Automatic Convergence Adjustment for Stereoscopy using Eye Tracking

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Abstract

When using stereoscopic displays, decoupling between convergence and accommodation can cause eyestrain. This paper proposes an adjustment method to automatically fit convergence at user fixation depth to accommodation by using eye tracking. Two different adjustment methods are proposed: one binocular, adjusting the images for both eyes, and one monocular, which adjusts only the image for the non-dominant eye. Preliminary results suggest better user comfort and a preference for binocular adjustment in high adjustment scenarios, while the adjustment is less noticeable with the monocular system.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1. Introduction

Recent years have seen an increase in the use of stereoscopic displays for movies and computer monitors, as technology has improved their image and color quality. There is a possibility for some visual discomfort in these systems, especially with longer use, mainly due to a decoupling of the convergence and accommodation demands [LIH07]. This happens when focusing on an object in a 3D-scene that appears in front of or behind the screen, which requires convergence at the object's depth while accommodation should remain at screen depth.

[PHTL01] suggested an approach to avoid this decoupling by changing the disparity of all objects to give the fixated object zero disparity. This approach would require tracking eye movement, which might be the reason why this method has not been implemented so far. [PHTL01] did, however, implement and test the system with a predefined fixation point.

This paper presents an implementation of the approach and a preliminary evaluation of how well it functions in real time with an eye tracking system actively determining user fixation. To this end, two methods of convergence adjustment are proposed, one binocular, adjusting convergence by changing the images for both eyes, and one monocular, adjusting convergence by changing the image for the user's non-dominant eye only. While changing only the image of a single eye will obviously result in a larger shift in that image, this shift is hypothesized to be less noticeable to the non-dominant eye.

Because of the need for a stereoscopic display allowing simultaneous eye tracking, an nVisor SX111 HMD with a binocular Arrington Research eye tracker is used. While the proposed adjustment methods are based on this setup, the same principles should also be applicable to single-screen stereoscopic displays.

To reduce the effect of erroneous fixation points and to make changes less noticeable, a moving exponential average of the fixation depth is used for the adjustment.

2. Convergence Adjustment Methods

This section presents our method for adjusting convergence with an HMD with optics focused at infinity. The method allows for arbitrarily positioned screens.

For an object to appear infinitely far away with regards to convergence, the user will need to have parallel view directions towards it. Thus, the goal of the adjustment would be to make the gaze directions towards the projection of a scene point located at the convergence depth appear parallel (see Figure 1 and 2). To simplify, only convergence depth is considered.

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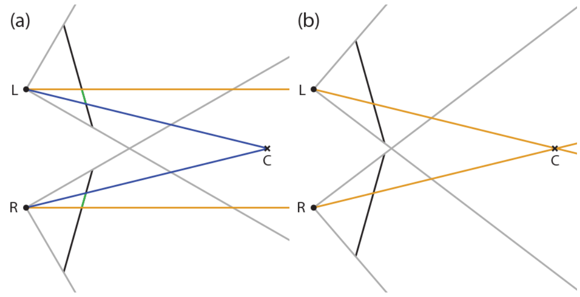

Figure 1: *The binocular adjustment method. (a): Before adjustment. The projection planes here match the physical setup of the HMD. The orange, parallel rays show the desired gaze direction. The green segment of the projection plane shows the offset necessary to shift the rays. (b): After adjustment. Because of the offset, the desired gaze directions have been shifted to intersect at C.*

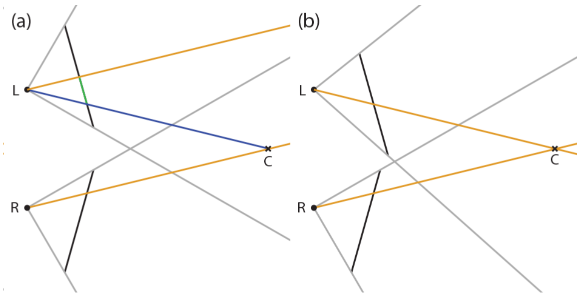

Figure 2: *The monocular adjustment method. (a): Before adjustment. Like the binocular method, except the desired gaze directions now follow the direction from the dominant eye, R, to C. (b): After adjustment. The image for the non-dominant eye (here left) is shifted, so both virtual gaze directions again intersect in C.*

The amount a screen has to be displaced is given by the difference between where two rays intersect the projection plane. The first ray extends from the camera to the convergence point. The second ray is the desired apparent gaze direction from the camera. The displacements are illustrated as green lines in Figures 1 and 2.

For binocular adjustment, the desired gaze direction is the forward direction from the cameras (as shown in Figure 1a). For monocular adjustment, the non-dominant eye is adjusted to the direction from the dominant eye to the convergence point (as shown in Figure 2a). The effect of the binocular adjustment is shown in Figure 3.

3. Results

In a preliminary test, four of five participants preferred viewing the scene with the adjustment systems.

Figure 3: *The adjustment system in effect. Top: An unadjusted setup, matching the physical HMD. Bottom: Both eyes adjusted. The direction from each eye towards the hummingbird would appear parallel.*

Participants generally found the monocular adjustment less noticeable for small to medium changes, while changes to very close objects led to situations where participants converged before the adjustment was in full effect, forcing the participant to shift their eyes again. While the binocular system was slightly more noticeable overall, it did not have this problem.

4. Conclusion

The convergence adjustment system has been implemented for both the monocular and binocular version and tested in an informal experiment. The system functions as expected in a test scene, but presents problems with large changes in adjustment.

A formal experiment conducted on non-affiliated participants would be neccessary to verify the effectiveness of the system, but preliminary results are positive. It could be relevant to examine how the adjustment affects the depth and size perception of participants as well as the comfortability of the system.

References

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