The Haptic Feedback Design of Augmented Reality Virtual Keyboard on the Air

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Abstract. With the promoting of the computing capacity system, the augmented reality (AR) technology has been gradually used in daily life application. And augmented reality on the hardware device can become smaller which is allowing user easy to carry. However, the location of virtual model in the AR technology on the reality just has air, which means people cannot touch the model actually. Therefore, augmented reality device still does not have ubiquitous haptic feedback equipment to give the user good haptic perception and operation experiment like other portable device such as mobile phone or tablet today. This study try to design the haptic feedback device for augmented reality virtual keyboard on the air, we use focus group to find the innovation idea of haptic feedback for augmented reality, and we create a simple and normal structure to achieve the goal without any high technology equipment. We hope this study cans give the reference for future study of augment reality haptic feedback and also influence the operate posture and interface of augmented reality device.

Keywords: haptic cognitive, focus group, ergonomics, human-computer interaction, Human-center Design.

1 Introduction

1.1 Development Trends of Augmented Reality

Since Boeing researcher Tom Caudell (1990) first coined the term "Augmented Reality"(AR),the computing capacity of AR technology system has been promoted and gradually used in life application [1]. With advances with technology, augmented reality on the hardware device can become smaller which is allowing user easy to carry. Augmented reality on the handhold mobile device is widely used in the daily life and has commercial value, such as smart phone or tablet can be used at anywhere after download the AR software program. Another example is head-mounted display (HMD) display device, which can show the virtual items and change while users turn their head, in order to provide user immersive experiment [2].More lightweight AR device can be mounted on the glasses, like the Google Glass. The iOptik is developed from military even can be installed on the contact lenses, that way the soldiers can see the aerial view of battlefield and focus on the battle situation at the same time[3].

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Different kinds of device show that investors believe that augmented reality is worth to develop and has a bright future.

1.2 Interactive of Augmented Reality

Augmented Reality can project the virtual image onto the real world overlap each other instantly, allowing users to experiment the interaction between real and virtual world by various kinds of input and output device, and has been applied in various fields now. For example, the theme park "The Wizarding World of Harry Potter" use AR technology combines with the map. User can see a three-dimension virtual building on the flat map and interact with the virtual model by blowing into the microphone .Another example is the fashion business combine with AR and then develop the Virtual Fitting Rooms (VFRs), which let buyers know what they look like when they dress on the clothes. This technology not only increase sales but also reduces the number of return [4]. AR technology also can use on the medical, surgical physician use augmented reality to superimpose the virtual surgery video on the actual surgery to let two kinds of experiences assist and improve each other [5]. Interior designer use AR technology place the virtual furniture in the real space to simulate the decorated situation, in order to make change and adjustment with customer earlier [6]. Industrial Technology Research Institute use HMD and AR technology develop "Air touch" application to do navigate and other function [7].These cases show augmented reality can use on the diverse application and then give the people image the future value and contribution of AR technology.

1.3 Haptic Feedback Plays an Important Role in Portable Device

Haptic feedback means by item stimulating the skin, human can understand the characteristics of the object such as shape, texture, temperature, force and other information. A comfortable haptic feedback even can promote the willing of people to purchase the goods [8-9]. The literature also pointed out that smooth surface touch screen would cause fingertip lose the haptic message when the people use the virtual screen. The typing accuracy of people will reduce when the surface loss the haptic feedback including the reaction force and edge feel [10], and also the reaction time is longer than physical keyboard. The touch screen with haptic feedback does help reduce input error rate and increase the input speed, and also reduce the using cognitive load when it compare with the normal touch screen [11].Therefore, most of touch screen such as PDA, smart phone and tablet would add the haptic feedback device when they use virtual keyboard. Apple, Sony and other manufacturers also apply for a patent for their unique haptic feedback device also show that mobile device manufacturers think seriously of the haptic feedback.

1.4 Haptic Feedback on the New Developments in Mobile Devices

The normal mobile touch device use vibration equipment to produce haptic feedback, however, only vibration is not enough to give sufficient haptic information for people.

That way, various manufacturers are also actively developing new types of haptic feedback in recent year. NEC Corporation and Tokyo Institute of Technology co-design the touch screen with force feedback. The sensor can detect the direction of finger movement, and then use cable pull the screen in the opposite direction to allow user feel the elasticity and tension from the object [12]. Also, some haptic feedback study focus on the pressing behavior, such as Japan KDDI touch screen showed in CEATEC Japan 2011 Business Electronics Show, using a piezoelectric element to make the really pressed down feeling for user when they operate the tablet [13]. And in CES 2013 U.S. Commercial Electronics Show, Tactus Touch Screen display its microfluidics technology, which can float the bump from the screen to form the buttons when user need, and make the tablet has really physical buttons to provide better haptic feedback [14].

1.5 Summary

In recent year, the augmented reality technology try hard to combine with mobile device, hoping to extend to more applications. It means we will need better device to provide better haptic feedback for helping operate. However, the devices such as tablet right now still have basic haptic feedback because the material of screen that user touch can provide basic tactile and force feedback even without any haptic feedback equipment. But in the future the head-mounted displays and augmented reality technology would use frequently on the portable device, virtual item appear on the air which cannot be touch directly, user can not feel anything while interact with virtual item. Therefore, how to let the skin sensor the haptic feedback while operating the virtual item on the air, is what we are focus on.

2 Related Works

2.1 The Importance of Distinguish the Haptic Feedback

Haptic is a touch of science, derived from Greek ἁπτικός (haptikos), means “the feeling which can contact”, and the response received from the object after touching the object is haptic feedback. Haptic feedback can divide into tactile, force feedback and proprioceptive feedback. Tactile let the people feel the texture, temperature and vibration. Force feedback show the direction of power, such as weight, inertia and object boundary. The proprioceptive feedback is related to location and postures [15], and in recent year study classifies the proprioceptive feedback as part of force feedback. Due to the design the virtual keyboard in the augmented reality would include tactile (keyboard vibration, buttons texture), force feedback (keyboard boundary and inertia) and proprioceptive feedback (control posture), finding which one is the mean type of feedback will significantly affect the design direction. That way, it is necessary to divide and understand different type of haptic feedback.

2.2 The Importance of Collect Concept

The design process has many kinds of judge criteria, and also it includes many intuitive behaviors to make the idea more diverse [16]. Therefore, collecting good idea is the key for create innovative design. In this time, we will use focus group to get the variety of new concepts. According to Jungk and Müllert (1996) argument, focus group consists of the following stages: (1) preparation phase, (2) judgment phase, (3) concept development stage, (4) implementation phase. The study uses focus group to get the inspiration and creativity of the haptic feedback from the user, evaluating and choosing feasibility structure to make the model by co-design with participate. Therefore, we delete the judgment phase.

2.3 Generating Haptic Feedback on the Screen Surface

The most basic idea of generating haptic feedback on the screen surface is making the surface changes with the image directly. With the movable array up and down, the surface can imitate the texture of the image [17-18]. The Tangible Media Group from MIT Media Lab also use movable array with different colors of light to make inFORM, which can produce dynamic user interface, by changing the actual object to generate haptic feedback of the physical tips, constraints and operational for user [19]. Microsoft developed Light-induced Shape-memory Polymer Display Screen, which use different wavelengths of light to make the surface change for different texture [20]. These study include the force feedback and tactile feedback, however, these equipment are too huge and complicate to easy carry away.

The vibration that normal portable device used is belonging to the tactile. However, the tactile feedback message from the vibration is limit, so some study use voltage to create more detail feedback. Mallinckrodt found the Electrovibration phenomenon in 1954, which use electric current to generate an adjustable friction on the skin, and then imitate different texture by changing the voltage to let the user understand the object texture information [21]. In recent year, Disney Research Team use Reverse Electrovibration to build the REVEL, which use voltage stimulates the skin to create different friction coefficient. When user slide the finger, the surface would produce different friction to imitate other surface, to let the user has the illusion of touch different texture.

2.4 Generating Haptic Feedback Beyond the Screen Surface

Because of the public place need to keep clean and other health issues, the device which can generate haptic feedback beyond the screen surface is created. User can feel the feedback on the air when they in the action. The usual way is let the user wear the equipment with vibration device such as gloves or ring, and then give the user vibration alert in the right time which was analyzed by the system calculates, to allow user to understand their operation is valid or not. UltraHaptics focus ultrasound at a fixed distance and then become an operation point, let the user can feel the haptic feedback on the air, and also user can control the interface beyond the surface with

the finger detect system [22]. The further design is to achieve surround haptic feedback by emitting directional air vortex from injection device. Making the skin feel different air pressure to create the haptic feedback is a famous direction of the haptic study. Due to the injection devices can install in different place, this design can reach the surround haptic feedback like surround sound, such as Disney Research Team create AIREAL [23] or Microsoft Research Team create AirWave [24].

2.5 Summary

Overall, the perception of haptic feedback for the augmented reality has a big breakthrough that the device is developed from normal vibrate alert to allow user feel the surface texture. But in the future direction of mobile devices, most of the equipment today is still too cumbersome, it would cause hard to control and unnatural in the operation. Also the technology demand of the haptic feedback is high to reach, it cannot rapid spread and use in the short term. Therefore, this study hope to design new haptic feedback way which use more concise device to break through the limit of huge equipment, increase the area that user can use. That way the device can reduce the burden of body carry and then it can break through the restriction of operate posture, and finally it would influence the innovation of the augmented reality interface.

3 Method

The research hopes to make innovation design modal for the haptic feedback of augmented reality keyboard on the air, breaking through the portable problem of the huge haptic feedback device to increase the control area and find the new operate posture. We try to create new type of haptic feedback technology by investigating the haptic feedback of physical keyboard and simulating the virtual keyboard operation process. The purpose of experiment is to find the simple, convenient and portable haptic feedback device, and discuss the future of the virtual keyboard interact with user. The main structure as follow:

3.1 Purpose

Due to the restriction of the equipment, human and time, we use focus group to co-design what kind of the haptic feedback is suitable for virtual keyboard in augmented reality, to find out the haptic feedback feeling that user really want. The purpose of the experiment is design the feasibility solution for haptic feedback device

3.2 Experiment Participants

The study default the student right now will become the haptic feedback device user in the next generation, so our experiment participants are students. In order to obtain the detail of information and advice, we choose the heavy internet users who use more

than 28 hour per week (NOWnews.com, 2012) on the internet and use the keyboard, the ages between 20 to 30 years old.

3.3 Experimental Execution

Each meeting contains 6 to 8 participants in addition to the host and recorder. The focus group would focus on haptic feedback, and the focus group would do three times. The process as follow:

Preparation Phase. The host would rent the place for discussion and prepare the pen, paper and different kind of keyboards for use, and then prepare the interactive mode. After participant arrive, the host would explain the experimental purpose, descript the relative design of the haptic feedback, and then let the participant operate different kind of keyboards to know the different haptic feedback feeling.

Concept Development Stage. After participant try on different haptic feedback feeling, the host would invite them to associate with the question "Design a device that allows the fingers to feel the haptic feedback from the virtual button". The question asks participant to draw or write down what type of the haptic feedback they want to feel when they touch the virtual button in augmented reality, also they need to design the form and how to achieve the goal. In addition, the research hope to create light and portable device for human, therefore the question would have some limit for its specification. After participant finish the question, host would invite them discuss their thoughts and advance some new element or idea. After first question, the second question would ask participant "consider the feasibility, design a haptic feedback device system" according to the conclusion of the first question. And then do the discussion again and create the final concept.

Implementation Phase. After focus group, we would collect the concepts from each participate, and then review each concept achieve what types of the tactile or force feedback, and also evaluate with the feasibility for us, to finish the haptic feedback device for augmented reality virtual keyboard on the air.

4 Results

4.1 Analyze and Evaluation

After collect the concepts from each participate, we classify and integrate these concepts to the main 14 different kinds of types (see Table 1), and then we discuss the feasibility one by one to discuss what we can do next.

The first three concepts mention the tactile feedback of the temperature, and it is a good point for the haptic feedback because we do not notice before the focus group. However, the basic idea of temperature feedback is just let the user feel different temperature, so that means the device with low specific heat material is enough, the cooling or heating device is not necessary. The concept of use electric flow that we cannot

Table 1. Haptic feedback concepts and the required material

	Haptic Feedback Concept	Feedback Type	Material Use
1	The temperature of button is different with the finger to let the user feel the feedback	Tactile feedback	Low specific heat material
2	Take the heat of the finger away when finger touch the button	Tactile feedback	Thermoelectric Cooling
3	Infrared radiation to let the finger feel warm	Tactile feedback	Infrared device
4	Use the electric flow to simulate the finger	Tactile feedback	Electric circuit
5	Spin something to rub the finger	Tactile feedback	Motor
6	Accelerate something to hit the finger	Force feedback	Magnetic repulsion force
7	Inflate the small balloon when finger touch and then deflate immediately	Force feedback	Inflator
8	Give some suction or sticky feeling to let the user know he already touch	Force feedback	Sucker structure or sticky material
9	Use linkage to make a plane up when the finger push down	Force feedback	Anything can make a linkage
10	Use foldable physical tension plane for user	Force feedback	Plastic film
11	Make the user's body become a touch interface	Force feedback	User's body
12	Use Non-Newtonian Fluid for touch	Force feedback	Non-Newtonian Fluid
13	Vibrate the nail to let the user know they already touch	Force feedback	Ultrasound device
14	Use air vortex to make the skin feel the pressure	Force feedback	Air vortex emit device

do better than the REVEL created from Disney Research Team, so this concept is not consider in our design. The last two concepts also have been done by other research and we consider our technology cannot beyond them, so they are also not in consider of our design. Use Non-Newtonian fluid is a new idea for us. The property of Non-Newtonian fluid is it would become harder when it suffer from the greater force. But we are not sure whether we can handle it or not, we pass this interesting idea unfortunately.

The basic idea of 5 to 11 concepts is take a physical thing to touch the finger when user does the press button action, and these haptic feedback concepts are proposed for many times, so we try to design our model with these concepts seriously. After analyze these ideas in deep, we find that we can install a small portable button under the finger to give the user haptic feedback when their finger push down, and that means to generate the haptic feedback for augmented reality virtual keyboard on the air, the high technology is not necessary. We can use the simple and normal structure to solve this problem. Although we would still use other concept to try, we need evaluate these concepts first. The idea of make the user's body become a touch interface has already done by many research and study, so we cancel this concept into the design.

And the concept of spin something to rub the finger and inflate the small balloon when finger touch and then deflate immediately need to use the motor, but the motor is too big to stall it on the finger. That way, we also cancel these two concepts.

To sum up, we would use a low specific heat material in our device to add some tactile feedback for user, and try to add normal physical button on the device. We believe this evaluation can hope us innovation a new haptic feedback device for augmented reality virtual keyboard on the air.

4.2 Design Prototype

To use the simple and normal structure to achieve the haptic feedback device, we use LEGO brick, button switch and the metal gasket to create our prototype. We use LEGO brick on the main structure for easy to adjust with different length of finger, and we choose the button switch which is easy to press to increase the sensitivity of detection. The metal gasket which is low specific heat material is added on the button to generate the tactile haptic of different temperature. The structure fix on the proximal phalanx and the button is below the fingertip. When the finger relaxes, the fingertip is free and would not touch anything. When finger starts to operate the virtual keyboard, due to the displacement degree of distal phalanx and middle phalanx is more than proximal phalanx, the fingertip would touch the metal gasket and feel the haptic feedback just like using the physical keyboard.

4.3 Evaluation of New Design

The advantage of our new design show that the device does not need to use any electricity circuit, it means the user would not worry about the electromagnetic damage even he wear the device for all day. Also, the device can easy to product because it only has basic structure without any new technology or material. And no matter what posture of the hand, such as raise or lay down, the user still can feel the haptic feedback if they do the typing action. That means the posture of operate the augmented reality can be change, people would need to raise the arm while type the virtual keyboard on the air. However, our design just shows one finger operate situation, the

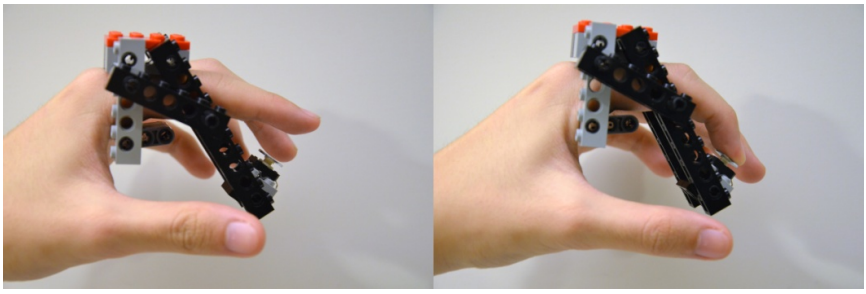

Fig. 1. Wear the prototype device in the relax situation and push action. The displacement degree of distal phalanx and middle phalanx is more than proximal phalanx obviously.

prototype now is still too big that the device would stuck each other if all the finger wear the device. Beside, the stability is not enough when finger push down, is has some offset problem on it.

5 Conclusion

To develop the haptic feedback device for augmented reality virtual keyboard on the air, we return to focus on people's feeling. We use focus group to find what kind of haptic feedback is user really wanted when they operate the augmented reality device. And we find a simple way to achieve the goal without electric to avoid the potential electromagnetic damage, and this idea can be produced easily because it does not use any high technology in it. Beside, our design can be used in different posture, we try to break through the limit of operate posture.

The next step we would simplify the structure to make the device lighter and more comfortable on the finger. And then we will expand the experiment from one finger to one hand, and use some method to compare the value between our design and physical keyboard, to improve the innovative device is really useful for operate the augmented reality virtual keyboard. Also, we would try other possibility concept from the focus group to find more possibility of haptic feedback. After the haptic feedback goal is achieved, our future development would focus on the new operate posture, try to find the new comfortable operate posture to let the user control augmented reality virtual keyboard easier.

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