

Ergonomic Approaches to Content Creation for 3D Displays

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Abstract

This paper presents ergonomic approaches to editing and evaluating content for 3D displays. Two 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.

Keywords : 3D displays, ergonomics, human factors, content creation

1. Introduction

Stereoscopic 3D displays (3D displays) have been hailed as the next-generation information display for more than 100 years. Although interest in 3D displays waves periodically, they 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 does 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.

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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 ease to use production environment. This project began since 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 reasons like 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. Simple and non-linear editing environment of this system used PC-based software to make the 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

These functions are unique to 3D content, and editing is much simpler with this system than it is with conventional linear editing systems requiring four VCRs. At the same time, the system made it easier to perform post-production tasks such as post-recording adjustment of 3D content in field-sequential format. 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 from LET'S Corporation. A high-definition version was also released in 2005. At present, the authors are using the editing system for content creation and educational purposes and are continuing to improve it.

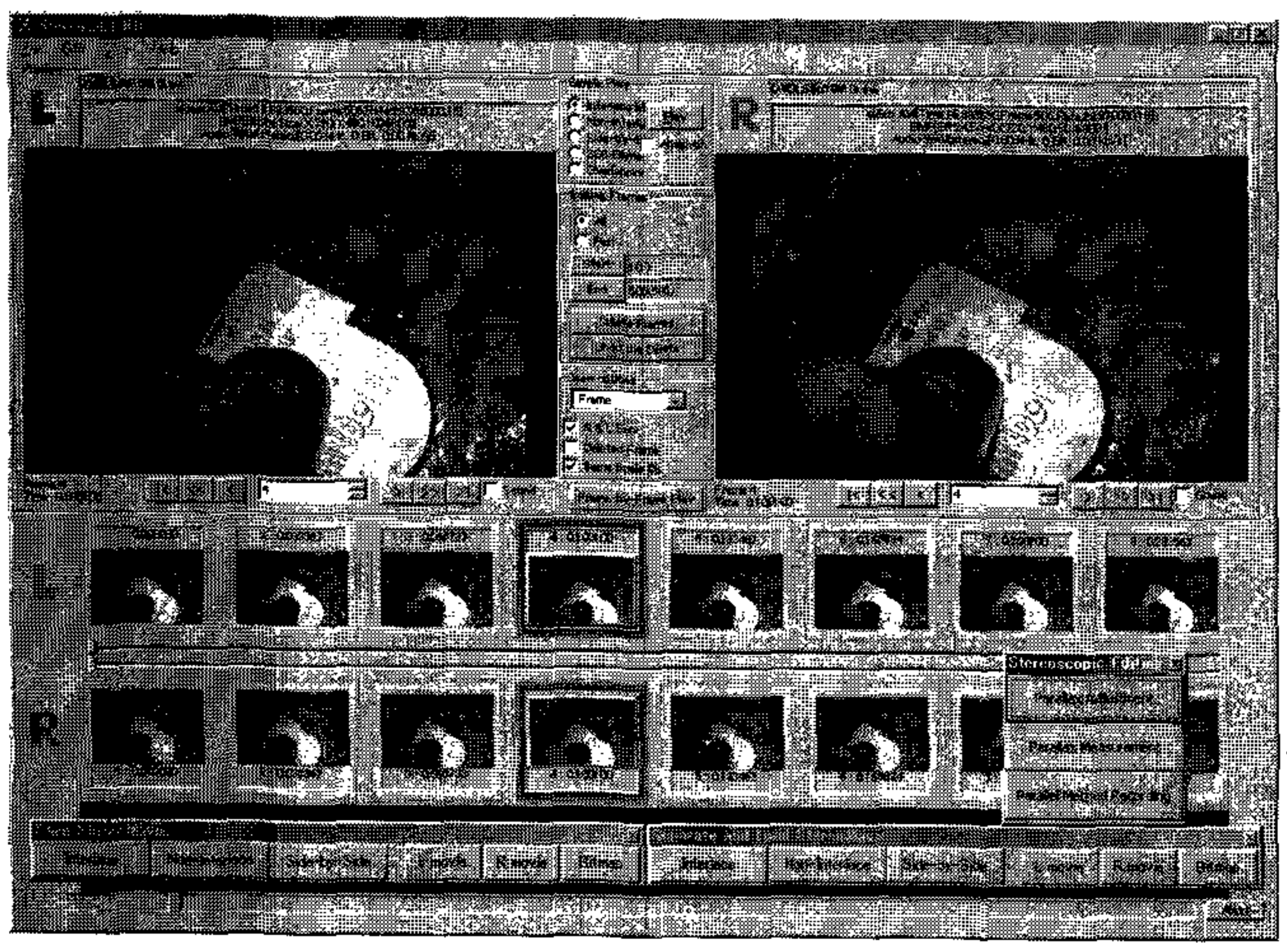


Fig. 1. Main screen of the editing system.

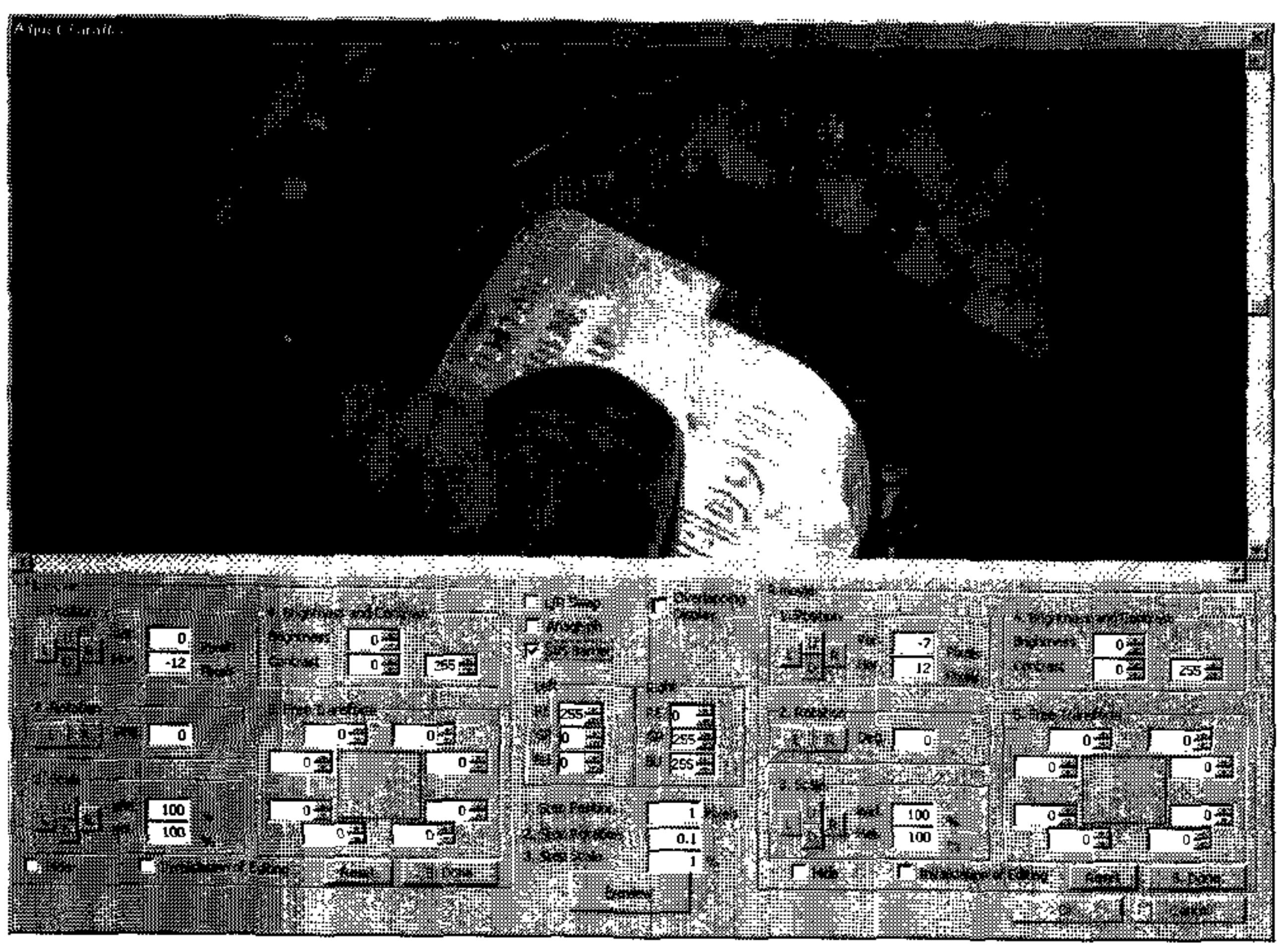


Fig. 2. Adjustment screen of the editing system.

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 relied basically 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 3D content, 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 Safety and guideline for 3D displays

With current 3D displays, fatigue is considered to be caused mainly by a mismatch in the optical system (the difference between accommodation and convergence distance). This mismatch is caused by the contradictions in the depth information obtained from accommodation and convergence, since accommodation is fixed near the display while convergence determines the position of the represented stereoscopic images (Fig. 3). In natural vision, accommodation and convergence provide identical depth information. Though the mechanism by which the mismatch causes asthenopia is unclear, the visual information is clearly unnatural. Therefore, to ensure safe viewing of 3D content, the various factors related to the fatigue problem, such as excessive or rapid changes in the parallax, must be considered during production.

Industry is now moving to create a market for 3D displays and is developing guidelines for producing 3D content. One item being considered is the ISO standards IWA3: Image Safety [8]. The IWA3 establishes the concept of image safety and defines the undesirable biomedical effects caused by moving images. Their undesirable effects include photosensitive epileptic seizures, visually induced motion sickness, and visual fatigue caused mainly by viewing stereoscopic images. In the future, content produced for viewing on 3D displays will likely conform to such kinds of standards or guidelines.

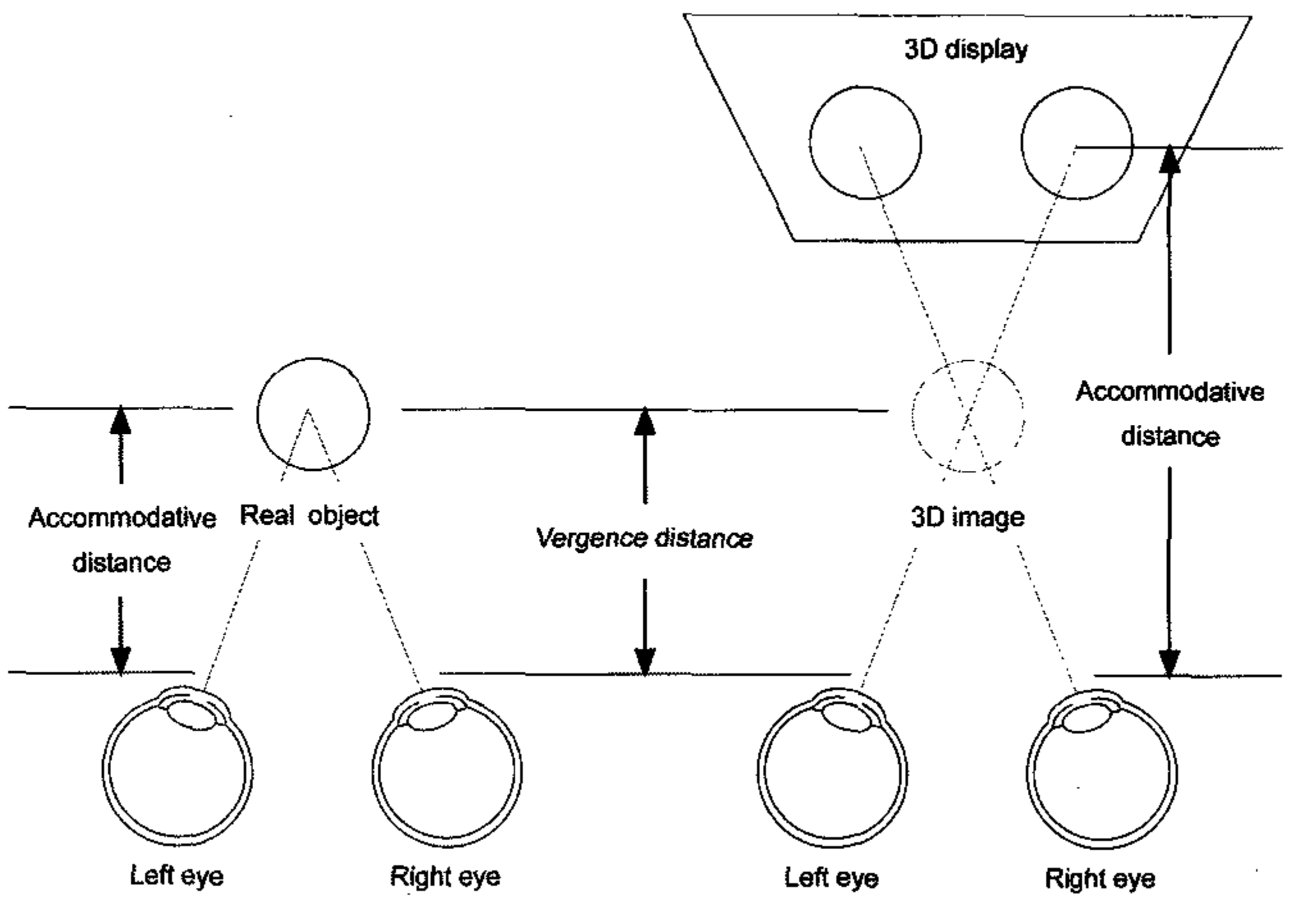


Fig. 3. Mismatch in the optical system.

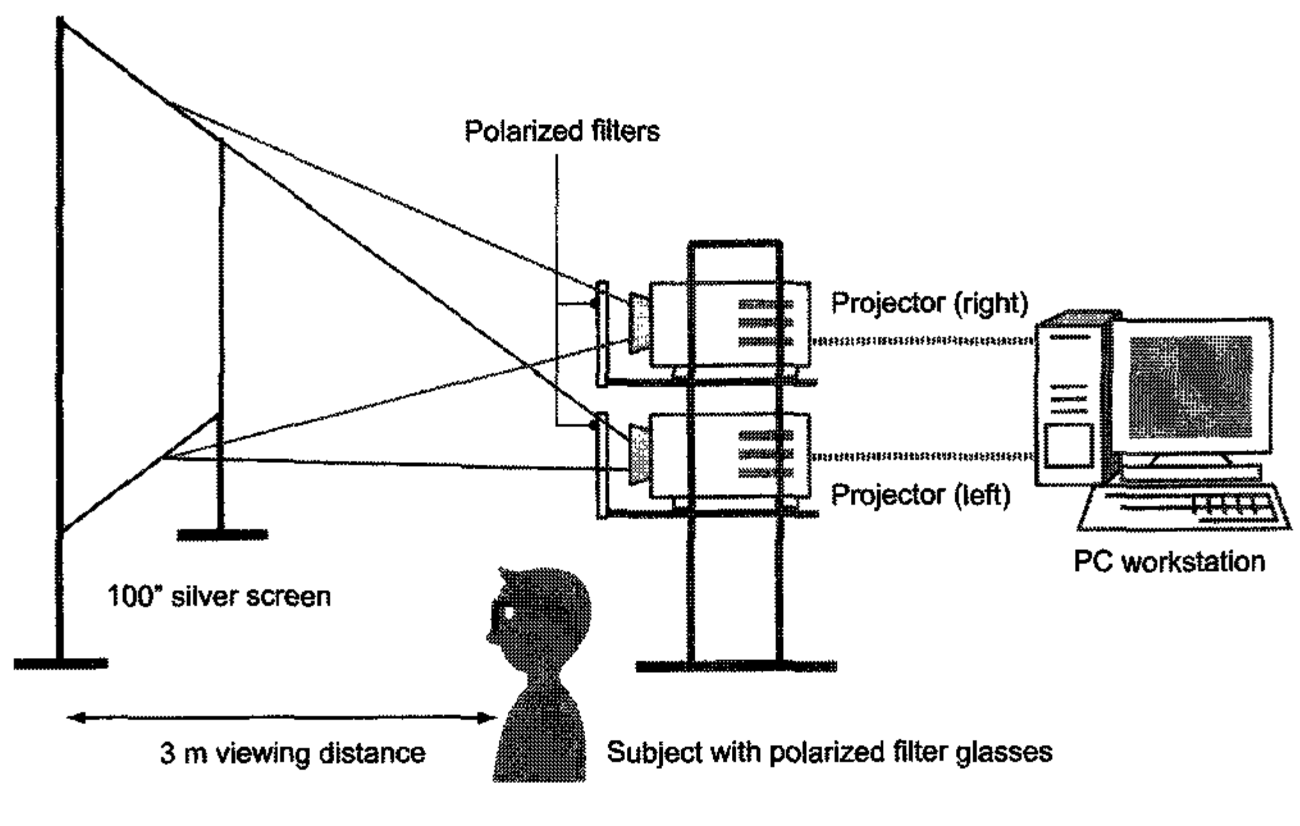


Fig. 4. Layout of experiment.

3.2 Examination of reference value on safety

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

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 [9] and shifting the images in the cross (in front of) or parallel directions (behind of the screen). The charts include various stereoscopic image samples and are provided by the institute of image. 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 [10]. The questionnaire consists of 28 items, and the items are classified into three factors concerning asthenopia, motion sickness and conditions of anterior eye. 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.

The highest rates of change for three symptoms - eyestrain, flickering, and bleariness - were analysed 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.

These results were in line with the results of several previous studies, such as the tendencies of psycho-physiological responses to be remarhable after continuing to gaze at stereoscopic images with more than 1 deg. Parallax [11][12]. Therefore, 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.

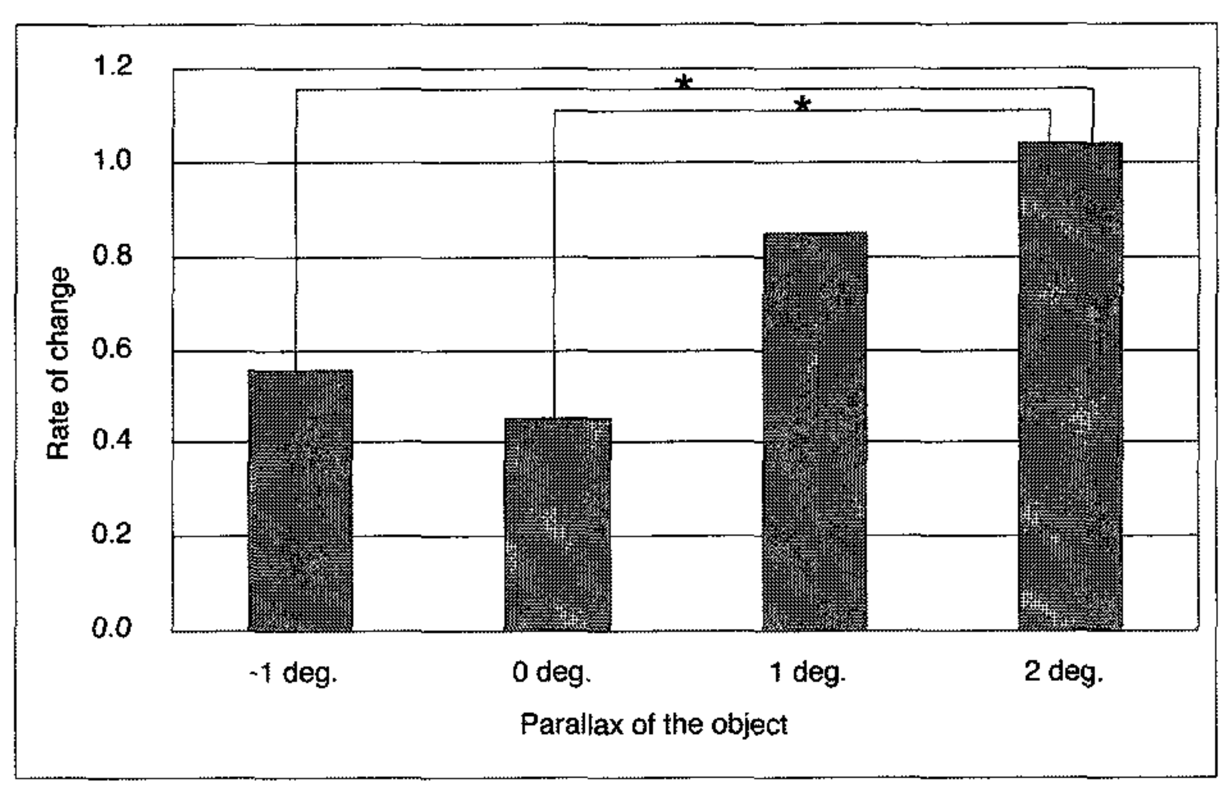


Fig. 5. Results for eyestrain.

3.3 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.

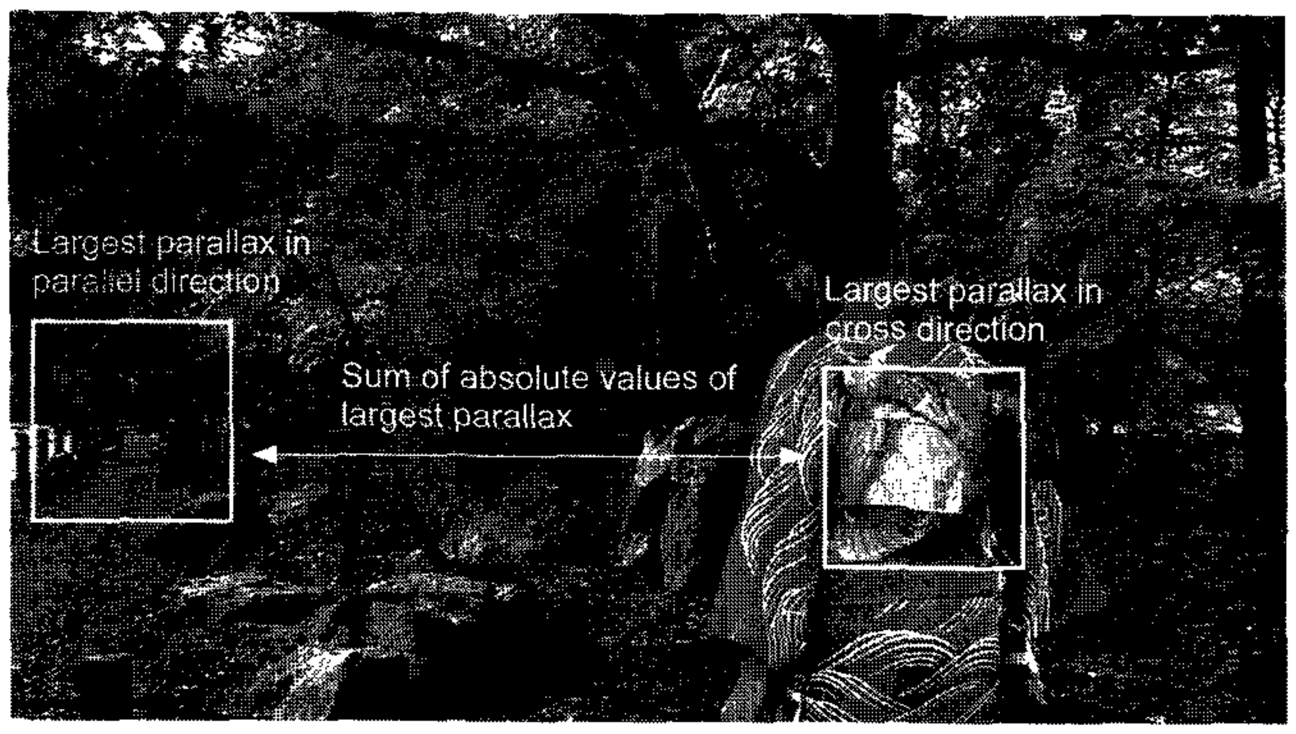


Fig. 6. Concept of the sum of the largest parallax.

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 was allowed to view all of the stimuli three times randomly.

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.

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).

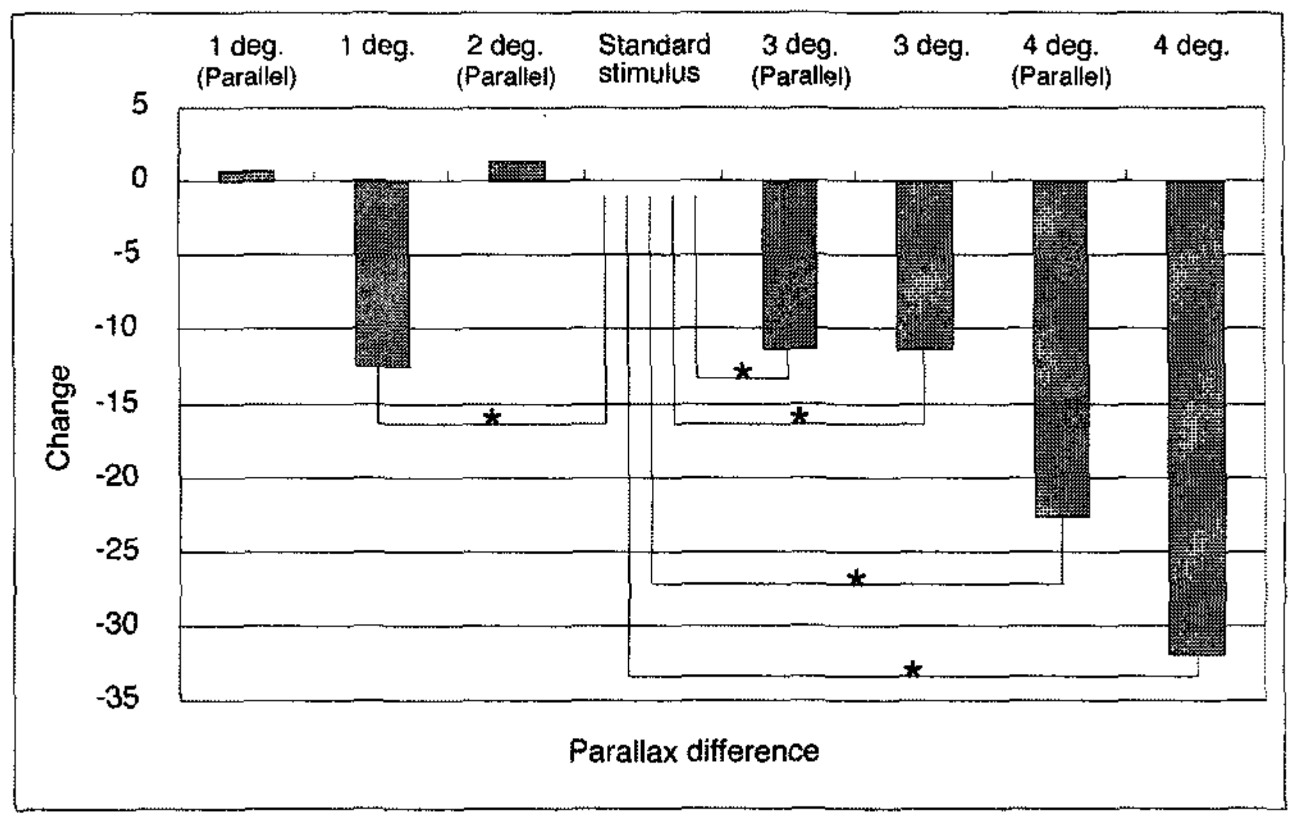


Fig. 7. Results for each sum of the largest parallax.

3.4 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 were imported into the evaluation system and the disparities between corresponding points on the

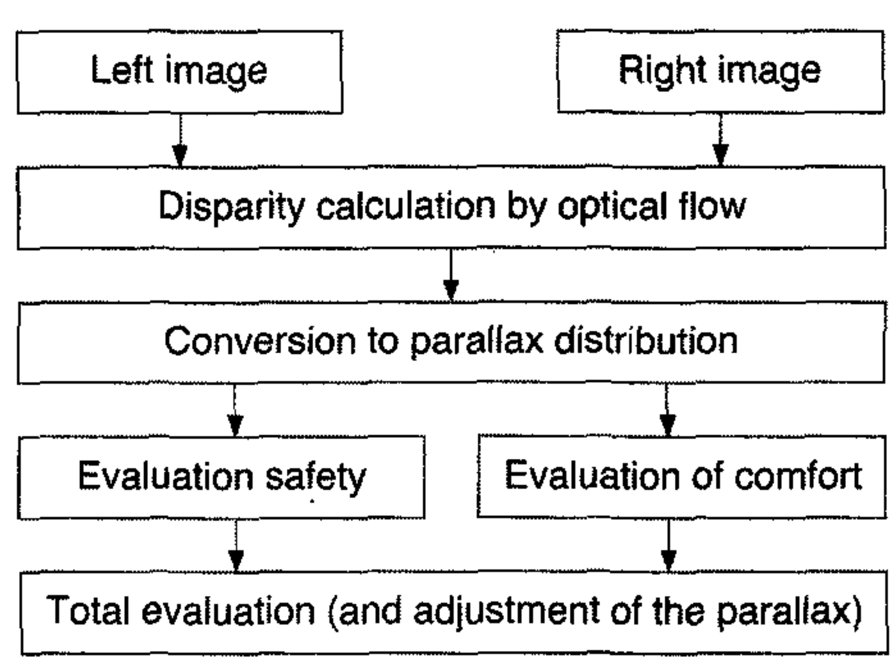


Fig. 8. Flowchart of prototype evaluation system.

Fig. 9. Sample image.

images were calculated by means of image process were 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 were converted into a parallax distribution. In this system, the screen size and viewing distance were input beforehand, and the evaluation was performed under the viewing condition.

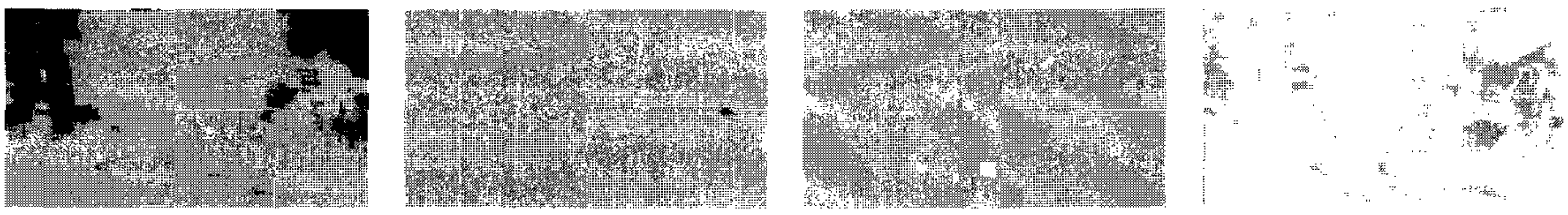
Using the reference value for safety as the threshold value, the prototype system judged an image "not safe" when the number of the pixels in the evaluation area exceeding the threshold value was greater than 10% of the image's pixels. The pixels inside the reference value were coloured differently from 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.

The prototype system's evaluations of viewing safety and comfort were visually expressed using as reference values of the results of experiments and precedent studies. Detailed examinations of the reference values, evaluation algorithm, and evaluation accuracy are necessary, however, since only a few sample images were verified.

4. Conclusions

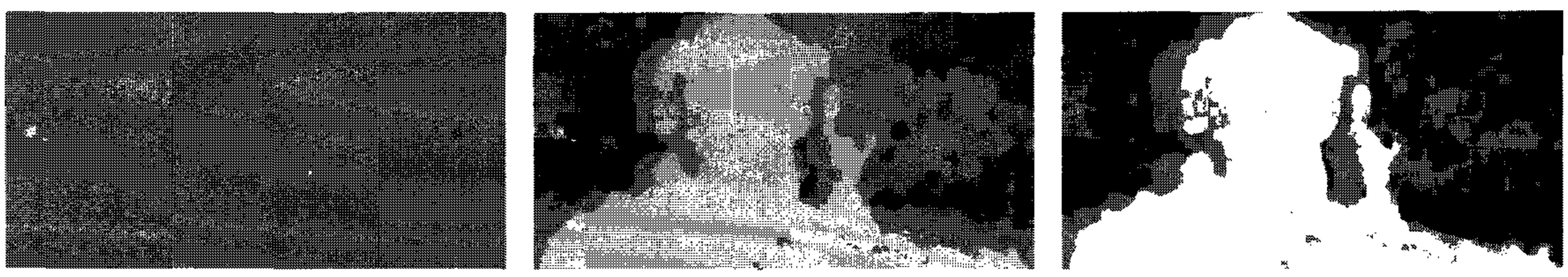
This paper introduces two systems for creating viewer-friendly 3D content. The authors expect these editing and



-1 deg. to parallel direction | Not shifted (0 deg.) | 1 deg. to cross direction | 2 deg. to cross direction

■ Exceeding threshold value in parallel direction □ Exceeding threshold value in cross direction

Fig. 10. Results of evaluation of viewing safety for sample images



1 deg. sum of parallax | 2 deg. sum of parallax | 3 deg. sum of parallax

■ Exceeding threshold range in parallel direction ■ Within threshold range in parallel direction

▒ Within threshold range in cross direction □ Exceeding threshold range in cross direction

Fig. 11. Results of evaluation of viewing comfort for sample images.

evaluation systems to be used together, not independently.

Although the practical application of the editing system has already began, the evaluation system is still in the prototype phase. The following tasks need to be carried before the evaluation system can be applied to 3D content creation.

(1) Development of an advanced algorithm using integration and differentiation of parallax for a time series.

(2) Evaluation of the peculiar phenomenon of stereoscopic images, such as the puppet theater effect and the cardboard effect.

(3) Examination of the interface design, such as the operation flow and the expression of the results.

Furthermore, the authors are aiming to develop an integrated editing and evaluation system for creating content ergonomically that permits scalable conversion for various 3D displays (including multi-view systems) and presentation environments (from large-sized screens to mobile terminals).

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