Exploring the Interactivity Issues of the Stereoscopic 3D Systems for Design Education

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Abstract. Stereoscopic 3D displays have been used by some research groups to present learning contents for education. However, in the highly interactive situations, the intertwined depth cues may result in symptoms that hamper the usability of such systems. In this research, an experiment was conducted to explore the interactivity issues. Thirty students were invited to participate in the experiment. The first task was to identify the differences between printed pictures and 3D virtual models. The second task was to point out ergonomic or design problems in a single piece of furniture or pairs of chairs and tables. Based on the analysis, discomfort caused by model rotation did contribute to the degree of overall discomfort. Even all participants had the background of using 3D modeling systems, some still experienced different levels of symptoms. Their comments indicated that adaptive adjustments of disparity and control response ratio were necessary in the highly interactive situations.

Keywords: Stereoscopic 3D Displays, Design Education, Interactivity Issues

1 Introduction

Given the potential benefits of offering the binocular depth cue, Stereoscopic 3D (S3D) displays have been used by some research groups to present learning contents for design education. These examples included the systems for learning descriptive geometry through stereoscopic vision (Guedes et al., 2012), and displaying the process of learning to build a handmade PC (Mukai et al., 2011). Some systems even allow users to interact with the digital contents. It was reported that stereoscopic displays did improve the performance of depth-related tasks, such as judging absolute and relative distances, finding and identifying objects, performing spatial manipulations of objects, and spatial navigating (McIntire et al., 2014). However, depth cue interactions should not be neglected (Howard, 2012; Mikkola et al., 2012). For instance, there were interactions among disparity and monocular depth cues, such as motion parallax, occlusion, shadow (or shading), linear perspective, and accommodation (Figure 1). Especially in the highly interactive situations, the intertwined depth cues may result in symptoms that hamper the usability of such systems. In this research, an experiment was conducted to explore the interactivity issues.

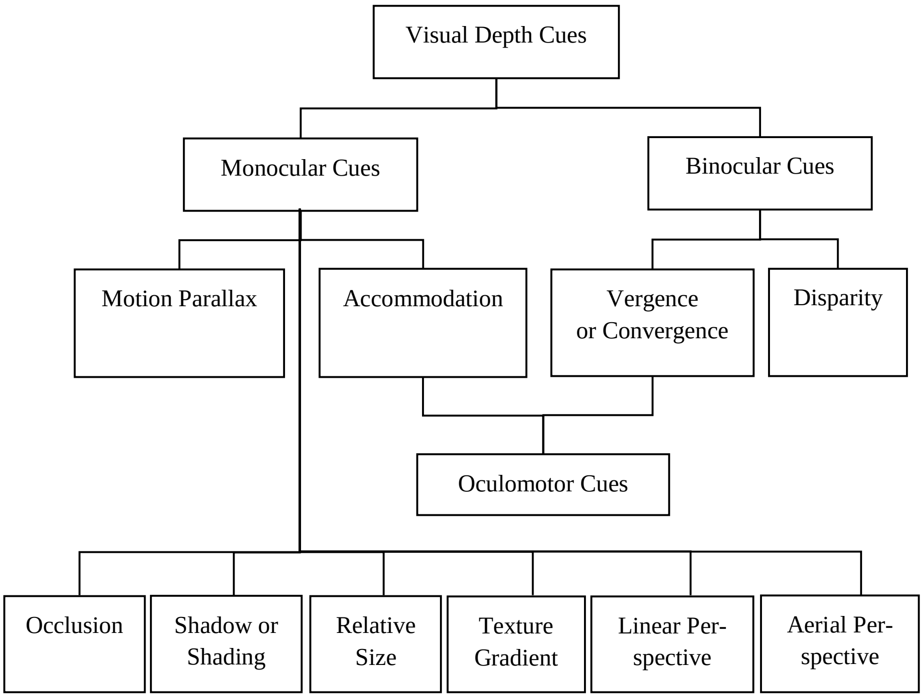

Fig. 1. The Classification of Visual Depth Cue

2 Literature Review

Although stereoscopic 3D displays were found to be useful for object manipulation tasks and for finding, identifying, classifying objects or imagery (McIntire et al., 2014), several content factors of stereoscopic 3D video could cause visual discomfort (Kim et al., 2013). For instance, large disparity and large amount of motion are two main causes of visual discomfort while watching stereoscopic 3D videos (Li et al., 2014). In addition, the in-depth motion generally induces more visual discomfort than the planar motion (Li et al., 2014). To reduce the visual fatigue in viewing rotational motions, it was suggested that a control of S3D exposure was required to enhance spatial recognition and reduce visual discomfort (Matsuura, 2013). For highly interactive systems, the interaction-induced symptoms could happen due to virtual grasping and manipulation for object transport and 3D selection (Kim and Park, 2014). While comparing the situations of cinema viewing versus video game playing using S3D TV, some research reported that video games present a strong conflict between vergence and accommodative demand. Therefore, people enjoyed cinema more than video games (Read, 2014). However, other research reported that for game playing and film viewing, system-task combinations could cause mild eyestrain and small changes in visual functions. Using a stereoscopic 3D system for up to 2 hours was acceptable for most users, including children and adults (Pölönen et al., 2013). For film viewing, age was negatively correlated with the symptom levels (Obrist et al., 2013). To resolve the issues of visual discomfort caused by interactive manipulations of S3D contents and increase the usability of such systems, in-depth studies and exhaustive experiments are necessary.

3 Learning Materials and the Stereoscopic 3D System

3.1 Learning materials and digital contents

Understanding the features of masterpieces in design history and analyzing products from ergonomic aspects are the basic training in product design education. Among different categories of products, furniture is a representative product in daily life. Therefore, using furniture as a training example is widely adopted in the classroom. In the experimental S3D system, the digital contents consisted of 3D virtual models of chairs, tables, and sofa, some were classic design masterpieces. These models were allocated in a virtual room for investigation (Figure 2).

3.2 The Stereoscopic 3D system for experiment

In order to create an S3D system for experiment, Visual C++ 2013 and Direct3D 11.1 was employed as the development tools. The authors modified and integrated the Direct3D stereoscopic 3D sample and Visual Studio 3D Starter Kit to construct a platform for importing 3D models in FBX format and displaying these models in either S3D or regular 3D mode. The program was running on the Windows 8 operation system installed in an Acer desktop computer with a GT640 graphic card. The images, with 1920×1080 pixels, were projected by a BenQ W1070+ projector on a 100-inch screen, and viewed by the shutter glasses, which were synchronized with the displays (Figure 3). The left-eye and right-eye images were sequentially displayed at a frequency of 120 Hz. Therefore, the refresh rate of the display was 60 Hz for each eye. In addition, the experiment system allowed users to adjust the effect of disparity (from 0 to 2, with initial value set to 1.0), by pressing the up/down arrow keys. To offer minimal interactivity, the users could change the mode or the direction of model rotation (Figure 4). At the beginning of program execution, the 3D models rotated in 1.0 rpm with respect to the vertical axis. The user could use the left button on the computer mouse to stop or regain rotation. In addition, the left and right arrow keys were used to control the clockwise or counter clockwise rotation, respectively. The “W” and “S” keys were used to control the zoom-in and zoom-out effects of the camera, respectively.

Fig. 2. Stereoscopic 3D displays and digital contents with different degrees of disparity

Fig. 3. The 3D projector and the shutter glasses for experiments

Fig. 4. Sample screen shots taken from different viewing angles and distances

4 Design of Experiments

4.1 Participants

Thirty students, 17 female and 13 male, were invited to participate in the experiment. They were senior students in college or graduate students enrolled in the master program, all majored in industrial or media design. In previous education background, they took courses relevant to the subjects of design history, human factors, and user interface design. The average age was 23.1, with standard deviation 3.0. All had normal or corrected-to-normal vision and none reported stereopsis problems in prior experiences. They all had the experiences of using 3D modeling systems and playing 3D video games.

4.2 Tasks and Procedures

In a laboratory with illumination control, each participant seated in front of a desk, with four meters away from the projection screen. Prior to the S3D experiment, participants adjusted the disparity parameter to the value they felt comfortable for continuing the major tasks. The first task in the experiment was to identify the differences between printed pictures and 3D virtual models for seven classic design masterpieces. The second task was to point out ergonomic or design problems in a single piece of furniture or different pairs of chairs and tables. Since the participants needed to make the judgment based on both their ergonomic or design knowledge and the information from depth cues, the second task was more difficult than the first one. In order to perform these tasks and locate furniture design features or problems, the participants needed to control the rotation and zoom-in/zoon-out of the scene. During the experiments, they were allowed to re-adjust the disparity value whenever necessary to maintain the comfortable level. After completing the tasks, participants indicated the degree of overall discomfort and the discomfort caused by rotation or zooming using a 9-point Likert scale, with 1 indicating slightly discomfort and 9 indicating extremely discomfort, respectively.

5 Results and Discussions

Before conducting S3D experiment tasks, the participants took 127 seconds on average to adjust the disparity parameters (Table 1). The average disparity value was 0.72, with standard deviation 0.44. Among 30 participants, 4 participants re-adjusted the disparity value during the experiments. This indicated that the initial value (1.0) was still higher than the one they could accept. Participants needed time to be prepared for experiencing S3D contents, and the individual differences should not be neglected. As for the performance of tasks, the average task complete time was 1437 seconds (standard deviation: 482). In the task of locating differences between printed pictures and 3D virtual models, 5.33 features, on average, were correctly identified out of seven classic design masterpieces. In the task of pointing out ergonomic or design problems in a single piece of furniture or different pairs of chairs and tables, only 2.23 features were reported correctly. The discomfort levels were 2.17, 1.90, and 1.40, for overall, rotation operation, and zoom-in/zoom-out operation, respectively. Based on the regression analysis, discomfort caused by model rotation did contribute to the degree of overall discomfort. Even all participants had the background of using 3D modeling systems, 26 of them still experienced different levels of symptoms, such as eye stress, eye fatigue, loss of focus, or dizziness. The comments of participants included the requirements of adjusting the control response ratio of interactive manipulations.

6 Conclusions and Recommendations for Further Work

Given the minimal interactions of S3D contents, such as rotating and changing the position of camera, visual discomfort was still reported by a group of participants who were familiar with 3D modeling systems and 3D video games. The comments indicated that adaptive adjustments of disparity and control response ratio were necessary to accommodate individual differences and enhance the usability of interactive and stereoscopic 3D systems. In this research, identifying image differences and locating ergonomic or design problems were the tasks performed by the participants. More active tasks, such as modifying the shape or the proportion of a S3D product model to fulfill the requirements for aesthetic or functional purposes, could be considered in future research works.

Table 1. Measurements of experiments

Measurements	Mean	Standard deviation
Time		
Disparity parameter adjustment time	126	97
Task completion time	1437	482
Disparity parameter value	0.72	0.44
Degree of visual discomfort		
Overall	2.17	1.88
Due to Rotation operation	1.90	1.90
Due to Zoom-in or Zoom-out operation	1.40	1.48
Task performance		
Number of differences identified	5.33	2.72
Number of design problems identified	2.23	0.82

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