International Color Consortium®

# White Paper #20

**Level: Introductory**
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## Digital photography color management basics

Photographers know that the world we live in and view is difficult to record on film, or even using a digital camera. Wouldn't it be wonderful if we could capture all the color and tone that we can see with our own eyes with our digital cameras! No need for fill-flash or fill cards, no need for additional lighting equipment; we could capture the scene as we saw it. That of course isn't possible. A scene might have a huge dynamic range, the tones between dark shadows and bright highlights that can be (in some situations) 10,000:1! I may want to print this yet the dynamic range of the print process might be 200:1 or less. Digital cameras do however "see" and record the world in a form that's quite different from how we see the world. The initial RAW data captured at some point has to be rendered to an image; an image as we want it to look, likely encoded into an RGB color space. This RAW data can be rendered to attempt to match the scene (as best the technology will allow) or the image can be rendered to create a pleasing reproduction of the scene. There's a big difference between the two and it's important to understand the differences. The actual scene we attempt to record may go beyond the scale of color, luminance, saturation, (you name it), that our devices can record, and beyond the ability of output devices to reproduce. Even scenes that do not can look dull if reproduced accurately. In most cases, when the rendering is such that we attempt to reproduce these items as closely as possible to the scene colorimetry, the measured color of the scene, we end up with an image that's not very pleasing when viewed on a display or printed (we have to view the digital image on something). Films have always included built-in contrast and colorfulness boosts, and highlight compression, to make pictures look better.

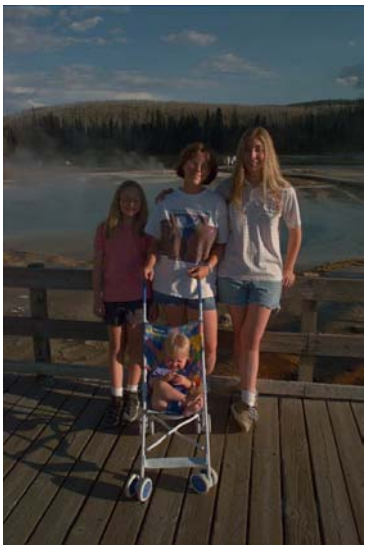
In technical jargon, the measured scene color the camera captures is known as Scene-Referred. Since we need to view this image on something like a display or a print, it's usually necessary to make the image appear more pleasing on the output device and to produce the desired color appearance the image creator wishes to express and reproduce. These image colors are known as Output-Referred. The need to fit the color gamut and dynamic range of the scene-referred data to output referred data is called rendering. The camera usually performs this rendering when you select a color encoding setting such as sRGB

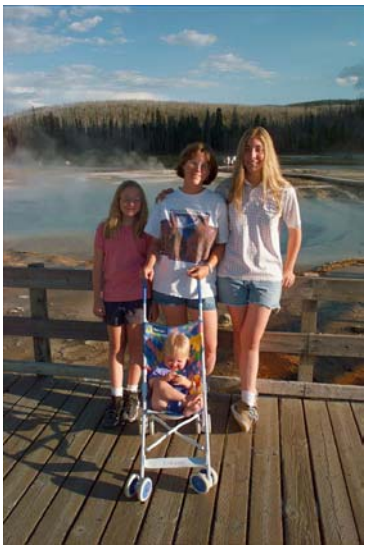
or Adobe RGB (1998). If the camera is set to capture just RAW data, the rendering becomes the job of the image creator; you the photographer. The creator of an image expresses their idea of how the scene should be reproduced on an idealized output device such as a standard display or print. The desired color appearance of an image you are editing is dependent on the output medium. This is not the measured color of the scene itself (scene-referred). An example of how a user would handle this output-referred processing would be using a RAW converter to produce the appearance they prefer from the RAW data.

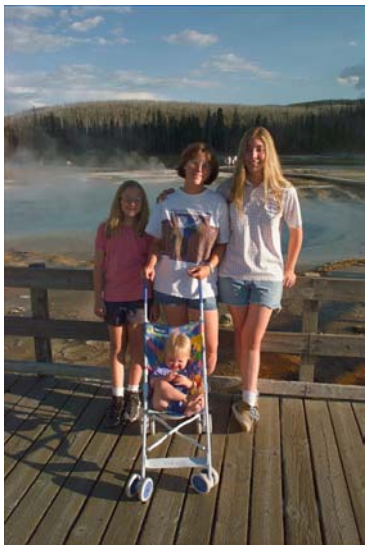
When you set your digital camera controls to capture an image (which is initially a RAW data file) into a color space (let's use sRGB in this example), there are two fundamental parts to this process: rendering the data and then encoding the data. In creating an output-referred image, the camera or computer system has to perform the color rendering processing before it can encode the result of the processing into sRGB. Because sRGB is rendered to output-referred data it cannot be used to accurately represent the scene appearance, or what some would call the colorimetry (measured color) of the scene. Therefore, first the data is rendered and this rendering process is based upon how a camera manufacturer feels they will produce the most pleasing image appearance for their customers. As such, this rending varies for different camera manufacturers, and perhaps even different models from the same manufacturer - the rendering is not standardized. Some cameras even custom render each scene. Think of this rendering process as a perceptual rendering of sorts; the rendering is that which the manufacturer feels produces visually pleasing color, not generally the colorimetrically correct color. This isn’t necessarily a problem; different film stocks have traditionally incorporated different looks, which are selected by the photographer based on their preferences. Many are under the mistaken impression that two sRGB encodings of the same scene from different camera brands should match but that is rarely the case; no more than two shots of the same scene on two different types of film, or two perceptual rendering intents from two different ICC profiles created by two different profile packages will match identically. However the degree of mismatch between cameras can be more pronounced than printing because the range of scenes captured is so much greater.

The second process after rendering the data is the actual data encoding which is standardized and unambiguous; the rendered data is encoded into sRGB in this example. Two identical renderings of the same scene will produce identical encodings in sRGB. The bottom line here is that when you produce an sRGB image file you aren't producing a colorimetric copy of the scene you took the picture of, you are producing an image as it would look rendered to an sRGB display or correctly previewed in an ICC aware application like Photoshop. The sRGB image file describes the picture on an sRGB display (output-referred). That display should behave, more or less, as described by the specifications that define sRGB (derived from a HDTV standard display of a specific phosphor

set/gamma/luminance and ambient condition). Of course if the display is profiled and the data being previewed has an embedded profile, the sRGB file or any tagged file for that matter, will preview correctly in an application like Photoshop. Nonetheless, what is being seen, and ultimately output, isn't a colorimetric representation of the actual scene (scene-referred). This is one reason why producing "accurate" color from a digital camera can be difficult. Accurate is in quotes since nearly every user has a different definition of what they mean or want when they say accurate. It should be noted that this rendering and encoding process isn't necessarily limited to the process of creating images using digital cameras.


Scene referred image


Camera A sRGB rendering


Camera B sRGB rendering

While it could be considered a bit of a color geek excursion, it is important to note the difference between a color space and a color encoding. A color space specifies the color coordinates (scaling), but not what medium the image in that color space is intended for. Most photographers understand that it is necessary to view prints and transparencies under some kind of defined and correct viewing specifications. If a transparency is 2 stops too dark, viewing that dark transparency on a light box that is 2 stops too bright isn't the right way to evaluate what is an under exposed transparency even if the image does appear better. If an image we are viewing on a display system is too dark, we don't increase the luminance controls to make the image appear lighter. We have defined references that describe how both the light box and the display should behave and how various types of imagery should be viewed. The color image encoding (which is sometimes called the color encoding) specifies the color space and what is called a reference medium, which describes the specifics of the medium on which the colors are being rendered. In other words, how images in a color space are ideally being viewed. The reference medium will specify such parameters as the white, black, and dynamic range of a printer or display as well as the environmental conditions under which the viewing of the image will take place. For example, the sRGB color space reference medium is that of a display

with a set of well-defined specifications on how this display behaves including the ambient light around this display. A CMYK color space reference medium is the press and paper for which the CMYK file will be output as well as the illumination under which the print is viewed. Color encodings provide a bit more detail about the color space based on a reference medium; how that data when output should eventually be viewed. Since digital camera systems need to take their original RAW capture data and encode that data into some RGB color space, such as sRGB, it's also important to recognize that the desired color appearance of an image you are editing is dependent on the output medium. If you want to be sure that your images will be reproduced correctly, it is necessary to communicate both the color space and the reference medium and viewing conditions.