Introduction to ICC Profiles

There is a fundamental problem inherent to the digital color reproduction workflow. Each device in a color imaging chain (e.g., camera, scanner, monitor, ink jet proofer, offset press, etc.) has distinctive characteristics and capabilities which cause it to capture or render color in its own unique manner. We say that each imaging device operates within its own specific, limited, color gamut and *speaks its own language* of color. Until ink is applied to a substrate, a digital image exists only as a collection of electronic signals (e.g., pixels) defined by numerical data—data that is subject to a wide margin of interpretation by any number of color rendering devices.

<u>The Need for Color Profiles</u>

Digital color data, i.e., combinations of RGB or CMYK numeric values, are not at all universal but highly device specific—based solely on the behavior of the specific devices that produce them. For example, one camera may "see" the color of an object and assign color data much differently than another camera. Likewise one monitor may interpret and project RGB triplet numbers quite differently than another monitor. Further down line in the workflow, once RGB triplet data has been converted to CMYK tonal percentages, color output is subject to the characteristics of the specific printing system applying the ink to paper (characteristics of a printing system include the visual results of the physical interactions of a particular ink and paper combination). The operational color space and color rendering gamut of a device or process, therefore, determines the scale of reference (the *language)* in which tri-chromatic color data is assigned by a device or within a process. Serious system communication and color data transfer problems occur when the scale of reference is different for each color capturing, editing, or color rendering device. In other words, when each device in a workflow is operating within the framework of a different gamut or color definition language, the success of color reproduction will be disappointing at best. It would not be surprising to expect that the final printed color may not even resemble the color captured with a camera or created on the virtual desktop!

The key to successfully interpreting and managing the transfer of virtual color is dependent on being able to precisely define the color gamut and operational behavior of the device with which it was produced. This can be accomplished by characterizing the color rendering capabilities of a device and creating a device specific **profile** that defines its color gamut. Without a profile to describe the color behavior of the device of origin, RGB triplets or CMYK percentages are ambiguous; they mean nothing (or at best provide generalized information) when sent to downstream devices. A device specific profile will give universal meaning to RGB and CMYK data. When a profile is embedded in or tagged onto an RGB or CMYK image, it is as if the image carries with it a language translator that can be consulted to translate the value of each RGB pixel or CMYK tonal percentage into the color language understood by the destination device.

International Color Consortium

In 1993, a cross-platform council called the International Color Consortium (ICC) was formed to develop a universal framework for creation of device and process specific color profiles. The ICC established a profile format wherein numeric data that characterizes the color gamut of a specific device or process can be directly linked to universally understood reference data (such as CIELAB or CIEXYZ). The International Color Consortium remains the regulatory body that supervises color profile protocols used by software vendors, equipment manufacturers, and end-users. All ICC profiles follow a certain naming convention protocol and use either an .icc or .icm file extension suffix.[1]

[1] ICC and ICM files are identical except for the suffix. The .icc extension was originated by Apple. Windows has traditionally used .icm (*image color management)*. Most application programs (including the Adobe Creative Suite) do not care whether a profile has an .icc or .icm suffix and will apply the file in exactly the same manner. There are, however, some Windows applications that will not recognize the .icc extension. Therefore, .icc suffixes should be changed to .icm when installed on Windows based systems.

What is an ICC Profile?

An ICC profile is essentially a complex look-up table that allows device *dependent* color data to be correlated to device *independent* reference data (i.e., a common reference color space/model such as CIELAB or CIEXYZ); much in the same manner that a translation dictionary provides word equivalents between two languages. Color management systems use the reference look-up tables within device specific profiles to accurately convert colors between dissimilar color rendering devices. Profiles do not alter the behavior of color rendering devices or systems; they are merely reference documents that give RGB and CMYK values universal meaning by associating each point of RGB or CMYK color, as produced by a certain color rendering system, to specific CIELAB or CIEXYZ values. In essence the profile will say that *this* RGB or CMYK number, as produced by *this* specific device, actually means "this" in terms of CIELAB or CIEXYZ. A typical profile will contain thousands of data points and extensive reference information. Converting color images always requires two profiles: a source profile that describes the colors in the file being converted, and a destination profile that tells the color management system what control signals are required to reproduce those colors on the destination device. Figure 1 illustrates a portion of a very simple RGB to CMYK transform.

Device Dependent Data From the Source

R	G	B
255	255	255
255	255	223
255	255	191
255	255	159
255	255	127
255	255	85

→

Device Independent Reference Data

L*	a*	b*
100	0	0
99.26	-5.26	15.31
98.65	-9.81	30.68
98.15	-15.89	31.25
97.76	-18.88	47.28
97.40	-21.66	65.87

→

Equivalent Device Dependent Data Sent to the Destination Device

C	M	Y	K
0	0	0	0
0	0	12.55	0
0	0	25.09	0
0	0	37.65	0
0	0	50.19	0
0	0	66.67	0

Figure 1

There are three main classes of device or system profiles:

1. Input profiles: Characterize devices that capture and therefore input color into a workflow—such as scanners and digital cameras.
2. Display profiles: Define the behavior of display systems (i.e., monitors).
3. Output profiles: Describe and define the gamut or the range of color that a printing system or other color output device is capable

of reproducing (e.g., a digital or offset press). Note that the interaction between ink and paper is a significant contributor to the gamut of the printing system.

We have focused on device profiles—profiles that characterize an actual color rendering device or a class of devices. There are also device independent profiles that describe entire color spaces. RGB and CMYK working space, or editing space, profiles describe average color rendering systems where images are created and retouched and are also an integral part of the color management system (working spaces include sRGB, Adobe RGB 1998, GRACoL 2006, etc).

Constructing ICC Profiles

ICC device profiles are sometimes supplied by equipment manufacturers (as in the case of some monitors and desk-top printers), but most often custom profiles made for specific devices and processes are the most accurate. To construct a custom profile three components are necessary: profiling software, a test chart, and a color measuring instrument. Once the color test chart is rendered (printed or displayed), a color measurement device is used to read the CIE L*a*b* (or CIEXYZ) values of each patch. The software "knows" the intended color value of each patch on the target. The software analyzes the *measured* L*a*b* data and correlates the actual displayed or printed color value to the intended color value of each patch. A look-up table is built that in essence says, "When this device renders this specific RGB or CMYK color value, it actually means '*this*' in terms of CIE LAB" (*cf.* Figure 1). The profile, therefore, provides a look-up table (a dictionary) defining how a device or a process displays colors and also a map of the range of the specific gamut that the device or process is capable of rendering. Once an ICC profile has been established, all users can know the color rendering capabilities, i.e., the color rendering "language," of the device.

Several different types of test charts are used for profiling. Some are meant to be scanned, others are designed for display by a monitor, and others are intended to be printed either by an ink jet, offset, or digital production system. Most profiling charts follow a subset of the IT8 format.[2] Typically, the more color patches displayed and measured, the more accurately defined the color space will be. However, smaller patch

[2]The IT8 target formatting protocol is defined by the IT8 Standards committee, a division of the American National Standards Institute (**ANSI**).

sets require the profiling software to use more interpolation between data points, often resulting in smoother tonal transitions. Profiling targets can either be designed where patches are arranged in an orderly fashion according to progressive tonal values or the patches can be randomly scrambled. Figure 2 shows a complex "scrambled" IT8 profiling test chart. It is important to note that a profiling test chart cannot cover every possible color combination. If it did, the look-up table would be too large to manage. Therefore, a certain amount of interpolation is always necessary—both when the profile is created and when profiles are linked together during the data mapping process.

Since the success of color management is dependent on the accuracy of profiles, it is critical that before a profile is created, the color rendering device must be in a calibrated and repeatable state. Likewise, given that a profile is actually a snapshot in time of a device's color output ability, it is important to maintain the validity of the profile by ensuring consistent color output response.

Figure 2

To summarize the profiling process (often referred to as the "three C's"):

Ensure Operational ***Consistency*** and ***Calibrate:***

1. Verify that the output device is properly calibrated (in a centered, known condition) and is operating in a stable and consistently repeatable state.

Characterize:

2. Output (print or display) a chart of known colors through the device being profiled. The chart must contain a reasonable

sampling of color combinations if the device is going to be properly characterized.

3. Use a colorimeter or spectrophotometer to measure the color value of every patch (yes, every patch; but we have automated instruments that can do the work!)
4. The profiling software compares the actual color values of the measured patches to the intended color values. The software then builds a profile which defines the color rendering behavior of the device. A lookup table is constructed which relates output values to universal CIELAB or CIEXYZ values.[3]

The Color Management Module

The color management module (CMM) is the software "engine" within a color management system that performs all the needed calculations to interpret, link, and convert color profiles between devices; thus ensuring the best visual color match as files are passed from device to device, color space to color space. The CMM works in the background as a resident of the Apple operating system (ColorSync); and in Windows based systems as the Windows ICM engine. Adobe also provides a CMM engine which is an option that is preloaded in the Creative Suite. As previously mentioned, since a profile by no means contains every possible color reference in a device specific color space, the CMM is called upon to do quite a bit of interpolation—always using CIELAB as the transitionary color space.

We will illustrate two separate scenarios of color signal data conversion using source and destination profiles:

RGB Data Translated Between Two Color Display Systems

When asked to display an RGB color of R156/G18/B185 as specified in a source file, the color management system will immediately consult the ICC profile embedded in *(tagged onto)* the source color file. The color management system learns the CIE LAB equivalent of the RGB triplet from the source file's profile look-up table. The look-up table within the destination (display) profile is then consulted by the color management module and it is concluded that, "knowing how this particular display

[3] The ICC has defined two color characterization systems for use as intermediate profile connection spaces - CIELAB and CIEXYZ. CIELAB is generally preferred since it is used by Photoshop and the Adobe Creative Suite, is the basis of international print standards and specifications, and is most readily used by most color management application programs and systems.

system renders color, in order to achieve a visual RGB value of R156/G18/B185 (which equals an L*a*b* value of L*: 39.59, a*: 70.54, b*: -68.74), I will actually need to send values of R162/G27/B174 to the display." The lookup table, therefore, aids with translation of the digital color values in the source file to new RGB values which compensate for the behavior/characteristics of the destination device—i.e., the display system.

RGB Data Transformed into CMYK for Print Output

The diagram below (Figure 3) illustrates a practical use of profiles by demonstrating the process of an RGB to CMYK file transform.

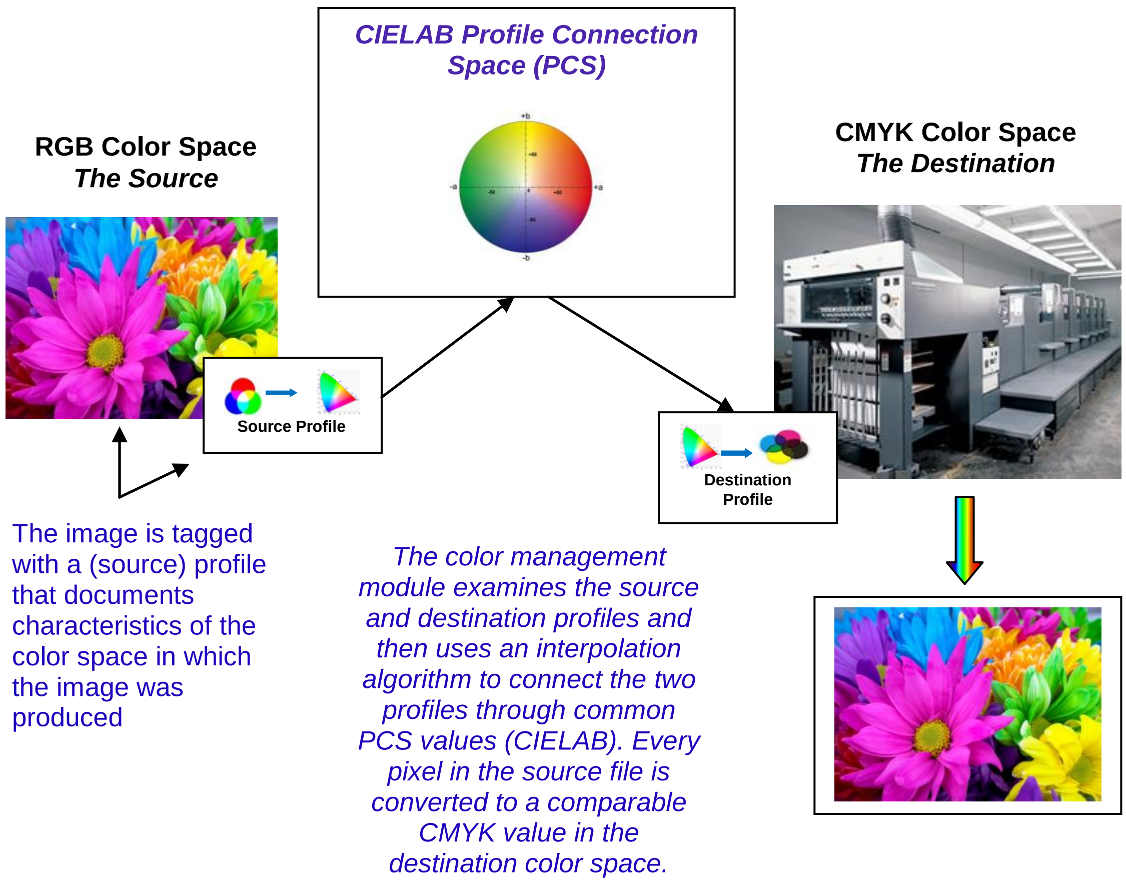

Figure 3

The RGB image is "tagged" or embedded with a source profile that defines and explains the color rendering behavior of the device that created it. The image carries the embedded profile wherever it goes. The color management module evaluates the embedded RGB profile to determine what actual colors (in terms of CIELAB) are represented in the file. The color management module then consults the CMYK destination/output profile which explains the gamut of the offset press. Finally, the CMM performs a device--to profile connection space (PCS)--to device transform correlating all source and destination data to device independent, universal CIE LAB values. RGB values are interpolated into the CMYK equivalents which will best represent the intended color of the image when reproduced in this particular offset printing system.

Profiles take on temporary roles of source and destination. During a color conversion, the source profile always represents the color that is being converted while a destination profile represents the output device.

Sappi Paper Specific Profiles

It is often said that paper is the fifth color of the four color printing process. Paper affects the hue of the highlights, contributes to the smoothness of tonal transitions in the quarter to mid-tones, illuminates the three quarter-tones, and determines a significant amount of print contrast in the shadows. The physical and optical properties of paper dramatically affect the dynamic range of color rendition, and the interaction between paper and ink on press provides significant contribution to the gamut of the printing system.

Sappi Fine Paper is pleased to provide paper specific CMYK ICC profiles for each of our sheetfed and selected digital papers in order to ensure that our partners have the best tools possible to achieve optimal results when preparing and printing CMYK files.[4]

The unique advantage of using an ICC profile customized for a particular Sappi paper grade is that multiple characteristics of the paper which contribute to color gamut (e.g., shade, surface finish, ink absorption, gloss, etc.) are accounted for in the profile.

The Sappi ICC profiles were created from IT8 7/4 (1617) targets embedded in a gray balanced, G7 qualified, press sheet printed with ISO 2846-1 defined inks to the GRACoL 7 specification.

ICC profiles may be loaded into Mac and Windows based systems for soft proofing and other purposes. Once installed in the computer system, an

[4] Sappi ICC profiles have been professionally constructed by Rochester Institute of Technology and are provided free of charge but without warranty of any kind.

ICC profile will be available for use by all "ICC profile aware" application programs and utilities. All Sappi profiles are configured in a format that has been standardized by the International Color Consortium (ICC).

For more information, and to obtain Sappi product specific ICC profiles, please call the Sappi Printer Help Line at (877) 727-7443 or send an e-mail request to dennis.dautrich@sappi.com.