Smartphone based accurate touch operations on an AR desktop

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ABSTRACT

The touch-based operations on a smartphone gives users a simple and intuitive interface. On the other hand, manipulating the screen without direct touch would be desirable for preventing infection of viruses. In order to implement such touchless interfaces, we propose a new operational manner on Augmented Reality (AR) based desktop. In our manner, the user operates his or her smartphone as an AR object in the virtual space. Every user shares the same virtual space, and each manipulates his or her own smartphone as the touching region on the virtual desktop. This operational manner contributes to intuitive manipulation and providing the feeling of AR objects as if they exist. The system helps the user perform accurate operations with little stress. In order to demonstrate the effectiveness of our operational manner, we have implemented a prototype system and conducted numerical experiments. We obtained favorable results and confirmed our manner is feasible.

Keywords: Augmented Reality, touch user interface, smartphone

INTRODUCTION

Recently, we have seen and used touch-based operations as a popular interface for smartphones and tablet PCs. In the interface, we interact with the devices through touching the physical surface of the screen. The manipulation of touch-based devices such as smartphones is usually simple and intuitive but not always convenient when multiple users operate a single device cooperatively. Allowing multiple users to operate the device enhances performance and collaboration on tasks (Nolte et al. 2015, Guo et al. 2019). On the other hand, participating multiple users requires a wide screen and correct responses for each user's independent touching, which are weak points for devices with a small screen such as smartphones and tablets. Also, it is desirable for some users to operate the screen without physical contact. Because touchless operations prevent viruses from infecting other users. It is especially true in the current situation of COVID-19 pandemic. In order to implement the touchless interfaces, researchers have proposed augmented reality (AR) based desktops or keyboards. AR based interfaces can be helpful in navigation with visual aids (Zhao et al. 2019, Reyes et al. 2020) and in multitasking scenarios (Ren et al. 2020). Most of them require interactions with virtual objects in the air, which are not very accurate. Some works have proposed methods for increasing accuracy of the interactions, for example, through utilizing visual and audio feedback (Chan et al. 2010), combining taps in the air (Plasson et al. 2020), and utilizing natural pen and touch inputs enabled by the seamless integration of a screen and AR contents (Reipschläger et al. 2020).

These works, however, focused on how to improve the accuracy of touch interactions in the air, and lack of the operational feeling provided by direct touch. We propose a new operational manner of AR based desktop. In our operational manner, a user takes advantage of his or her smartphone to interact with an AR object on the screen displayed in the virtual space.

Our final goal is to realize a new AR based interface that provides a real touch feeling to AR objects through touch interactions with their smartphones. As a prototype, we implement a desktop system that satisfies the following three points: (i) Intuitiveness similar to physically operating a smartphone or a tablet, (ii) Accuracy that enables the user to complete desktop operations as intended, and (iii) Operational feeling of real existence of the virtual screen in touching it.

AR Desktop

We have implemented a prototype system of the AR based desktop system. We call it "AR Desktop", and Figure 1(a) shows it. We made the desktop be displayed in front of the user and set the home position of fingers at the center of the smartphone. The location of the smartphone is recognized through an AR marker attached at the top of it, as shown in Figure 1(b). The AR Desktop screen consists of a cursor, an icon, and a reference point represented by a black dot at the center of the screen (Figure 2). The cursor follows the smartphone by referring to the coordinate of the smartphone, which is determined by recognizing the AR marker and adjusted to the home position of the finger. Once the cursor reaches the location where an icon of an application resides, the user can apply one of the following four operations: (i) tap to launch the application, (ii) double-tap or drag to move the icon, (iii) pinch-out to zoom in the application screen, and (iv) pinch-in to zoom out the application screen. Notice here that the drag operation means moving the smartphone with the icon while touching its screen, being toggled through the double-tap operation. The AR Desktop also supports the flick operation, which can be operated at any position and has the following two functions that: (i) creates a new screen in the flicking direction and switches to it automatically if there is no screen in that direction, and (ii) switches the current screen to the next screen in the flicking direction if there are two or more screens.

The reference point is used to hold the cursor corresponding to the user's finger when the direction of user's head changes. The correspondence should automatically be corrected depending on the difference between the reference point and a physical marker. In the current version, the users are supposed to align the reference point with the physical marker. We are planning to automate this feature.

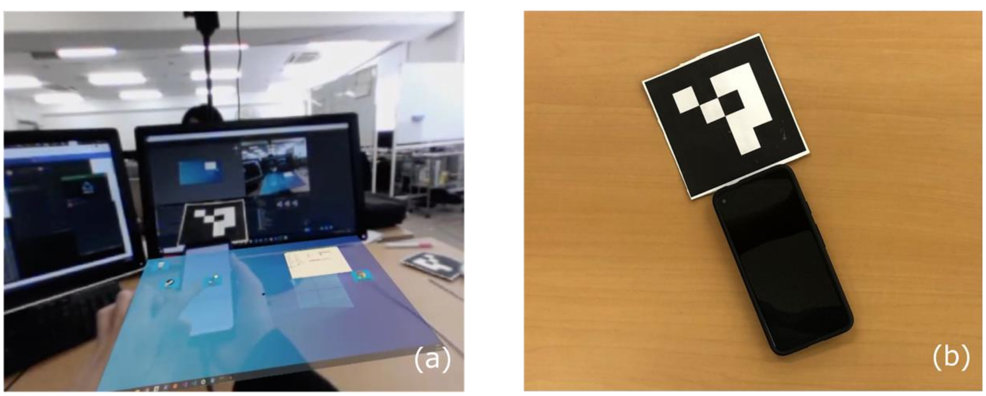


Figure 1: (a) A prototype AR Desktop and operations on it, and (b) a smartphone and AR marker at the top of it

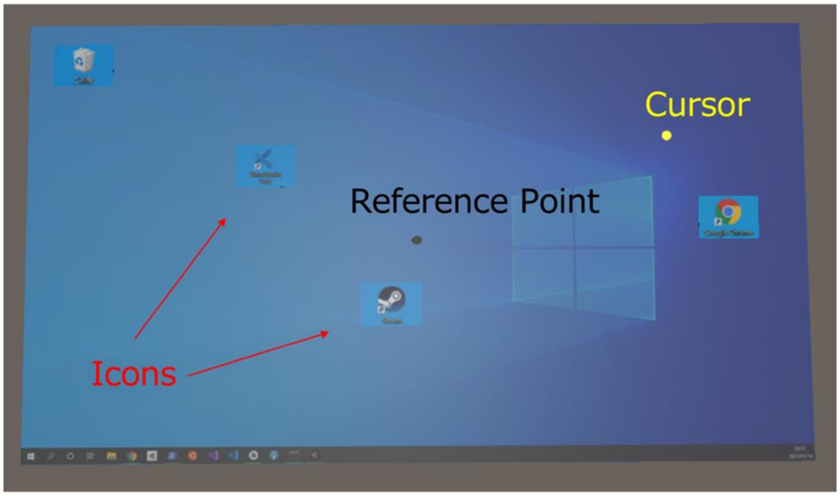


Figure 2: Components of the AR Desktop

EVALUATION

IMPLEMENTATION OF AR

In implementations of AR, there are roughly two kinds of approaches. One overlays virtual things represented by CG on the real world through a transparent screen, and the other one synthesizes a single image from the virtual things and the real world image using a head mount display (HMD) with a front camera. We adopted the implementation with an HMD and used VIVE Pro Eye as the HMD. Also, we utilized Google Pixel 4a as a smartphone that recognizes touch operations and indicates its location through an AR marker attached at the top of it.

SUBJECTS

We had twelve students, who consist of ten males and two females, from our laboratory conduct experiments as subjects. Most of them had some experiences of AR; six subjects experienced it with a head mount display (HMD), and four subjects had some experiences of interaction with AR objects in some way. Eight subjects reported that they were familiar with manipulations of a smartphone or tablet, and the other ones reported that they knew only basic operations.

EXPERIMENTS

Before the experiments, we gave them a brief introduction of this research and explanation of the purpose of the experiment, and then distribute smartphones. We utilize Google Pixel 4a with the AR marker for this purpose. We also make each subject wear an HMD, which is VIVE Pro Eye. In order to calibrate our system, we had each subject put his or her fingertip with the smartphone at the bottom-right and top-left corners in a rectangle region where a cursor is movable. Through the calibration, the location of each subject's fingertip is synchronized with the one of the cursor. The calibration includes the purposes of not only initializing the AR Desktop, but also preventing the AR marker from accidentally going out of the range of view of a camera when the subject operates the AR Desktop.

RESULTS OF EXPERIMENT

In order to demonstrate the effectiveness of our operational manner, we have conducted two numerical experiments on our prototype system. As requirements for the AR Desktop to satisfy, we first evaluated intuitiveness and accuracy through verifying the following two points in our experiments:

1. Subjects can intuitively understand touch operations without explanation.
2. Subjects can operate the AR Desktop as intended without a cursor.

In the following, we refer to these verifications as V1 and V2, respectively. After the experiments, we asked the subjects about their operational feeling and then evaluated the last requirement.

In Experiment 1, to verify V1, we had the subjects conduct the following seven tasks in order: (1) launching an application by tapping a corresponding icon, (2) moving an icon by double-tap, (3) moving an another icon by drag, (4) zooming in an application screen by pinch-out, (5) zooming out an another application screen by pinch-in, (6) creating a new screen by flick, and (7) switching the screen by flick. Figure 3 shows whether the subjects felt that each touch operation was intuitive or not. As shown in the figure, most of them felt that all touch operations were intuitive, except for the only two operations; double-tap to move icons and flick to create a new screen. As for the subjects who were familiar with touch operations were concerned, more than half of them answered that double-tapping to move icons and flicking to create a new screen were intuitive as shown in Figure 4.

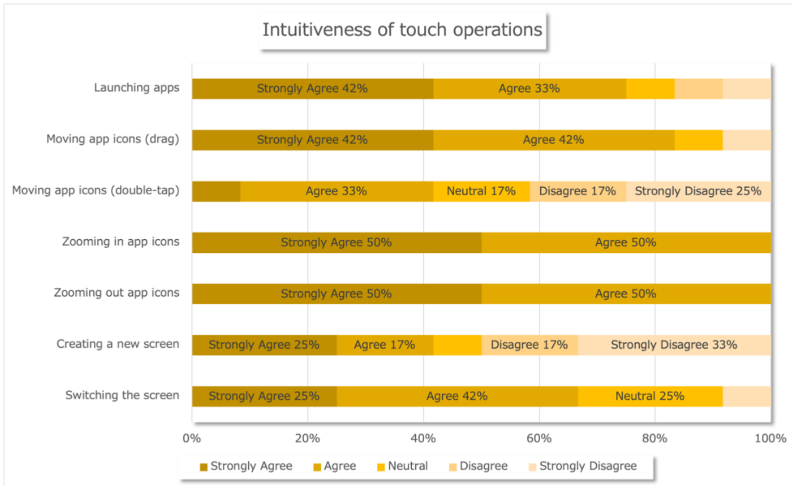


Figure 3: Intuitiveness of touch operations for all subjects

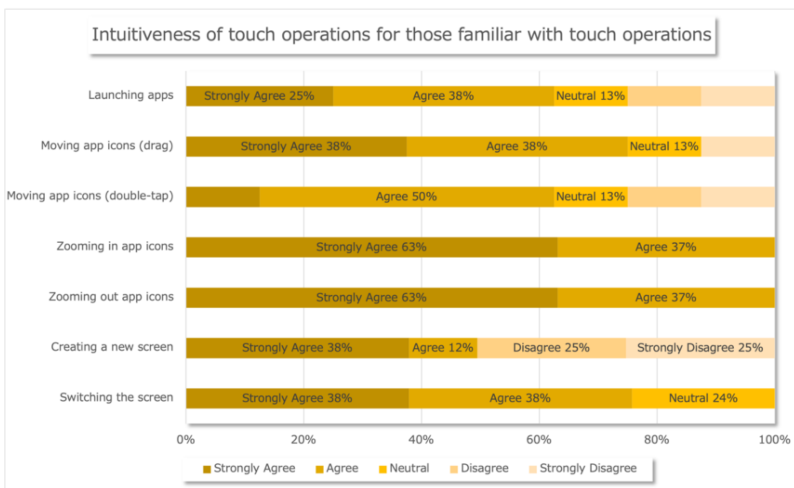


Figure 4: Intuitiveness of touch operations for those familiar with touch operations

In Experiment 2, we had the subjects perform the tasks from (1) through (5) of Experiment 1 without cursor to check V2. As a result, half of the subjects who the position sync worked well successfully completed all tasks except the last one (5) as shown in Figure 5, even though they could not see the cursor. Regarding Task (5), most of the subjects failed to complete the operation without cursor, though all of them completed it with cursor.

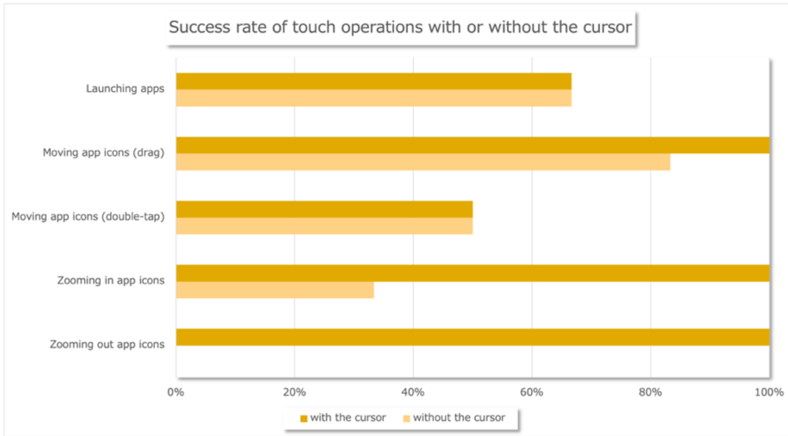
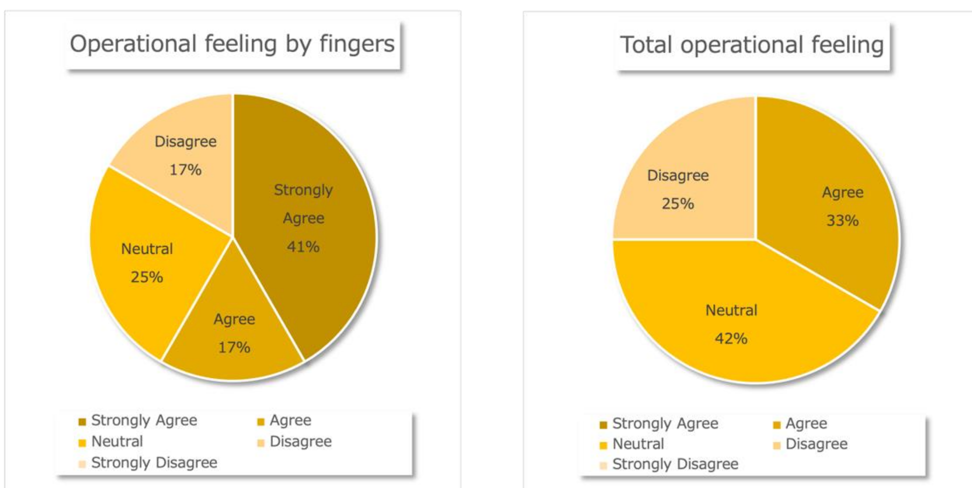


Figure 5: Success rate of touch operations with or without the cursor

After the experiments, we asked the subjects some questions. Their answers, as shown in Figure 6(a), show that most of them felt like physically operating the AR Desktop screen with their fingers. They also said that the total operational feeling was not bad, as shown in Figure 6(b). Thus, we were convinced that our operational manner satisfies all the three requirements: intuitiveness, accuracy and operational feeling.



(a) Operational feeling by fingers (b) Total operational feeling

Figure 6: Answers to (a) operational feeling by fingers and (b) total operational feeling

CONCLUSIONS

We have proposed an accurate and intuitive operational manner on the AR based desktops through touching the users' own smartphones. This operational manner let us not only accurately perform touch interactions with desktop in 3D space, but also intuitively implement most touch operations such as launching, moving, and switching screens. We have also confirmed that it is possible to operate the system without the cursor assistance when the calibration is successfully done.

As future work, we are planning to add automatic correction of the correspondence between a cursor and user's finger to our prototype system. In addition, we plan to extend our operational manner so that it enables multiple users to work collaboratively on the virtual large screen.

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