DepthChecker: An ergonomic evaluation system for stereoscopic content

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Abstract
Production of stereoscopic (3D) content has increased due to the development of camera and display systems in Korea and Japan. The authors have studied to quantify the depth sensation of 3D images and to evaluate them. Based on our previous research, the authors developed an evaluation system named "DepthChecker" to measure 3D content combining by left and right images in real-time. Also, DepthChecker was designed with a creator-friendly interface including graphical outputs and a control unit. The content creators can evaluate their 3D content and easily ensure safety and comfort by checking parallax distribution according to the viewing conditions from mobile to cinema.

Keywords: stereoscopic images, binocular disparity, content evaluation, content production, safety and comfort

1. Introduction

The production of 3D content, such as movies and games, has increased due to the development of display and camera device technologies in Korea and Japan. Most 3D content produces depth sensation in the current display technologies by binocular parallax, slight disparate retinal images from each eye. Many creators focus on 3D effects such as depth sensation and naturalness in the entertainment industry. However, it is necessary for creators to consider an observer's visual fatigue while viewing 3D content. Because of this, a 3D workflow is longer than a 2D one. The main cause of visual fatigue is considered as unnatural conflicts between convergence and accommodation that can affect the ability to fuse binocular images. In addition, if an observer watches 3D content under different forms of display (mobile phone, television, home theater, etc), this factor then also influences the parallax problem. Depth sensation and maximum parallax is not only influenced by the amount of shift between the left and right (LR) images, but it is also changed by screen size and viewing distance.

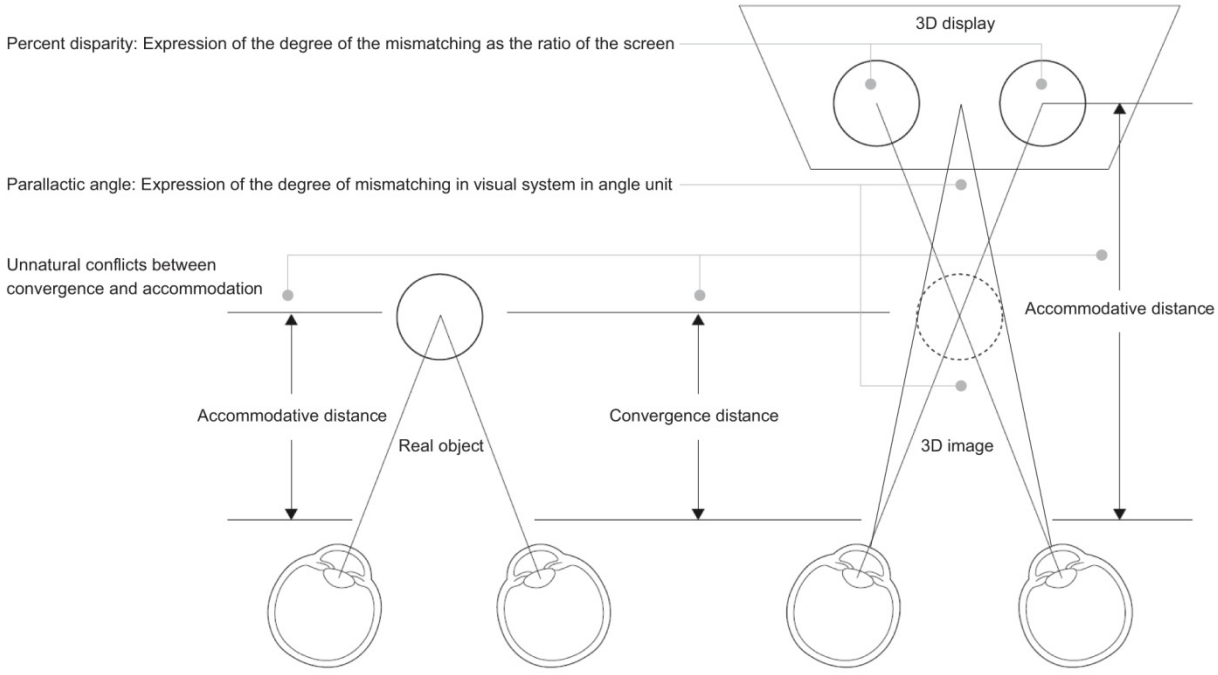

Figure 1 Unnatural conflicts between convergence and accommodation and the expressions

Although the creators are required to make 3D content suit the specific viewing conditions, it is difficult to understand the systematic theory of parallax. Therefore, the creators should ascertain the depth sensation to replay the 3D images or to rely on past experience in order to verify the appropriate parallax amount. For example, the researcher used experiments to define the depth sensation based on a parallax angle by considering the viewing conditions. Experimental results are difficult to apply this method to production field because the creators have often checked to depth sensation as amount of pixel shift or a percentage of the screen from LR images (Figure 1).

The creators must consider two aspects including safety for preventing visual fatigue and comfort by providing proper depth sensation in 3D content. The authors developed a support system so the users can take advantage of ergonomic research results on the 3D images. This system can visualize binocular parallax by evaluating 3D content in accordance with the end user's viewing conditions. This paper describes the experimental development and the main functions of this system. Even the novice creators can easily use it to set the proper parallax for producing safe and comfortable 3D content.

2. Past related researches

2.1 Ergonomic evaluation system [1]

The authors examined a method to evaluate 3D content using stereo matching to extract the parallax distribution from LR images. Based on the reference of parallactic angles obtained from psychological experiments, the authors developed a prototype system for evaluating the viewing safety and comfort of 3D content. The system provided the thresholds for defining the safe parallax range in the cross and parallel directions corresponding to the viewing conditions. Creators not only became easy to apply the related knowledge and accumulated data to the field of 3D production, but also were able to propose a new flow called ergonomic evaluations in the stage of 3D production.

2.2 Scalable conversion system [2]

The authors examined scalable 3D image conversion method and developed a prototype system based on the above mentioned evaluation system. Parallactic angle and depth sensation in 3D content are affected by viewing distance and screen size as well as the LR offset. The amount of parallax and visual load increase with shorter viewing distance or larger screen size, even if the LR offset is fixed. In order to respond to this situation, it was necessary to correct the offset value for different viewing conditions by applying the algorithms of the evaluation system. The scalable conversion system aimed to evaluate and correct the amount of parallax corresponding to the various viewing conditions for viewing safety and comfort. The authors examined the effectiveness of the prototype in the case of the screen size expansion. Concept of scalable conversion is shown in Figure 2.

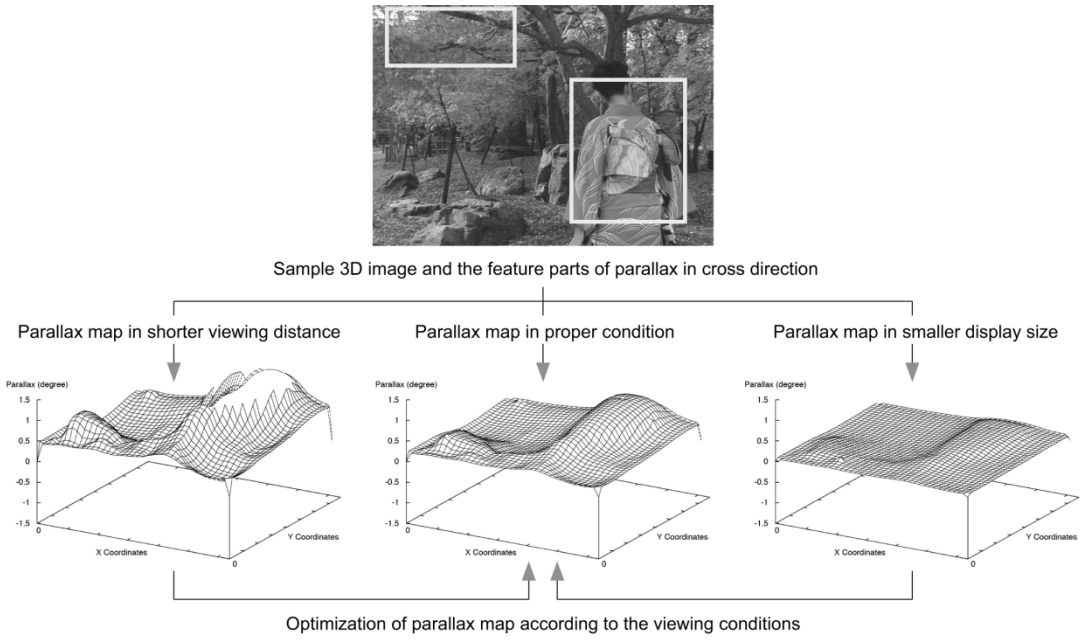

Figure 2 Concept of scalable 3D image conversion

2.3 Creator-friendly 3D camera system [3]

The camera parameter settings must correspond to viewing conditions for suitable depth sensation before filming 3D images. Such a complex process could cause a usability problem for the creators. The authors focused on improving the usability in shooting 3D content, constructed an experimental camera system, and examined semi-automatic camera configuration function with focus on viewing safety. In the prototype camera system, the authors applied two functions for camera control. One evaluates the viewing safety of 3D content using above mentioned past works. The other corrects the camera parameters based on the evaluation results. Specifically, the parallax amount and shift amount of each pixel when replaying image were calculated corresponding to the viewing environment defined by the creators. This system extracts the maximum parallax amounts in the cross and parallel directions and collates them with the safety thresholds through image processing. The correction function sets the camera filming conditions to keep the parallax amounts within the thresholds. The flowchart of the functions is shown in Figure 3.

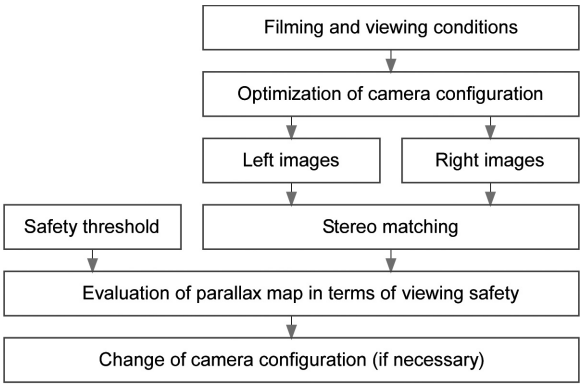

Figure 3 Flowchart of developed 3D camera system

3. Development of 'DepthChecker'

When producing and presenting 3D content, it is important to consider various factors: excessive or poor parallax from inter-camera distance, screen size and viewing distance, etc. It is necessary to incorporate them into the production flow for reducing of the creators' workload. Therefore, the authors developed an ergonomic evaluation system named 'DepthChecker' that enables the creators to evaluate and optimize 3D content for various viewing conditions. This system has a function to collate the results of image processing to the predetermined parameters and to visualize the parallax distribution with a color depth map. From a hardware perspective, this system consists of a set-top box and a controller.

The creators input a video signal from a 3D camera to the set-top box that performs the image analysis of LR offset using high-speed stereo matching (block matching). The input signal is compatible to three 3D formats: separated LR images from dual input, side by side, and top and bottom from single input. The output signal is also compatible to three 3D formats: line by line (interleave), side by side, top and bottom. The creators can operate the jog dial to select the functions: PREVIEW, HORIZONTAL, VERTICAL, SUPER on the controller while watching the monitor. The creators can select a proper 3D image format for a 3D display device using the PREVIEW function. The HORIZONTAL and VERTICAL functions operated to evaluate the horizontal and vertical disparity in 3D content. Evaluated result of horizontal disparity can also be superimposed on live images on the screen by the SUPER function. These functions enable the creators to compare the depth sensation instinctively felt by the user with the objective result evaluated by the parallax amount.

Figure 4 'DepthChecker' system layout

Figure 5 'DepthChecker' controller

When analyzing the horizontal parallax, the creators select each parameter specified by the operator on the operation board and pass it to the internal calculation engine for reflecting it on the evaluation video. The creators set the viewing distance and screen size by

considering the end user's viewing conditions. Then the creators specify the allowable range of positive (in the front direction) and negative (in the back direction) parallax amounts. Then the result of evaluated parallax distribution is displayed as a mixed color with a 7-step gradient from blue color (positive parallax) to red color (negative parallax) in real-time by considering the viewing conditions. The visualized depth sensation enables the creators to intuitively grasp the deviation range from the allowable degree of parallax in accordance with various camera shooting environments. Furthermore, the creators can set the exclusion threshold values in the measurement by specifying the percentile to control the measurement range of pixels from all the pixels of image.

The DepthChecker offer an intuitive user-interface with properly designed menus. All the jog dials on the controller are always controllable and have an immediate reaction on the screen. Therefore, the creators are easy to understand the functions of the system for evaluating the depth sensation. In addition, the authors developed the functions for data logging and a log viewer for easily grasping the evaluation result of depth sensation in order to accumulate the effective data for safe and comfortable 3D content. The data logging items include displaying the maximum parallax amounts in the cross and parallel directions, and the whole parallax distribution in time series inside a video.

Figure 6 Screen shot of 'DepthChecker'

4. Summary

In this paper, the authors introduced the development of the DepthChecker that evaluate and assist in adjusting depth sensation based on the authors' past researches. The authors applied a creator-friendly design to the interface of DepthChecker using ergonomic approach. This system is expected to effectively use in the following fields;

- Optimization of parallax distributions in 3D filming
- Evaluation of parallax in editing and distributing 3D content
- Training for stereographers in 3D content production

For future tasks, the authors will examine the relation between the depth sensation and representation, such as storytelling by considering the 3D effects, and the feedback to the production process utilizing the functions of the DepthChecker.

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