Disparity analysis of 3D movies and emotional representations

Takashi Kawai, Masahiro Hirahara, Yuya Tomiyama, Daiki Atsuta, Jukka Häkkinen

Department of Intermedia Art and Science, School of Fundamental Science and Engineering, Waseda University, 3-4-1 Okubo, Shinjuku, Tokyo 169-8555, Japan; Institute of Behavioural Sciences, Siltavuorenpenger 1-5, P.O. Box 9, FI-00014 University of Helsinki, Finland

ABSTRACT

The authors have analyzed binocular disparity included in stereoscopic (3D) images from the perspective of producing depth sensation. This paper described the disparity analysis conducted by the authors for well-known 3D movies. Two types of disparity analysis were performed; full-length analysis of four 3D movies and analysis of emotional scenes from them. This paper reports an overview of the authors’ approaches and the results obtained from their analysis.

Keywords: 3D movies, binocular disparity, content analysis, parallactic angle, depth chart, emotional representation

1. INTRODUCTION

With the expansion of stereoscopic (3D) images to various sectors such as movies, television and videogames, there is increasing interest in the production and evaluation of 3D image content. To date, 3D images have been evaluated from the perspective of the imbalance in the visual system, primarily vergence-accommodation conflicts. The results of such research have been used to formulate guidelines for presenting 3D spaces within the range of a certain parallactic angle. In contrast, the authors have analyzed the binocular disparity included in 3D images from the perspective of producing depth sensation. Collaborating with the International 3D Society (I3DS) and the Japan Committee (I3DS-J), the authors quantitatively conducted the characteristics and trends in the disparity included in internationally popular 3D movies, with the aim of providing useful knowledge for future content production. This paper describes an overview of the authors’ approaches and the results obtained from their research.

2. METHODS FOR DISPARITY ANALYSIS [3]

In the disparity analysis, initially image processing was performed to compute the optical flow, and the pixel disparity of corresponding points within the left and right frames was determined. The viewing distance and screen size were assumed, and the pixel disparity was converted to the parallactic angle and analyzed. A block-matching algorithm was used to compute the optical flow, and the recursive cross-correlation method was used for faster processing. Only data from these calculations whose consistency had been assured by means of an LR-check were analyzed.

3. 3D MOVIES FOR DISPARITY ANALYSIS

Disparity analysis was conducted for the following four 3D movies:

- "Avatar (20th Century Fox, 2009)"
- "Cloudy with a Chance of Meatballs (Sony Pictures, 2009)"
- "Tangled (Walt Disney Pictures, 2010)"
- "How to Train Your Dragon (Paramount, 2010)"

*tkawai@waseda.jp; phone +81 3 5286 2853
All of the 3D movies selected for disparity analysis were Blu-ray 3D versions designed for home viewing. The pixel disparity for each movie was calculated. The pixel disparity was converted to the parallactic angle, and the assumed conditions for the viewing environment were a 50" TV from the 3H position (distance equivalent to three times the height of the screen). In the conversion, 65 mm was used as inter-pupillary distance.

4. RESULTS OF FULL-LENGTH ANALYSIS OF 3D MOVIES

4.1 Procedure

First, image processing of one frame per second was performed for each of the 3D movies, and the parallactic angle included in each frame was calculated. The 90 percentile (%ile), 50%ile and 10%ile of the parallactic angle included in each frame were plotted in a time series as near, center and far representative values for the 3D space. A percentile is the value in which the distribution of measurements is arranged from smallest to largest and displayed as a percentage.

For the purpose of comprehensive visualization of changes in the depth direction of 3D space throughout the entire movie, each representative value was converted into a 10-second moving average.

In this paper, the 90%ile represents the maximum value in the crossed disparity, and the 10%ile represents the maximum value in the uncrossed disparity. The reason for not using 100%ile as the maximum value is to avoid including misdetected data during image processing. In using the 90%ile value, 50 frames were randomly extracted from the entire "Tangled" movie and compared with the manually measured values. Correlation coefficients were determined for the 95%ile, 90%ile and 85%ile and the manually measured values. Since the correlation coefficient between 90%ile and the manually measured values was the highest, it was decided to use as a representative.
4.2 “Avatar”

Figure 2 shows the results of a disparity analysis for “Avatar”. It can be seen that the 3D space is being used in a wide range in both crossed and uncrossed disparity throughout the entire movie. From two hours after the movie started, the maximum values for the crossed and uncrossed disparities tended to decrease.

![Figure 2. Results of disparity analysis for “Avatar”](image)

4.3 “Cloudy with a Chance of Meatballs”

Figure 3 shows the results of a disparity analysis for “Cloudy with a Chance of Meatballs”. Throughout the entire movie, the maximum value in the uncrossed disparity was maintained at a fixed level. In addition, in the second half of the movie, the maximum value in the crossed disparity increased in accordance with the storytelling.

![Figure 3. Results of disparity analysis for “Cloudy with a Chance of Meatballs”](image)
4.4 “Tangled”

Figure 4 shows the results of a disparity analysis for “Tangled”. Compared to “Avatar”, the use of the 3D space in the uncrossed disparity is notable. There were “reaching moments” - scenes characterized by increase of the maximum value in the crossed disparity, in which the viewer involuntarily stretches out a hand - can be seen.

![Figure 4. Results of disparity analysis for “Tangled”](image)

4.5 “How to Train Your Dragon”

Figure 5 shows the results of a disparity analysis for “How to Train Your Dragon”. It can be seen that the 3D space is being utilized in both crossed and uncrossed disparity throughout the entire movie. In addition, the cycle for increase and decrease of maximum values is comparatively short.

![Figure 5. Results of disparity analysis for “How to Train Your Dragon”](image)
5. DISPARITY ANALYSIS FOR EMOTIONAL SCENES

5.1 Purpose

In this paper, “emotional scene” is the term used to describe parts in the movie when the characters depict delight, anger, sorrow, or pleasure in order to emotionally engage the viewer. Although such scenes also occur in 2D movies naturally, the binocular disparity can be utilized to make the emotional scene more various in 3D movies.

Figure 6 shows one example of an emotional scene thought to have been subjected to disparity modification. This is a scene excerpted from the disparity analysis of the first half of “How to Train Your Dragon”, in which the psychological struggle of the main character is depicted. From the standpoint of disparity modification, the maximum values for the crossed and uncrossed disparity are shifted in the direction to expand the 3D space, and then suddenly decreased and held for a certain period of time. For this reason, it can be considered that the disparity is being controlled to correspond to the change in the main character from psychological tension to relax.

As the disparity modification in such emotional scenes occur various parts in the 3D movies analyzed in this paper, it was decided to conduct a basic analysis regarding disparity modification and emotional representation.

5.2 Methods to analyze emotional scenes

Figure 7 shows the four basic patterns for disparity modification in 3D content. Accordingly, emotional scenes with characteristic depth sensation were extracted, and categorized and compared with quantified disparity modification patterns and levels, with the aim of understanding basic trends in the unique 3D presentation for specific emotional expressions.

First, 109 emotional scenes with characteristic depth sensation were extracted from the 3D movies analyzed in this paper. In extracting these scenes, the three of the authors, each of whom has normal binocular vision, viewed the movies in their entirety several times as coders. The extracted emotional scenes were evaluated using a five-point rating scales based on the basic emotions defined by P. Ekman. Ekman defined six basic emotions expressed by universal facial expressions that are not culturally dependent: Anger, Disgust, Fear, Happiness, Sadness and Surprise [4]. An average score was calculated for each emotion, and the emotion with the highest score was determined as the basic one expressed in that scene. Table 1 shows the number and rate of emotional scenes that were extracted as the results for categorization of the basic emotions expressed in those scenes.
For the quantification of disparity modification in the emotional scenes, the changes in the center and range of the 3D space were used as indexes. The indexes were calculated as the amount of change in the parallactic angle between the initial frame of the extracted scene and the frame with the maximum range. Figure 8 shows the method for quantification.

![Figure 7. Four basic patterns for disparity modification](image)

<table>
<thead>
<tr>
<th>-</th>
<th>Anger</th>
<th>Disgust</th>
<th>Fear</th>
<th>Happiness</th>
<th>Sadness</th>
<th>Surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>8</td>
<td>5</td>
<td>23</td>
<td>31</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>Rate (%)</td>
<td>7.3</td>
<td>4.6</td>
<td>21.1</td>
<td>28.4</td>
<td>13.8</td>
<td>24.8</td>
</tr>
</tbody>
</table>
5.3 Results of analysis of emotional scenes

Figure 9 shows the results for changes in the center and range of the 3D space, calculated from individual emotional scenes and averaged for each basic emotion - in other words, the disparity modification trends for each basic emotion.

As shown in figure 9, during each basic emotion the range of the 3D space expands, however the degree differs depending on the type of emotion. On the other hand, for the center of the 3D space, the change direction differs depending on the type of the emotion. The center of the 3D space in scenes categorized as Disgust or Surprise changes nearer to the viewer. In contrast, in scenes categorized as Fear, the direction changes farther away from the viewer.

Based on the results of an analysis of variance for these two factors - the basic emotions (six types) and the change in 3D space (center and range) - it was confirmed that there was a significant difference in the main effect of the change in 3D space (p<.05). Multiple comparisons determined that there was a significant difference among indexes expressing the change in 3D space for the basic emotions of Fear, Happiness and Surprise (p<.05).
6. CONCLUSION

This paper described the disparity analysis conducted by the authors for well-known 3D movies. The full-length analysis of the four movies found that the distribution of representative values for parallactic angle was not uniform over time but rather appeared to change in response to storytelling, etc. There were also notable differences among the movies. From the standpoint of the depiction of depth sensation, a wide diversity of efforts were exerted in each of the movies. Moreover, in the 3D movies analyzed, almost all of the maximum values for the crossed and uncrossed disparity were confirmed to be within the range of a parallactic angle of ±1.0 degree.

In the analysis of emotional scenes with characteristic depth sensation, in all of the basic emotions, the range of the 3D space was expanded, however this trend differed depending on the type of emotion. The changes in the center and range of the 3D space are experienced by the viewer as changes in the distance to the object and depth of the space. This analysis did not extend to confirming the intent of the creators and verifying the response of viewers, nevertheless the results are thought to suggest a possible association between disparity modification and the depiction of specific emotions.

For this research, the following three points are considered to be further tasks:

- Examination of validity and efficiency of the method used for disparity analysis [4]
- Increase in the number of movies considered and application of the findings for production techniques
- Detailed analysis of emotional scenes and verification of the effectiveness of disparity modification

ACKNOWLEDGEMENTS

Many people cooperated in promoting this research. The authors would like to express their gratitude to those members of I3DS and I3DS-J involved in this work, and the following stereographers who were in charge of the production of the 3D movies analyzed in this paper and gave important suggestions for the authors; Mr. Chuck Comisky, Mr. Rob Engle, Mr. Buzz Hays, Mr. Phil McNally and Mr. Robert Newman.

This research was partially supported by the Japan Society for the Promotion of Science, Grant-in-Aid for Challenging Exploratory Research 2011 – 2012 (23650054, Takashi Kawai).
REFERENCES