Color Management

Why Color Management?

The key to making sense of color management lies in understanding why it's even necessary. After all, you just want your images to "look right"—on screen and paper. Well, this is asking quite a lot. The world's oldest color management tool, whose complexities are still not fully understood, comes in pairs which rest in sockets conveniently centered above the nose. The interaction of rods, cones, cornea, et al provide a wider gamut, greater dynamic range, and superior color balance than any hardware/software combination on the market. Digital cameras, scanners, monitors, and printers are all attempts to mimic characteristics of human vision, within their limitations. It is in the context of understanding and compensating for these limitations that color management can lead us to images that "look right".

Spectrum, Dynamic Range, and Gamut

Our universe contains an incredibly broad spectrum of wavelengths. Only a tiny fraction of this spectrum is visible to humans. We call this "light". Consider for a moment the wide array of hues, subtle contrasts, and tonal ranges we can see. It's pretty impressive. No single input device (scanner, camera sensor, film) can record the entire range of visible light. What these devices can do, with remarkable accuracy, is capture a subset of the visible spectrum. An input device's ability to distinguish between varying levels of light is described by its **dynamic range**. And the wider the dynamic range, the more distinguishable colors it can record. Fair enough, but we must view the captured colors through an output device, like a monitor. An output device is defined by its **gamut**—the specific range of colors it can reproduce. Unfortunately, the dynamic ranges of input devices do not match completely the gamuts of output devices. There are large areas of overlap, to be sure, but a scanner can capture colors a monitor simply can't display.

In addition, we have this long-standing tradition of actually recording images onto paper. And printers (output devices) have an entirely different—and smaller—gamut than that of monitors. Again, there is significant overlap, but there are many wonderful onscreen colors that just cannot be printed.

It only gets worse. In the digital realm, input and output devices must attach numerical values to the colors they interpret. But each type of device "sees" slightly (and sometimes not so slightly) differently. So, the same color object can produce markedly different color values on each device. It's also common that two *different* color objects produce an *identical* color value on one or more devices. In short, a monitor RGB value of *150,100,60* does not refer to the same color as a scanner RGB value of *150,100,60*. And neither of these, by the way, correspond well to the way our eyes respond to an RGB value of *150,100,60*. Now send an RGB value of *150,100,60* to the printer and you're guaranteed to have an original, screen view, and printout that are significantly different.

RGB vs CMY(K)

The issue of printing brings up a final obstacle. Scanners, camera sensors, and monitors rely on an RGB (red, green, blue) color model. In this **additive** model, all known colors can be reproduced by mixing two or three of these primaries in varying proportions. It's additive because 100% red, green, and blue produce pure white. Conversely, a complete lack of these primaries results in pure black. This model is based on the way our own eyes work. Embedded in our retinas are 3 layers of cones. Each layer responds to long, medium, and short wavelengths, respectively—roughly corresponding to red, green, and blue light. It is from just these three receptors that our entire visible palette is created.

The vast majority of printing devices however, from lasers, to inkjets to commercial presses use a **subtractive** color model. CMY (cyan, magenta, yellow) inks are used in combination to produce a wide array of colors. In the subtractive model, 100% cyan, magenta, and yellow produces black. Lay down no ink and you have white. An inherent impurity of the inks themselves necessitates use of a fourth ink, K(black) to reach a truer black. And of course, white—more precisely paper white—is dependent on the media used when printing.

A Solution

After all this, getting your image to "look right" may seem an impossible task. But it is for exactly this purpose that color management exists. In the following section we'll take a look at the ways to compensate for the seemingly incompatible nature of input and output devices, and how to reconcile their numerical color values with the way we actually perceive color.