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Demystifying Color Science: an Applicable Color Management Approach for Photographers Working with Cultural Heritage

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Abstract

This paper begins with the transition from analog to digital photography, and the expanding role of the now digital museum photographer. The problems of color accurate digital image capture of art and artifacts are discussed, and a simple method using readily available tools to calibrate monitors, profile cameras, and adjust the profiles to obtain color accurate RGB files is presented.

The Transparency

In the past, photographers didn't have to think much about color science. Large format color transparency film was the primary medium for the photographic reproduction of art. Photographers needed to do little else than evenly light with properly color balanced bulbs, focus accurately and expose according to the rated film speed. The color science was left to the film manufacturer and the film stocks were formulated to create a pleasing result from an average scene. The photographer chose a favorite film, calculated an exposure, and selected a processing lab, then hoped for predictable results that were visually appealing. Once the transparency was in hand the photographers' job was complete, and color matching was now the responsibility of the printer. Through his best efforts the printer would now attempt to match the color and tonal range of the transparency onto the printed page using a mixture of inks. The transparency served as the match target, but the printer was limited to what was captured on the sheet of film. He could do little else than match the possibly not so accurate transparency. We all know the experience of falling in love with a painting through a reproduction in a book, and then finally being able to see the original, and being surprised by how different it looked. Although there are a number of complex color science explanations for this experience the principal reason is the limitations of the color transparency film with its short tonal range, which causes steep contrasts and over saturated colors. Remember that these films were designed to give a pleasing result from an average scene not for the accurate reproduction of art. Despite the limitations however, there was a comfort with the transparency; it always seemed to produce a sharp, snappy and bright image. Digital photography has been around now for well over a decade but many photographers have been reluctant to give up the comfort of the simple transparency. The new digital technologies are complex and not easy to master, but by learning to use them properly we now have the tools necessary to produce consistently color accurate reproductions of artwork.

The Photographer's Expanding Role

The photographer's role today has expanded outward in both directions from where it was. Imagine the environment of a sound recording studio with an engineer seated before a large panel of dials, knobs and meters; welcome to the world of digital imaging. The photographer can now essentially become his own film manufacturer, because he can, through his camera software, adjust the tonal curve and color response of his imaging device before he even takes the picture, creating his own custom 'film' for each situation. On the other end the photographer can do his own prepress work, making CMYK separations specifically adjusted to a given press, and with the ability to soft proof - that is, being able to see on his monitor exactly how an image will look as it comes off the printing press. But does a photographer really need to understand the complex science of color with all it charts, graphs, matrix algebra, the CIE, ICC profiles, color appearance models, metamerism, luminance variation, spectral response and such? The answer is no, he need not understand it all, but certain aspects he must understand completely. The most important of these is the fact that the mind/eye and camera/eye looking at the same subject see it differently. How, why, and what can the photographer do about this fact are the questions.

Metamerism

The word colorimetry is "a synthesis of two words, color and metrein (Greek meaning 'to measure'). It is the science of color measurement" (Berns, p.45, 2000). The measurement of color as well as the reproduction of color is heavily dependent on the concept of metamerism. Metamerism occurs when "two samples with different spectra appear to match under one illuminant but are different under another illuminant" (Sharma, P.68, 2004). "The entire color industry is based on the ability to produce metameric matches between colors with different spectra" (Myers, p.2, 2000), and the ability to match color is "based on the principle of metamerism" (Berns, p.45 2000). Not only is there spectra metamerism, when two objects match in color under one illuminant but not under another, but also observer metamerism when different observers may see the same object differently under the same illuminant. Thus it becomes clear that because there is so much variation with the experience of seeing colors due to metamerism that some sort of standard or reference point is necessary to form the basis of color matching abilities. This reference must account for the three variables, the illuminant, the object, and the observer.

Color, or the experience of seeing color is dependant on three components, first, there must be light (and not all light is the same), second, there must be an object, and third, an observer. For the purposes of this paper we will assume that the first and second of these components are constant and the observer will vary between the camera/eye and the mind/eye.

The Observer

The first thing to establish is a reference point for the spectral response of the observer. Due to varying color vision between individuals and imaging devices "the CIE has come up with the concept of the standard observer" (Sharma, 2004, p. 83). The CIE is the International Commission on Illumination and they have made a reference model that "takes into account all factors that affect the way we see color" (Sharma, p. 85, 2004). The objective of the CIE standard observer is to serve as a set of reference curves that mimic the spectral response of the average human mind/eye experience, while accounting for the illuminant and object. The CIE's 1931 2° standard observer color matching function provides the spectral reflectance curves, as well as a mathematical representation of the average human's color vision at a 2° viewing angle. The 2° angle describes the viewing angle of the eye when the viewer is looking at an object 18 inches away, or at a normal viewing distance (Sharma, 2004). This is the first component to matching color; this serves as an observer reference with which one can begin to predict how color is perceived.

Camera Profiling

For accurate color reproduction using a digital camera, it would be ideal if the digital camera's spectral sensitivities matched the spectral sensitivities of the CIE's 1931 2° standard observer color matching function. "...... a camera's spectral sensitivities should be a linear transformation of the human visual system's spectral sensitivities." (Berns, 2001, p. 2). However, digital cameras do not meet this criterion, and this is the main cause of color inaccuracies within digital images. To account for this mismatch in spectral sensitivities, ICC camera profiles are generated for the specific camera/lens/imaging device. This process begins with imaging a target of known values with the device to be profiled. The resulting target image is compared, in the profiling software, to the known target values and a device specific ICC profile is created. This profile acts like a 'software filter' that corrects for the mismatch between the spectral sensitivities of the CIE standard observer (mind/eye) and the imaging device (camera/eye). But as good as these profiles might be, through experience, photographers have learned that they are only a starting point. Even with an accurate camera profile, most photographers realize they need to color correct the resulting images in Photoshop to more closely match the original, risking irreversible damage to the image files. Yes, Photoshop will damage a file. This has been demonstrated in many forums, so it must become the work of the photographer to achieve a more accurate image before the file is opened in Photoshop to minimize or eliminate any adjusting that needs to be done post capture.

To sum up what has been covered so far: the camera/eye and the mind/eye see the world differently but camera profiles can be generated to correct for this mismatch, however these profiles are not the magic bullet for achieving color accurate image files, and in fact there is new research that begins to explain why images created in profiled workflows still need color correction in Photoshop.

A paper entitled *Color Error in Digital Imaging for Fine Art Reproduction* by Robin Myers investigates the reproduction accuracy of a profile when applied to custom color chart. First a profile was created using a ColorChecker SG chart and three different profile making software applications. Each of the three profiles was then applied to the three test images and the Delta E (ΔE) was calculated. The result is three sets of target images, each set created with a different profile making software and each applied to the three different test charts. The test charts are a ColorChecker, ColorChecker SG, and a custom test chart made of patches painted with artist acrylic paints. In each case the custom test chart had the largest ΔE. Also addressed in this paper is an investigation into the neutral channels within the profiles. This paper concludes that errors are introduced within the neutral, and also profile-making software is skewed towards a good reproduction of the ColorChecker charts. The end result is accurate reproductions of ColorChecker charts but skewed colors of artwork in digital images when these profiles are applied (as evident in the custom test chart). Mr. Myers experiments clearly show these skewed results.

Does this mean that photographers should give up on the practice of camera profiling? Absolutely not, what photographers must do is learn to work with camera profiles in a new way.

Monitor Calibration and Profiling

Let's step back for a moment and ask an important question. What is the ultimate goal for the digital photographer or better yet what should be the goal? The goal is the creation of a color accurate RGB file. But what defines an accurate RGB file and how can photographers trust it? Although there is technology available that allows one to physically measure the RGB values of, for example, a Picasso painting (if the conservators would even allow such measurements to be made on a regular basis), and compare these values to the RGB values of the image; this is not a practical method for the working photographer. Photographers are left dependent on the monitor: the new transparency. The photographer must rely on his mind/eye comparing the original to the camera/eye image on the monitor. It is therefore very important that the monitor displays the RGB values of an image accurately. Fortunately, reliable tools are available to calibrate and profile monitors to a standard that can be repeated. But photographers can run into problems here in terms of consistency. There are two different types of monitors available: cathode-ray-tube (CRT) and liquid-crystal display (LCD). LCD monitors offer advantages when compared to CRT monitors. LCD monitors are brighter, flicker free, and are considered more stable then CRT monitors. However LCD monitors can present the viewer with a disadvantage because the image color and tonality vary depending on the viewing angle (Sharma, 2004). It is suggested that until more advances are made in LCD technology CRT monitors be exclusively used to evaluate the accuracy of RGB images.

The International Standards Organization (ISO) provides specified settings for monitor viewing conditions within the

ISO standards document entitled *12646 Graphic technology – Display for colour proofing – Characteristics and viewing conditions*. This standard provides the entire industry with guidelines for establishing a consistent viewing station. In a color managed digital imaging studio, the same image on every monitor should look exactly the same whether it's a PC or a Mac (device independent). In fact, the image should and can look exactly the same on a monitor in any studio or print shop in the world.

Now the photographer has a monitor that will display an RGB image accurately in both color and tonal values. This is the important first step, but there is still the problem of the mismatch in seeing between the mind/eye and the camera/eye as well as the problems of camera profiling. The simple solution to these problems is profile-editing, sounds difficult but in practice it's very simple.

A Simple Method: Profile Editing

Lets call this "a simple method for achieving color accurate RGB image files when imaging artwork without the need for post capture color correction in Photoshop." Although there are other methods, the following describes this simple method using Better Light's Viewfinder software but can also be adapted to other cameras and software.

Start by setting up the camera and lights to image a piece of art, let's say a Picasso painting. Place the ColorChecker color chart in front of the painting and do a prescan image of it. Gray balance using the white, black, and gray values of the chart as reference points. Look at the prescan, ignoring the color for now, and adjust the tone curve to match the look of the gray values in the chart. Adjust the exposure and the curve as needed, back and forth until you arrive at a pleasing result. Save the curve as the 'basic tone curve' and the exposure as your 'basic exposure.' Do a medium resolution scan of the color chart and use the profile making software of choice to create a profile. Import the resulting profile into the camera software and apply it to a new prescan. At this point don't change anything in the exposure or tone curve just do another medium resolution scan of the colorchart. Open the resulting color chart image in the Profile editing software of choice and compare the image to the actual chart, then adjust the image using the various software tools as necessary to better match the tonal scale and color. Save the resulting profile as the 'basic profile.' The photographer now has a 'basic curve' and a 'basic profile,' these are the starting points for imaging artwork.

Now do a prescan of the painting, applying the 'basic curve' and 'basic profile.' Look at the prescan but ignore the color for now, just look at the tonal scale and adjust the exposure and tone curve until the painting and the screen image match. When satisfied with the tonal scale, look at the color of the image; if an accurate color is seen, then do a final scan. However, if some of the color is not right then do a medium resolution scan and open the resulting image in your profile editing software.

For example, Figure 1 is an image with the 'basic camera' profile applied that shows an incorrect hue in the bureau. Figure 2 is an image with the 'basic profile' that has been edited to correct for the incorrect hue in the bureau. It now matches the perception of the mind/eye.

Figure 1. (left) *Image with 'basic profile.'*
Figure 2. (right) *Image with edited 'basic profile.'*

Use the software tools to correct the image colors until you achieve a match. Then save the profile as 'basic profile Picasso'. Apply this new adjusted profile to a new prescan in the camera software and repeat the process as necessary until the prescan image matches the color and tonal scale of the painting. Then do a final scan, that when opened in Photoshop will match the painting with no post capture color correction necessary.

Conclusion

To summarize, this paper describes the move from analog to digital photography, and the photographers expanding role. Also discussed are the problems of color accurate digital image capture of art and artifacts, and a simple method using readily available tools to calibrate monitors, profile cameras, and adjust the profiles to obtain color accurate RGB files has been presented.

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Author Biography

Natalie Russo has an undergraduate degree in Fine Art Photography from Rochester Institute of Technology (RIT), 2000. The next four years were spent working with Allen Phillips as a digital photographer for both the Smithsonian National Museum of the American and at the Wadsworth Atheneum Museum of Art in Hartford, C.T. 2004 brought Natalie back to RIT for a Master of Science Degree in Print Media, where she worked with Dr. Franziska Frey on her thesis research. Currently Natalie is working as a Senior Photographer at the Yale University Art Gallery.