BIPC DIGITAL IMAGING STUDY GROUP
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BY-THE-NUMBERS COLOR CORRECTION[1]

Problem

How can you match the colors of different digitized versions of the same film image, made by different scanners?

Background

This is hardly what you'd call a common problem. It came up as I was preparing material for a teaching session on digital photography. I had four scans of the same 35mm film frame made by four different film scanning processes. Colors of the scans were very different, and I wanted to eliminate the color differences so that one could see the differences in other qualities of the four scans—notably resolution and dynamic range—without the distraction of the differing colors.

However, it seemed a worthwhile exercise for presentation to the Digital Imaging Study Group, as it was a challenging color correction task—probably more challenging than the more usual task of color correcting a single image. I hoped that what I learned would carry over to other, everyday color correction work.

Solution

To help in this effort, I bought a copy of *Professional Photoshop*[2] by Dan Margulis, a respected work on the subject, now in its fourth edition. Rather than tackling the whole book in one gulp, I decided to use the techniques discussed in Chapter 2, Color Correction by the Numbers. I had heard of Margulis teaching colorblind people to do color correction, and I figured that would carry me far enough in the subject to be a good first bite.

Highlights of Margulis' basic method

In this chapter of his book, Margulis argues that significant progress toward color correction can be made without any selection of parts of an image. His argument is that if part of an image is noticeably the wrong color, that same color cast is probably affecting the rest of the image. The camera doesn't see as the eye does, and the task in color correction, as in other aspects of image editing, is to restore to the image what the eye saw. When we look at a scene we don't see a color cast; we just see the scene, and the eye takes care of removing what the camera will see as a color cast. Then later we look at the print and discover to our horror that the horses are pink.

Margulis' basic technique is to use the Curves adjustment of Photoshop to correct color. A single set of curves (R, G, and B curves) can be used selectively to control the color

[1] See also paper #2002-06 in this series, *Curves*, by Ray Mines.

[2] Margulis, Dan. *Professional Photoshop: The classic guide to color correction*. Wiley Publishing, 2002 (ISBN 0-7645-3695-8.

adjustment applied to different parts of an image. Margulis claims that a monkey can do it. After struggling with my four scanned images, I have to take off my hat to that monkey!

The concept of color *correction* implies that the color of the image differs from some standard that we want to bring the image into line with. He suggests the following principles, which effectively constitute that standard:

- Colors should be believable. One of Margulis' examples is a pair of horses in front of a rank of flags on a building. The horses have a decidedly pink cast. Another is a photo of a matador preparing to dispatch a bull. The bull looks yellowish green. Margulis says our viewer will not believe the horses were pink or the bull yellow-green.
- The image should use the whole range of available tones. This means that we can generally identify a darkest, or shadow, point in an image and a lightest point, or highlight. These should be the darkest and lightest *significant* points in the image. There may be lighter or darker points, but if they aren't significant, you won't care if you blow them out. Margulis recommends $31^{R}30^{G}30^{B}$ for shadows and $238^{R}240^{G}243^{B}$ for highlights. These values, translated from CMYK, are to me a long way from the ends of the black-white continuum. (I think Bob Stoner recommended $10^{R}10^{G}10^{B}$ for shadow and $244^{R}244^{G}244^{B}$ for highlight.)
- Flesh tones should be the color of flesh, not a pumpkin or a strawberry. Margulis recommends, for example, $214^{R}169^{G}141^{B}$ for a light-skinned Caucasian. He gives suggestions for other fleshtones in his book. (Stoner: $209^{R}162^{G}143^{B}$.)
- Certain items can be recognized as correctly being neutral in tone. Such areas should have equal R, G, and B values.

In my task, I did not need these guidelines, as I had a fixed standard to correct to. I liked the color of one of the four scans, so my job was to adjust the other three to match it as closely as I could.

The idea, then, is to plant Color Samplers at strategic points on the image and use curves to bring the colors to the desired, "corrected" values.

My application of the method

The photo

The photo I used as my subject was an undistinguished snapshot of a street in Paris. I had no reason for choosing this image over others except that (1) I already had a commercial scan of it available, and (2) I've used it for other purposes, so it's like an old friend. Figure 1 shows the photo.

Figure 1. The photo

The scans

I accumulated four scans of this photo. In the interest of keeping this document reasonably small, I will not include the graphics of all four scans here. But I will comment on them and will present small prints of them, before and after color correction, at the meeting where I present this paper.

- ♣ The Photo CD scan I've had for five years (2200 ppi). I was satisfied with the quality of this scan until I saw the results from my Nikon scanner.
- ♣ A scan I made on my Nikon IV ED scanner (2900 ppi). Good color, a better rendition of the sky.
- ♣ A scan Ken Hales made on his Epson 2450 flatbed scanner (2400 ppi). It's a very soft image with an unattractive reddish-brown cast. This was an early effort by Ken on to scan film on this scanner.
- ♣ A scan Ray Mines made on his Nikon 4000 (4000 ppi). Possibly a bit sharper than the Nikon IV ED scan, but awful color: generally washed out except for bright electric reds. Again, a fledgling effort by the owner of the scanner.

The process

1. I decided I liked the Nikon IV ED image best and would use it as my standard. I tried to correct the other three images to the same color.
2. After a brief and abortive flirtation with CMYK (the first eight chapters of Margulis' book describe everything in terms of CMYK), I decided to do my work in RGB color.

3. I set color samplers at four points that I thought would provide relatively good coverage of the range of tones, if not colors, in the image. The locations of the color samplers are shown in Figure 2.

Figure 2. Image schematic showing color sampler points

Sampler 1 is on a near-white building, near the center of the photo.

Sampler 2 is on a deep crimson storefront panel near the lower right.

Sampler 3 is in a light blue sky area near the top of the photo.

Sampler 4 is on a woman's sweater that is a near-neutral middle gray, lower left.

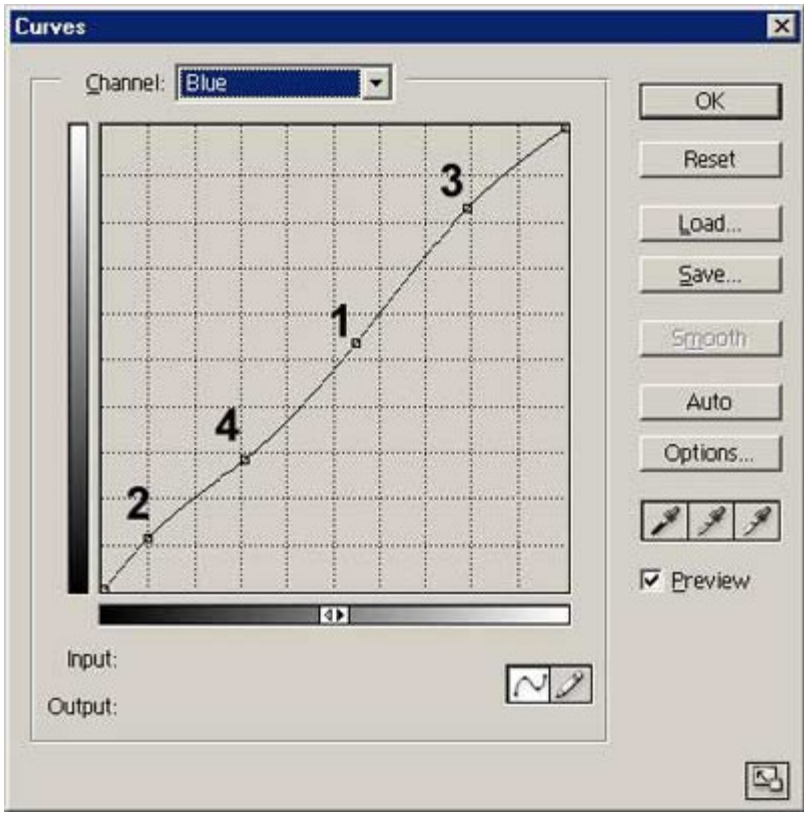
4. After an abortive first pass in which I did adjust luminosity first (this was not among Margulis' instructions; I guess monkeys know instinctively to do that), my first step was to make a monochrome layer and adjust its luminosity. I used the Channel Mixer in monochrome mode to blend equal proportions of the R, G, and B channels, then used a Curves adjustment layer to match the grayscale values across all four scans. Table 1 shows the grayscale values at the color sampler points for each of the scans. The task was to bring all values to the target values in the right-hand column.

Table 1. Grayscale values at the four sample points for each scan

	Nikon IV ED	Photo CD	Epson 2450	Nikon 4000	Target
1 White building	45	53	47	45	45
2 Red panel	85	83	81	77	85
3 Sky	6	5	13	17	6
4 Woman's sweater	72	75	65	59	72

5. The method for making the adjustments was straightforward, if a bit tedious. The Curves dialog box for adjustment for the blue channel on one of the scans is shown below. (I used a similar box for the initial grayscale adjustment, and the process was the same.)

Figure 3. Curves dialog box illustrates how adjustments were made



6. I then discarded the monochrome layers and used another Curves adjustment layer to bring R, G, and B values into match on each image. To make this clearer, Table 2 shows the channel values that need to be adjusted to match the target. In all, there were 12 matches to be made: 3 images; grayscale, red, green, and blue for each. It seems like many more than that.

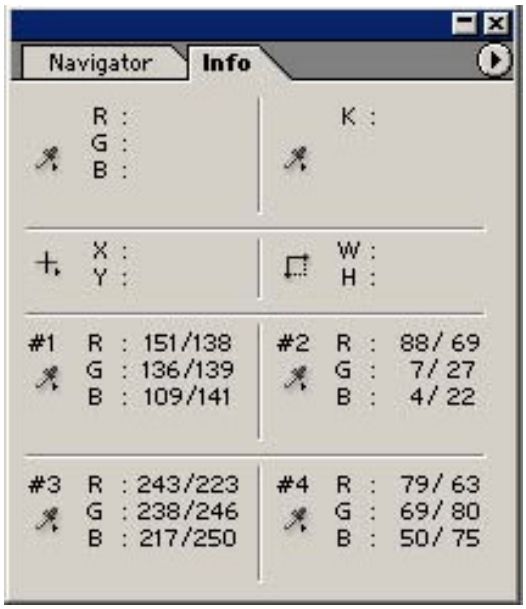
Table 2. Red, green, and blue values at the four sample points for each scan

		Nikon IV ED	Photo CD	Epson 2450	Nikon 4000	Target
1 White building	R	138	133	151	143	138
	G	139	147	136	143	139
	B	140	141	108	143	140

		Nikon IV ED	Photo CD	Epson 2450	Nikon 4000	Target
2 Red panel	R	66	52	88	120	66
	G	27	37	7	11	27
	B	22	33	4	19	22
3 Sky	R	223	225	242	223	223
	G	245	255	239	239	245
	B	251	255	218	252	251
4 Woman's sweater	R	77	62	49	65	77
	G	78	71	68	74	78
	B	70	74	49	73	70

7. To guide the adjustment process, I referred to the values in the Info Palette (see Figure 4) and compare them with the values in the target column of Table 1. Then, holding the input value constant, I moved the points vertically until the output value matched the target. This work was sometimes tedious but not difficult.

Figure 4. The Info Palette shows R/G/B values at all four sample points



8. Once I had completed all the adjustments, I had to go back to the curves and straighten out some segments that had become kinked and were distorting colors in areas between the sample points. This completed the process.

Results, and what I learned and didn't learn

1. Upon close inspection the final images do not match exactly, but they match a lot better than the uncorrected images did.
2. I feel much better prepared to use curves adjustment for color correction than I did before I went through this exercise.

3. From what I know so far, I would certainly try again to correct color without selection or masking.
4. Making a tonality (luminosity) adjustment before color correction was a good idea in this instance, and I would try it again the next time I use the *by-the-numbers* method for color correction.
5. This job would be easier, and the results better if Photoshop had more color samplers.
6. Don't mess around with CMYK unless you have a clear reason to. Understand the consequences: squashing the color gamut. (I think I'll regret this statement after I've done the next item.)
7. Margulis is a real master. I'm looking forward to learning more from him as I digest more of his book.