

Open Palm Menu: A Virtual Menu Placed in Front of the Palm

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ABSTRACT

Virtual and mixed realities make it possible to view and interact with virtual objects in a three-dimensional space. However, the location to display menus in three-dimensional space and the means of manipulating them are often problems. Existing studies developed methods of displaying a menu in the air or on the body. In this paper, a menu system is proposed that appears in front of the user's palm (of the non-dominant hand) when he/she opens that hand. The user employs the other hand (dominant hand) to then interact with the menu. Using the space around the body as opposed to projections onto actual limbs makes it possible to display more items in more varied layouts. Additionally, the user can control rendering of the menu by opening or closing the hand. Being adjacent to the palm of the open hand also enables the user to adjust the hand position to operate the menu more comfortably or to move the menu to an area where it is easier to view. In this study, we conducted an experiment to develop the menu design guidelines to ensure smooth menu operation, designed an optimal menu, and tested that menu by determining the ease of use in interacting with our modeling application.

CCS CONCEPTS

- Human-centered computing → Gestural input, Mixed / augmented reality, Virtual reality

KEYWORDS

Gestural input, Mixed reality, Virtual reality, Head-mounted display, Menu

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1 INTRODUCTION

Owing to the emergence in the market of new, inexpensive head-mounted displays (HMDs), virtual reality (VR), mixed reality (MR), and augmented reality (AR) technology have become relatively familiar to most users. These technologies make it possible to view and interact with virtual objects in a three-dimensional (3D) space via gesture operations [1,2]. The method of interaction, however, is far from refined. Menus are required to facilitate interaction with these objects; nevertheless, a location to display these menus in the field of view and the method by which the user should interact with them must be determined. A general method is to display menus floating in air. Calaco et al. [3] used a touch menu that placed in the center of the user's field of view. However, this menu limits the user's visibility of the objects or tasks that it obscures. On the other hand, when the menu is placed on the edge of the user's field of view, it is not easily operated because it is difficult to view.

In the HoloStudio application [4], menus fixed at arbitrary places in the environment are used. This method results in the menus transcending the user's field of view when the user moves or turns his/her head. It is therefore necessary in this case to fix the menu at a user-friendly position each time.

Grubert et al. [5] proposed the method to perform tasks such as menu operations using a smart watch or a smartphone in the AR space. These devices could reduce the workload and the task completion time, since they can display information such as menus at any position. However, the users have to wear these devices in addition to HMD.

Methods that employ the user's body as a display area of the menu have also been proposed. He et al. [6] presented a method to display a menu centered in the palm of the hand. This method was compared with the two methods of displaying the menu (1) floating in space in the center of the user's field of vision and (2) in a fixed position in the environment near the virtual object. Most participants preferred the proposed palm-based menu because it was easier to view and use. However, on account of the limited size of the display area (hand), the amount of information that could be displayed on the proposed menu was restricted.

To alleviate this problem, we previously proposed a method of displaying the menu on the user's forearm [7], which provided a wider surface area to accommodate the menu. Additionally, it retained the advantage of the user being able to easily move the menu while moving their arm to make the menu easy to view and use. However, even though the user could freely move menu, this method resulted in most of the user's

field of view being consumed by the hands and arms, thus making it difficult to simultaneously observe the menu and other virtual objects in the environment.

In this paper, we propose the Open Palm Menu (Fig. 1), which appears in front of the user's palm (of the non-dominant hand) when opening that hand. The user employs his/her other hand (dominant hand) to then interact with the menu. Employing the space around the body as opposed to projections onto actual limbs enables the display of more items in more varied layouts. Additionally, the user can control rendering of the menu by opening or closing the hand. Being adjacent to the palm of the open hand also makes it possible for the user to adjust the position of the hand to operate the menu more comfortably or to move the menu to an area where it is easier to view.

In this study, after we had conducted an experiment to develop the menu design guidelines to ensure smooth menu operation, we designed an optimal menu and tested it by investigating users' experiences in interacting with the modeling application we had developed.

2 OPEN PALM MENU

2.1 Displaying the Menu

In the proposed Open Palm Menu, the menu is displayed in front of the palm by opening the fingers from the state where the closed hand is placed perpendicular to the user's face (Fig. 2). Conversely, when the user closes the fingers, the menu is hidden (stored). This menu is displayed adjacent to the hand as long as the user's hand remains open.

2.2 Implementation

In this study, we implemented the Open Palm Menu system in both VR and MR spaces. A head-mounted display (Oculus Rift DK 2) was used for the VR and MR space presentation. A real-world image was acquired via a stereo camera (Ovrvision Pro) for the MR space presentation. The image and menu widget—virtual objects—were presented with the HMD. The positions of



Figure 1: Concept image of the Open Palm Menu.

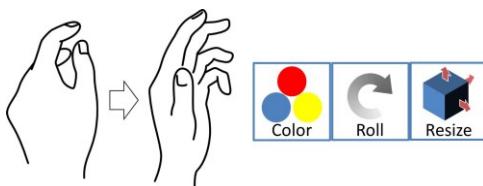


Figure 2: Method of displaying the Open Palm Menu.

the palm, fingers, and forearm were acquired using a small motion tracker (Leap Motion) attached to the front of the HMD. In addition, Unity 5.3.5 was used for the development environment.

3 EXPERIMENT TO DEVELOP MENU DESIGN GUIDELINES FOR SMOOTH OPERATION

3.1 Purpose and Overview

We conducted an experiment to develop the menu design guidelines (display range, layout) to ensure smooth menu operation. Using both horizontal and vertical menu layouts, we collected quantitative data, such as the selection time (the duration of time from the moments she/he touches the cube to the moment she/he touches each menu item) and the number of errors. We also collected qualitative data, such as user comments after the experiment. These data were used to develop the menu design guidelines to ensure a smooth menu operation.

3.2 Conditions and Procedures

In this experiment, we employed the VR space to eliminate such unpleasant factors as tracking errors. A similar technique was also employed by Ragan et al.[8]. The participants were 14 males (aged 21 to 23; all right-handed). We conducted a preliminary experiment on the accessibility of the menu item sizes. Of these sizes, we adopted the smallest: 6 cm × 6 cm. Additionally, the menu items were set to be at least 10 cm from the left hand at all times to ensure that the left and right hands do not contact each other (Fig. 3). The number of items was seven, which fit within the field of view with the left hand in the center.

The experiment was conducted in accordance with the following procedural steps:

- (1) Touch the two small cubes that are set in the front and center of the field of view with the left hand and the right hand, respectively, to set the position of both hands to the initial position for each selection (Fig. 4 (a)).

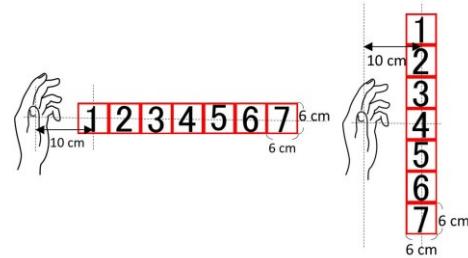
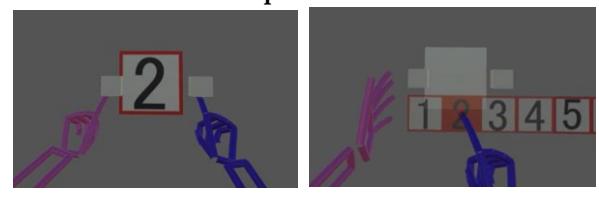


Figure 3: Horizontal and vertical menus used in the experiment.



(a) Display a number (b) Select an item

Figure 4: Procedures.

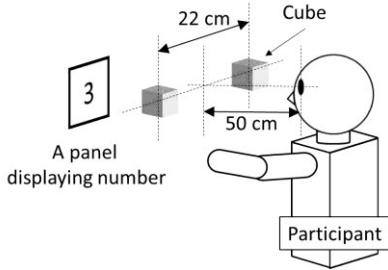


Figure 5: Experimental environment.

(2) Display the menu (horizontal menu or vertical menu) from the left palm, and select the same item as the number (random numbers, 1 to 7, displayed on the front (Fig. 4 (b)).

(3) Repeat procedures (1) and (2) as one selection until each item has been selected five times (for a total of 35 times). The experiment followed a within-participant design. The participants engaged in two sessions (two menu directions). To become familiar with the menu system, each participant had a practice session before each actual session. We instructed participants to select items as quickly and accurately as possible. To eliminate the order effect, the orders of the two menu directions were counterbalanced.

Two cubes to be touched by the participant in procedure (2) were set in the center of the field of view to be the same height as the participant's head. The distance between the cubes was set to 22 cm. This distance was adopted because the right hand was at the approximate center position of the horizontal and vertical menus when displaying the menu. The distance from the head to the midpoint of the two cubes was set at approximately 50 cm (the angle from the user's head is 12.4°) (Fig. 5).

In addition, after the experiment was completed, we asked the participants to note which menu was easier to operate in the respective horizontal and vertical layouts and to provide comments.

3.3 Result

Fig. 6(a) shows the average selection time. “Ave.” is the average selection time for all items. We analyzed the average menu selection time by a two-way factorial repeated measure analysis of variance (ANOVA; seven items and two menu directions).

There was a significant main effect for both items ($F(6, 13) = 19.0, p < 0.001$) and menu direction ($F(1, 13) = 5.3, p < 0.05$). Moreover, their interaction was significant ($F(6, 78) = 2.3, p < 0.05$). A simple main effect test between the two menu direction conditions for each item condition revealed that, for items 4 to 7, there was a significant difference ($p < 0.05$). A simple main effect test between the seven item conditions at each menu direction condition revealed that the simple main effect was significant for items in either menu direction.

Furthermore, post-hoc test (Ryan's method) revealed that there were significant differences between items 1 to 3 (items close to the left hand) and items 5 to 7 (items far from the left hand) for the horizontal condition ($p < 0.05$). There were significant differences between items 1 to 4 (items in the front

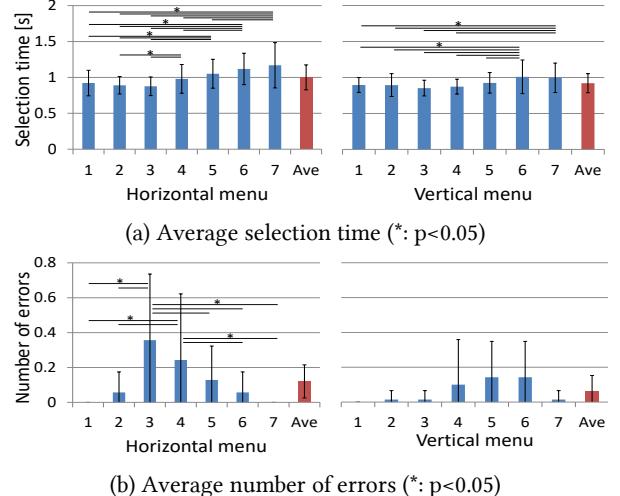


Figure 6: Results.

and above the left hand) and items 6 and 7 (items below the left hand) for the horizontal condition ($p < 0.05$).

Figure 6(b) shows the average of number of errors. “Ave.” is the average number of errors for all items. We additionally analyzed the average of number of errors by a two-way factorial repeated-measure ANOVA (seven items and two menu directions). There was a significant main effect for only the item ($F(6, 13) = 5.3, p < 0.001$) and their interaction was significant ($F(6, 78) = 3.7, p < 0.005$). A simple main effect test between the two menu direction conditions for each item condition revealed that, for item 3, a significant difference existed ($p < 0.001$). A simple main effect test between the seven item conditions revealed that, for only the horizontal condition, a significant difference existed ($p < 0.001$). Furthermore, post-hoc test (Ryan's method) revealed that there were significant differences between items 3 to 4 (items near the center) and items 1 to 2 and 6 to 7 (items near the end) for the horizontal condition ($p < 0.05$).

We asked the participants to note if it was easier to operate the horizontal or vertical menu. Ten out of 14 participants chose the vertical menu; four participants chose the horizontal menu.

3.4 Discussion

3.4.1 Average Selection Time. The average selection time for the horizontal menu (Fig. 6(a)) showed that selection times for items close to the left hand (1 to 3) were significantly shorter than those for items far from the left hand (5 to 7) [Design Guideline 1]. This result is believed to be due to many participants having placed the left hand near the center of the field of view; thus, items far from the left hand were displayed at the edge of the field of view, and they required a longer amount of time to view and select.

In the case of the vertical menu (Fig. 6(a)), the selection times for items in front and above the left hand (1 to 4) were significantly shorter than those for items below the left hand (6 to 7) [Design Guideline 2]. This result is considered to have been due to many participants placing the left hand below the center of the field of view so items below the left hand were displayed

at the edge of the field of view. Moreover, they required more time to view and select, as in the horizontal menu.

It is considered that the display range selected to ensure a smooth menu operation based on Design Guidelines 1 and 2 did not considerably change, even if the sizes of the items changed.

The average selection time for items 4 to 7 of the vertical menu was significantly shorter than that of the horizontal menu. In addition, there were more participants who felt that the vertical menu was easier to operate than the horizontal menu. These findings suggest that the vertical menu was easier for users to operate than the horizontal menu [Design Guideline 3].

3.4.2 Average Number of Errors. The average number of errors for the horizontal menu (Fig. 6(b)) showed that the number of errors for items near the center (3 to 4) was significantly higher than those of items near the end (1 to 2 and 6 to 7). This is because the right hand was nearer to the items near the center (3 to 4) when the participant displayed the menu, and those items were sometimes mistakenly selected.

Although this may have been attributed to the experimental condition, the right hand was often placed beside the left hand in actual work. In addition, there was a comment that “it was difficult to operate because the right hand was very close to the menu items when displaying the horizontal menu.” These findings suggest that menu designs must take into account the position of the user’s hand [Design Guideline 4].

4 APPLICATION

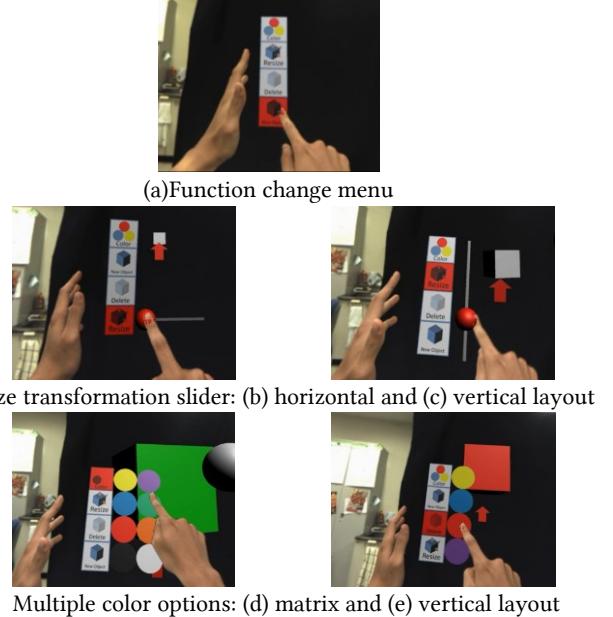
We introduced a 3D modeling application using the Open Palm Menu, as shown in Fig. 7. In this application, virtual 3D objects could be placed freely within the 3D space via gesture operations. Using the Open Palm Menu, we implemented the following functions: (i) object creation/deletion, (ii) scaling, and (iii) object color adjustment. These functions are switched by selecting the function change menu.

The function change menu that is selected first after displaying the menu was vertically arranged (Fig. 7(a)), following Design Guidelines 3 and 4. Then, in keeping with Design Guidelines 1 and 2, the 24-cm-long vertical-size transformation slider was arranged near the palm (Fig. 7(c)), and the 12-cm-long horizontal-size transformation slider was arranged slightly above the side of the palm (Fig. 7(b)).

Design Guidelines 1 and 2 indicate that the menu should not contain more than four items (rows) vertically and more than three items (columns) horizontally. Thus, both the vertical layout (Fig. 7(e)) and the matrix layout of two columns and four rows (Fig. 7(d)) were designed to display multiple color options.

In the above menu [7], up to four items with sizes of 6 cm × 6 cm can be simultaneously displayed. By comparison, in the new menu implementation, it is possible to display up to 12 items of the same size (also 6 cm × 6 cm), without obscuring the user’s field of view with his/her arm or hand.

Three volunteers (two males, one female, aged 22 to 23 years; all right-handed) participated in testing the application in the VR space. After completing the testing, we asked the participants to provide their impressions of the menu. We obtained various



Size transformation slider: (b) horizontal and (c) vertical layout

Multiple color options: (d) matrix and (e) vertical layout

Figure 7: Modeling application.

feedback.

Regarding the scaling function, two participants commented: “I could operate the vertical size transformation slider as easily as I could the horizontal size transformation slider.” For the color adjustment function, all participants commented: “I could operate the vertical menu as easily as I could the matrix menu.” These comments suggest that the menu arranged in the range based on the design guidelines can be smoothly operated.

Regarding the opening of the hand to activate the menu and following the palm, one participant commented: “I think I will get tired after operating the menu in this way for a long time, since I have to keep lifting up my left hand.” In contrast, other participants commented: “I can easily and intuitively activate and deactivate the menu” and “I can display the menu in a convenient position in my field of view.” These comments suggest that the menu system is suitable for tasks that do not require the menu itself to be displayed for a long time, as well as those that frequently require altering the state of the menu’s activation and position.

5 CONCLUSION

In this paper, we proposed the Open Palm Menu displayed in front of the palm for use in 3D space, such as VR, MR, and AR spaces. The user can control rendering of the menu by opening or closing the hand, and the menu is easily moved (by the user moving their hand) to any position that is most convenient.

After we had conducted an experiment to develop the menu design guidelines to ensure smooth menu operation, we constructed an optimal menu and investigated its ease of operation by users interacting with our introduced modeling application.

In future work, we intend to compare the proposed menu system to those that are displayed in the air and on the body to ascertain its relative effectiveness and usability.

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