Jack Boffa
CS 448I
2/13/2018

Simulation of HDR Displays on Standard Displays Using Eye Tracking

Abstract

For a final project, I propose a software system that uses gaze data from an eye tracker to simulate a high dynamic range display on a standard display. Typically, images with a wide range of brightness values must have their intensity values compressed to fit the range of brightness levels a screen can produce. However, such tone mapping is quite noticeable to the user and often fails to look realistic. By leveraging information on where the user is looking, it would be possible to properly expose the image at the center of the user's gaze, while adjusting the rest of the image accordingly.

Motivation

High dynamic range (HDR) is one of the most prominent areas of exploration and development in modern display technology. For many years, advances in screens and projectors focused on increasing resolution. While manufacturers still value HD quality, the craze of cramming ever-increasing numbers of pixels into screens has mostly subsided. This is likely because screens already possess a high enough pixel density that further improvements would barely be noticeable. The greatest remaining gap in realism of displays lies in available levels of contrast and dynamic range.

Although lots of progress has been made in manufacturing HDR displays, the technology is still prohibitively expensive. By emulating the effects of an HDR display in software, it would be possible to provide users a similar experience at only the cost of a standard display plus an eye tracker. Without great expenditure, users could experience digital media such as photography and video games with a much greater level of depth and realism.

Related Work

Many researchers have studied the specific ways in which the eye responds to differing levels of light. Sharpe et al. (2005) published an effective method for estimating the eye's response to specific wavelengths. In an attempt to preserve realism, I may need to reverse any adaptations encoded in existing images or in the monitor. These functions can help me with this [1].

Additionally, I will need to account for the eye's sensitivities under bright light versus low light. This could involve separately modeling photopic vision (bright light in which cone cells dominate) and scotopic vision (dim light in which rod cells dominate). Kalloniatis and Luu (2005) summarize a lot of the research that has been done on the perceptual differences of these methods of vision [2].

Ledda et al. (2004) proposed a model for the adaptation of rods and cones to differing light scenarios. In their paper, they account for the accommodation of the eye to different brightness levels, and account for the perceptual qualities at each level. Their model also accounts for time dependent scenarios, meaning that they examine how long photoreceptors take to adapt fully [3]. Given that they developed their models specifically with computer graphics in mind, I believe I could benefit from adapting many components of their model into my software.

Implementation and Milestones

I plan to use an eye tracker to retrieve the position of the user's gaze on the screen, many times per second. I will use high dynamic range images that map pixels to real-world radiance values as closely as possible, as this will aid with perceptual accuracy. Every time a new gaze position is recorded, I will re-calibrate the exposure of the image so the gaze point is well exposed. Knowing the dynamic range of the eye at this specific sensitivity level, other values in the image can be adjusted to be brighter and darker; pixels at the edge of the dynamic range could be blown out or fully dark.

In the preliminary implementation, I shall use a fixed dynamic range for the virtual eye (perhaps something on the order of 8 to 10 stops). This range will hold under all lighting conditions. When the user shifts their gaze, I will immediately adjust the pixels at that point to be perfectly exposed, and change other pixels to be over- or under-exposed. Calculating the correct exposure will involve averaging the radiance of the pixels within some region of the gaze position, then setting that to output mid-range pixel values (near 128 on a 0-255 scale).

I will expand this prototype to account for differences in the eye's sensitivity in different light levels. Ideally, a spot of the image in full sunlight will still look a bit brighter than a spot in the shade, even after adaptation. The eye may also realistically have different dynamic range levels at different levels of accommodation. To create greater realism, adding a temporal component would be ideal. This would involve interpolating between old and new exposure levels over time every time the gaze changes. As an example, adjusting to bright light might happen almost immediately while adjusting to a lower light level could take several seconds.

At this point, the effect should be quite realistic. If time permits, I could expand the simulation further by adding additional effects the eye might experience in the real world. One possibility would be to model the color after-effects that one sees when staring at a bright object such as the sun. These halos could follow the center of the user's vision for several seconds until they gradually fade. It would also be interesting to experiment with display techniques that intentionally induce eye strain. This would simulate the feeling one gets when staring at a brightly illuminated surface, and could subconsciously help the user distinguish light from dark. However, I have not researched whether there are well-studied ways of inducing eye strain on a standard display.

Works Cited

[1] Sharpe, Lindsay T., et al. "A luminous efficiency function, V*(λ), for daylight adaptation." *Journal of Vision* 5.11 (2005): 3-3.

[2] Kalloniatis M, Luu C. Light and Dark Adaptation. 2005 May 1 [Updated 2007 Jul 9].

[3] Ledda, Patrick, Luis Paulo Santos, and Alan Chalmers. "A local model of eye adaptation for high dynamic range images." *Proceedings of the 3rd international conference on Computer graphics, virtual reality, visualisation and interaction in Africa*. ACM, 2004.