Color Appearance in Image Displays

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Abstract

Color appearance models extend basic CIE colorimetry as embodied by XYZ tristimulus values and the CIELAB color space to enable prediction of appearance attributes (brightness, lightness, colorfulness, chroma, saturation, hue) across a wider range of viewing conditions (illumination color and level, surround, background, *etc*.). Research on the formulation and testing of color appearance models progressed to the point that CIE models could be published in the late 1990's (CIECAM97s) and significantly refined and improved several years later (CIECAM02). While better color appearance models will almost certainly be derived in the future, CIECAM02 provides a very effective method to predict color appearance for relatively simple patches of color on essentially uniform backgrounds and surrounds.

Colorimetry in its many forms from XYZ to CIECAM02 JCh has been successfully applied in the development and characterization of all types of image displays from photographic film, to the early development of color television, to color printing technology, to modern digital systems. However, image displays also present additional challenges since the color stimuli vary significantly in size and are arranged in complex spatial and temporal arrays (still and moving images). In many imaging applications, traditional colorimetric models are very helpful because the spatial and/or temporal variations in color are approximately replicated between original and reproduced images. However, in some cases it is necessary to reproduce colors across significant changes in spatial and temporal scale or to pull a color out of one context and reproduce its appearance in a completely difference spatio-temporal context. In such cases, colorimetric models that do not explicitly account for more complex spatial and temporal properties of the visual system (and the stimuli) might not provide satisfactory results.

To address these more complex appearance issues, color appearance models have become part of a natural process of scientific evolution and been joined with models of spatial and temporal vision to create image appearance models. Such models allow the prediction of color appearance across much more complicated changes in viewing environments and have a number of applications including image and video quality metrics and the rendering of high-dynamic-range images and video. The iCAM framework illustrates one approach to image appearance modeling that has been developed recently and continues to be refined.

This presentation reviews the history of the development of colorimetry for image displays from CIE XYZ, to CIELAB, to CIECAM02, to image appearance models and presents some recent experimental results. In addition, some future directions for related research are briefly previewed. The specific research topics from the past, present, and future are listed below.

Previous research results that will be reviewed include:

- Use of an image appearance model to predict perceived image quality attributes such as sharpness and contrast,
- Rendering of high-dynamic-range (HDR) images through the modeling of local adaptation to luminance and contrast, and
- HDR video rendering through modeling the time-course of chromatic adaptation.

Recent research on image color appearance and quality is also described as follows:

- Evaluation of HDR rendering accuracy and preference,
- Measurement and enhancement of perceived color gamut volumes,
- The effect of surround on image appearance,
- Adaptation to noise in image displays, and
- The derivation of orthogonal opponent-colors dimensions for image quality modeling.

Lastly, some research topics that are just underway and aimed at improving fundamental aspects of colorimetry for image displays are briefly introduced including:

- Improved HDR rendering techniques,
- An HDR photographic and color appearance survey,
- Spectral adaptation modeling,
- Transformability of primaries,
- Color difference modeling in color appearance spaces,
- Perceived color gamuts and the perception of brilliance,
- Observer metamerism and a fully specified system of colorimetry, and
- An educational resource aimed at putting it all together for future scientists.