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Potential Effects of Dynamic Parallax on Eyesight in Virtual Reality System

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Abstract

Virtual desktop office and VR theater become popular. Using HMD at high frequencies and for a long time has become an indispensable requirement. Whether this will affect the user's eyesight is one of the major concerns. This paper presents an investigation of a dynamically changed parallax for 2D content in VR systems and potential effects on eyesight. By controlling the horizontal movement of the left and right views, parallax is continuously and slowly adjusted within comfort zone. This can alleviate the static fixation of the eyes to the fixed distance of the display, relieving visual discomfort and reducing the degree of visual impairment. The experimental results show that dynamic parallax can alleviate the visual discomfort of watching videos in HMD and reduce the potential adverse effects on eyesight to some extent. Moreover, the uniform variation parallax has a better effect than the jump parallax.

Index Terms: General and reference—Cross-computing tools and techniques—Evaluation; Computing methodologies—Computer graphics—Graphics systems and interfaces—Virtual reality;

1 Introduction

In recent years, virtual office and VR theater become popular [1, 2]. Users can enjoy large screens and work and play games in VR. Therefore, using HMD at high frequencies and for a long time has become an indispensable requirement. However, the accommodation and the convergence often are mismatch, resulting in visual fatigue. Therefore, how to alleviate the visual discomfort and reduce the adverse effects on eyesight is an important research topic.

Many researchers have proposed different methods to alleviate the visual fatigue. The most effective way is to control the parallax in stereoscopic displays [3]. Disparity remapping [4,5] and disparity shifting [6, 7] were proposed to manipulating the binocular disparity. Another common method to decrease visual fatigue is to use depth-of-field (DOF) blurring [8, 9]. We proposed a novel method which continually changed the parallax of the screen to adjust the convergence. Correspondingly, the ciliary muscles constantly are exercised. If the parallax changes within the comfort zone, and the speed is small enough to not produce additional negative influence, this method can reduce visual discomfort. Some studies have shown that dynamic parallax can affect visual fatigue during using 3D display devices [10]. However, no one has used dynamic parallax to alleviate visual fatigue.

To change the parallax of the image, some researchers apply a horizontal image translation to increase the overall 3D quality of experience, which shifts horizontally the left and right views of the original stereo pair in traditional 3D displays [11, 12]. Our approach is similar to theirs. We used two screen objects to provide images for the left and right eyes respectively and horizontally shifted them in HMD. Different moving direction and speed would make the parallax changing in different ways. We designed the experiments to study the effectiveness of dynamic parallax in relieving visual discomfort. We also explored the different effects of parallax changes in uniform and in jump.

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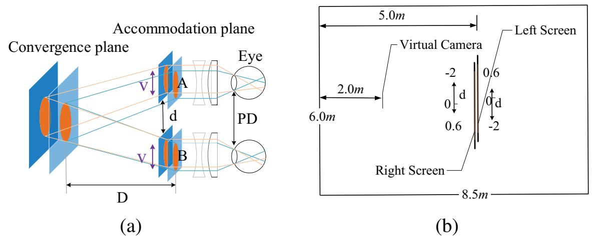

Figure 1: (a) Parallax change principle. (b) Virtual room layout.

2 Methods

2.1 System Design

We use two screens objects to display images for the left and right eyes respectively (see Fig. 1(a)). We assume that the center of the field of view on the accommodation plane is point A. In the crossed disparity state, the screen position of the right eye seeing is at the left of the point A, and the screen position of the left eye seeing is at the right of the point A. It is contrary in the uncrossed disparity state. According to this theory, the size of the two screens objects and the video content played are exactly the same.

We need to strictly set the speed and range that parallax moves. Not only is the range of parallax large enough to allow the lens to move significantly, but also the parallax is always within the comfort zone. Studies have shown that the comfort zone of parallax is $\pm 1^{\circ}$ [13, 14]. Changing speed might play a more crucial role in visual comfort than parallax magnitude [10]. We conducted a simple pre-experiment to find a suitable range and speed. Finally, we set the parallax magnitude to $(-0.76^{\circ}, 0.23^{\circ})$, corresponding to the left and right screen moving range to $(-2cm, 0.6cm)$ in Unity3D (The positive directions of the left and right screens are left and right respectively) and set the speed to $0.01cm/s$ (see Fig. 1(b)).

We use Unity3D to build a virtual room (see Fig. 1(b)). The virtual room size is $6m \times 8.5m \times 4m$. There are two screen objects in the room with the size of $2.76m \times 1.55m$ (16 : 9 aspect ratio), which provide images for the left and right eyes respectively. Both screens are at $3m$ away from the camera, which is the focal plane of HMD. The angle of view maintains 45° to ensure minimal visual discomfort. The system has three parallax settings: static parallax (SP), uniform parallax (UP) and jump parallax (JP). In the SP group, the two screens are coincident and located at the center of the visual field of the virtual camera. which is zero disparity location. In UP

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and JP groups, the two screens move from zero disparity to the left and right in the opposite direction with the same speed. The speed in UP is $0.01cm/s$ and the speed in JP is set to $0.05cm$ every 5 seconds to ensure that the parallax change distance is as same as UP group.

2.2 Experiments

We designed a within-subject experiments to verify the effectiveness of dynamic parallax. Subjects watched the virtual screen in a virtual room for one hour. All subjects performed 3 groups in the same order (SP, JP, UP) for 3 consecutive days. We used three different phases of the "National Treasure" documentary with a resolution of 1920×1080 as the experimental videos. The HTC VIVE was used for virtual reality equipment.

Twenty subjects (11 males and 9 females, 20-25 years old), mostly recruited from universities participated in the experiment. Their myopia, hyperopia, and astigmatism are less than 4.00 diopters, 2.00 diopters, and 1.50 diopters respectively. All subjects provided the written informed consent before the experiments and they did not know the purpose of the experiments.

Before and after the experiment, the subjects' eyesight was measured both subjectively and objectively. Subjective measurements included Visual fatigue Scale (VFS) [15] and Simulator Sickness Questionnaire (SSQ) [16]. Objective measurements included visual acuity (VA) and pupil diameter (PD). PD was measured using a refractometer (Nidek CO. LTD. W. ARK-1s) and VA was measured using a vision acuity chart (Nidek CO. LTD. W. SSC- 370).

3 Results

In the experiment, we obtained the changes in score between pre- and post-watching in each group. For VFS, SSQ, and VA, the Friedman test was used for statistical analysis because they are ordered variables. For the PD, the general linear model (GLM) method was used because they are normal variables [17].

For the VFS, it was found that dynamic parallax could effectively alleviate eye strain ($\chi^2(2) = 10.145, p = 0.006 < 0.05$) and nausea symptoms ($\chi^2(2) = 6.125, p = 0.047 < 0.05$). And uniform parallax was more significant for relief. For the SSQ, there were progressively significant differences in nausea ($\chi^2(2) = 15.571, p = 0.000 < 0.05$), disorientation ($\chi^2(2) = 7.542, p = 0.023 < 0.05$), and overall motion sickness ($\chi^2(2) = 11.065, p = 0.004 < 0.05$) among the three groups. The level of visual discomfort in the UP group is the lowest. The JP group took the second place. According to the results of visual acuity and pupil diameter, although there was no significant difference among the three groups, the uniform parallax had a tendency to reduce the degree of the visual impairment.

4 Conclusion

This paper proposes a method for dynamically adjusting parallax to reduce the adverse effects of using HMDs on eyesight. By controlling the movement of the left and right views, the parallax is adjusted. We conducted the experiment to verify its effectiveness. Subjective and objective results show that dynamic parallax can mitigate the visual discomfort of watching videos in HMD. And the uniform parallax has a better effect than jump parallax. This method can be applied in many fields in the future such as VR cinema and VR office that require long-term immersion or high-frequency use. We think that the conclusions remain valid in the case of watching a standard stereoscopic screen. But further experiments are needed to confirm this. In the future, we also need to explore more suitable dynamic parallax parameters to achieve better effects in relieving visual discomfort.

A limitation in our study is that all subjects performed the experiment in the same order. The influence of human adaptability on the results cannot be excluded. However, if the effect of relieving visual discomfort is due to human adaptability, we can infer that using HMDs at high frequencies will produce adaptability and not adversely affect eyesight.

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