Disparity modifications and the emotional effects of stereoscopic images

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ABSTRACT
This paper describes a study that focuses on disparity changes in emotional scenes of stereoscopic (3D) images, in which an examination of the effects on pleasant and arousal was carried out by adding binocular disparity to 2D images that evoke specific emotions, and applying disparity modification based on the disparity analysis of famous 3D movies.

From the results of the experiment, for pleasant, a significant difference was found only for the main effect of the emotions. On the other hand, for arousal, there was a trend of increasing the evaluation values in the order 2D condition, 3D condition and 3D condition applied the disparity modification for happiness, surprise, and fear. This suggests the possibility that binocular disparity and the modification affect arousal.

Keywords: stereoscopic images, disparity modification, emotional effect, pleasant, arousal

1. INTRODUCTION
Stereoscopic (3D) images are becoming established, mainly in the movie field. To date, studies have been carried out on the effects of 3D images on human body from the point of view of safety, such as vergence-accommodation conflicts, and the visual fatigue associated with this [1]. The results of these studies have been used in formulating guidelines, such as representing 3D space within a fixed range of parallactic angle [2]. In contrast, in the future, it is necessary to deepen our understanding of the comfort of 3D images, thereby clarifying and enhancing their merits.

Against this background, recently there have been attempts made by 3D image creators to systematize and share the creation techniques [3], and attempts to analyze the binocular disparity in 3D images by researchers [4]. The authors have continued disparity analysis of 3D images from the point of view of expression of emotion and binocular disparity. Specifically, disparity analysis of famous 3D movies was carried out, and the parallactic angle of emotional scenes was extracted. Then the time series change in parallactic angle included in each scene was analyzed with the center and range of the represented 3D space as indexes. From the results, trends for each emotion were found for changes in parallactic angle [5].

The authors defined this characteristic change in parallactic angle as “disparity modification”, and focused as a unique method for expressing emotions in 3D images. Also, an experiment was carried out to examine the effects on the psychological reaction of viewers when binocular disparity was added to 2D images that were intended to evoke specific emotions, and when disparity modification was applied.

2. DISPARITY ANALYSIS OF EMOTIONAL SCENES [5]

2.1 Methods for disparity analysis
Disparity analysis was conducted for the following four 3D movies, and the Blu-ray 3D version for home viewing was used in each case.

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First, image processing was performed to calculate the optical flow in one frame per second, and the pixel disparity with the corresponding points in the left and right frames were obtained. The viewing environment was assumed to be a 50 inch television viewed at a distance of three times the height of the screen (3H), and the pixel disparity was converted into parallactic angle and analyzed. A block matching algorithm was used for calculating the optical flow, and a recursive cross-correlation method was used for faster processing. The relationship between pixel disparity and parallactic angle is shown in figure 1.

![Figure 1. Pixel disparity and parallactic angle [5]](image)

The 90 percentile (%ile), 50%ile, and 10%ile of the parallactic angle included in each frame are used to be representative values for near, medium, and distant reproduced 3D spaces, respectively. In order to make the change in the depth direction of 3D space easier to understand, each representative value was converted into a 10 second moving average. Percentile is a value that represents the distribution of measured values ranging from the smallest as a percentage, and in this paper the 90%ile is taken to be the maximum value of the crossed disparity, and the 10%ile is taken to be the maximum value of the un-crossed disparity.

2.2 Disparity changes in emotional scenes

Next, characteristic emotional scenes in terms of the depth sensation were extracted in each movie, and analyzed. In this extraction, the three of the authors who have normal binocular vision were coders, and all movies were viewed several times. The extracted emotional scenes were evaluated using a five-point rating scales using Ekman’s basic emotions [6] as items. The average score for each item was calculated, and the item with the highest scores was classified as the basic emotion expressed in that scene. Then, quantification of disparity changes was carried out for the four emotions that 10 or more scenes were classified; happiness, surprise, sadness, and fear.

There are four types of basic patterns of disparity modification in 3D images as shown in figure 2. Therefore, in quantification of disparity changes of emotional scenes, two indexes were selected: the center and the range of the 3D space. Each index was quantified as the amount of change in the parallactic angle between the first frame of each scene and the frame with the maximum range. The quantification method is shown in figure 3.
Figure 2. Basic patterns for disparity modification [5]

Figure 3. Quantification of disparity changes [5]
The results for the average rate of change in the center and the range of the 3D space calculated from the classified scenes for each emotion are shown in figure 4. In the disparity changes in center of 3D space, the direction of change differed depending on the type of emotion. In the changes in range of 3D space, differences were found for each emotion. In this paper, these results were experimentally examined for the psychological effects when applied to other 3D images, using disparity changes of each emotion as parameters for the disparity modification.

![Figure 4. Parameters for disparity modification](image)

**3. EXPERIMENT**

**3.1 Stimuli**

The International Affective Picture System (IAPS) [7], a large scale set of color photographs that evoke emotions, was selected as the experimental stimuli. In the IAPS, each image was evaluated by two-dimensions containing “pleasant” and “arousal”. The evaluation values of IAPS were compared with Russell’s circumplex model of emotion [8], and 15 types of image were extracted for the experiment. The circumplex model is shown in figure 5. Specifically, three each of images that were considered to evoke the emotions of happiness, surprise, sadness, fear or no emotion (NE: Not Emotional) were selected as follows.

- **Happiness**: Images for which the values of pleasant were high, and the values of arousal were average
  - IAPS1710, IAPS2057, IAPS5830
- **Surprise**: Images for which the values of pleasant were average, and the values of arousal were high
  - IAPS5920, IAPS5940, IAPS7640
- **Sadness**: Images for which the values for pleasant and arousal were both slightly low
  - IAPS2810, IAPS2900, IAPS9220
- **Fear**: Images for which the values for pleasant were low, and the values for arousal were high
  - IAPS6313, IAPS6510, IAPS6570
- **NE**: Images for which the values for pleasant were average, and the values for arousal were low
  - IAPS7004, IAPS7006, IAPS7009
3.2 3D conversion and disparity modification

IAPS is a set of 2D images, so the extracted 15 images were converted into 3D images. Depth-maps were created manually in accordance with the monocular information contained in each image, and 3D images that contained binocular disparity were rendered.

In addition, modified 3D (M3D) conditions were set for the 3D images which applied the disparity modification for each emotion as parameters. In the disparity modification, the center and the range of the 3D space were calculated for each 3D image, and the parameters were reflected as the ratio of these. Also, only 2D and 3D conditions were prepared for the NE images.

Figure 6 shows average representative values of the converted and the modified 3D images.

Table 6. Average representative values of converted and modified 3D images
3.3 Equipment
The experiment was carried out individually in a darkroom. The stimuli were presented using a 24 inch polarizing filter 3D display (P240W, HYUNDAI IT) with the glasses. The viewing distance was 90 cm which corresponded to about 3H.

3.4 Participants
The participants were total 20 of male and female university students (19-25 years old) whose binocular vision was confirmed by the Stereo Fry Test. Also, the purpose and the method of the experiment were informed to the participants in advance, and the consent of all the participants was obtained.

3.5 Measurement
In the experiment, the participants were required to evaluate each image using a Self-Assessment Manikin (SAM) [9]. SAM consists of a two-dimensional scale of “pleasant” and “arousal”. Each dimension was represented by graphic figures, and the participants evaluated each dimension in nine levels. SAM is used for evaluating IAPS images.

3.6 Procedure
In the experiment, a total of 42 images were prepared: three images under three conditions (2D, 3D, and M3D) for each emotion, and three dummy stimuli (NE) under two conditions (2D and 3D). The 42 images constituted one set, and each participant was required to evaluate three sets.

The stimuli were presented for five seconds each in random order, with 10 seconds blank between stimuli for evaluation time. Three minutes rest was provided between the sets, and a total of 126 trials were carried out by each participant. Before the experiment, the participants practiced with images that were not used as the stimuli, in order to familiarize with evaluation using SAM.

3.7 Results
(1) Pleasant
The average values for pleasant under each condition for each emotion are shown in figure 7. From the results of the two-way analysis of variance (ANOVA) test, a significant difference (F=288.251, p<.01) was found in the main effects of the emotions.

![Figure 7. Average values for pleasant](image)
(2) Arousal

The average values for arousal under each condition for each emotion are shown in figure 8. From the results of the two-way ANOVA test, significant differences were found for the main effects of the emotions ($F=152.588, p<.01$) and for the main effects of the conditions ($F=58.872, p<.01$).

![Figure 8. Average values for arousal](image)

4. CONCLUSION

This paper describes a study that focuses on disparity changes in emotional scenes of 3D images, in which an examination of the effects on pleasant and arousal was carried out by adding binocular disparity to 2D images that evoke specific emotions, and applying disparity modification based on the disparity analysis of famous 3D movies. From the results of the experiment, it was found that the evaluation values for pleasant and arousal under 2D conditions showed similar trends as the original values of IAPS. This suggests that each image generally evokes the intended emotion.

For pleasant, a significant difference was found only for the main effect of the emotions, so it is considered that the subject matter in each image itself affected rather than the experimental conditions. On the other hand, for arousal, there was a trend of increasing the evaluation values in the order 2D, 3D and M3D conditions for happiness, surprise, and fear. This suggests the possibility that binocular disparity and the modification affect arousal. For sadness, the reason that no significant difference was found between 3D and M3D conditions is considered that the amount of modified disparity was smaller than the other emotions. However, a significant difference was found between 2D and 3D conditions, so it is considered that arousal is increased for sadness also by adding binocular disparity.

In addition, the disparity modification applied in the experiment was an expansion of the range of the 3D space for each of the emotions. Therefore, there is a possibility the increase in parallactic angle associated with expansion of the range is the cause of the increased arousal, rather than disparity modification of each emotion. In order to verify this and obtain knowledge that will contribute to the comfort of 3D images, the following three issues remain:

- The effects when disparity modification with parameters for different emotion is applied
- The effects when disparity modification is applied to images that aren’t intended to evoke specific emotions
- Examination of time series disparity modification for moving images
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