Air-Jet Button Effects in AR

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Abstract. Providing haptic cues can generate increased levels of presence in users as they interact with tangible objects. In this paper, we present button effects delivered by air-jet displays with the aim of providing click-like sensations when virtual buttons in an AR environment are pressed. We derive the profile of the haptic output by measuring the force profile of real physical buttons. To validate our concept, we have built an AR system featuring a cellular phone model which users can tangibly manipulate through a physical AR marker object. When users press a button on the model, they experience a corresponding click-like feeling at their fingertip. In this way, our system enables users to press a button on an AR model and experience a force profile generated by our pneumatic array directly derived from the act of pushing a button in the real world.

Keywords: Air-jet, button effect, AR, fingertip point extraction.

1 Introduction

In order to provide immersive interaction, multisensory feedback composed of visual, auditory and haptic elements needs to be merged together in an appropriate way. Many researchers have shown that performance is substantially improved when haptic sensations are added to visual and auditory environments [5]. We suggest that appropriate haptic cues are an essential component required to support the simple and natural manipulation of widgets and controls such as buttons, sliders and joysticks. Indeed, a haptic button has been a popular mechanism for controlling computer VR applications and the force profile for buttons has been implemented on kinesthetic devices such as the PHANToM™ in several APIs in order to present the realistic feeling virtual buttons. However, these devices are expensive and due to their bulk

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and desk-based interaction paradigm, unsuitable for many AR scenarios. Tactile devices which present stimuli to the skin may be more suitable in this instance. Of these, pneumatic tactile devices, which feature an array of air jets directed onto the skin, are lightweight, able to provide pressure and to modulate the shape it is displayed in [1]. In addition, they are cost-effective and they have unconstrained workspaces when compared to kinesthetic feedback devices.

As the demand for additional haptic cues in AR increases, applications are being implemented for educational, military, entertainment and medical training purposes. There are several systems that use kinesthetic feedback devices to provide force feedback in AR. Kenneth Fase *et al.* proposed a system that features virtual training for welding tasks using a 3DOF haptic device [6]. Matt Adcock *et al.* have developed medical simulations using the PHANToM^{TM} [8]. Also, Christoph W. Borst *et al.* presented haptic feedback for virtual panels using a force feedback glove [4]. In addition to force feedback, there have been some attempts to combine tactile feedback with augmented reality. Buchmann *et al.* used buzzers mounted in a glove in an urban planning workspace so that users could feel vibration when their hands made contact with an AR model of a city block [12]. Another application is based on an air-jet display consisting of 100 air nozzles and which provides feedback force of objects through an external air receiver [14].

In this paper, we present a button effect delivered by an air-jet display for interaction with a tangible AR object. In order to use appropriate pressure values in our system, we captured real button pressing forces and time plots. Furthermore, we propose a method which extracts the tips of the fingers by finding the convex hull points of the hand object and constraining the radius of palm. We use this in our AR environment, so that users can naturally interact with our haptically enhanced virtual object with their hands.

2 Pneumatic Tactile Interface

In order to produce the sensation of clicking a button, pneumatic tactile system is adopted in this paper since our pneumatic display can deliver appropriately changing stimuli to the surface of the skin as the button moves through the process of being pressed.

2.1 System Configuration

The existing air-jet system is used to presents button effect of the tangible object [13]. Overall configuration of our air-jet system is simple such that a user attaches air-jet display on the fingertip and input commands are coming from PC through an RS232 serial communication to Mexx ATMega 128 microprocessor controlling the state of the valves. As the valves, Yonwoo Pneumatic YSV10s are used to control the flow of air. The overall system configuration is shown in Fig.1. It consists of an air supplier, regulator, interface and control board, and pneumatic tactile display. The air supplier provides pressurized air and the regulator keeps the pressure.

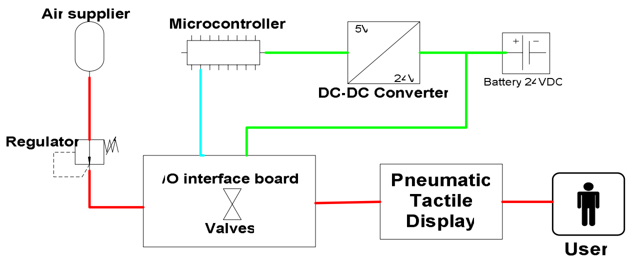

Fig. 1. System configuration of pneumatic tactile interface

The air-jet display forms 5x5 arrays on the finger pad and additional 5 air nozzles which are contacted each side of finger in order to produce the lateral force. The display features air nozzles with an external diameter of 2.4mm and internal diameter of 1.5 mm. Figure 2 illustrates the display design. In order for more natural interaction, the air-jet stimulates the fingertip of index finger which usually used to press buttons. In accordance with our previous psychophysical experiments, it can deliver richer information since air-jet display is mounted on fingertip while feeling of buzzers on the finger nails may be missed for some users as Volkert Buchmann mentioned [12].

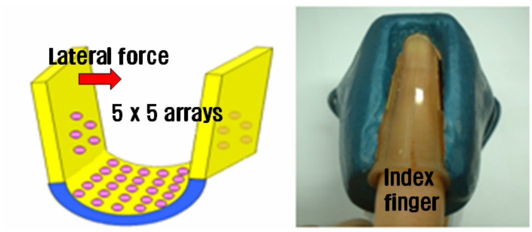

Fig. 2. Display design

3 Experiments on Measuring Force and Time of Buttons

In the previous study on PTI (Pneumatic Tactile Interface) [13], we concluded our experimental data could support that we could deliver cue capability to grow or shrink in magnitude by increasing number of air-jets, and sensory threshold for pneumatic cues are considerably greater than those for vibration cues. Thus, we implemented button effects with pneumatic tactile display by modulating the intensity of air-jet. Therefore, when a button of virtual models is pressed, users are able to feel button clicking feeling. In order to produce button effects, pressing force of the real button is measured and then applied to the pneumatic tactile system. In addition to the force profile, time value is one important factor for producing the button effects. Therefore, experiments have been conducted to figure out the pressing force and time value.

3.1 Experimental Set-Up

Creating the click-like sensation which makes people believe as if they press the physical button is desirable goal of our work. The characteristics of virtual buttons are reported in the literature [11]. In order to produce click-like feeling, we measured the forces while users press the real button. In order to measure the force-profile of physical buttons of the cellular phone [7], Tekscan's FlexiForce® Sensors A201-1(0-1 lb. force range) and a real button panel were used [Fig.3.].

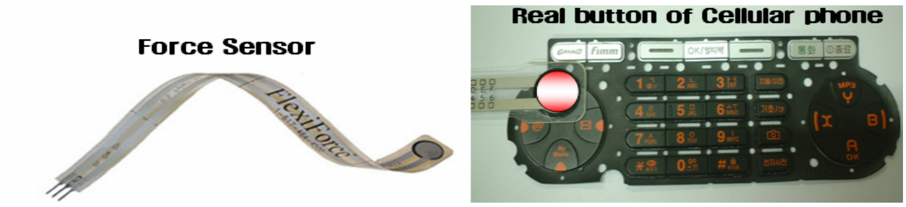

Fig. 3. Measurements on button force

Basically, this sensor is equal to potentiometer; namely, the output of the sensor is proportional to the input force. AD converter in ATmega 128 is used to convert analog input to 10 bit digital data. Also, low-pass filter is adopted in order to avoid the interference of high frequency.

3.2 Force - Displacement Curve Experiment

The total length of a physical button is 0.2 mm. In order to find out the force profile of this button, we measured force data as pressuring down the button with 0.005 mm increment by using micrometer and 3000 samples were acquired at each length. As shown in Fig. 4. the measurement data of real button clicking force is similar to the well known virtual button force model. In other words, at the initial position force is linearly increased, then it suddenly decreasing, and then the force is increased remarkably. Also, it describes the average force of first peak which is about 160(0.7 N) and the average force for dead band is 93(0.4N).

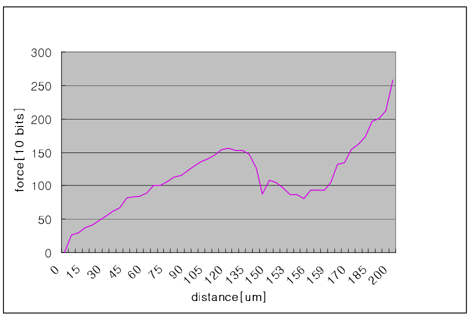

Fig. 4. Result of measurement of button force

3.3 Force - Time Curve Experiment

The timing is also key factor to provide button effects by the air-jet display. We conducted another experiment in order to find out the timing information and the characteristics of force profile related to the time. Eight subjects were participated in this experiment and they pressed the same button 20 times and all data were automatically saved as xls file format. Fig. 5. illustrates the result of experiment.

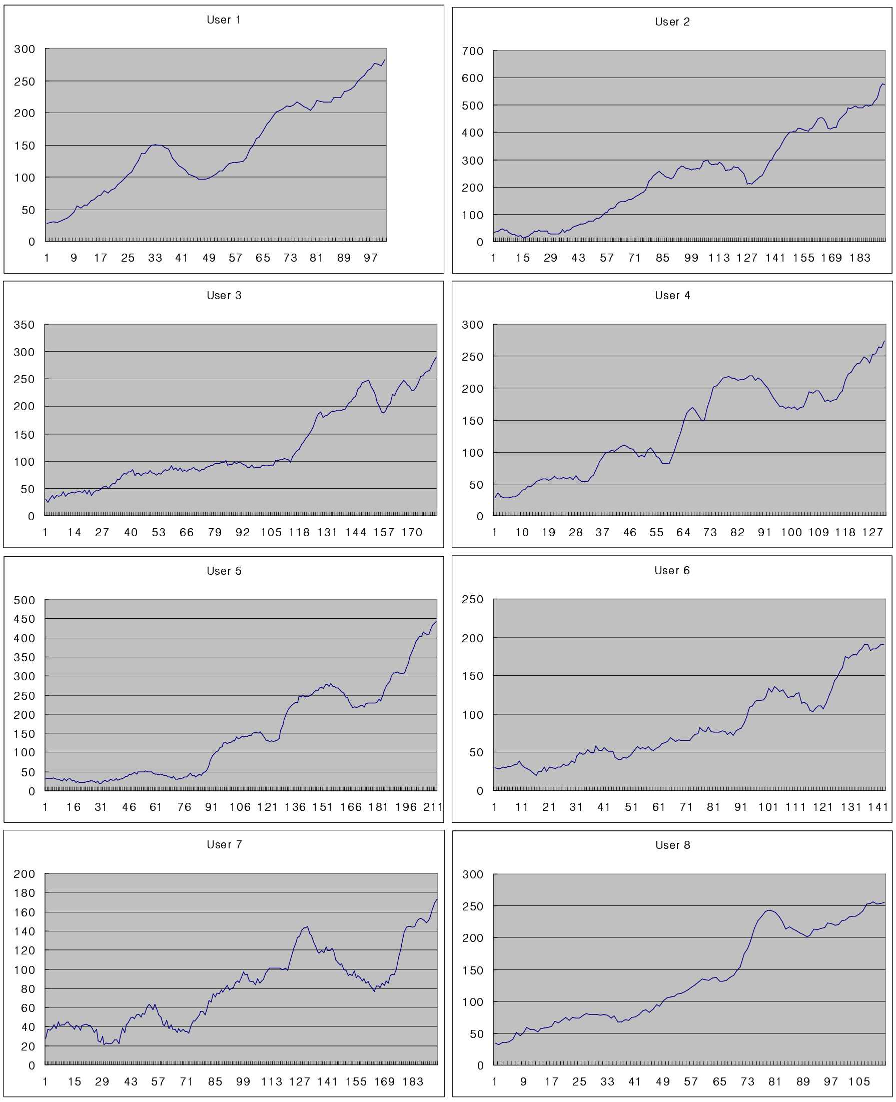

Fig. 5. Result of experiment on measuring force-time curve for a real button

These graphs show slightly different force profile comparing to the results described in section 3.2 since the acceleration while pressing the button may be affected to the results. Also, since the button of cellular phone has short length and the dead band time is too short to sense, the real force profile of button shows small dead band. The average time for initial increasing band is about 200 msec and the average time for dead band is 60 msec [60 msec = (30 samples x 1 sec) /500 samples].

3.4 Mapping Displayed Force to Pressure

Pressure can be obtained by following equation:

$$\text{Pressure [psi]} = \text{Force [pounds-force]} / \text{Area [inch}^2\text{]}. \tag{1}$$

That equation refers that if the force and area are known, we can generate the same amount of jet force at the nozzle. As we described the size of tube is known factor and mean of 500 sample force data is given in Fig. 5. Therefore, button effects delivered by air-jet display are provided according to the results of experiments. In order to produce force (0.7 N), the area of tubes should be calculated.

$$\text{Area [inch}^2\text{]} = \boldsymbol{\pi r}^2. \tag{2}$$

In our display, the radius of tubes is 0.75 mm (0.0295 inch) so the area of each tube is 0.002734 [inch^2]. Therefore, 58 psi is required to produce the first peak force (0.7 N), when only one air-jet nozzle is used. However, by increasing the number of air-jet nozzles, less pressure is needed since total pressure is distributed into several air-jet nozzles. For example, six air-jets produce the same amount pressure at about 10 psi.

4 Interaction with Tangible Object in AR

The primary goal of our system is to integrate the pneumatic feedback derived from the pressure measurements of the real button with an AR system which allows the user to interact with graphical virtual models. We aim to add touch feedback to this graphical AR environment. To achieve this we focused on a model of a cellular phone and developed an AR system which displays the model and detects the user's fingertip position. When the user's finger touches a button on the phone model, we display the stored button pressure profile on our pneumatic array, in order to create the physical sensation that the button is being clicked. Typical fingertip detection systems rely on fiducial markers [2] attached to various portions of the hands, but this is unsatisfactory as problems of occlusion can occur, and also it can be both unnatural and inconvenient to use. Our system extracts the fingertip points by locating the convex hull points of the hand and using the palm as a constraining radius. Thus we allow the users to naturally interact with the virtual object using their hands. This system is explained in more detail below.

4.1 2D Based Fingertip Point Extraction and Collision Detection

The vision-based fingertip capture interface enables a more natural and intuitive style of interaction. In our system, users are able to interact with virtual objects using their hands and experience the results of their interactions through our pneumatic tactile display. They are able to push buttons on the augmented virtual game-phone, and feel corresponding tactile sensations. This system is enabled by a 2D based fingertip point extraction and simple collision detection.

In order to extract fingertip points, we use the “3 coins algorithm” [3]. However, this leads to the generation of a large number of convex hull points so we filter this data with the constraint that the fingertips must be relatively close to the palm: within 1.5 times its radius. We visually detect and display the hand using a combination of a skin color distribution detection algorithm [9] and a segmentation system designed to reduce visual occlusion [10].

4.2 Implementation

After the 2D finger position has been attained, this data can be easily integrated into the coordinate space of the 3D model. A simple collision detection algorithm then determines if the user is close to or touching a virtual button. When the user’s finger is near a button, we display a blue ‘cursor’ on its tip and if that blue point collides with a button, the air-jet button effect is displayed. Figure 6 shows the user’s fingertip approaching a button (left) and when it is on a button (right).

Fig. 6. Fingertip point extraction and providing air-jet button effects

5 Conclusion and Future Work

The proposed system produces button effects whereas most tactile displays have mainly provided weight, shape, meaningful texts and so on. By conducting the experiments on force-distance and force-time curve, it became possible to generate jet force at the nozzle according to the physical clicking force. In AR environment users are usually not perceived any haptic feedback, since augmented objects do not provide physical haptic feedback. In addition, manipulating the widget such as buttons, sliders, and joysticks is related to the performance of the task. Therefore, we provide button effects delivered by air-jet display while interacting with tangible objects for immersive interaction.

From the several fundamental studies, we examined air-jets let users feel the button effects and interact with an augmented object impressively. However, evaluation of this system will be done in the future to see effectiveness of our system. Also, not only button clicking feeing but also the shape of button will be provided.

Acknowledgments

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