High Dynamic Range Display System

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Abstract

The High Dynamic Range display uses active light emitting diodes behind a high-resolution color liquid crystal display to provide luminance levels ranging from 4,000 cd/m^2 to less than 0.05 cd/m^2. These benefits are achieved at no cost to the performance of a conventional LCD which is used as an integral part of the High Dynamic Range display.

Introduction

Conventional display technology lacks the capability to show luminance-realistic renditions of all but very dim scenes. Even high-end displays offer less than a 500:1 dynamic range with at most a peak luminance of 500cd/m^2. This creates an unfortunate limitation between the capability of a computer and the human visual system, both of which are easily capable of processing a dynamic range that is up to three orders of magnitude higher.

The High Dynamic Range (HDR) display solves this problem through a unique combination of existing liquid crystal display (LCD) technology and a spatially active backlight composed of high brightness light emitting diodes (LEDs).

Conventional LCD Technology

A conventional LCD is made up of an LCD and a fluorescent tube backlight. Due to losses in the polarizer and color filters the LCD transmits only 8-10% of the light from the backlight. The dark state is created when the pixels of the LCD block the light as much as possible. Usually this results in approximately 200 or up to 500 times less light output than in the white state. Since this ratio is fixed, increasing the intensity of the backlight to improve brightness unfortunately also increases the intensity of the dark state - turning black to grey.

High Dynamic Range Display

The HDR display replaces the uniform backlight of a standard LCD with an active matrix array of high brightness LEDs. Each LED can be individually controlled, creating a brightness ranging from zero to over 50,000cd/m^2 in a reasonable viewing angle. As in the conventional display, a LCD is used on top of this active backlight to further modulate the light. The corresponding white state is approximately 4,000cd/m^2. In the dark state of the combined device the LEDs are off or close to off, resulting in a very low overall output. Like the LCD pixels, the LEDs have an 8-bit controller to create different shades of grey. The result is a display with high brightness, dark blackness, high contrast and a very large number of addressable shades per color through various combinations of LED and LCD settings.

High Dynamic Range Display (left) next to comparable conventional display (right). Notice high brightness bloom in the top window of the Stanford Memorial Church image.

The LEDs used in the HDR display are significantly larger than the LCD pixel. The LCD corrects for this known low resolution pattern by over-sharpening the LCD image as necessary and veiling luminance effects mask any imperfections at high contrast boundaries. This resolution mismatch makes it possible for the HDR display to operate inside an 8-bit infrastructure (DVI standard, graphic card, etc) even though it is inherently a 16-bit per color display. The extra data required to drive the LED array is less than 1% of the data going to the LCD and can thus be easily hidden inside the conventional video signal.

Further Benefits

In addition to offering a very wide luminance range, the approach of having a low resolution LED backlight and a high resolution color LCD has two other advantages:

- Using tri-color LEDs instead of white LEDs, it is possible to achieve a much larger color gamut. With its 16-bit capability the HDR display is then able to make full use of this wide gamut.
- Flashing the LED array in sync with the LCD refresh can create a strobe effect which significantly reduces motion blur and other response-time related artifacts.

A full description of the HDR display and associated psychology theory can be found in the following paper:

H. Seetzen, W. Heidrich, W. Stuerzlinger, G. Ward, L. A. Whitehead, M. Trentacoste, A. Gosh, A. Vorozcovs, "High Dynamic Range Display Systems", ACM Transactions on Graphics, special issue on Proc. of ACM SIGGRAPH 2004 of ACM SIGGRAPH 2004, August 2004