Using HDR Display Technology & Color Appearance Modeling to Create Display Color Gamuts that Exceed the Spectrum Locus

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High-Dynamic-Range (HDR) Imaging

If you had an HDR display, what would you do with it?
Measuring Gamuts

Lightness/Chroma Boundaries for a Display Technology

Lightness

The brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting.

Note. — Only related colours exhibit lightness.
Chroma

Colorfulness, chromaticness, of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting.

Importance of White

- Both lightness and chroma (perceptions) are relative to an area that appears white.
- Change the white for a constant physical stimulus — lightness and chroma change.
- Can we use this to our advantage in image displays?
Changing the stimulus that appears white, impacts the appearance of all other stimuli in the scene.
Historical Examples

- Stained Glass Windows, Photographic Transparencies

Computational Question

Can we design a display with a perceived color gamut that would exceed the perceived gamut of the spectrum locus on a traditional display?
Chromaticity Gamuts!

• Almost no information on appearance!

MacAdam Limits
Appearance Gamuts

CIECAM02

- Lightness - Chroma - Hue
- Brightness - Colorfulness - Hue

Our Procedure

- Change Diffuse White Point Relative to Display Primary Maxima
- Compute Affect on Appearance Gamut (CIECAM02)
Some Details

- Typical CRT RGB Primaries
- Diffuse White Point 100 cd/m²
- Primary Max Luminances Increased by Factors of 2
- Diffuse White : Black = 100 : 1
- Various Surround/Flare Assumptions

Computational Procedure

1. Set Viewing Condition
2. Set White Point and Black Point
3. Generate a data set of random display scalars in RGB
4. Compute the set of XYZ's from the data set of RGB scalers and the conversion matrix MN

- CIECAM02
- Compute the set of Lightness, Chroma, Brightness, and Colorfulness from the set of XYZ's

- MATLAB Convex Hull
- Determine display gamut from data set in Lightness, Chroma, Brightness, and Colorfulness

N = N + 1

Plot Gamut for each N against the MacAdam Limits
**Lightness-Chroma Gamuts**

Red = MacAdam Limits / Spectrum Locus

**Colorfulness-Brightness Gamuts**

Red = MacAdam Limits / Spectrum Locus
Gamut Summary

- 11-bits Exceeds Spectrum Locus in Appearance
- 8-bits below Diffuse White
- 3-bits above Diffuse White

- Diffuse White = 100 cd/m\(^2\)
- Display Max = 800 cd/m\(^2\)

Viewing Conditions

- Effect is Larger in Illuminated Surround
- Dark Surround - Lower Perceived Contrast
- Effect of Flare on Gamut Volume Diminishes with Increased Luminance Headroom

- Details in Forthcoming Color Research & Application Paper
Image Examples

Image Examples
Image Examples

Image Examples
The Practicality

- High-Dynamic-Range Displays Required
- Becoming Available: e.g. Brightside Technologies
- New Image Encoding Also Required

Homebrewed HDR

3500 cd/m² : 0.01 cd/m²
(350,000:1 Contrast)
Measurements of Display Performance

• Color Appearance
• Not just Chromaticity Gamuts & Contrast Ratio
• BUT ... How Those are Used ... and the Impact of Viewing Conditions

• CIECAM02 Appears to be an Effective Tool

Thank You

Rod Heckaman’s graduate studies funded by the Macbeth-Engel Fellowship in Color Science