The Chroma Zone

Munsell Color Science Laboratory Newsletter Spring 1995

Color Gamut Mapping

What do you do if the colors in your image produced on one device are not reproducible on a second device? This problem of mapping gamuts between devices has been described by conventional wisdom as an art rather than a science. Our experiments are aimed at changing this by testing current gamut mapping techniques and devising new ones. By testing simple images of colored spheres created in a 3D rendering program we hope to determine the usefulness of different gamut mapping algorithms in different regions of color space.

The full gamut of the monitor on which the experiments will be run is considered the color gamut of the original device. This gamut is represented in CIE 1976 (L*a*b*)-space as a device-independent color space. In this space we can calculate C* or chroma and h_{ab} or hue angle. Now we can create new gamuts meant to represent a second, gamut limited device by limiting the color space in L* (lightness) or chroma. For example, L* for the original device ranges from a value of 0 to 100, but in the second device it may only range from 20 to 80. For chroma, the gamut is only limited at the high end of the scale. We can then map one color attribute, say chroma, while keeping hue angle and lightness constant.

The gamut mapping techniques to be tested can be described as mapping a color attribute value of the original device gamut to the second device in linear piece-wise segments. The methods span the range defined by these two extremes: 1) linearly mapping the minimum and maximum color attribute values of the original device to the minimum and maximum color attribute values of the second device and 2) a one-to-one mapping of reproducible color attribute value up to the maximum value possible and thereafter clipping the values to that of the maximum of the second device. In-between these two extremes the size and location of color compression can be changed by setting different parameters in the different gamut mapping algorithms.

The gamut mapping techniques have been implemented on the Macintosh using MATLAB. The implementation allows examination of the plots of the colors in color space. So far, four basic linear mapping techniques have been implemented. They can be used for compression at the bottom and top of the gamut in L* or for compressing chroma. In addition, the algorithms allow for the compression of images dependent on the range of colors available in the image as well as the device. That is, if the gamut of the image to be reproduced does not span the complete original device gamut, less compression is needed to fit it in the second device gamut. In addition to these algorithms, a simple scaling of (gamma corrected) RGB values will be compared.

Currently, I am working on restricting the number of possible algorithms and parameter settings to a workable number, setting the limits of the gamuts for each image, designing and setting up the experiment and developing further mapping techniques:

• There are an infinite number of possible settings that can be used in the algorithms. I need to limit this to an adequate number of testable conditions.

• The images can be analyzed to find means and medians of the color attributes of the spheres in the images. The gamut limits need to be large enough to adequately test the algorithms but not too large to be unrealistic and destroy image quality.

• I am looking for just the right software for experimental presentation and the recording of the subjects' responses. Pairs of images processed by the different algorithms will be compared to the original image. The subject's task is to choose the one from the pair that is more like the original. Because of the large number of algorithms, a very large number of pairs need to be presented and a large number of responses need to be recorded.

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• Techniques are being developed that will hold saturation (C*/L*) constant while chroma or lightness is compressed as well as a von Kries type algorithm that alters the location and shape of the gamut.

- Ethan Montag

Ethan is a Post-Doctoral Fellow with the MCSL. He earned his Ph.D. at UC-SanDiego working with Robert Boynton.

Image Noise and Quantization in the Capture of Color Images

It was after working for many years in industrial R&D that I enrolled as a part-time Imaging Science Ph.D. student. Although I did not have extensive experience in the color science area, I became interested in the research being carried out by Professor Roy Berns and his students on improving colorimetric reproduction via multi-channel imaging. It was therefore natural that I chose to do dissertation research that combines my background in imaging with Roy's interest in multi-spectral image capture. His research initiative, which is aimed at helping art museums in archiving, conservation and providing better reproductions of their collections, was described in *The Chroma Zone*, Winter 1993.

I am addressing image noise propagation in such systems, which can show up as unwanted variation, for example, from pixel-to-pixel. This contributes to the appearance of graininess and artifacts in viewed scenes, and can also impede signal detection and other image processing procedures.

The dissertation research provides an analysis for image noise in three-color and multispectral image capture. I am analyzing the noise in terms of its physical origins and how it propagates through various signal transformations. To do this, I include the affect of: the detector's spectral sensitivity, dark and shot noise, signal matrixing and nonlinear signal transformations. The precision used for signal storage, i.e. quantization, is also being analyzed and compared with stochastic noise levels.

My primary emphasis is on electronic capture by CCD imagers which are common in electronic imaging systems. The same analytical approach, however, can be used to understand how error is propagated when we transform measured data between various color spaces, *e.g.*, spectral reflectance to tristimulus values and then to CIELAB or CIELUV.

A CCD camera-based system will be used to capture several multispectral images. I will evaluate the resultant image noise and compare it with performance that would be predicted by the analysis. As an example, multispectral image capture application, I will also investigate how well a camera with more than three color channels can distinguish between metameric samples under an illuminant that results in identical tristimulus values.

I informally presented the initial results of my work in the Munsell Color Science Laboratory to several fellow imaging science and color science graduate students, and faculty. The comments were helpful and I look forward to completing the remainder of my research.

- Peter Burns

Peter is a Ph.D. student at the Center for Imaging Science, of which the MCSL is a part. With support from his employer, Eastman Kodak, he is currently working on his dissertation research.

Short Course Sign-Up Now!

The Munsell Color Science Laboratory is offering a series of short courses for 1995.

Courses in Color Measurement and Formulation include: Principles of Industrial Color Measurement, June 5-7,1995 and an additional optional day on Industrial Instrumental Color Matching, June 8, 1995.

Courses in Color Science for Electronic Imaging Systems include: Device-Independent Color Imaging, June 12-14, 1995 and Color-Appearance Models: Theory & Practice, June 15-16, 1995.

Call 716-475-7189 for more information.

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