Accurate has become an untrustworthy word, so let's make it clear. When we say we want accurate, we mean pleasing.

Profile accuracy vs. quality profiles

Ask photographers if they want accurate color and they'll answer, "Yes, of course." But what is accurate color? The only true definition of accurate color is colorimetrically correct color, defined by the measured, spectral properties of an object under a fixed light source (illuminant).

When colorimetrically correct color is sent to a display or output device, it often doesn't look as we wanted it to. Variables in devices' gamut and dynamic range affect the output, making it look considerably different from the scene we viewed, measured and photographed.

Unfortunately, "accurate color" has become a marketing buzz phrase. Log onto the Web pages of any color management manufacturer and you'll likely see the term "accurate color" without any explanation of what it's supposed to mean. We really want *pleasing* color, not accurate color. We want color that appears, on any device, as we remember the scene or as we hope to express the image to others.

Accurate ICC profiles, not accurate color, define the behavior of output devices (displays and printers). But how do we determine if the profile is accurate? No one wants inaccurate profiles or poor color output after spending the time and money to implement instrument-based color management.

The process of building an ICC profile begins with sending a series of known solid colors to a device. Each color has a specific LAB value. Then you measure the colors using a colorimeter for a display or a spectrophotometer for a print. Software compares the measured colors to the original LAB color values and builds an ICC profile based on that data.

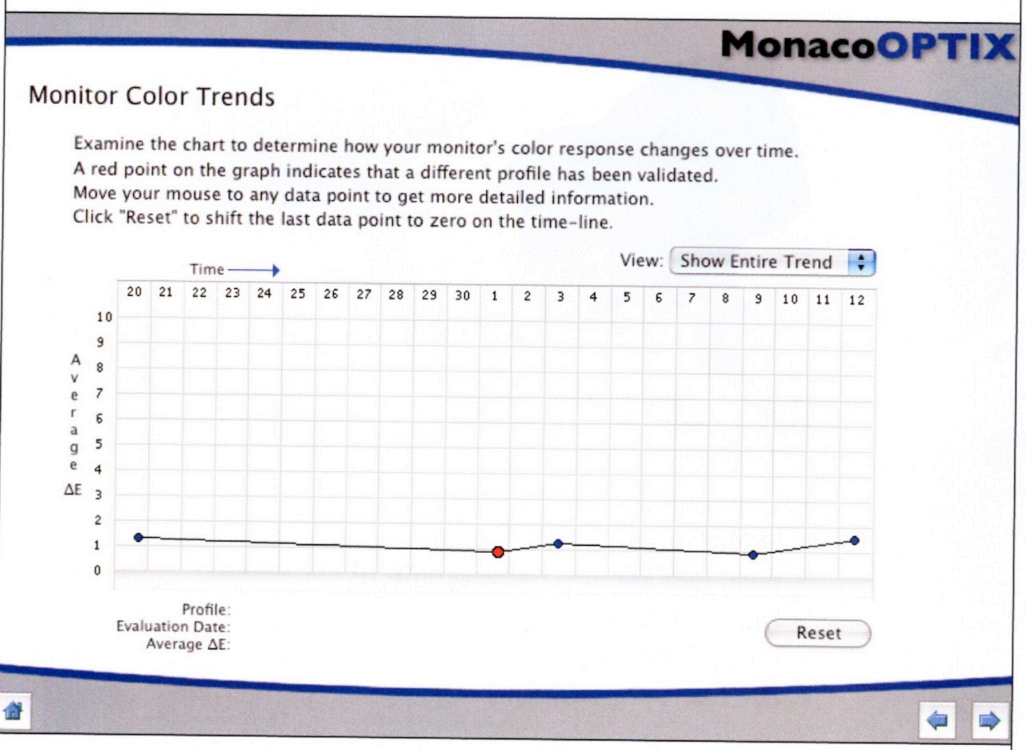

Figure 1. A trending graph from OPTIX software shows how the calibration of the display has drifted over time.

Most of today's instruments are consistent in measuring the same color every time you use it. But how accurately do they measure the colors used to build the profile? How can an instrument define its own accuracy, as some claim it can? Is that useful?

It *is* useful to define consistency by measuring how closely a device reproduces the same color over time. It's useful to define the differences between colors and color measurements, which is expressed as a deltaE value (see sidebar).

Some color management software provides a measure of how consistently a device such as a display reproduces colors over time. The software provides a graph that compares the deltaE of all the colors measured every time you calibrated the display (**Figure 1**). This is called *trending*. The differences tell us how far the device's color output drifts from measurement session to measurement session, and indicate how stable the display is. If the deltaE is rather high, say 3+, you should probably calibrate the device more often.

Trending measurements do not report the accuracy of the profile or any single set of measurements!

Some software products report profile accuracy as *validation*, but the set of values is useless. Validation uses the same instrument that built the profile to tell you the accuracy of the profile, based on its own measurements. This is preposterous. The same instrument used to make the profile can't be used to measure its own accuracy. You decide to build a 12x20-foot deck, and you measure out the foundation using your

THE MEANING OF DELTAE

LAB is a perceptually uniform color space that allows us to put a value on the difference between two colors, as a human would perceive them. "Perceptually uniform" describes a numeric increase or decrease that we perceive as matching in intensity or stimulation.

Suppose you have a light dimmer that can be rotated from zero to 10, and each increment visually appears to be twice as bright, even though it's probably not. Because LAB is perceptually uniform, we can numerically define how closely two colors appear to match.

If I have three color swatches that look similar but not identical, how can I tell which two are closest to each other visually and numerically? Using the LAB color space, I can measure and calculate the differences and provide a numeric scale that matches our perception of change. This calculated value is called deltaE (ΔE).

A deltaE of 1 is considered to be the threshold of noticeable difference between two colors. In other words, if I have two color patches that measure less than deltaE 1.0, the patches would appear to be a perfect match.

As the value increases, the differences become more noticeable. In the printing trade, if the measure of a print and a proof falls within a deltaE range of 3 and 6, the match is considered acceptable.

To complicate matters, there are different methods of calculating deltaE, due to the evolution of color and imaging science. The original calculation was not uniform for all colors, so newer calculations were developed. For example, deltaE 2000 is better suited for measuring small differences in color. When software reports a difference in color using deltaE, it's useful to know which formula was used.

Figure 2. The image on the left in the test file above was processed in ColorThink Pro to extract all of the unique colors represented on the right. There are 40,918 unique colors that make up the entire image. RGB and LAB values for each color are specified in the list below the images.

right foot because you believe it is 12 inches long. If you measure it a second time using your right foot and get the same result, is this an accurate measure of 12x20 feet? Using this process alone, there's no way to know.

The problem with software that tells you the accuracy of your profile is that it uses the same instrument to measure both sets of patches, without a reference of known accuracy. The so-called accuracy values supplied by the software, usually as deltaE, aren't at all reliable, just as measuring the deck foundation twice with your foot isn't reliable.

If you've blocked out your foundation with a tape measure that is accurate to 1/100 inch and find it's really 11x19 feet because your foot isn't exactly 12 inches long, measuring again using a ruler with 1/10,000-inch accuracy won't make a difference. The first tape measure was sufficient for the task, since you can't cut wood with 1/10,000-inch precision. Any possible difference in scale between 1/100 and 1/10,000 inch is functionally insignificant.

To measure color, you could use a $10,000 reference-grade Minolta CS-1000A Spectroradiometer, which is vastly more precise than the colorimeter or spectrophotometer you used to take your initial measurements. It could measure the difference between itself and the original instrument, providing a deltaE value of profile accuracy based on the original measured data. But that's not the kind of information you need.

It takes a spectroradiometer that can measure the wavelength of light 1nm (1 billionth of a meter) intervals to measure true profile accuracy. An X-Rite Eye-One Pro Spectrophotometer that measures light in 10nm intervals is more than capable of measuring the data necessary to build quality profiles.

What we need from manufacturers are

Unfortunately, "accurate color" has become a marketing buzz phrase. Log onto the Web pages of any color management manufacturer and you'll likely see the term "accurate color" without any explanation of its supposed meaning.

specifications based on the reference grade instrument measurements, or simply an end to dubious "profile accuracy" values. It would be more useful for companies to provide trending data to help users gauge how devices may change over time and how often we need to calibrate them.

Sometimes, the simplest techniques are the best. One way to gauge the general accuracy of your display profile is to view images of known color qualities and compare that to a printed image. The ultimate goal here is to produce a good screen-to-print match.

There are instances when viewing a huge number of solid pixels in context makes a lot more sense than measuring them; **Figure 2** shows a case in point. The images on the left and right are the same with respect to the number and unique colors of each pixel. I've taken a utility called ColorThink Pro and converted all the unique color pixels on the left into a list of color patches on the right. I could build a target of these colors and measure them, but it makes more sense to view and evaluate the image on the left than a big array of solid color pixels.

Sometimes it's necessary to measure individual color patches because our eyes can be fooled (see "In Color Management, You Can't Believe Your Eyes," www.ppmag.com/reviews/200511_rodneycm.pdf). Other times, you simply need to see it in context as a true image using the instruments on either side of your nose. ■