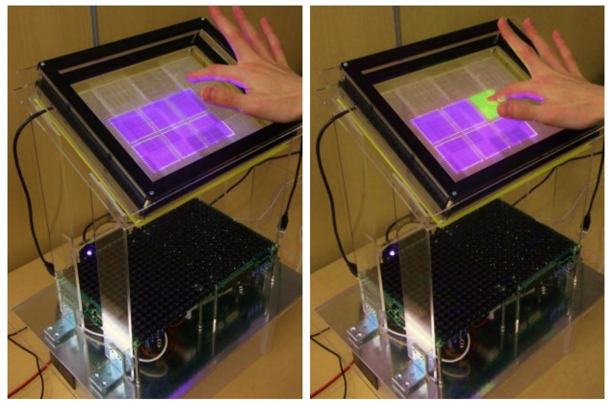

Figure 1: Over view of the proposed system.

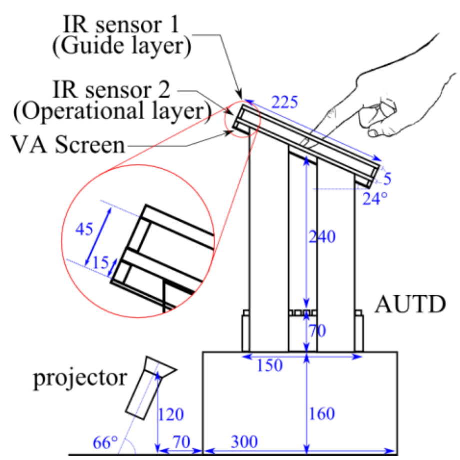

Figure 2: The side view of the system. The thickness of IR sensors is 5mm.

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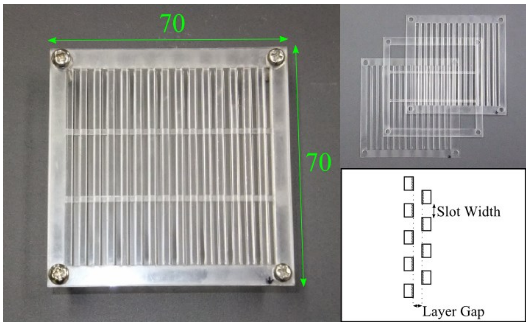


Figure 3: The photo and structure of VA Screen.

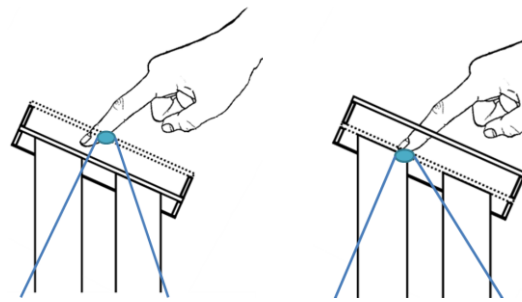


Figure 4: The illustration of stimulating rules for blind touch. Blue circle represents ultrasound focus and the position of tactile stimulation. The left picture is while searching buttons. The first joint of the finger is simulated. The right one illustrates pushing a virtual button. The focus is made at the fingertip.

In this paper, we explain the summary of our previous contactless touch screen system first, and then show the strategy of blind touch interaction. We construct the proposed system and evaluate the efficacy.

2 Contactless Touch Interface with Tactile Sensation

As the newest related work, we proposed contactless touch interface with tactile sensation and constructed the prototype system [8]. The view is similar to Figure 1 and 2, but it has only one IR sensor. The system contains Visuo-Acoustic Screen (VA Screen), a visual projector and airborne ultrasound phased array. The image is projected to VA Screen from behind of it. IR sensor detects insertions and movements of finger without any marker. Airborne ultrasound phased array makes a focus at the finger position and gives tactile stimulation to users by ultrasound radiation pressure through VA Screen. This system can show some kinds of tactile sensation by changing stimulating patterns. The device was demonstrated in Demo Session of WHC 2013.

VA Screen is a special screen shown in Figure 3. VA Screen has three features: (1) good scattering plane for displaying the visual projector images, (2) transparent for airborne ultrasound, and (3) cutting off the air flow streaming through the screen. Property (2) is necessary for stimulating the user's skin with the ultrasound coming from the back of the screen. Property (3) is desirable for preventing the fingers from feeling air flow induced by the ultrasound beams [14]. We searched the suitable parameters of Slot Width and Layer Gap in Figure 3 and selected the best parameters in our fabrication restrictions. In our acrylic prototype, the Slot Width is 2mm and the Layer Gap is 0.5mm. The screen can transmit 95% of the wave amplitude at 60Pa sound pressure and pass only 27% of the air flow in our typical case [7].

3 Strategies for Blind Touch

One of the most attractive features of haptics interface is blind touch interaction. We expand the previous system and embed the potential for blind touch operation, where the user can send commands without gazing the screen.

3.1 Proposal for Blind Touch Mechanisms

To enable blind touch interaction, users need three kinds of information without watching the screen. (i) The distance from the operational plane or screen surface while searching buttons. (ii) The lateral positions of buttons on the screen. (iii) The result or response from the touching action. In our proposed system, we add an extra plane before the operational plane for giving this information (Figure 4).

The first plane (Guide layer) controls finger position and informs the kinds of button. While Guide layer detects the insertion of finger, airborne ultrasound phased array makes a focus at the inserted position. While users search buttons, they move their finger keeping the presented stimulation position at the first joint of the finger. This adjustment enables to keep the distance between Guide layer and Operational layer. By changing stimulating patterns according to the finger position and buttons positions, users can know the positions of buttons and the kinds of them. Therefore, this structure satisfies the requirement for (i) and (ii) without visual information.

The second plane (Operational layer) offers the interaction to the buttons. When Operational layer detects the finger at the button's position, visual response and tactile feedback to the fingertip are produced. Users can distinguish this stimulation from one given at Guide layer because the stimulated positions and patterns are different. Then users can also obtain (iii).

In order to examine the feasibility of this strategy, we construct the system and conduct user test.

3.2 System Set up

The photo of constructed system is shown in Figure 1. The screen size is 180 x 240mm. The screen has a slant of 24 degree. As VA Screen, we made large VA Screen by arraying the structures of Figure 3 side by side. Airborne Ultrasound Tactile Display (AUTD) [9] used in this system has 498 ultrasound transmitters which emit 40 kHz sound and make about 3gf ultrasound radiation pressure at the focus. The diameter of the focus is 1cm. AUTD can adjust the pressure levels to 320 grades with 2 kHz. The distance from AUTD and operational layer is 240mm. The IR sensors are commercial one for adding touch function to a normal flat panel display. This sensor can detect two-point touch gesture but we only use single touch in the experiment. The distance between VA Screen and IR sensor 2 is 15mm and that between VA Screen and IR sensor 1 is 45mm. IR sensor 1 detects the insertion and its position and IR sensor 2 only detects the insertion of the finger. We estimate the finger position only by IR sensor 1. The projector is commercially available pico-projector (Optoma PK320). IR sensors, AUTD, and the projector are connected to a computer that controls the overall system.

3.3 Experiment of Blind Touch Interaction

3.3.1 Experimental Setup

To examine the feasibility of the proposed method, we conduct blind touch input test. The projected virtual buttons are shown in Figure 5. These buttons are assigned with numbers from 1 to 6. The sizes of buttons are 50mm x 50mm. The gaps between buttons are 5mm. The subjects are 6 males in their twenties, whose dominant arm is right. The subjects are instructed to insert

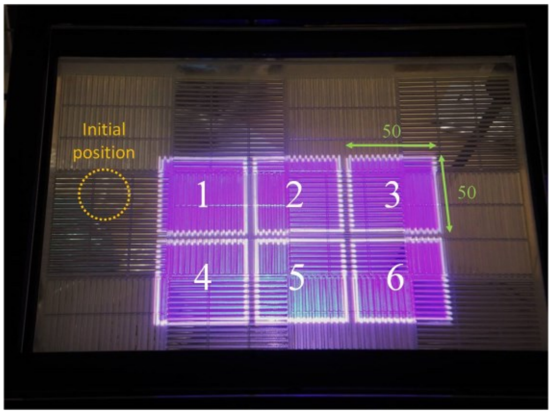


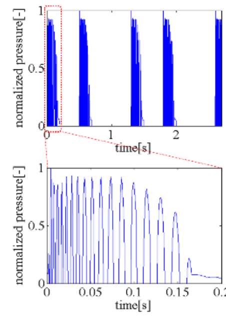
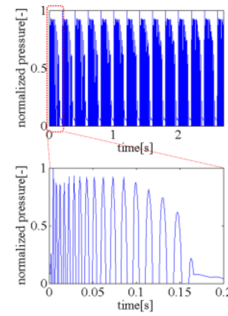
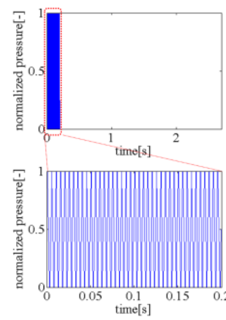
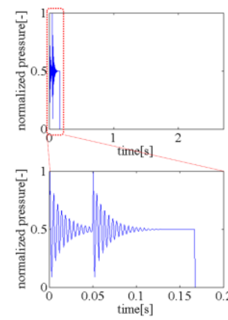
Figure 5: Arrangement of buttons for user study.

their forefingers of their dominant arms to Guide layer and search buttons in that layer and push buttons in the directed order. The order of the button selection is {1,2,3,6,5,4} or {1,4,5,2,3,6}. Each order is conducted 3 times, so the number of total tasks is 6 and the total times of pushing buttons are 36. Subjects start their tasks at the initial position shown as a circle in Figure 5. They are told to push buttons only once, but allowed to try again if they couldn't feel the tactile feedback of pushing button. The patterns of stimulation are shown in Table 1. We use three waveforms of stimulation and combine with rhythms. While the finger is in guide layer but isn't poisoned over buttons, we stimulate it continuously (upper-right in Table 1). On the other hand, if the finger is over a button, we make rhythmic stimulation (upper-left in Table 1). In "rhythmic" stimulation, we repeat 0.2sec stimulation time and 0.3sec break time. We insert 0.6sec break time after n repeats for the assigned number n to that button, which enables subjects to count the stimulated numbers and know the button's number before pushing the button. The minimal time for recognizing button number 6, for example, is 3.3sec. The responses of button push are distinguished by the difference of tactile stimulation. If buttons are pushed, subjects get strong tactile stimulation at the fingertip (lower-left in Table 1). If there is no buttons at the pushed point, the response is relatively weak stimulation (lower-right in Table1). Both stimulations are emitted only once when the sensor of Operational layer detects the finger's insertion. While the examination, subjects hear white noise and their eyes closed. Before the beginning of the experiment, subjects are explained the way to use the device and the order of pushing buttons in this experiment. After that, they are given around 3minutes for training. We record all inserted positions and measure the time it takes to push buttons.

3.3.2 Results

The results are shown in Table 2. "Push correct buttons" are the number of times subjects push correct buttons. "Extra insertions" are the number of times a subject inserts the finger to Operational layer beyond 36, the minimal number of insertion times. This number is obtained by subtracting 36 from the number of times Operational layer detects finger's insertions. "Push within 15sec" is the number of times subjects push next buttons within 15sec. We calculated average time and standard deviation among the operations which were done within 15sec. The time of 15sec are decided from Figure 6. Figure 6 shows the distribution of the required time to push a button. This graph shows the number of times the subjects required from a seconds to b seconds for selecting the next buttons, where the x-axis is written as "a-b." In

Table 1: Waveform of tactile stimulation.

Finger position	Over buttons	Out of buttons
Guide layer	 Make a rhythm (plotted in the case of no.2)	 Repeat continuously
Operational layer	 Output once	 Output once

this figure, most of the selections are done within 15sec (82%). Therefore we suppose the case where the selection is finished within 15sec is a smooth interaction.

The high ratio of pushing correct buttons show that subjects can recognize the buttons' positions and numbers by the tactile stimulations in Guide layer before pushing. However, some extra pushing is also detected. Most of them are occurred while searching buttons. From Figure 6, we distinguish smooth interaction and awkward interaction with the border of 15sec. In the smooth interaction, subjects move their finger to the next button smoothly and confirm the button's number and push it soon. However, if subjects lose their finger's position, they search around large area to get their position and move to the next button. The time to accomplish these tasks is much longer than the smooth interaction. Therefore, we evaluate the average required time only for the smooth movement. In the smooth movement, the average time to push buttons is 6.5 seconds.

4 Conclusion

This paper proposed a contactless touch interface with tactile sensation which supports blind touch interaction using aerial tactile stimulation. In the system, users could interact with it without touching the screen surface and get tactile feedback. The components of the system were VA Screen, a visual projector, airborne ultrasound phased array and a pair of IR sensors. The proposed method had two interaction planes before the visual plane, Guide layer and Operational layer. Guide layer gave tactile stimulation to the first joint of a user's finger as guide stimulation before the finger reach to Operational layer. The stimulations had multiple patterns, which enabled the users to identify the buttons without seeing them. To confirm the efficacy of this method, we

Table 2: Results of user experiment.

The subjects ID	A	B	C	D	E	F	total
Push correct buttons[times]	35/36	36/36	35/36	32/36	32/36	35/36	205/216
Extra insertions[times]	1	4	5	7	13	7	37
Push within 15sec [times]	32	27	28	31	27	33	178
AVE within 15sec	6.09	6.06	6.89	7.92	7.82	4.54	6.50
SD within 15sec	3.07	2.38	3.10	3.66	2.82	2.10	3.10

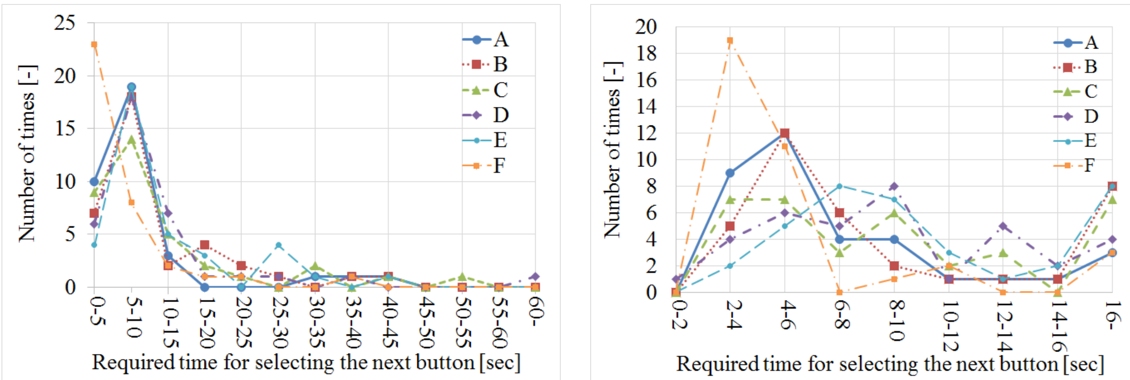


Figure 6: Distribution of required time to select buttons. The left graph and right one plot the same data with different x-axis resolutions.

conducted a user study. The results of the blind touch test conducted for 6 healthy subjects showed they could recognize the positions and kinds of buttons at a high success rate. They consumed 6.5 seconds to select the next buttons in average.

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