Human Factor Research of User Interface for 3D Display

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Abstract. The user interface for the observer to interact with 3D image has been discussed. The appropriate touching range and suitable size of the 3D image are relative to depth (disparity) of the 3D image. According to experimental results, when disparity of the 3D image is large, size of the 3D image is necessary to be larger to let the observer precisely judge that finger tip is touching the 3D image or not.

Keywords: User Interface, Interaction with 3D image, Appropriate Touching Range, Suitable Size of 3D Image.

1 Introduction

More intuitive and natural human-machine user interface (UI) is a tendency, such as from keyboard and mouse to touch panel. It is convenient and easy for users to interact with computers by using finger or stylus. However, general touch panel, smart phone or tablet, can only provide 2D image for user, and the user only makes a 2D interaction on the panel. On the other hand, although three-dimensional (3D) interaction is achieved by using camera or embedded optical sensor to catch user's position or movement, the user still watches 2D image without depth information [1]. Obviously, 3D display provides more realistic experience for observers, so 3D display has been more and more popular in many applications recently. Thus, the next step human-machine user interface should be 3D display with 3D interaction; that is, users can touch and interact with 3D image they watch, as shown in Fig.1. Nevertheless, there are maybe some issues for the user interface of 3D display as the observer makes 3D interaction with the 3D image.

Most of 3D display technology provides 3D image for observer by using binocular parallax, which means that the 3D display shows different image to left and right eye of the observer individually [2] [3]. However, the discrepancy between accommodation and convergence causes visual stress and leads to visual fatigue for observers [4]. There is still cross-link between accommodation and convergence when one eye of observer is occluded [5]. On the other hand, it must be blocked some part of 3D image by use's hand when the user wants to touch or interact with the 3D image. With

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blocking some area of the 3D image, it may result in more serious mismatch or unstable for accommodation and convergence to cause some visual issues or mistakes. For example, the observer is more difficult to fuse those two images as mentioned above to create a 3D image, or even affects the observer's judgment on that finger tip is touching the 3D image or not. Therefore, a series of human factor experiments have been done in order to provide designing reference for the user interface as 3D image with different disparity, including the appropriate touching range and suitable size of 3D image.

Fig. 1. A schematic plot of 3D interaction with 3D image

2 Methods

2.1 Apparatus

An Acer 15.6 inch 3D notebook with pattern retarder mode was used to provide the 3D button for the subject. A prosthetic hand (or called finger tip) was used to be the subject's hand in following experiments, because sizes of subjects' hands were different and it was difficult to fix the subject's hand in the same position during experiment. The experimental parameters are shown in Fig. 2. Viewing distance of subject was 60 cm in front of the 3D notebook, and the button depth (disparity) was 0 cm and 0° when 3D button was displayed on the 3D notebook.

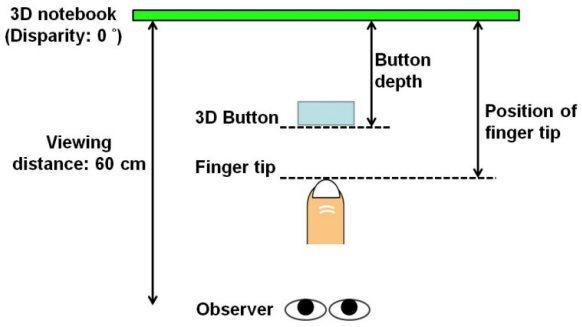

Fig. 2. Experimental parameters

2.2 Stimuli

Two kinds of button depth (disparity) were presented, 4.5 and 8.6 cm (disparities: 0.5° and 1°) with the interpupillary distance of the subject 65mm to prevent much visual discomfort [6] [7]. And in each session, distance between 3D notebook and finger tip was changed from 1~7 (button depth: 4.5 cm) and 5~11 (button depth: 8.6 cm) cm separately. In addition, blocking ratio was estimated by blocking area with finger tip divided by area of the 3D button without blocking in viewing position. There were four blocking ratios in each session, 20%, 40%, 60%, and 80%.

2.3 Subjects

Seventeen subjects, who had normal, uncorrected vision or wear optical correction to be corrected-to-normal vision, participated in this experiment. Subjects' ages were from 16 to 24 years. All subjects had normal stereoscopic vision and were unaware of the experimental hypotheses.

2.4 Experimental Setup

The device for measuring subject's perceived depth of the 3D button and experimental setup are shown in Fig.3. Before doing experiment, subject used the handle to align the blue sheet with the position where subject felt the 3D button was, in other words, subject's perceived depth of the 3D button. Additionally, the subject was fixed at the chin bracket to make sure that the position and viewing distance of different subjects were similar. Finally, the finger tip was moved by the mobile stage.

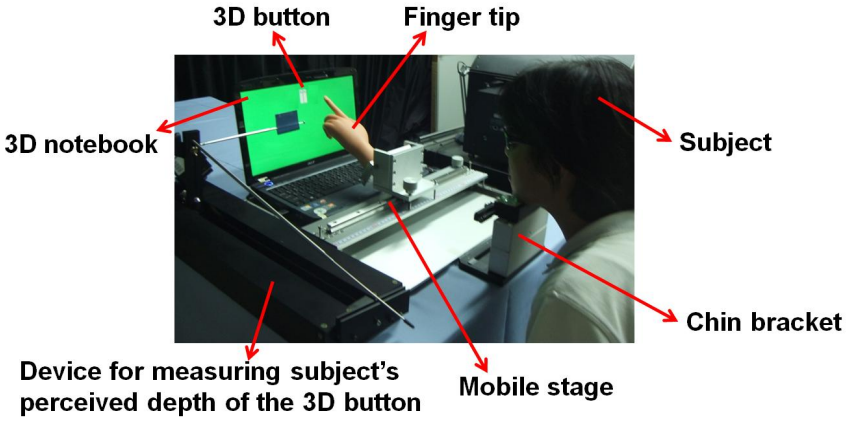

Fig. 3. Experimental setup

2.5 Procedure

First, the subject was instructed to close eyes to avoid seeing movement of finger tip. The finger tip was put randomly within 1~7 (button depth: 4.5 cm) and 5~11 (button depth: 8.6 cm) cm depending on which session. Second, the subject opened eyes, and selected which situation between 3D button and finger tip he perceived, over-touching, touching, or non-touching, as shown in Fig.4. In some cases, the subject felt that the button became a 2D button without depth or even could not fuse left and right eye image to be a 3D image; those two cases mentioned above were counted as non-touching.

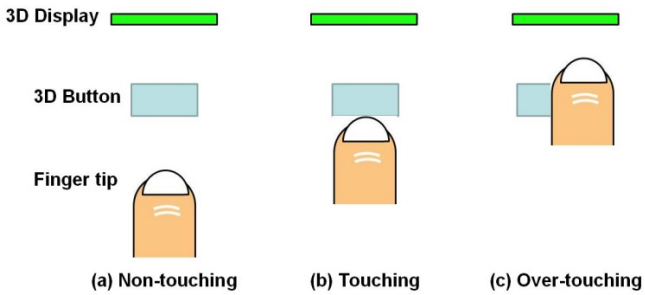

Fig. 4. Three kinds of situation between 3D button and finger tip

3 Results

3.1 Button Depth: 4.5cm (disparity: 0.5°)

As mentioned earlier, subjects were asked for measuring perceived depth of the 3D button before doing experiment. The average subjects' perceived depth was 4.4 cm; it was similar to button depth, 4.5 cm. On the other hand, with blocking by finger tip, the average subjects' perceived depth became 4.0 cm, which meant that blocking by finger tip reduced a little the subjects' perceived depth of the 3D button, as shown in Table 1. Further, the experimental result of subjects selecting different situations between 3D button and finger tip is shown in Fig.5. The appropriate touching range was 3~4 cm, for percentage of subjects selecting touching were 90% and 96%. Subjects also could judge over-touching and non-touching situation clearly. For instance, when finger tip was removed away from the 3D notebook to 6~7 cm, percentage of subjects selecting non-touching were 90% and 100%. Besides, regardless of blocking ratio, the average percentages of subjects selecting touching were similar, as shown in Table 2. It meant that blocking ratio did not influence subjects' judgment as 3D button with small button depth and disparity.

Table 1. The average subjects' perceived depth for button depth of 4.5 cm

Average subjects' perceived depth of the 3D button (Button depth: 4.5cm, disparity: 0.5°)	
Without blocking	With blocking
4.4	4.0

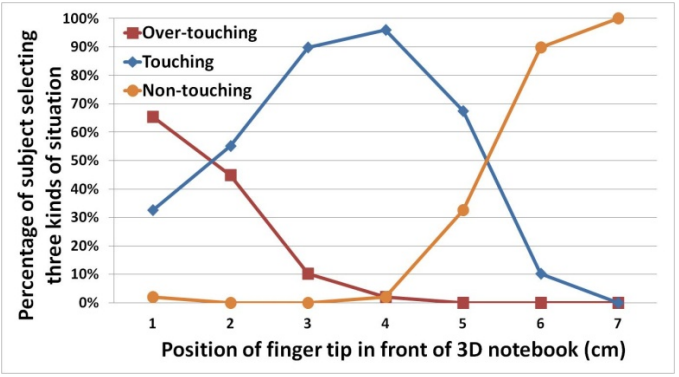

Fig. 5. Experimental result for subjects selecting different situations with different position of finger tip as depth of 3D button was 4.5 cm

Table 2. Average percentages of subjects selecting touching with different blocking ratio

Button depth: 4.5cm, disparity: 0.5°				
Blocking Ratio	**20%**	**40%**	**60%**	**80%**
The average percentage of subjects selecting touching within appropriate touching range	**97%**	**90%**	**90%**	**100%**

3.2 Button Depth: 8.6 cm (disparity: 1°)

The average subjects' perceived depth was 8.2 cm; it was still similar to button depth, 8.6 cm. However, with blocking by finger tip, the average subjects' perceived depth became 7.1 cm, as shown in Table 3. It meant that blocking by finger tip reduced more seriously the subjects' perceived depth of the 3D button than that of button depth of 4.5cm. The experimental result of subjects selecting different situations between 3D button and finger tip is shown in Fig.6. The appropriate touching range was 7~8 cm, for percentage of subjects selecting touching were 83% and 92%. Comparing Fig.6 with Fig.5, subjects' accuracy of judgment was lower not only within the appropriate touching range, but also without it. For instance, when finger tip was removed away from the 3D notebook to 10~11 cm, percentage of subjects selecting non-touching were only 47% and 62%. Moreover, according to Table 4, the average percentage of subjects selecting touching was decreased when blocking ratio was

increased. It might result from convergence being hard to fuse as the 3D button with large disparity and mismatch between accommodation and convergence was more unstable [8], so subjects' accuracy of judgment was reduced and subjects were necessary to have more information to judge that finger tip was touching the 3D image or not.

Table 3. The average subjects' perceived depth for button depth of 8.6 cm.

Average subjects' perceived depth of the 3D button (Button depth: 8.6cm, disparity: 1°)	
Without blocking	With blocking
8.2	7.1

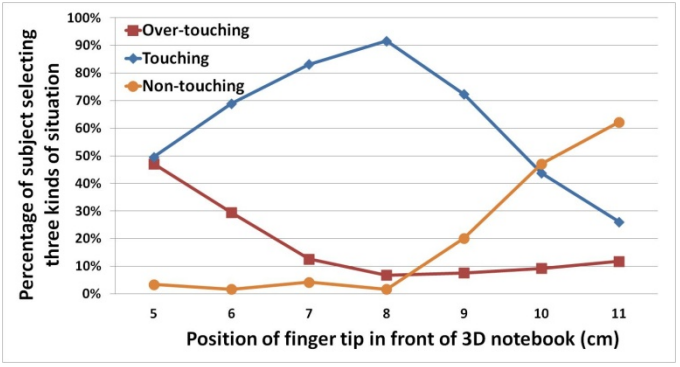

Fig. 6. Experimental result for subjects selecting different situations with different position of finger tip as depth of 3D button was 8.6 cm.

Table 4. Average percentages of subjects selecting touching with different blocking ratio.

Button depth: 8.6cm, disparity: 1°				
Blocking Ratio	20%	40%	60%	80%
The average percentage of subjects selecting touching within appropriate touching range	91%	88%	88%	76%

4 Conclusion

A series of human factor experiments have been done in order to provide designing reference for the user interface of 3D display as 3D image with different disparity, including appropriate touching range and suitable size of 3D image. According to excremental results, regardless of disparity of 3D image, the appropriate touching range is both about 1 cm, but blocking by the finger tip reduces more seriously the

subjects' perceived depth of 3D image with large disparity than that with small disparity. Besides, when disparity of 3D image is large, size of 3D image is necessary to be large to let the observer precisely judge that finger tip is touching the 3D image or not because they need more information. In conclusion, if observers want to interact or touch the 3D image with large disparity, size of the 3D image should be larger than that with small disparity.

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