Status Report

High Dynamic Range (HDR) Display

CIS-Kodak New Collaboration Research Grant

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Background

The purpose of this project was to construct a High Dynamic Range (HDR) Display for use as a research tool in support of graduate student activities within CIS – specifically those activities of Messrs. Zhang, Kuang, and Heckaman, respectively, that study and characterize:

- novel techniques for visualization of high-dimensional image data for interpretation and utilization,
- high dynamic range digital photography: image display and perception
- brilliance, contrast, colorfulness, and the perceived volume of device color gamut.
As introduced by Sunnybrook Technologies (Figure 1), the HDR display utilizes existing LCD array and DLP projector technologies for displaying images to human observers that approach the entire range of the human vision system where an expanded, perceptual gamut of brighter, purer colors and perceptual effects such as brilliance and local contrast can be studied. These technologies are well characterized in commercial imaging applications, and their adaptation to HDR applications is just becoming known through implementations in a number of known research organizations.

### Status

- **Current**

  A prototype, HDR Display was constructed as shown in Figure 2 below and consists of a Plus Vision U-235 DLP Projector that images the grayscale or B&W version of an image onto a sandwich which, in turn, consists of an Edmond Scientific Y43-943, 50 groove per inch, Fresnel lens to collimate the projector beam and two diffusers and a LCD panel taken from a 15” Apple Cinema Display. The LCD panel and the projector are driven by a dual-headed video card in the backplane of a G5 Mac.
The resulting image (see Figure 2 below) when viewed head-on to the LCD panel measures up to 3,500 cd/m² in brightness, a black point below the capability of our instrumentation to measure (less than 0.02 lux), and a full-on/full-off, estimated contrast ratio approaching 5 orders of magnitude. The display has been roughly characterized to determine colorimetric repeatability with fully acceptable results. Spatially, the image is reasonably aligned with the LCD panel with a moderate, yet acceptable, amount of pin-cushion* due to the projector lens provided the full field of the display is not utilized.

* The pin-cushion observed in Figure 2 is due to the digital camera used to take this picture.
While the image of the display is very striking when viewed – both in terms of its dynamic range (high brightness and extremely low blackness) and uniformity across the field, there are two of issues that are in process of being resolved.

- Slight interference between the Fresnel lens’ grooves and the LCD pixel pitch is observed in the form of a moiré pattern at the edges and on axis of the field. The remedy is to purchase a fresnel lens having a groove pitch as close as possible to \((m + 0.35)\) times the LCD pixel pitch, \(m\) any positive integer.

- At high levels of brightness, a noticeable degree of speckle from scattering in the diffuser is observed. Currently, we are looking to replace this diffuser with an engineered-surfaced or holographic diffuser and/or trading off viewing angle with diffuser angle and degree.

Neither of these issues are unmanageable assuming our remaining budget is sufficient.

**Current plan**

1. Perform an extensive colorimetric characterization of the display \(\text{Nov 2005}\)
2. Develop a color and tone rendering schema and software \(\text{Jan 2006}\)
3. Develop spatial alignment software
4. Integrate and test software \(\text{Feb 2006}\)
5. Display operational for psychometric testing evaluation \(\text{Mar 2006}\)

**Publications**

Two papers based on HDR display technology have been accepted for publication:

- R. L. Heckaman and Mark D. Fairchild, Expanding Display Color Gamut Beyond the Spectrum Locus without Violating the Laws of Psychophysics, ISCC/IS&T Special Topics Conference, CIC 13, November 11, 2005, Scottsdale
- R. L. Heckaman and Mark D. Fairchild, Expanding Display Color Gamut Beyond the Spectrum Locus, *accepted for publication*, Color Research and Applications, John Wiley & Sons

**Other Collaborative Agencies**

As a direct result of this work and the work of others in the Munsell Color Systems Lab in the area of HDR imaging, we are hopeful of developing further relationships with display manufacturers such as Sharp, Phillips, Apple, and Kodak. Additionally, we have a collaborative relationship with the Computer Graphics Laboratory, Cornell University, in the development of HDR displays and the beginnings of a yet-to-be-defined relationship with Cypress Semiconductor Corp., Cambridge, Massachusetts, in the development of HDR display and imaging technology.

**References**


4. Loyd A. Jones and H. R. Condit, The Brightness Scale of Scenes and the
   (1941)

5. Jiantao Kuang, Research Proposal: High-Dynamic-Range Digital Photography:
   Image Display and Perception, Munsell Color Science Laboratory, 2004