Ergonomic content creation for 3D display

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Abstract

This paper introduces two systems for editing and evaluating 3D content. The systems, a non-linear editing system and an evaluation system, were developed to improve viewing safety and comfort for 3D content observers and provide better usability for the creators from the viewpoint of ergonomics.

1. Introduction

3D displays have been hailed as the next-generation information display for more than 100 years. Although interest in 3D displays waxes periodically, they still are not widely used. While the displays themselves have problems, such as difficulty in presenting auto-stereoscopic images to groups, the main reasons for their limited use are a lack of suitable applications and content and the visual fatigue suffered by observers.

While display technology has advanced, content creation technology has not. Recent developments in display technology, for example, have lessened the visual fatigue problem. Consequently, the main problems hindering the adoption of stereoscopic displays are the lack of content and the fatigue caused by content expression. The authors have developed systems for creating stereoscopic 3D images through actual production studies in the fields of medicine [1] [2], culture [3] [4] and entertainment [5]. This paper introduces two systems developed by the authors that improve safety and comfort for observers and provide better usability for the creators of 3D content.

2. Non-linear editing system for 3D content [6]

The purpose of developing a non-linear editing system was to provide content creators with an easy to use production environment. This project was started from 2000. At that time the authors focused on the editing process in 3D content creation.

In those days, tape-based editing was the mainstream method for creating content. In the 2VCR system, 2 VCR units were used to record each source for the right and left images. This required four or more synchronized VCRs, which made this system quite expensive and difficult to operate. A 1VCR system using the field-sequential 3D video format offered simpler editing, but the recorded content was difficult to adjust for disparity, etc.

To ideally present 3D content, the disparity in the right and left images should be adjusted to correspond to the display size and the visual distance. However, many content creators at that time found this difficult to do. Therefore, the authors developed an efficient system for editing 3D video content. This system's simple, non-linear editing environment used PC-based software to make the unique adjustments required to present 3D content. The editing system provided the following main functions.

(1) Import and export right and left video files in various formats

(2) Display right and left video files on a time base

(3) Adjust horizontal and vertical disparities

(4) Adjust image size and rotation

(5) Adjust brightness and contrast

(6) Correct keystone distortion

3D video content was much simpler to edit with this system than with conventional systems requiring four VCRs. At the same time, the system made it easier to perform post-production tasks. Digital non-liner editing seemed to offer greater benefits for 3D content creation than for 2D content creation.

The standard TV version of the editing system was commercially released in Japan in 2003 as a software package. A high-definition version was released in 2005. At present, the authors are using the editing system for content creation and educational purposes and are continuing to improve it.

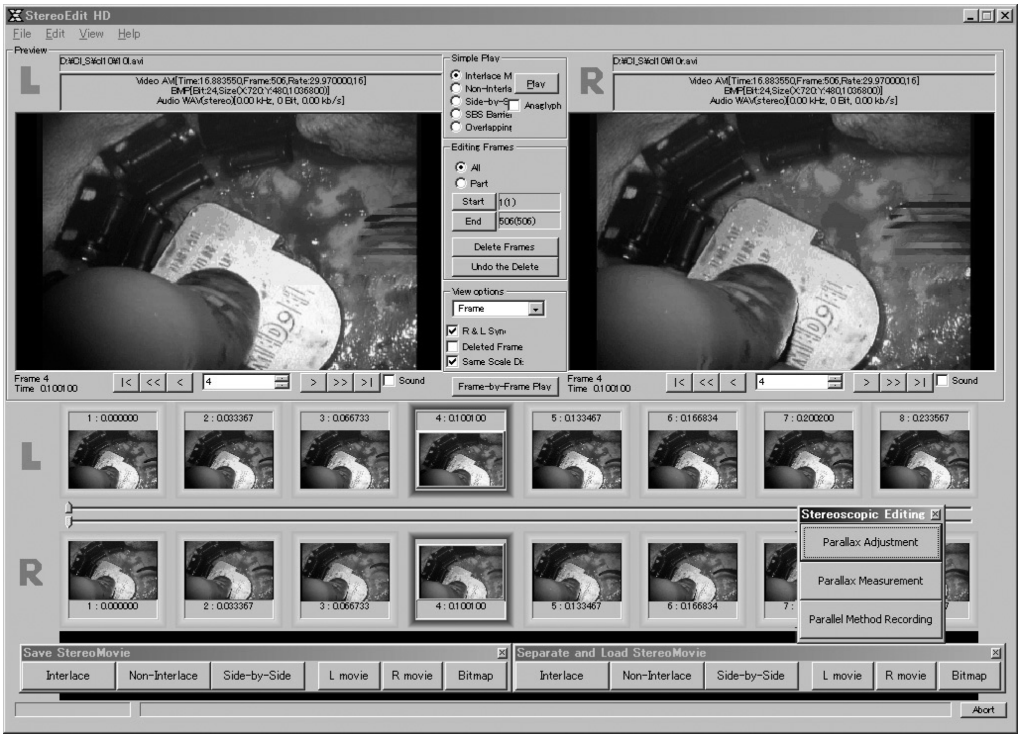

Figure 1 Main screen of the editing system

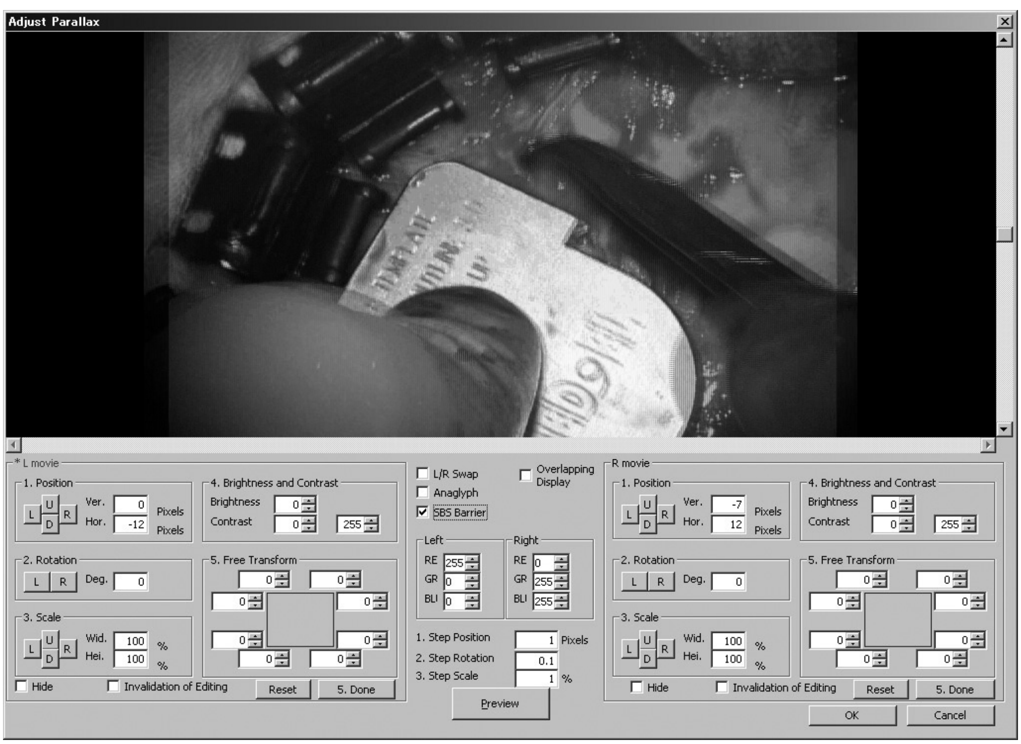

Figure 2 Adjustment screen of the editing system

3. Ergonomic evaluation system for 3D content [7]

After developing the editing system, the authors examined the problem of 3D content creation. They focused on simplifying the perception of depth in terms of safety and comfort. In the previous production process, parallax evaluation basically relied on the experience of the creator or by actually presenting the content. This was because beginner creators found it difficult to appropriately adjust the parallax of 3D content. Excessive parallax may cause visual fatigue, while insufficient parallax - the result of excessive concern for viewing safety - reduces the attractiveness and value of the stereoscopic images, since such images more closely resemble 2D images.

In this project, the authors examined the reference value for parallax in terms of its viewing comfort as well as its viewing safety, and developed a prototype evaluation system.

3.1 Examination of reference value on safety

To examine the reference value in terms of viewing safety, the authors used high-definition quality stereoscopic images (1280*720 pixels) to investigate the subjective symptoms of asthenopia before and after an observing session.

Ten stereoscopic images with identical content but different parallax were used as experimental stimuli. These stimuli were created by extracting ten different images from the standard charts of stereoscopic images [8] and shifting the images in the cross (in front of) or parallel directions (behind of the screen). Four conditions were created: 2 and 1 deg. in the cross direction, and 0 and -1 deg. in the parallel direction.

Table 1 Conditions of experiment on safety

Condition	1	2	3	4
Direction	Parallel	-	Cross	Cross
Parallax (deg.)	-1	0	1	2

The experimental stimuli were projected on a 100" silver screen using a polarized filter system. The observers (eight graduate students with normal stereoscopic vision) viewed the stimuli from a distance of 3 meters. Ukai's questionnaire was used to investigate asthenopia [9]. Each observer was shown the experimental stimuli under one of the four conditions in random order for a total of 15 minutes. Each image was presented for 15 seconds. Before and after each viewing session, the subjective symptoms of asthenopia were investigated.

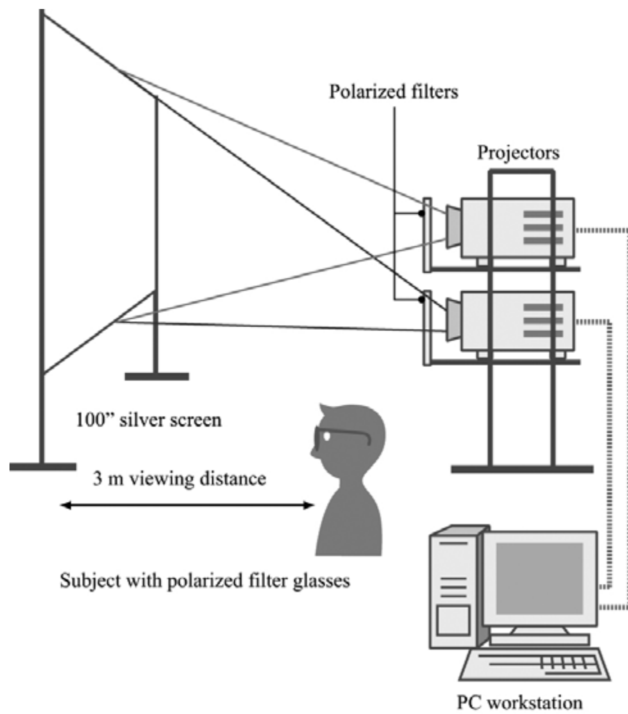

Figure 3 Layout of experiment

The highest rates of change for three symptoms - eyestrain, flickering, and bleariness - were analyzed using the ANOVA test. The main effect of parallax was significant ($p < .05$). The results showed that the threshold for visual fatigue seemed to lie between 1 and 2 deg. in the cross direction.

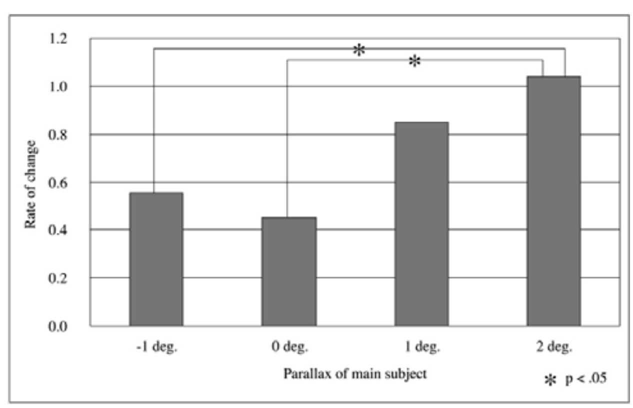

Figure 4 Results for eyestrain

Since these results were in line with the results of several previous studies, the authors assumed a safety range for parallax of the main subject to be about 1 deg. in the cross direction and the average pupil distance in the parallel direction.

3.2 Examination of reference value on comfort

The HD-quality images used in the study of viewing safety were also employed to subjectively examine the reference value for viewing comfort. The authors used the image's parallax distribution as the index for evaluating viewing safety and comfort. The sum of the absolute values of the largest parallax in the cross and parallel directions was used as a simple means of quantifying the parallax distribution related to viewing comfort.

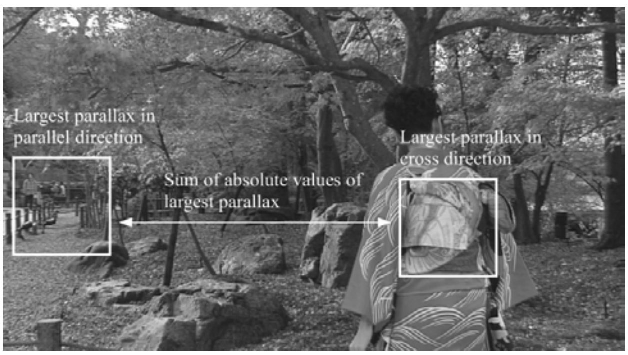

Figure 5 Concept of the sum of the largest parallax

Eight stereoscopic images with identical content and different sums of parallax were used as experimental stimuli. The experimental stimuli were presented in the same layout used in the experiment of viewing safety, with seven types of comparison stimuli presented during each session. The comparison stimuli were presented after the standard stimulus and evaluated with magnitude estimation. The observers were ten graduate students with normal stereoscopic vision. Each stimulus was presented for 10 seconds, and each observer viewed all of the stimuli three times in random order.

Table 2 Conditions of experiment on comfort

Condition	1	2	3	4*	5	6	7	8
Sum of parallax (deg.)	1.0	1.0	2.0	2.0	3.0	3.0	4.0	4.0
Cross direction (deg.)	0.0	0.5	0.0	0.5	0.0	1.0	0.0	1.75
Parallel direction (deg.)	1.0	0.5	2.0	1.5	3.0	2.0	4.0	2.25

* Condition 4 was used as the standard stimuli

The results of the ANOVA test showed that the score for the standard stimulus was significantly higher than the score for the other conditions except in the cases of 1 and 2 deg. in the parallel direction.

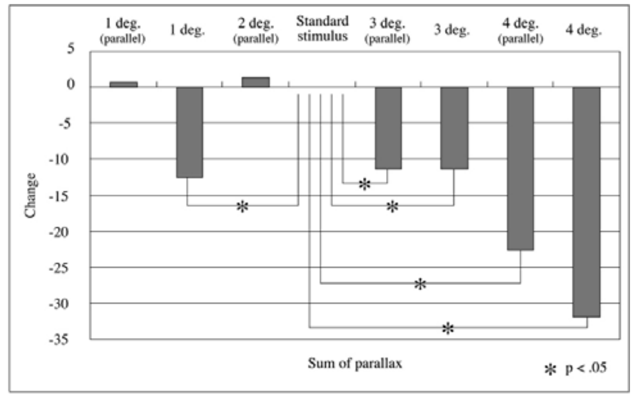

Figure 6 Results for each sum of the largest parallax

The results prove that the sum of the largest parallax in the cross and parallel directions affects the comfort of viewing stereoscopic images. In this experiment, it was most positive in the case of 2 deg. of the sum of parallax and tended to become negative as the parallax increased. Few studies have been done on viewing comfort, so the reference value for viewing comfort was assumed to be the sum of the largest parallax in the cross and parallel directions at about 2 deg. (about 1 deg. to the front and back of the screen).

3.3 Prototype evaluation system

Using the reference values obtained from above mentioned experiments, the authors developed PC-based software for evaluating the viewing safety and comfort of 3D content. In this prototype system, the right and left images of a frame are imported into the evaluation system and the disparities between corresponding points on the images are calculated by means of image processing in order to extract the optical flow. The disparities are then converted into a parallax distribution, and compared with the reference values. Since the parallax changes according to the viewing conditions (screen size and viewing distance) even when the content is identical, the disparities are converted into a parallax distribution. In this system, the screen size and viewing distance are input beforehand, and the evaluation is performed under the viewing condition.

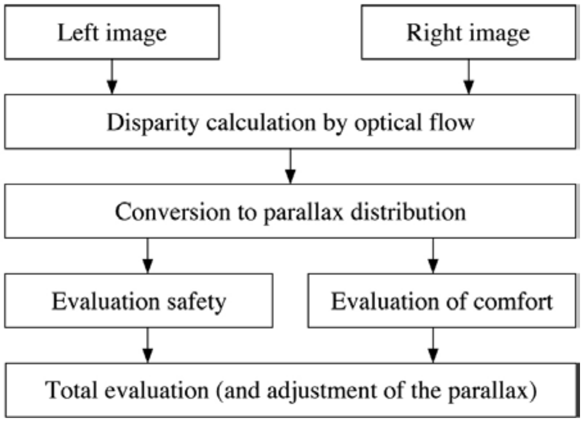

Figure 7 Flowchart of prototype evaluation system

Figure 8 Sample image

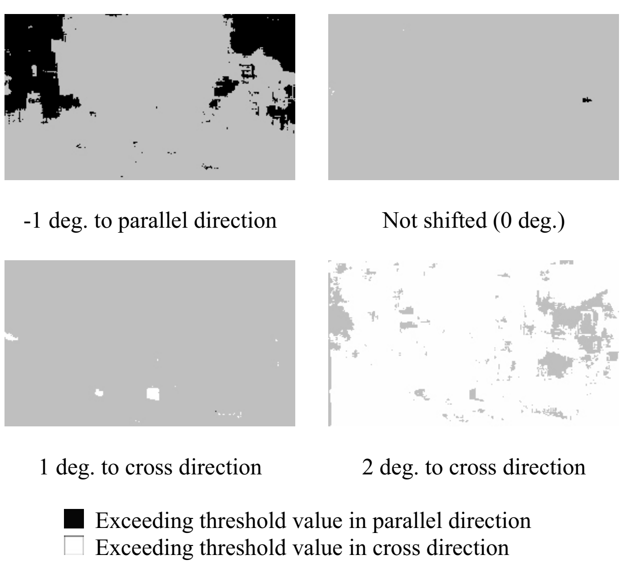

Figure 9 Results of evaluation of viewing safety for sample images

Using the reference value for safety as the threshold value, the prototype system judged an image "not safe" when the number of the pixels in the evaluation area exceeding the threshold value was greater than 10% of the image's pixels. The pixels inside the reference value are colored differently from those outside the reference value, allowing inexperienced creators to quickly grasp the amount of parallax in the content.

On the other hand, by setting the threshold range for viewing comfort using the reference value in highly evaluated sample images, the prototype system evaluated an image as "comfortable" to view when the number of the pixels within the threshold range in both the cross and parallel directions exceeded 20% of the image's pixels.

Since several sample images were verified, detailed examinations of the reference values, evaluation algorithm, and evaluation accuracy are necessary.

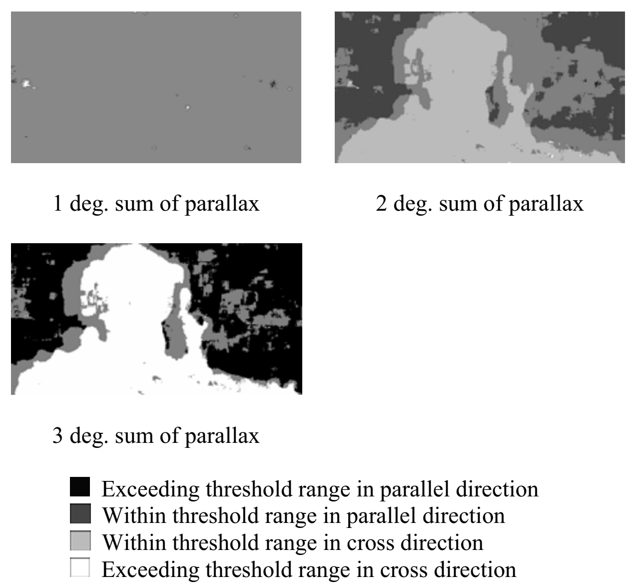

Figure 10 Results of evaluation of viewing comfort for sample images

4. Conclusions

This paper introduces two systems for creating viewer-friendly 3D content. The authors expect these editing and evaluation systems to be used together, not independently. The aim is to develop an integrated editing and evaluation system for creating ergonomic content that permits scalable conversion for various 3D displays (including multi-view systems) and presentation environments (from large-sized screens to mobile terminals).

5. Acknowledgement

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6. References

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