International Color Consortium®

White Paper #17

Level: Introductory
Date: April 2005

Using ICC profiles with digital camera images

There are two kinds of ICC profiles that can apply to image files created by digital cameras: color space profiles and input profiles.

It is important to understand that, except for applications like copying art and product photography where the picture is supposed to exactly match the original captured, pictures usually don't match the scene from a color measurement, or even necessarily an appearance standpoint. Typically, the contrast and color saturation will be boosted (especially in the midtones) to the extent allowed by the reproduction medium (and consistent with a "natural" appearance in the expected viewing conditions), and specular highlights will be compressed for printing (and viewing on typical displays). This scene-to-picture color processing is called "color rendering" (as defined in ISO 22028-1). More complicated things can also be done. For example, some cameras individually color render each scene, considering its dynamic range and key. "Digital scene re-lighting" algorithms that attempt to compensate for uneven scene illumination are also used.

When a camera is producing image files that contain standard color encodings, such as sRGB, Adobe RGB (1998), or ProPhoto RGB (a.k.a. ROMM RGB), it is performing the color rendering, and the image encoded doesn't represent the scene, but rather the camera's attempt to create and encode a pleasing reproduction of the scene (a picture). These encodings are called "standard output referred" since they encode the colorimetry of the picture on a standard output reference medium. In the case of sRGB, the reference medium is a standard CRT display. In the case of ProPhoto (ROMM) RGB, the reference medium is the ICC perceptual intent reference medium reflection print. The Adobe RGB reference medium is currently in the process of being defined, but will likely be a 160-200 lux D65 white point wide gamut additive RGB display (using the Adobe RGB primaries), viewed in a dim surround, with the same luminance ratio as the ICC perceptual intent reference medium.

So, when a digital camera creates an image file using a standard color encoding, the correct ICC profile to associate with that file is the profile for the color encoding used, not a "camera" profile. If one tries to create camera profiles for such files by photographing a target, the results will generally be sub-optimal because the profile will in effect be trying to undo the color rendering applied by the camera to get back to the scene. There will almost always be errors, in part because of the limitations of reflection target based characterization. Also, for most applications the actual scene color will be less pleasing than the color-rendered picture. Furthermore, all cameras apply white balancing, so a different profile is required for each white balance setting. Likewise, different placement of the characterization target white on the tone scale can produce different results. Cameras that apply digital scene re-lighting will have characteristics that are different at different places in an image, and therefore are not undo-able using an ICC profile. Finally, for cameras that perform image specific color rendering, the profile created is only certain to be correct for the image of the target, since the color rendering applied may be different for other scenes photographed.

There is also the case where a camera puts out files containing raw or scene-referred image data. If the raw image data results from capture using a color filter array (e.g. the red, green and blue color values are captured by different pixels), a special camera raw processing application is needed to create a viewable color image. In most cases, these applications (for example Adobe Photoshop camera raw) create standard output referred images, as would the camera. Camera raw processing is valuable because the user can guide the color processing applied to the raw image data, thereby eliminating the losses that result from incorrect white balancing or color rendering. These choices can be made without loss, after the picture is taken, to create the finished image file.

A very few cameras and camera raw processing applications (e.g. the Adobe DNG converter) put out scene- (or focal plane-) referred image data. These are typically professional camera backs that are designed for studio use. In this case it can be appropriate to create a camera profile that represents the scene in the ICC PCS using the colorimetric rendering intents. However, simple reflection target based characterization will often not produce the best results. It may be better to use the camera spectral sensitivities to calculate the transformation matrix, which will be illumination dependent. Ideally, this calculation will be optimized to the spectral radiance distributions expected for the scene to be photographed. Also, the perceptual intent of these true camera profiles should include color rendering to the ICC perceptual intent reference medium, and should be used for general photography. Camera profiles will typically be specific to particular shooting conditions (illumination, camera exposure settings, scene dynamic range, key, etc.).

In summary, in most cases the profiles that should be used with digital camera images are the appropriate standard color space profiles, which are generally available. It is only when professional cameras that produce scene-referred

image data are used that true camera profiles are appropriate. Reproducing relative scene colorimetry or appearance is primarily appropriate for specialized applications such as copy work, and product or catalog photography where scene color matching is the reproduction goal. Expressing relative scene colorimetry or appearance may also be appropriate in applications where the primary color rendering will be applied manually or with special purpose tools later in the reproduction process.

Unfortunately, there is a lot of misunderstanding around this topic, and little valid published information. Camera color rendering is sometimes inadequate to meet user needs. Camera profiles provide a way to apply color transformations, and in some cases there are controls in the profile creation software that allow photographers to create custom tweaked profiles to accomplish a specific purpose. ICC profiles can be used in this way to correct for color rendering deficiencies in specific images or groups of images. However, using camera profiles to compensate for inadequate color rendering can cause profile management, workflow, and interoperability problems, and there is a lot of user dissatisfaction. It is also somewhat misleading to think of these profiles as camera profiles, because in most cases they are essentially image correction profiles, or color re-rendering profiles.

Also, ICC color management workflows generally assume that the colorimetry expressed in the PCS is of a [color-rendered] picture, and not of a scene. There is currently no mechanism to indicate that the colorimetry represented in the PCS by a camera profile is relative scene colorimetry. Even if there were, use of the PCS to contain relative scene colorimetry is not fully compatible with current ICC workflows, which assume color rendering has been performed. This distinction is especially important with respect to highlight reproduction. Many scenes contain highlights that are brighter than the tone in the scene that is reproduced as white in a picture. An important part of the color rendering process is selection of the tone in the scene that is considered "edge of white", and graceful compression of brighter tones to fit on the reproduction medium (between the "edge of white" tone and the medium white).

An ICC working group has been formed to attempt to address issues with the use of ICC profiles in digital photography applications, but at present progress is difficult. Even if improved characterization targets (such as narrow-band emissive targets) and profiling tools are introduced, colorimetric intents will still be illumination specific, and perceptual intents will optimally be scene-specific. Some argue that scene-to-picture color rendering should be restricted to in-camera processing and camera raw processing applications, and correction of color rendering deficiencies limited to image editing applications.