Acceptable System Latency for Gaze-Dependent Level of Detail Rendering

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Abstract

Human visual system is unable to perceive all details in the entire field of view. High frequency features are noticeable only at a small angle of 1-2 degrees around the viewing direction. Therefore, it is a reasonable idea to render the coarser object representations for the parafoveal and peripheral visions. A core problem of this gaze-dependent level-of-detail rendering is minimisation of the system latency. In this work we measure how fast should be the whole process of rendering and visualisation to prevent that level-of-detail change will be visible for human observers. We measured in the pilot experiment that even for distant periphery, the change from coarser to fine object representation should take less than 28 ms.

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.6]: Methodology and Techniques—

1. Introduction

A goal of the *level-of-detail* (LOD) technique [Cla76] is quick change between coarse and fine representation of the object geometry. As the human visual system (HVS) is unable to perceive all details in the entire field of view but only at a small angle of 1-2 degrees around the viewing direction, it is a reasonable idea to render the coarser object representations for the parafoveal and peripheral visions. In this gaze-contingent graphics systems, the angular distance between momentary gaze location and position of the object in the screen space, will be a determinant of the model simplification.

A core problem with the implementation of such system is minimisation of the *system latency*. The gaze direction must be captured by the eye tracker, image must be rendered, and finally the display device needs some time to present an image on the screen. If the total processing time would be too long, the observer could see the object changes between coarse and fine representation.

In this work we investigate how short should be the system latency to make LOD modifications imperceptible to human observers. We perform a perceptual experiment, in which visibility of LOD change for various angular distances from the gaze direction and for different system latency is investigated.

2. Gaze-dependent LOD

A gaze-dependent LOD system similar to our implementation has been proposed in [LE97]. The remote monocular eye tracker was used to measure the viewer's real-time gaze location and simplify the object geometries with the eccentricity. In this work we investigate a perception of the LOD change in the real time rendering application. Therefore, we used apparatus and techniques that enable the fastest possible rendering and visualisation of an image.

In our gaze-dependent rendering and visualization system (see Fig. 1), the observer looks on the display. Her/his gaze direction is captured by the eye tracker, which computes the gaze point location on the screen. The graphics engine uses this gaze location to render the scene. The scene contains objects whose complexity depends on the eccentricity. The object close to the gaze point consists of a larger number of triangles than its simplified version seen from a high angle.

3. Experimental evaluation

The main goal of the experiment was to find the acceptable system latency, i.e. how fast the object should be redrawn on the display after changing the LOD level to avoid noticing this change by human observer. The experimental procedure is presented in Fig. 2.

We repeated this procedure for 10°, 20°, and 35° angular distances between initial gaze position and rendered objects. The experiment was performed for a group of 10 volunteer observers. The eye tracker worked at a 60 Hz frequency, i.e. we was able to replace objects not earlier than after 17 ms delay. The rendering has been finished in less than 4 ms. Additional latency derived from the display. We tested the display working at 30 Hz, 60 Hz, 120 Hz, and

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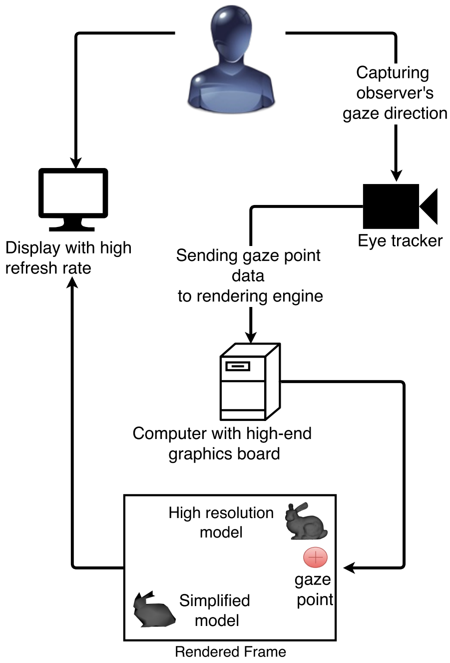

Figure 1: *Diagram of the gaze-dependent rendering system.*

144 Hz refresh rates, which corresponds to the delays of 33 ms, 16 ms, 8 ms, and 7 ms, respectively.

The results of the experiment are presented in Fig. 3. The plot shows the normalised ratio of correct answers as a function of the display frame rate. The ratio of 0.5 (horizontal dashed line in Fig. 3) is equivalent to the random choice, i.e. indicates inability to distinguish between reference and simplified models. In our study only for the display refresh rate of 144 Hz and the angular distance of 35° the results are close to this line. In all other cases the system latency was to long to ensure imperceptible change of the level-of-detail.

4. Conclusions and future work

In this work we conducted an evaluation of the acceptable system latency for the gaze-dependent LOD rendering. Our study included a psychophysical experiment which allowed us to evaluate perception of the LOD change for various system latencies, ranging from 54 to 28 ms, and for different viewing angles. The results of the experiment show that the total system latency in our gaze-contingent system is too long for the imperceptible LOD change. In future work we plan to test faster eye tracker, which captures the gaze location in less than one refresh cycle of the display (less than 7 ms in our case).

Acknowledgements

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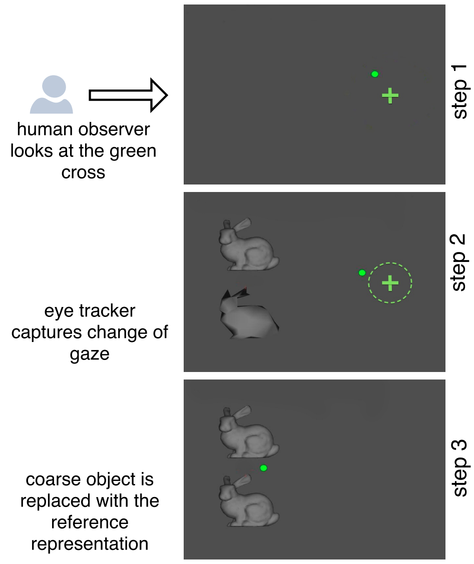

Figure 2: *The green spot depicts the observer's gaze location captured by eye tracker. In the first step, observer looks at the green cross plotted on the grey background. After a second two objects are shown on the left side of the screen: a fine representation of the object geometry and its reduced version with lower number of polygons. The simplified version of the object is replaced with the reference one as soon as the gaze moved away from the initial position. In the third step observer decides, which object is drawn is the coarser version.*

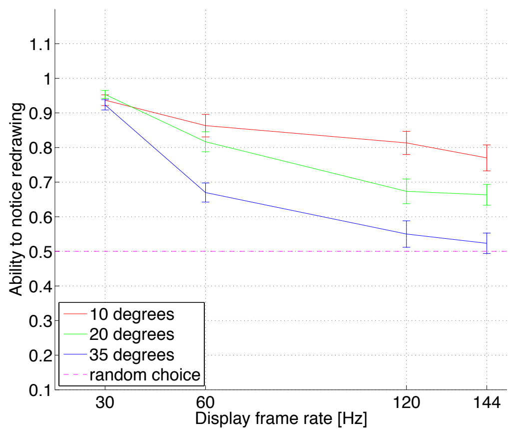

Figure 3: *Results of the perceptual experiment. The error bars show the standard error of the mean.*

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