A Depth Adaptation System Based on Perceptual Horopter Effect

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***Abstract*—This paper presented a depth adaptation system. At first, the proposed method uses saliency detection algorithm to determine visual attention, and then it applies depth shifting to reduce convergence and accommodation conflict. We also took human perceptual effect into consideration, and proposed an iso-perceptual disparity curve for horopter remapping. By using subjective tests, subjects are asked to score overall preference and comfortable feelings on the stereo images.**

Keywords-component; depth adaptation, disparity shifting, perceptual horopter.

I. INTRODUCTION

3DTV technology has matured and became part of consumer products in resent year. People can enjoy 3D experience not only in the movie theaters or in the theme parks, but also at home or even on mobile devices. 3D content may still cause discomfort after a long time watching. These algorithms may still cause artifacts such as making people feel dizzy while watching 3D content, have excessive rendering range, or even feel much more fatigue compare to ordinary 2D viewing. Therefore, remapping algorithm recently receive considerable attention, Lang et al. [1] proposed non-linear disparity mapping operators to alter perceived scene depth, which was necessary for content adaption to different viewing geometries. Hanje Park [2] proposed an efficient 3D adjustment method of an object in a pair of stereo images by utilizing a planar approximation in the 3D space, and therefore improves the overall quality. While our works focus on convergence-accommodation confliction and human perceptual horopter, both aimed to reduce fatigue and enhance 3D effect. The paper is organized as follows. Section II describes the proposed algorithm. In section III, we set up an experiment to evaluate subjective views. Section IV provides the conclusion and future work.

II. PROPOSED METHOD

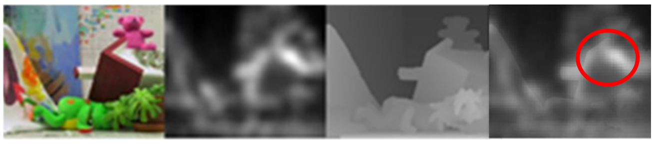
The proposed method takes visual attention and viewing eccentricity as input. By considering the geometry of viewing condition and comfortable zone effect, we can adjust depth map for specific viewer position to enhance 3D experience and reduce visual fatigue. The detail of proposed depth adaptation system is explained in following sections.

A. Saliency Map

We proposed depth adaptation method based on saliency detection algorithm, so system can apply depth shifting and depth scaling on the region where people may focus on. The conventional saliency map in based on J Harel's method[3], however we should also concern the effect that near objects may draw more attention.

$$s_o = k \times s_d + (1-k) \times s_c \qquad (1)$$

where S_d is the depth map, and S_c is the saliency map. By combining these two map with coefficient *k*, we can get the overall stereo saliency map S_o. The final combined saliency map is in Fig.1.



(a) (b) (c) (d)

Figure 1. (a) Color image. (b) Saliency map by Harel's method. (c) Depth map by stereo matching. (d) weighted result of (b) and (c), and the red circle implies region for shifting.

B. Depth Shifting

As in Chang's work [4], they applied disparity shifting in order to move all the disparities into the comfortable zone. Different to their work, we apply disparity shifting in order to move high saliency object to zero disparity. Therefore can reduce discomfort cause by convergence and accommodation confliction. The shifting algorithm, is according to relation between perceived depth and disparity,

$$Z = \frac{e \times D}{e-d}, \qquad (2)$$

$$d_{ad} = e - \frac{(e-d_{ori}) \times (e-d_s)}{d_{ori} - d_s}, \qquad (3)$$

where *Z* is the perceived depth, and e is the interocular distance which is usually 6.5cm. *D* is the viewing distance and *d* is the disparity. We maintain the order of perceived depth to be constant. Then can get (3) to adjust the new disparity d_{ad} from relation between the original disparity d_{ori} and the disparity of the highest saliency object d_s.

C. Depth scaling by horopter effect

In the third stage, human factor is being concerned that human can discriminate two objects because of parallax, which is defined as the difference of angle on retina rather than the difference of pixels offset. Fig.2 shows the horopter while eyes fixate F, and points on the circle all have the same disparity on retina.

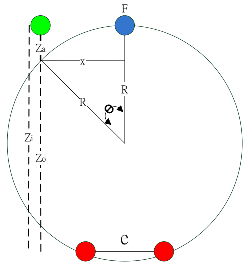


Figure 2. Retinal correspondence. When the eyes fixate F, the theoretical horopter is the Vieth-Muller circle.

Thus from human perception aspect in [5], the iso-perceptual disparity curve is well explained on above as circle rather than a straight line. Conventional works seldom consider this horopter effect due to screen size and viewing distance. If screen size is much smaller than viewing distance, the horopter effect can be neglect.

$$\sin\theta = \frac{x}{R} = \frac{2\times Z_i \times x}{\left(Z_i^{\,2} + \left(\frac{e}{2}\right)^2\right)} \tag{4}$$

$$Z_o = Z_i - (R\times(1-\cos\theta)) \tag{5}$$

where Z_i is the perceived depth which is related to viewing distance. X is the horizontal distance from the center of image, and R is the radius of virtual horopter. We can solve the perceived depth Z_o by equation (4)-(5), and match the iso-disparity curve.

III. Experimental Result

In Fig.3, we show the result of original red-cyan image and our proposed image. Comparing with the original image, our results can be easier to fuse on the predicted regions, which is the bear and the head. In order to evaluate our works, we set up experiments for subjective tests. The subjective tests were conducted on 22" 3D display. And ten observers participated in our experiment, including 3 women and 7 men. We choose viewing distance at 3H, where H represented the height of 3D

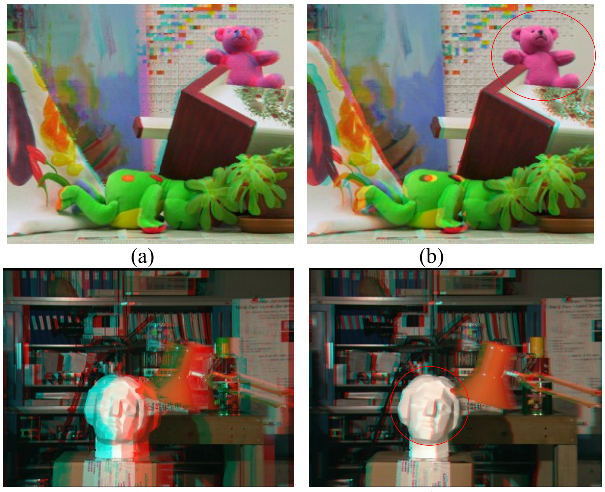


Figure 3. Result of the proposed method. (a)(c) The original red-cyan images. (b)(d) Our result by applying depth shifting and depth scaling.

display, and we adopt ITU 500-1 recommendation [6] to decide the evaluation process. Ten test images including indoor and outdoor scene are shown at random order. The subjects were asked to score both in comfort feelings and overall preference from 1 to 5. Results are depicted in Fig. 4.

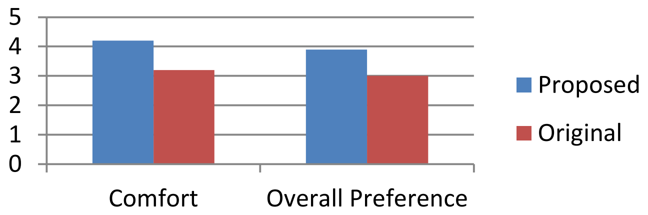
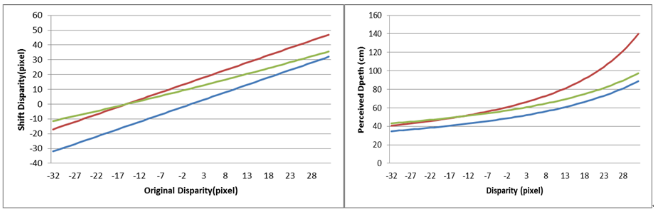


Figure 4. Results of subjective evaluation.



(a) (b)

Figure 5. Depth Shifting Curve (a) X-axis is the original disparity and y-axis is the shifted disparity. (b) X-axis is the original disparity and y-axis is the perceived depth. Blue line is original data. Green line is shifting on perceived depth domain. Red line is shifting on disparity domain.

As depicted in Fig.5, directly shift disparity value (From blue line to red line) can cause nonlinear distortion on perceived depth domain.

IV. Conclusion

This paper proposed a novel depth adaptation system. We first extract depth information from image pair, and adapt saliency detection algorithm to decide region for depth shifting and scaling. Depth shifting is then applied to reduce convergence and accommodation confliction. Whereas depending on viewing distance, the algorithm can remap the iso-perceptual disparity curve to fit geometry model of horopter. The proposed system can produce a more comfortable and reality 3D experience.

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