Methods for Producing 3D Video Contents Suitable for e-Learning: A Pilot Study

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Abstract: In this paper, samples of 3D video contents for e-learning were produced and were evaluated in terms of both "sense of three-dimensionality" and "ease of viewing." The results suggested that a scene which both the teacher and learning objects appeared together in the movies, where the camera-object distance was 1.0 m, enabled the production of 3D video instructional materials having a good "sense of three-dimensionality." In addition, the results demonstrated that the appearance on the screen of a teacher with the learning objects made instructional videos easier to view, as compared with the case where the teacher didn't appear.

Keywords: learning contents, 3D video, three-dimensionality, e-learning

1. Introduction

In recent years, a variety of studies have been conducted on the effectiveness of using three-dimensional (3D) displays for visual presentations, and on the use of virtual reality technologies for education [1][2][3][4]. In addition, now that 3D video technology is becoming practicable, the advent of 3D television broadcasts is fast approaching.

3D video can be defined as motion images that utilize the parallax effect provided by the difference in viewing position of our two eyes, to produce the visual sensation of seeing objects projecting in front of or behind the display or screen on which they are displayed. A widely known method of creating 3D video is to combine two images taken by a twin-lens image capture device called a 3D camera. In a 3D camera the two lenses are separated by a distance equal to the mean human interocular distance (65 mm) and the device can adjust the intersection point of the optical axes of the lenses (cross point). A research has clearly shown that the sense of three-dimensionality and the appearance of the image varies greatly with the setting of the cross point and the position of the displayed object [5].

At the same time, software for creating 3D video has been developed, enabling easy creation of 3D instructional materials [6], using readily available equipment. However, since the viewing of displayed 3D video tends to cause visual fatigue in viewers [7], methods for creating instructional materials must be investigated carefully.

In view of this, the purpose of this pilot study was to create prototype 3D video contents assuming a context of e-learning for information-technology-related education and to examine the 3D video contents while focusing on both three-dimensional sense and ease of viewing.

2. Method

2.1 Equipment for 3D video

Figure 1 shows the equipment for the display of 3D video in this research. Some of the methods used to display 3D video include the anaglyphic method, the polarization method, the liquid crystal shutter method, and the lenticular method. In this study, oriented to e-learning, the polarization method, which enables use of presentations in the form of streaming videos, was chosen. The screen (2.5 m×2.0 m, approx. 120-inch diag.) was set at a distance of 2.0 m from examinees, so that the video was displayed within their viewing angle.

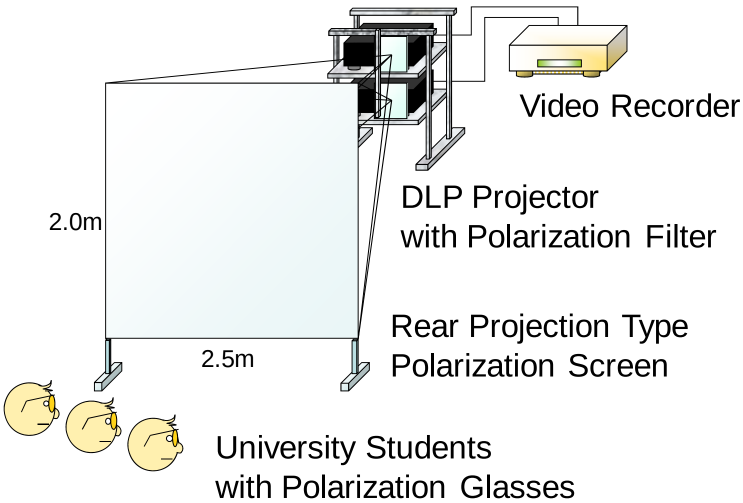

Fig 1: Equipment for 3D video contents

2.2 Contents

The 3D video was evaluated under three different settings for cross point, which is a key parameter of 3D cameras; specifically, 2.0 m, 3.0 m, and 4.0 m, because the teacher appeared at a suitable size on the screen. Additionally, the distance between the camera and subject (teacher or other object of focus) was set from 0.5 m to 5.5 m. Two objects to be captured were prepared for the video scenes, each arranged by combining four cubes of side length 7 cm. In capturing the 3D video, one of these objects was placed at the cross point position (control object), and the other object (target object) was located at 11 different positions, by moving it progressively in 0.5-m intervals from the 3D camera.

2.3 Experimental Design

An investigation was designed for 20 university students to evaluate the 3D video contents. In this investigation, the 3D video contents in 33 patterns (3 cross point settings × 11 target object positions) at intervals of 3 seconds, always in the same order, were shown and evaluated subjectively by the subjects to rate each pattern for "three-dimensionality" and "ease of viewing" by selecting one of four ratings.

In addition, to assess the perceived position of the target object, the subjects indicated where they considered the target object to be in relation to the control object at the cross point, on a scale of –10 to +10, where "+" indicates that the target object appears in front of the control object, and "–" indicates that the target object appears behind the control object.

Note that it was explained to the subjects that when the target object appeared to extend behind the screen it was expressed as "sense of depth," and that when the target object extended beyond the front of the screen it was expressed as "sense of projection," and they were instructed to answer "0" when the target object appeared to remain within the plane of the screen.

2.4 Results and Discussion

Figure 2 shows the results of the investigation in relation to "sense of three-dimensionality." The results clearly show that the maximum sense of depth was experienced when the target object was positioned between 1.0 m and 2.0 m from the 3D camera. Additionally, the results relating to the perceived position of the target object (Figure 3) show that as the target object moved further and further away from the 3D camera, "sense of projection" decreases but "sense of depth" increases.

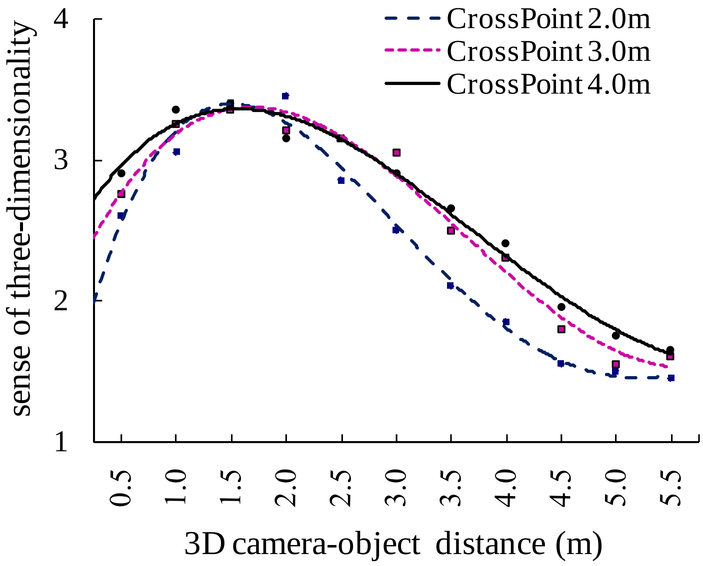

Fig 2: "Sense of three-dimensionality" on 3D camera-object distance

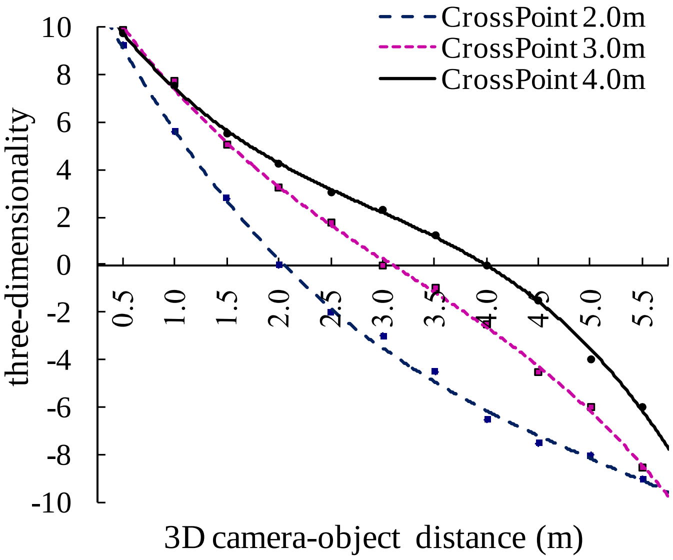

Fig 3: "Sense of three-dimensionality" on Perceived position

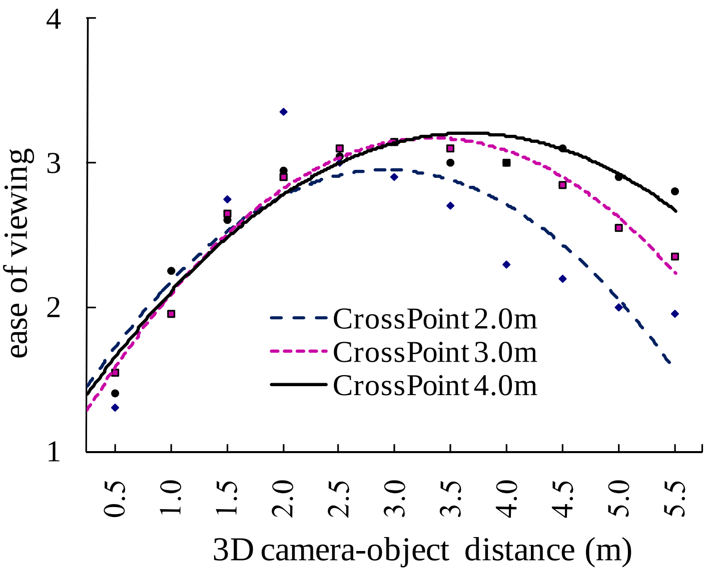

Fig 4: "Ease of viewing" on 3D camera-object distance

Figure 4 shows the test results relating to "ease of viewing." The results made clear that regardless of cross point, the displayed images were difficult to view when the distance between the 3D camera and the target object was between 0.5 m and 1.0 m. This was likely due to the high angle of convergence of the subjects' eyeballs, a kind of cross-eyed effect, at this distance, resulting in some physiological strain. It was also found that for a cross-point position of 2.0 m, the ease of viewing deteriorates when the object was more than 4.5 m from the camera, and that a cross point position of 4.0 m resulted in better "ease of viewing" than did the other cross point settings. The reason for the results is that when the cross point position is 2.0 m, the displacement between the target objects on the screen is high, approaching the limits of binocular fusion. The above results suggested that a cross point setting of 4.0 m, and setting the 3D camera about 1.5 m from the objects to be captured resulted in relatively good ease of viewing and "sense of three-dimensionality."

3. Creating Effective 3D Video Contents

3.1 Subjects and Contents

Based on the results explained in the previous chapter, prototype 3D video contents, depicting scenes in which a teacher showed objects, was created and their effectiveness was examined. The subjects in this case were 11 university students enrolled in information-technology-related courses in the Faculty of Education. The content shown by the teacher was the configuration of computer hardware. The specific displayed object was a PCI-bus IEEE 1394 board. For our experiment, a 3D video featuring a scene of the teacher showing an object was produced. Note that the 3D video produced by the same equipment as used in the previous chapter.

3.2 Experimental Design

Using the display equipment shown in Figure 1, an experiment was designed to compare two factors within the same group of the subjects. The first factor was the method of display (hereinafter "display method"); the second factor was the distance between the 3D camera and the target object (hereinafter "presentation distance"). To assess display method, two settings were used in order to clarify the influence on "sense of three-dimensionality" and "ease of viewing" of the teacher appearing in the background. The first was a scene in which the teacher appeared together with the object, and the second was a scene in which the teacher did not appear together with the object. In addition, two settings were used for camera position, 1.5 m and 1.0 m from the object of the scene.

In this study, first, samples of 3D video were displayed and then were checked verbally with the subjects to confirm that they could each see the presented images stereoscopically. Next, the four 3D videos prepared for the test were repeatedly displayed, and the subjects were asked to rate them for "sense of three-dimensionality" and "ease of viewing."

3.3 Investigation

For this investigation, a paired comparison test was used. In comparison to a reference setting in which the teacher and object were displayed together at a display distance of 1.5 m, the other settings for both "sense of three-dimensionality" and "ease of viewing" were evaluated. These subjective measures were rated on a scale of 0 to 10 (11 values) with the reference video assigned the median value of 5.

3.4 Results

Showing of sample video revealed that one of the subjects could not stereoscopically recognize the 3D video images adequately; thus, this person was excluded, and the remaining 10 subjects were used in conducting the investigation. The results were expressed as scores and individually calculated.

Figure 5 shows the results of the paired comparison for “sense of three-dimensionality.” The results of a two-factor distribution analysis showed a significant difference at the 5% level in interaction between “display method” and “display distance” ($F(1,9) = 5.33$, $p < 0.05$). Thus, the single main effect was analyzed. The results showed significant difference (MSe = 2.62) due to the presence or absence of the teacher at a display distance of 1.5 m ($F(1,9) = 17.47$, $p < 0.01$); due to the display distance when only the object was displayed ($F(1,9) = 36.00$, $p < 0.01$); and due to the display distance when the teacher was displayed with the object ($F(1,9) = 101.83$, $p < 0.01$). In addition, at a display distance of 1.0 m, a tendency to a significant difference was found due to whether or not a teacher was present in the scene ($F(1,9) = 3.64$, $p < 0.01$).

The above results clearly demonstrate that the greatest sense of three-dimensionality under the conditions of this experiment was achieved when the teacher and object appeared together, and when the object display distance was 1.0 m. The results also show that when the object appeared alone with an object distance of 1.0 m, a greater sense of three-dimensionality was achieved as compared with the case of teacher and object appearing together with a display distance of 1.5 m.

Figure 6 shows the results of the paired comparison for “ease of viewing.” The results of a two-factor distribution analysis revealed no significant difference in interaction between “display method” and “display distance” ($F(1,9) = 0.20$, $p > 0.10$). Then the main effect for each factor was analyzed. The results showed a significant difference due to “display method” ($F(1,9) = 17.47$, $p < 0.01$). In contrast, no significant difference due to “display distance” was found.

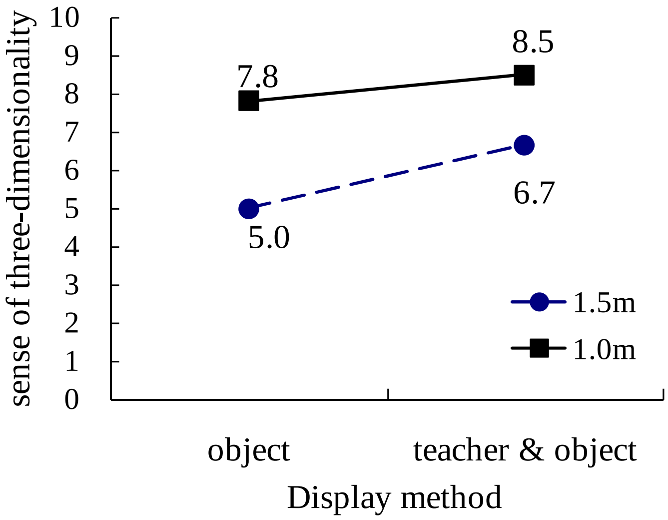

Fig 5: “Sense of three-dimensionality” on display method

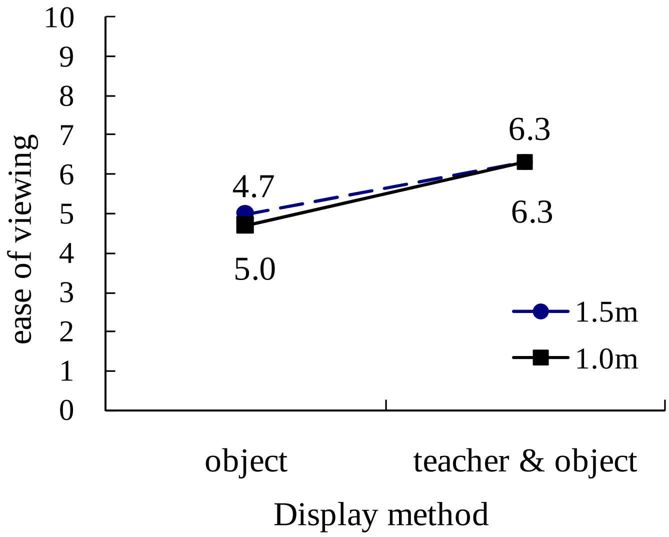

Fig 6: “Ease of viewing” on display method

The above results clearly indicate that the presence of the teacher in the background when objects were shown in the 3D video results in greater ease of viewing.

3.5 Discussion

A comparison of three-dimensionality showed that the setting in which the camera was positioned 1.0 m from the object resulted in a greater “sense of three-dimensionality” than that given by a camera-object distance of 1.5 m. Apart from other considerations, the distance between camera and object clearly has a strong influence on the sense of three-dimensionality.

Our comparison of ease of viewing showed that the presence of the teacher in the background made the viewing of objects easier. In the case where a background image appeared within the field of view (when the teacher was absent from the view), the angle of convergence of eyeballs needed to be reduced. This means that the angle of convergence needs to be adjusted substantially when looking back to the object. Since the angle of convergence of the eyeballs needs to be adjusted within a short period of time, this leads to an evaluation of “difficult to view.” In contrast, when the teacher appeared in the background of the 3D video, the difference in eyeball angle of convergence when looking at the teacher and looking at the object is relatively small. For this reason, the range of adjustment of eyeball convergence angle is small, giving rise to a subjective impression of “easy to view.”

4. Conclusion

In this study, samples of easy-to-view 3D video contents suitable for use in e-learning environments were developed. Then, they were evaluated in terms of both “sense of three-dimensionality” and “ease of viewing” and the results were examined in relation to methods of developing such contents. The results suggested that a set up in which both the teacher and displayed objects appeared together in images, where the camera-object distance was 1.0 m, enables the production of 3D video instructional materials having a good "sense of three-dimensionality." In addition, the results demonstrated that the appearance on the screen of a teacher together the learning objects made instructional videos easier to view, as compared with the case where the teacher did not appear.

In future studies, it is necessary to focus on other types of scenes, and to clarify the differences between 3D displays.

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