Munsell Color Science Laboratory Newsletter **Fall 1994**

Observer Metamerism: Precision of Color Matches and Accuracy of Color Matching Functions

Overview

Standard color-matching functions are designed to represent the mean color-matching response of the population of human observers with normal color vision. When using these functions, two questions arise. Are they an accurate representation of the population? And what is the uncertainty in color-match predictions? The accuracy question has been addressed a number of times, but is perhaps best answered by the successful use of the CIE standard observer for over 60 years. The uncertainty question is equally important, but has received less attention. CIE publication 80, "Special Metamerism Index: Change in Observer," provides a technique for predicting the range of color matches that observers might make, but the accuracy of this recommendation has been questioned recently. We have undertaken a project to address the accuracy and precision of color matching functions, and evaluate the CIE-recommended technique among others.

Experiment

To address these questions in the dual contexts of human visual performance and cross-media color reproduction, a color-matching experiment was undertaken in which twenty observers (uniformly distributed in age from 20 to 60) made matches between 7 different colors presented in both reflective and transmissive color reproduction media and a CRT display viewed through an optical apparatus that produced a simple, split-field stimulus. In addition, a single observer repeated the experiment 20 times to quantify intra-observer variability. The reflective samples were printed samples from a digital photographic printer and the transmissive samples were 4x5 photographic transparencies. For each of the matches, the color matches were measured with a telespectroradiometer from the viewpoint of the observer. The spectral data were recorded such that various sets of current and future color-matching functions could be evaluated.

Results

The results are being used to evaluate the accuracy of three sets of color-matching functions, to quantify the magnitude of observer variability, and to compare inter- and intra-observer variability in color matching. Figures 1 and 2 illustrate typical results. The data points in the figures illustrate the CIELAB difference (CIE 1931 Standard Colorimetric Observer) between the green print sample and the CRT-generated match. Figure 1 presents the results for 20 observers while figure 2 shows similar data for 20 matches made by a single observer. The smaller ellipses in each figure are 95% confidence intervals on the mean results and the larger ellipses enclose 95% of the matches. It can be seen that the inter-observer variability is significantly larger than the intra-observer variability. Also, figure 1 shows that the mean match for the population of observers is equal to the prediction of the standard observer for this sample. Figure 2 shows that the average match for this one observer is significantly different than the standard observer (the small ellipse does not include the plot origin). The results vary for different color samples, but the standard observer always makes a prediction that is part of the match distribution of our population.

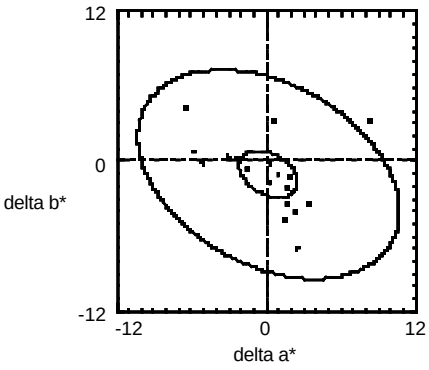

Figure 1. Distribution of 20-observers' matches for a green print sample.

-over-

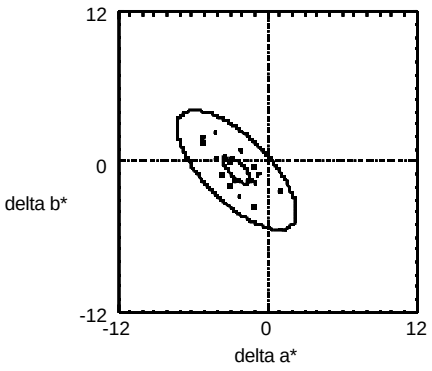

Figure 2. Distribution of 20 matches by a single observer for a green print sample.

Ongoing Work

The data are being analyzed with respect to 3 sets of color-matching functions (CIE 1931, CIE 1964, and Stiles-Burch) to determine if one set is more accurate than the others. In addition, these results are being compared with current CIE recommendations on observer metamerism for the prediction of 95% confidence ellipsoids and the data will be used in an attempt to formulate a complete standard observer system that includes not only mean color-matching functions, but the variances and covariances of these functions. Such a system could be used to predict uncertainty ellipsoids along with matches. The magnitude of observer variability in this experiment also provides a quantitative estimate of the limit of cross-media color reproduction accuracy that need not be exceeded.

Acknowledgments

The experimental work described above was carried out this past summer by Jason Gibson, a recent graduate of the Imaging Science B.S. program and Rick Alfvin, a Color Science M.S. student. Rick will be completing the analysis of the data as his M.S. thesis and giving a presentation of the results at the upcoming ISCC Pan-Chromatic Conference in Williamsburg this February. This research is being funded by the New York State Center for Advanced Technology in Electronic Imaging Systems.

—Mark D. Fairchild

ALUMNI NEWS

Dear Friends, Howdy! No, I didn't fall of the face of the earth. I'm living in New Hampshire (Cow Hampshire as some affectionately call it) and working in Bedford, MA at Iris Graphics. I've been here since April of '93. (I received my MS in Color Science in '91 and did some graduate work in the PhD program until '93.)

I remember when I first got here for the interview. My future boss, John Ingraham was showing me examples of prints made on the Iris printers - absolutely beautiful, photographic quality and incredible color! John said something along the lines of - "should you accept the position, you're job will be to improve color." I felt like I was entering the opening scene of *Mission Impossible*. But, I took on the challenge and it's been a wonderful, albeit sometimes frustrating, learning experience ever since.

Jim Enge and Jennifer Laskin - also RIT Imaging Science graduates - are the other members of the color group here at Iris. They got the wonderful task of training me on how to clean, maintain, (break) and fix the printers. They also showed the finest in Wendy's, McDonald's and Pizza Hut dining. It's been a blessing working with them and we've also become close friends.

When I finally got up to speed, thanks to the patience of my colleagues, my first project was to use the Iris software and LUT algorithms to make a monitor-to-print color match. What a nightmare! This **was** *Mission Impossible*! Fortunately a new more pressing project came along, and then another project, and then another project, and then John, my boss, asked where the monitor to print match was. Back again to *Mission Impossible*! But this time we took on the "photographic industry" attitude of "in a photo, the original scene is gone. So forget the original, the customer just wants an image with lots of punchy color and good fleshtones." And we got great looking RGB images printed on the IRIS.

I didn't give up on making the monitor and the print match, though. After an enhancement was made to the IRIS LUT technology, I developed a method for using the IRIS LUT to make the monitor closely match the print (the print is the standard). I'm still not completely satisfied - I want a perfect match.

My current project involved scanners, monitors and printers. I've been able to get my hands on many different scanners. It has been fascinating to watch the project develop from just an idea into the Printasia product introduced at Photokina '94. Calibrating everything will keep me busy for a little longer!

Don't worry, though, my life isn't all work. I've found a great church and made lots of friends. And my horse, Beast, is still trotting around and messing up the stall for me to clean.

Hope things are challenging and fun for everyone else!

- Amy D. North

ARTICLE IDEAS

Would you like to hear about any particular subject? Feel free to call Colleen Desimone at 716-475-7189 with your suggestions for short articles.

Munsell Color Science Laboratory
Rochester Institute of Technology
Chester F. Carlson Building
Rochester, NY 14623-0887
Editor: Colleen M. Desimone