

# An Interactively Virtual Extended Display on Transparent HMD

Daiki Masaki<sup>1</sup> and Mitsunori Makino<sup>2</sup>

<sup>1,2</sup> Department of Information and System Engineering, Chuo University  
1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan  
E-mail: <sup>1</sup>a12.m7ya@g.chuo-u.ac.jp, <sup>2</sup>makino@m.ieice.org

**Abstract:** In this paper, an AR-based expansion of PC display is proposed, which makes us work more effectively with multi windows. Wearing a transparent head-mounted-display, a user can see three virtual extended screens of PC, as well as an actual screen. When he/she bobs or weaves his/her head, the virtual screens are correspondingly displayed/hided on the HMD. The feature contributes to preventing the virtual screens from obstructing his/her view. The result of user-test shows usefulness of the proposed system.

## 1. Introduction

It is usual way for us to use multiple windows when we work with a PC. Especially, inputting sentences/data on a window with viewing some windows is common. In that case, arranging all the windows in one layer with suitable size is preferable for us to do efficiently. Thus we need a large display and/or multiple displays to have enough space for the arrangement. Shibata reported that working on PC with a large display or multiple displays is more effectively than one with a small display or single display, respectively [1]. As extension of the main display for PC.

In many countries/areas, especially in Japan, a smaller and lighter PC is strongly required for us to carry so that shipment of laptop PCs in Japan is more than ones of other PCs [2]. However, such PC causes difficulty to arrange in one layer on a small screen, as well as another displays cannot be connected due to portability of the PC. Therefore, achievement both of portability and larger display to arrange windows must be discussed.

Using virtual reality (VR) technology, we can virtually get space as large as we need. Recent development of head-mounted-display (HMD) is suitable to allocate windows in a virtual space with portability. On the other hand, VR technology usually takes our eyesight from the real world, so that an input interface must be presented in the virtual space. Additionally, we can hardly recognize small size of characters/data if the system can present captured image in low resolution. It may cause unnatural sense for users when they want to use usual input devices such as mouse and keyboard.

In this paper, we consider the augmented reality (AR) technology [3] for the extension of PC display, which presents virtual images overlapped on the real world. Using a transparent HMD, we propose an AR-based expansion system of PC display, in which a user can see three virtual extended screens of PC, as well as an actual screen and usual input interfaces in the real world with normal visibility. When he/she bobs or weaves his/her head, the virtual screens are correspondingly displayed/hided on the HMD. The feature contributes to preventing the virtual screens from obstructing his/her view. The proposed

system contributes to achieving larger area to show windows with portability. The result of user-test shows usefulness of the proposed system.

## 2. Proposed System

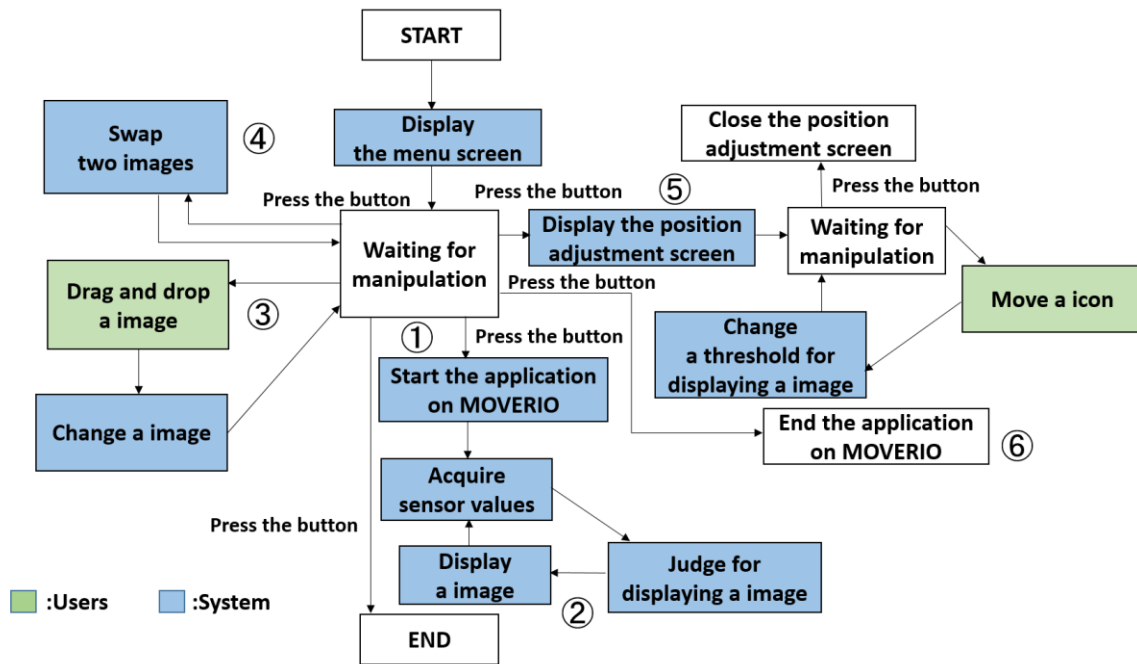
The proposed system runs both on Microsoft Windows PC and EPSON MOVERIO bt-200, a see-through HMD with Android OS [4]. It has two modes of setting and display. In the setting mode, a user can allocate three JPEG images to display on virtual space. The setting must be operated by real PC window and input devices (mouse and keyboard). In the display mode, the PC and the HMD collaborate for the extension of display. Through the HMD the user can view the overlapped images (windows) on real scene. When he/she look at the image from an anterior view, the system displays the image at the allocated position in the setting mode. Otherwise when the system detects his/her bobbing or weaving of his/her head from the image, the system hides the image to give him/her enough visibility in the real world. Thus the input devices and materials in the real world can be normally seen even in the display mode. The acceptable range of user's face for displaying the window is adjustable in the setting mode, which can be easily transited from the display mode. When the start button in the menu screen is pressed, the application on the HMD is started and the face direction is saved on the proposed system as the PC screen direction. The proposed system uses it as a criteria to display images.

**Table 1. Specifications of "MOVERIO" [4]**

<b>Size of screen</b>	0,42 inch (16:9)
<b>Resolution</b>	960 × 540
<b>OS</b>	Android [4.0.4]
<b>CPU</b>	TI OMAP 4460 1.2Ghz Dual Core
<b>RAM</b>	1GB
<b>Memory</b>	8GB
<b>Weight of Headset</b>	88g

**Table 2. Specification of PC**

<b>PC</b>	SONY VAIO Duo 13
<b>Memory</b>	4000MB
<b>CPU</b>	Intel Core i5-4200U CPU M 350 160Ghz
<b>OS</b>	Windows 8.1 64bit
<b>GPU</b>	Intel(R) HD Graphics Family 1792MB
<b>Programming language</b>	JAVA
<b>Development environment</b>	AndroidStudio , GCC



**Figure 1. the transition diagram of the proposed system**

Figure 1 shows the transition diagram of the proposed system. In the Key behaviors shown as 1-6 in the figure, the proposed system works as follows.

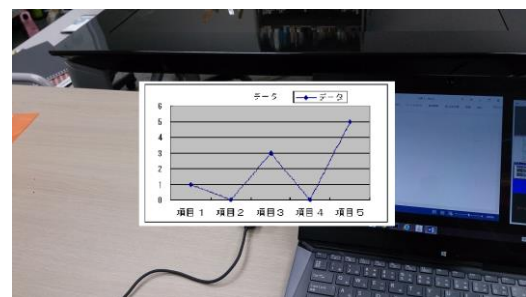
1. Start the application on MOVERIO  
When the start button in the menu screen is pressed, the application on MOVERIO starts and the face direction is saved on the PC as the PC screen direction. After that, the proposed system always acquires the face direction by the sensors mounted on MOVERIO.
2. Display images  
The proposed system displays a image set by users on MOVERIO when the face direction is contained within a range set by users.
3. Set images  
Users can set images on the proposed system via drag and drop.
4. Swap images  
When the swap button in the menu screen is pressed, two images are swapped.
5. Adjust position  
When the position adjustment screen start button on the menu screen is pressed, the position adjustment screen is displayed. Users can change thresholds for displaying images by moving the icons on the position adjustment screen.
6. Finish the application on MOVERIO  
When the application finish button is pressed, the application on MOVERIO finishes.

### 3. Evaluation of the proposed system

Figure 2 and 3-5 show a scene of the use of the proposed system and a user's view with the proposed system, respectively. Figure 6 and 7 are screenshots of the menu screen on PC. Figure 8 is a screenshot of the position adjustment screen on PC.



**Figure 2. A scene of the use of the proposed system**



**Figure 3. A user's view when the left image is displayed**

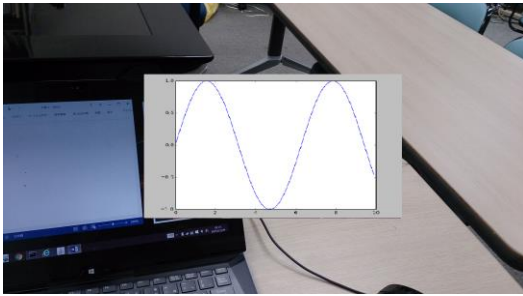


Figure 4. A user's view when the right image is displayed

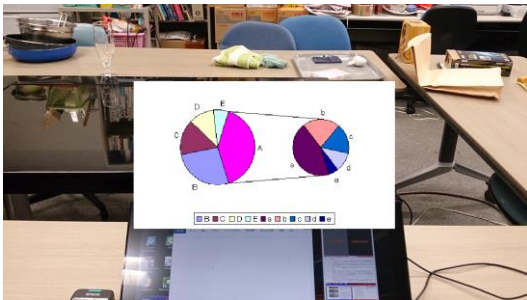


Figure 5. A user's view when the upper image is displayed



Figure 6. Menu screen (English sentences are superimposed on the screen shot)



Figure 7. Menu screen when users set images via drag and drop

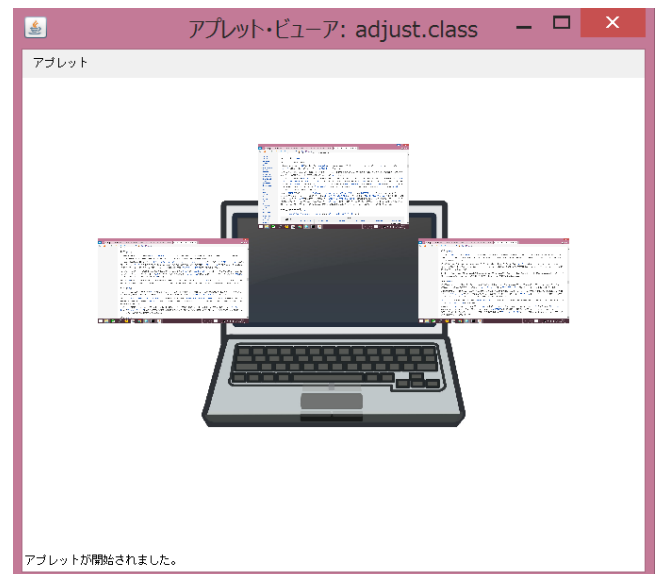


Figure 8. Position adjustment screen

For evaluation of the proposed system, 9 Japanese undergraduate students and 5 Japanese office workers experienced two sets of data input work, with/without the proposed system. Table 3-6 show the result of questionnaire to them. In the table, the rating ranges from a(best) to e(worst) or 1(best) to 4(worst).

**Table 3. Evaluation about operability**

	a	b	c	d	e
<b>3.1 Useful way for display image</b>	8	4	1	1	0
	1	2	3	4	
<b>3.2 The way of displaying images by user's face direction is more intuitive than what using mouse</b>	5	6	2	1	

From 3.1 and 3.2 in Table 3, it is shown that the operation by the user's bobbing/weaving his/her head is easy and more intuitive for them than that by mouse.

**Table 4. Evaluation about function**

	a	b	c	d	e
<b>4.1 Accuracy of recognition of face direction</b>	5	8	0	1	0
<b>4.2 Visibility of a image displayed on MOVERIO</b>	4	5	3	2	0

From 4.1 in Table 4, it is shown that the calibration and the judgement for displaying image are accurate. However, the proposed system doesn't work properly in places that it can't acquire a terrestrial magnetism because it uses a geomagnetic sensor. 4.2 in Table 4 has a low evaluation more than others. The main reason why users rate a low evaluation is that images are difficult to see because of MOVERIO screen is small.

**Table 5. Evaluation about experiment**

	1	2	3	4
<b>5.1 Congestion of the real PC screen</b>	6	7	1	0
<b>5.2 Data input work is easier</b>	3	8	2	1
<b>5.3 View securing when transmitting the screen</b>	3	8	3	0

From 5.1 and 5.2 in Table 5, it is shown that the proposed system can improve decreasing in efficiency by screen size of laptops. From 5.3 in Table 5, it is shown that users can secure the view of the real world. This shows that the proposed system appropriately deals with the individual difference by system calibration.

**Table 6. Comprehensive evaluation**

	1	2	3	4
<b>6.1 The improvement of work efficiency by using the proposed system</b>	3	4	6	1
<b>6.2 Benefit of the system</b>	12	2	0	0
<b>6.3 Portability</b>	8	6	0	0
<b>6.4 Space-saving</b>	12	2	0	0

From 6.1 in Table 6, 50% of users choose a low evaluation. There are opinions that it is hard to watch informations because the HMD has too small view range.

From 6.2 in Table 6, the proposed system is useful for user's work using a laptop while viewing many informations. From 6.3 and 6.4 in Table 6, it is shown that the proposed system is portable and space-saving.

## 4. Conclusion

In this paper, using a transparent HMD, we propose an AR-based expansion system of PC display, in which a user can see three virtual extended screens of PC, as well as an actual screen and usual input interfaces in the real world with normal visibility. Detecting bobbing and weaving his/her head, the virtual screens are correspondingly displayed/hided on the HMD. The feature contributes to preventing the virtual screens from obstructing his/her view. Therefore, the proposed system contributes to achieving larger area to show windows with portability. The result of user-test shows usefulness of the proposed system.

## 5. Acknowledgement

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