

A Real-World Color Management Journey to Digital...

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Abstract

Color management systems encompass image capture, prepress, and presswork. It requires device calibration, characterization, and process control. In the end, it produces printed color correctly the first time and every time. When special-caused variations are encountered in a color-managed workflow, root cause analysis and process insights are necessary for problem-solving and process improvement. This paper takes a close look at the use and modification of digital camera profiles for improved performance.

Introduction

A beauty of being in the academic world is that we can pursue knowledge in an ideal situation with no compromise. A possible short-fall of being academic is that we may not function effectively when entering into the real world. As we study fundamentals in college, it's good that we also prepare ourselves for real world experiences. Such experiences may be acquired from our own mistakes; better yet, from someone else's mistakes. So, life is a journey, not a guided tour. Taking a color management journey is just the kind of attempt to push the limits from what we learned from classrooms and textbooks to the uncharted real world.

Literature Review

Textbooks are useful for beginners. Color management textbooks, such as *Real World Color Management* (Fraser, Bunting, and Murphy, 2003) and *Understanding Color Management* (Sharma, 2003), provide students with initial understanding of the subject matter. Textbooks are also useful for teachers to devise hands-on lab assignments that help students to comprehend important color management concepts and skill sets.

There are plenty of "how-to" information covered in textbooks regarding digital camera profiling. With today's profiling software, it's easy to build a digital camera profile. But, it is difficult to assess how good a digital camera profile is. It's also difficult to know how to modify a profile for improved performance. This article will focus on qualitative aspect of profile analysis, e.g., visual analysis of pictorial color images due to differences in digital camera profiles.

When performance of a profile does not meet expectations, identifying the root cause is crucial before finding a solution. For example, an article, in *Test Targets 3.0*, demonstrated how white point variations in digital image capture can be reconciled effectively by building digital camera profiles under similar white point conditions (RIT, 2003). The other example, by Don Hutcheson (2003), showed how to build a scanner profile with greater shadow differentiation. Hutcheson discussed the modification of an input scan by introducing an opaque patch as the maximum density in a transparent scanner profiling target, and then normalizing the maximum darkness of the raw scan to the opaque patch prior to the scanner profiling (IPA webinar, 2003).

Objectives

A digital camera profile should account for both the camera and the lighting conditions. Since lighting conditions vary at picture-taking locations, it's not clear if a digital image file downloaded with a standard camera profile embedded is better than if it isn't. A follow-up question becomes, "What happens to a digital image when assigned to different RGB profiles?" Therefore, the first objective of this study is to explore the effect of digital camera profile on color image reproduction.

When poor image quality results from a color-managed workflow, root-cause analysis of color image reproduction problems may suggest that the input profile is the culprit. For example, mixed lighting can cause discrepancies between the captured profiling target and the subject matter. It would be useful to find out if a profiling target can be corrected for lighting discrepancies prior to digital camera profiling. This is the second objective in this study.

Methodology

We're blessed with modern equipment and materials for digital imaging practices at Rochester Institute of Technology. The input device used in this study was a Nikon CoolPix 5000 digital camera. We used GretagMacbeth ProfileMaker 4.1.5 for profile construction and CHROMiX ColorThink 2.0 for profile inspection. Adobe Photoshop CS and InDesign 2.0 were used for imaging processing and pagination on Max OS X (version 10.3.3). An Epson 2200 inkjet was used as the initial test bed. All images were repurposed to Heidelberg Sunday 2000 web press with FM screening for final publication. In other words, this paper not only

tests for the effect of digital camera profiles, but also the late device-binding nature of the RGB-based color management workflow (detail not included in this paper).

Effect of digital camera profiles

To test the effect of digital camera profile on color image reproduction, we used the “assign profile” feature to compare the effect of two RGB color spaces. In this experiment, we compared a digital image assigned to Adobe RGB space and the same image to a custom digital camera profile. The following outlines the experimental procedure:

1. We decided to have our group photo with the school courtyard as the background. We took the photograph at the peak of the crab apple blossom season. The digital camera profiling target, GretagMacbeth ColorCheckerDC, held by my colleague, Franz Sigg, was first captured (Figure 1).

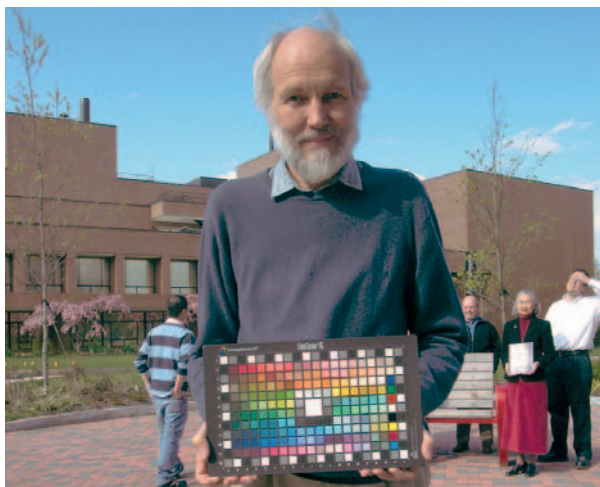


Figure 1: Profiling target captured outdoors.

2. The group photo was taken as a series of digital images on a leveled tripod. QuickTime VR was used to make panoramic stitching. Initial profiles embedded in raw captured images were ignored, and the pano image was saved as a legacy file.
3. The legacy file was opened in Photoshop. We assigned Adobe (1998) RGB profile to the file and saved it as an embedded RGB file.
4. The legacy file was opened again in Photoshop. The image was assigned to the custom digital camera profile, and saved as an embedded RGB file. Notice that digital values of the two files are identical. The difference is the profiles assigned to them.
5. Both embedded RGB images were paginated in an InDesign document and output, with appropriate color management settings, to the printer.

Modifying a profiling target

We considered a number of picture-taking locations for a group photograph in this publication. We stumbled upon an indoor lighting condition that proved to be challenging. There was a discrepancy between the lighting for the profiling target and the lighting in the group photo. To be specific, the scene for the group photo was illuminated by multiple light sources, i.e., some amount of indirect daylight in the foreground, tungsten halogen lighting from the right side, and overhead fluorescent lighting in the school lobby. Yet, the profiling target and the face of my student, Wiphut Janjomsuke, were primarily illuminated by the indirect daylight and it was under-exposed (Figure 2).



Figure 2: Profiling target captured indoors.

To overcome lighting discrepancies between the scene and the profiling target file, we explored the effect of modifying the profiling target prior to digital camera profiling with the following procedure:

1. Construct a digital camera profile with the initial profiling target.
2. Open legacy pano image in Photoshop CS and assign the initial digital camera profile to the image, and saved it as an embedded RGB file.
3. Instead of making image-dependent adjustments, we modify the profiling target using the Image/Adjustments/Levels tool in Photoshop; then use the modified image to build a new digital camera profile.
4. Open legacy pano image again in Photoshop CS and assign the new digital camera profile to the image, and saved it as an embedded RGB file.
5. As before, we paginated both embedded RGB images in an InDesign document and output it to the printer for visual assessment.



Figure 3: Outdoor group picture assigned to the Adobe (1998) RGB profile.

Results & Discussion

A quality color reproduction begins with a good input profile. We will discuss the result of using the correct camera profile for the outdoor photo first. We, then, focus on modifying the profiling target in order to overcome a poorly exposed indoor group photo.

Effect of digital camera profiles

A digital image, initially captured by a digital camera, may or may not contain a profile. Figure 3 shows the appearance of the outdoor group photo when Adobe (1998) RGB profile was assigned. Notice that the skin tone and red bricks are over saturated than one would expect; so are the green grass and blue sky.

The centerfold of this publication shows the appearance of the same image when assigned to the custom digital camera profile. Here, we see the bias of the red, green, and blue primaries, as defined in the Adobe (1998) RGB color space, has been replaced by the sensitivities of the digital camera. The image looks more real-life like.

Indeed, the color of RGB values in a digital file is a function of its colorimetric definitions. For example, 200R, 100G, 50B, assigned to two different RGB color spaces (Figure 4), will have two distinct color appearance. The camera profile was very effective in rendering true color of the scene without human intervention.

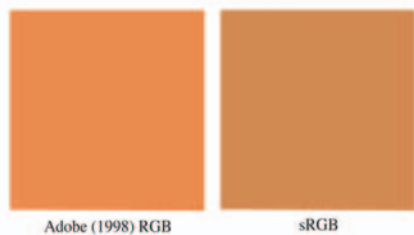


Figure 4: Two different colors with identical RGB values.

Modifying a profiling target

A custom camera profile is ineffective when lighting conditions and exposure differ between the profiling target and the scene capture. Figure 5 shows the under-exposed ColorChecker and its lightness histogram. The dark appearance of the white patch, located at the lower left of the ColorChecker, corresponds to the low digital count in the histogram. The major adjustment in the initial profiling target was to normalize highlight digital values.

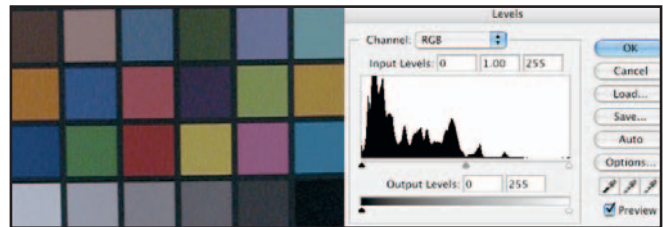


Figure 5: Initial Macbeth ColorChecker and its histogram.

The right side of Figure 6 shows the effect of the indoor picture with the initial digital camera profile. Due to under exposure of the profiling target and mixed lighting, the group photo was over corrected and became too light. To modify the profiling target, initial RGB digital counts of the image highlight, i.e., 174R, 174G, and 176B, were adjusted to 240R, 240G, and 240B using the Levels tool in Photoshop's Image/Adjustments menu. In other words, lightening highlight of the profiling target compensates for additional lighting contribution in the scene that was not accounted for in the profiling target. The profile, built from the modified profiling target, was able to render the group photo (left side of Figure 6) closer to the appearance of the scene. The side-by-side comparison of the indoor group picture, particularly in the highlight region, reflects the effectiveness of the adjustment.



Figure 6: Indoor group photo assigned to the initial (right) and modified (left) digital camera profile.

We can also see the gamut volume difference between the initial and the modified camera profile with the use of ColorThink 3-D display (Figure 7). Here, we see that the initial profile (in wire frame) has greater sensitivity in highlight and red region of the color space than the modified digital camera profile (in color solid).

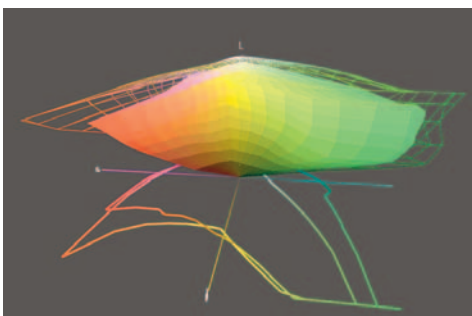


Figure 7: Gamut volume of initial and modified profiles.

Conclusions

Digital camera manufacturers are not in the position to offer camera profiles to end users that account for both the hardware and the lighting conditions. If they do, supplied profiles are only good as a first approximation. When end users construct digital camera profiles, lighting and exposure must be accounted for and be consistent. This is where quality and productivity may be maximized in applications such as direct mail catalogs and portrait photography where lighting conditions are controlled and repeatable.

Unexpected events will happen in a color management journey. Solving the problem due to mixed lighting by modifying the profiling target suggests that we can learn from the experienced, e.g., Don Hutcheson and published work. While Hutcheson (2003) demonstrated

how a tonal range of a scanner profile may be extended, we demonstrated how mixed lighting and exposure deviation can be corrected in digital camera profiling. The adjustments require insights of the process. By exploring and sharing these insights, we will become more and more confident as we push our color management limits into the uncharted territory.

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