Perception of Whiteness

There are a number of white objects around us—paper, textiles, photographs, and painted objects, for example. And being perceived as white often plays an important role in their value as commercial products. For this reason, many studies have been conducted on methods to evaluate and enhance perceived whiteness since about 1935. But the perceived whiteness evaluation formulas proposed until now are empirical based on the results of visual evaluation without consideration of the visual mechanism. Also, existing whiteness formulas are only applicable under the CIE illuminant D65 or C. The evaluation method under an arbitrary illuminant is not established.

I thought from a different angle and developed a new index based on a color vision model and named it “C/V index.” I conducted visual evaluation experiments in my laboratory and investigated the predictability of this index. I have confirmed the effectiveness of the index to predict the perceived whiteness under an arbitrary illuminant and over a large range of hues. But I needed more experiments to reliably establish the performance of the index.

Fortunately, I had an opportunity to visit Munsell Color Science Laboratory from April 2007 to March 2008. At MCSL, I conducted a visual evaluation experiment using a sample set provided by the research committee for whiteness in the Color Science Association of Japan. I compared the predicted performance between the C/V index and existing whiteness indices and found that the C/V index was one of the best indices to predict perceived whiteness. I am preparing to submit a research paper on the result with Professor Mark D. Fairchild.

I have had many productive days at MCSL the past eleven months and am very sorry to have to go back to Japan soon. I would like to express my gratitude to all who have supported my activities in MCSL.

~ Ichiro Katayama, Miyagi National College of Technology

Camera Color and Noise

I came to MCSL in April 2007 as a visiting scientist from Nikon Corporation, Japan. My research interest is the spectral sensitivity optimization of a color image sensor, particularly considering the effect of noise.

Digital still cameras have been widely used for the last ten years and their technology has been developing dramatically. The resolution of consumer digital still cameras has increased about ten times. Even a digital camera with a 12 M pixel image sensor is not uncommon on the market today. This enables users to print pictures from these cameras in large format. So the user demand for high quality image capture is increasing. But color reproduction as well as resolution accounts for the image quality and increasing of resolution makes decreasing pixel size if the total sensor size is the same. A smaller pixel captures a smaller amount of photon energy increasing the likelihood of noisy images. Thanks to the development of image sensor technology, the sensor noise has decreased, but photon detection inherently contains uncertainty, photon shot noise. As a result of this, even a perfect sensor will exhibit noise fluctuation. With regard to a color image sensor, the captured signal should be transformed in order to represent proper color reproduction. This transformation depends on spectral sensitivity and modulates noise components. So the design of spectral sensitivity should consider both colorimetric and noise performance.

A photon shot noise model was formulated using the spectrum quantum efficiency and the definition of ISO sensitivity. Then I conducted computer simulations to evaluate colorimetric and noise performance of RGB

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peak of 630nm and narrower bandwidth could show about 40% less noise along the $a^*$ axis. This was explained by the noise propagation in the course of the color transformation. But the longer R peak wavelength caused the approximation of color matching functions to worsen. So I proposed a four-channel color image sensor that had two red channels. One had its peak wavelength at 600nm and the other at 630nm. Adaptively selecting one of two red channels could give better colorimetric and noise performance.

This result was demonstrated using Metacow, http://www.cis.rit.edu/mcs/METACOW

~ Hideyasu Kuniba, Nikon Corporation, Japan

X-rite Supports Measurement Project and More

In June 2007, Jon Nisper and Tom Lianza of X-rite visited the Lab at the invitation of Mitch Rosen. This brief visit evolved into a collaboration between X-rite and the Lab leading to the funding of a significant measurement and instrumentation project. During meetings that day, we identified existing and future instrumentation capabilities that would enable X-rite to reach some important goals over the next few years. The main requirements they had were bispectral spectrophotometry — the measurement of visible fluorescence — and goniophotometry — the measurement of reflectance as a function of the angle of incidence and angle of detection. Our discussions solidified in their funding the purchase of a bispectral spectrophotometer and upgrading our existing goniophotometer (a Murakami GSP-10x, on long-term loan from Avian Technologies).

Through the course of the fall, a purchase was negotiated with Eastman Kodak to purchase their Labsphere BFC-450. That instrument is capable of bispectral measurements and the characterization of fluorescence within the visible range. X-rite’s immediate need for the BFC-450 is to increase their understanding of the fluorescence of office papers and other substrates.

Our existing goniophotometer represented a very good start towards the needs of X-rite. However, it was configured only for in-plane measurements. These in-plane measurements limit the materials characterization to a single slice of the full BRDF (Bi-directional Reflectance Distribution Function). In January 2008, the significant modifications to the device were complete, and it appears to be functioning as expected.

With the instrumentation capabilities in place, the remaining task involves creating large database of paper properties. Many, many hours of measurements remain. Even with these measurements ongoing, the instrumentation has been used for other applications in the Lab, including characterizing artists’ materials (under the Mellon project) and in the course Color Measurement Laboratory I to help educate our graduate students. We are confident that these projects represent only the very beginning of applications for these advanced measurement capabilities afforded by this new instrumentation.

The success of the 2007 work has already lead to X-rite’s renewal of the project for the first half of 2008. They are very excited about continuing our collaboration, and have been extremely supportive of our concurrent research leading to scholarship in the color measurement field. Look for new research in LED lighting, goniometric materials properties, instrumentation performance, and other work moving the science of color forward into places traditional instrumentation cannot go.

~ Dave Wyble, MCSL