Disparity Remapping by Nonlinear Perceptual Discrimination

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Abstract

This paper presents a nonlinear disparity remapping processing to adjust the disparity information to be suitable for human visual system. The proposed algorithm is based on psychological experimental result about incremental disparity discrimination. We evaluate the proposed method by subjective-view, and the result shows that our nonlinear disparity remapping not only improves perceptual feeling, but also provides a much more comfortable viewing experience.

Keywords--- Stereo perception, Disparity remapping, visual comfortable.

1. Introduction

With 3D technology development, people get more chance to have 3D vision. In recently years, many researchers have pay attention on stereoscopic 3D reconstruction. Such works involve stereo matching to generate depth map form two views captured by stereo camera. Also some works focus on 2D/3D conversion, these algorithm generate depth map by estimating monocular cues from 2D image[1]. Depth-image-based rendering (DIBR)[2] adapt color image and depth map to synthesis two views or multi-views on 3D display. Human can therefore enjoy 3D video in the theater or at home. But few of them discuss the interaction with human visual system. There could be some health issues occurring. People may feel dizzy after watching a long term 3D movie or have the problem to discriminate depth accurately. These phenomenon raise a new issue between stereoscopic and human visual system. Therefore, adjusting disparity information to provide more comfortable 3D vision becomes an important issue. The capabilities of our visual system and depth perception have been the topic of some research in human visual system[3]. And algorithms are addressed to solved these annoying effect when viewing stereo image. Disparity remapping would be a solution for comfortable 3D content. Before applying DIBR to acquire two view image on 3D display, 3D content are presented in one color image plus disparity information. Therefore some research considered the viewing distance, viewing angle and other parameter that related to human 3D perception. And these works proposed operator or algorithm on disparity post-processing. A depth map reallocation method for improving 3D effect [4] consider boarder effect, regions next to screen borders are hard to be protruded even with considerable negative parallax. Disparity remapping algorithm recently receive considerable attention: Lang et al. [5] proposed non-linear disparity mapping operators to alter perceived scene depth, necessary for content adaption to different viewing geometries. We propose an exponential function to adjust information for nonlinear remapping in the followings.

Section 2 describes the psychological result and pro-posed method. The experimental setup and results are de-scribed in Section 3. In Section 4 discussion of nonlinear remapping and the future direction are given from the pro-posed algorithm and compare the result. Finally, we conclude this paper in Section 5.

2. Author guidelines

Different from real world stereo vision, 3D display has its limitation due to confliction between accommodation and convergence. This confliction may cause user with fatigue and uncomfortable viewing experience. Therefore the entire depth range should remain in comfortable zone. Based on this idea, we proposed a method to efficiency arrange depth map in the restricted range. The algorithm is to enhance stereo acuity by adjusting gray scale of disparity map. Ste-reo acuity is measured as increment depth discrimination in psychological experiments. The increment depth discrimination function relates the ability to recognize changes in relative depth between two stereoscopic targets as a function of their distance from the horopter. From the result in [6], our ability to discriminate disparity is as an exponential function of disparity pedestal. This means that our depth perception is more sensitive and accurate on the display plane, while it decreases as objects move away the display plane. Therefore, in the region that is far from display plane, steps between disparities were enhanced. Whereas in the region that is near the display plan, difference of disparities was compressed. According to human incremental depth discrimination function, the algorithm change original disparity property as linear distributed to exponential distributed. The idea is similar to gamma correction in color image. But here we use this concept on disparity map, the original disparity will be enhance or reduce according to its intensity. The new disparity map value O(x,y) are adjusted from the original depth map D(x,y) by the following equation:

$$O(x,y)=\begin{cases} 255\times\left(1-\left(\dfrac{D_{\max}-D(x,y)}{D_{\max}-D_{\min}}\right)^{\gamma}\right) & if\ D(x,y)>128 \\ 255\times\left(\dfrac{D(x,y)-D_{\min}}{D_{\max}-D_{\min}}\right)^{\gamma} & \text{others} \end{cases}, \quad (1)$$

where γ satisfies the following equation, i.e.

$$\gamma = k^{\frac{|D_{avg}-D(x,y)|}{D_{avg}}}, \quad (2)$$

where D_{max} and D_{min} are the maximum and minimum of original depth map. D_{avg} is average of D_{max} and D_{min}. Thus, if D(x,y) is greater than average, corre-sponding to near side pixels in the original disparity map, will give rise to exponents smaller than 1. Therefore, inversely with intensity 255, an increase of the disparity step will be observed. While D(x,y) is smaller than 128, corresponding to pixels with far side pixels in the original disparity map, will result in exponents smaller than 1 and a decrease of the disparity. For D(x,y) equal to average will produce an exponent equal to one, and no modification of the original input is obtained. The greater the distance from the disparity mean value, the stronger the enhancement. Figure 1 is the result of our pro-posed algorithm, and the original disparity map was artificial assignment. The adjusted disparity map is as expected to reduce the difference of disparity around intensity at 128, and also to enhance detail of near side object. After applying nonlinear remapping, color image and disparity map are synthesized by DIBR. Figure 2 shows the new matching curve. X axis are the original disparity and Y axis is adjusted disparity. The curve has sharp slop both on the high and low disparity intensity. Thus enhance disparity change on the near and far side.

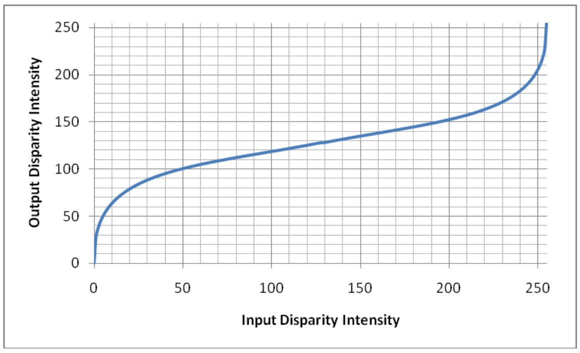
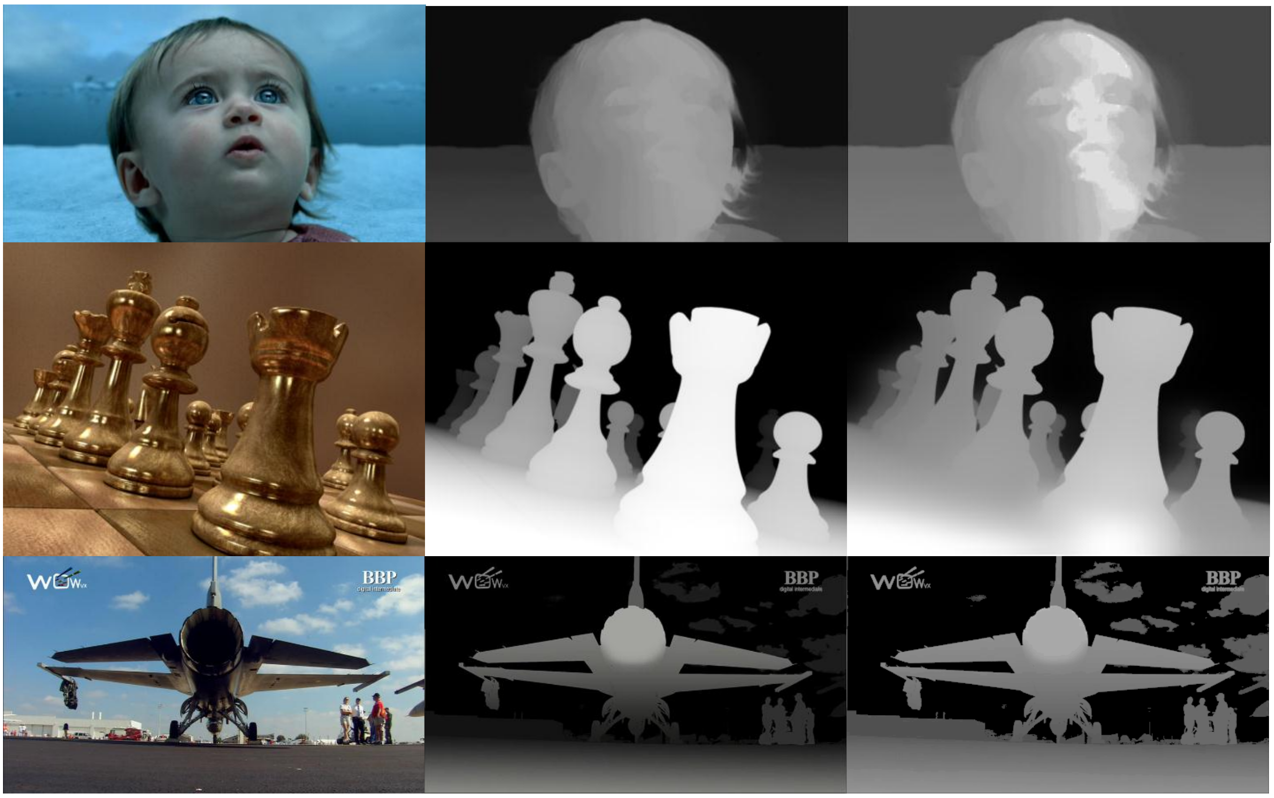


Figure 2. Matching curve of proposed algorithm X axis are the original disparity intensity, Y axis is the disparity after remapping.



(a) (b) (c)

Figure 1. The result of nonlinear disparity remapping. (a) Original 2D image (b) Original disparity map (c) Proposed disparity map. The first row is Data1; the second row is Data2; the last row is Data3 in the experiment.

Table I. PROPERTY OF THE 3D DISPLAYS USED IN OUR TEST

Type	Samsung 2233RZ	ViewSonic PJD6381
Size	22''	80''
Resolution	1680x1050	1024x768
Glasses	NVDIA GeForce 3D Vision Glasses	NVDIA GeForce 3D Vision Glasses
Viewing Distance	75cm	300cm

3. Experimental Result

In order to evaluate performance of the proposed method, we set up an experiment for 3D comfortable feelings. By wearing NVIDIA shutter glasses at the viewing distance of 75cm and 300cm, subjects are asked to score the stereo perception in viewing comfort and protruded effect. (Score 5 is the best and score 1 is the worst)

(a) (b)

Figure 3. Display used in the experiment.(a) Samsung 2233RZ (b) ViewSonic PJD6381

A. Instrument

We utilize 3D display with NVIDIA shutter glasses, We set up the experiment at viewing distance at 75cm and 300cm, comparing algorithm in different condition. At viewing distance of 75cm, we utilize 3D display. While at viewing distance of 300cm, ViewSonic Projector 6381 were set up for the experiment. The detail of these two type display are list in Table I.

B. Subjects

The eight subjects are divided into two groups: Engineers are composed with people who have skill in develop algorithm; Naïve viewers are composed with people who have no specialist in 3D perception field.

C. Experimental process

i. Preparing experimental data.

We prepare three types of image with depth map generated by handmade and 2D/3D conversion. The color images are composed with indoor scene and outdoor scene. This is to compare the algorithm under different scene model.

ii. Apply remapping algorithm.

According to the proposed method, we adjust disparity map by adapting nonlinear remapping.

iii. DIBR generate two views.

By considering viewing distance, we use DIBR to synthesis two views where pixels remain in the comfortable zone.

iv. Evaluating 3D quality

The participants watched the three types of color image with their original and proposed disparity map in the random order. They were asked to rate each image in two factors, visual comfort and protrude effect.

Table I I. AVERAGE GRADES OF ORIGINAL AND PROPOSED METHOD WITH SAMSUNG 22233RZ

	Viewing Experience	Original Image	Proposed Method
Data1	Comfortable	2.75	4.125
	Protruded Effect	3.25	4.375
Data2	Comfortable	3	4.375
	Protruded Effect	3.625	4.25
Date3	Comfortable	3.125	2.875
	Protruded Effect	3.25	3.125

4. Result and Discussion

Table II and table III are the average grades comparing original image and proposed method. Data 1 and data 2 are regarded as indoor image, where data 3 represented outdoor image. Result shows that nonlinear depth remapping provides better 3D experience in visual comfort and with higher protruded effect. Also from table II shows that the proposed method is more effective on indoor image than outdoor image. The average grade on data1 and data2 are higher than data3. By asking subjects feeling, it seems that the proposed algorithm utilize exponential mapping to enhance difference disparity between objects, especially for near side objects.

Comparing result in table II and table III, that means at viewing distance 75cm with Samsung 3D display and 300cm with ViewSonic 3D projector. The proposed method get better performance in 22'' display, this could be the fact that the algorithm did take display size and resolution into account. Therefor the remapping mechanism is not well tuned for 80'' projection screen, and viewers could not experience as well visual improvement as in 22'' display did. For the future work, we will modified algorithm to change matching curve both considering viewing distance and screen size.

Table III. AVERAGE GRADES OF ORIGINAL AND PROPOSED METHOD WITH VIEWSONICE PROJECTOR

	Viewing Experience	Original Image	Proposed Method
Data1	Comfortable	3	4.25
	Protruded Effect	3	4
Data2	Comfortable	2.875	4
	Protruded Effect	3.375	4
Date3	Comfortable	3.375	3
	Protruded Effect	3.25	3.75

5. Conclusions

In this paper, we propose a novel method to compensate nonlinear effect on stereo perception. This algorithm increases disparity steps, both on the near and the far side. The result shows that this work increases 3D feeling both on the foreground and the background objects, and also decreases the uncomfortable feelings. In future, we will extend this work to 3D video source and consider other factors between disparity map and stereo perception.

References

[1] Chao-Chung Cheng, Chung-Te Li, and Liang-Gee Chen, "An Ultra-Low-Cost 2D-to-3D Conversion System," *International Symposium, Seminar, and Exhibition of Society For Information Display(SID)*, Display Week 2010.

[2] W.-Y. Chen, Y.-L. Chang, and L.-G. Chen, "Real-time depth image based rendering hardware accelerator for advanced three dimensional television system," IEEE Intl. Conf. Multimedia and Expo., 2006.

[3] Howard, I. P., and Rogers, B. J. 2002. Seeing in Depth. Oxford University Press, New York, USA.

[4] Chung-Wei Lin, Wen-Chao Chen, Hong-Tu Yu, An-Chun Luo and Fang-Hsuan Cheng "A Depth Map Reallocation Method for Improving 3D Effect" IDMC.3DSA.ASIA .DISPLAY"10, P75-78, April 2010.

[5] Lang, M., Hornung, A., Wang, O., Poulakos, S., Smolic, A.,and Gross, M. 2010. Nonlinear disparity mapping for stereoscopic 3d.ACM Trans. on Graphics 29, 3, 75:1–75:10.

[6] J. Siderov and R. S. Harwerth, "Precision of stereoscopic depth perception from double images," Vision Res. 33, 1553–1560~1993.

[7] http://www.business-sites.philips.com/sites/philipsbs/3dsolutions/