Color Management Using ICCv4 Profiles

Gary Dispoto, Ingeborg Tastl, Jack Holm; Hewlett-Packard Company; Palo Alto, California, USA

Abstract

In today's world, professionals and consumers capture scenes or original art; modify the images; build composite images; create documents; display them on a variety of different devices; move the data between systems; reproduce it on different media using different printing technologies; and potentially re-capture the data and feed it back into the system, while proofing and previewing along the way. The devices, drivers, applications, and operating systems involved all inherently interpret and reproduce colors differently. Unambiguous interpretation of color data and color transforms that can achieve the desired results at many points in the system are necessary. Reproducing an image on different devices may require a re-optimization of the colorimetry considering the source image appearance and the source and output medium capabilities and viewing conditions. This paper describes how all of this can be achieved by using the latest version of ICC color management.

Introduction

Many commercial printing and publishing businesses are undergoing a transformation from a conventional workflow using offset presses, to a digital workflow using digital presses. The move from conventional to digital workflows and equipment brings with it a number of technical challenges in the production of high quality output. Moreover, traditional printing applications such as advertisement, financial transaction and billing, entertainment, and knowledge transfer are being challenged by online applications. In order for these applications to continuously result in a printed end product, the printed form has to provide and demonstrate value to the user over the electronic form. Opportunities include on-demand printing of manuals and books with no warehousing, and personalization, where every page printed can be different. These opportunities arise from a currently still prevailing human preference for printed books and personalized printed material.

In a conventional offset printing workflow, jobs are created and assembled by graphic designers. Conventional graphic arts scanners produce fully rendered CMYK files that are prepared to be printed using offset lithography standards such as SWOP, Euro, or Toyo. The color-separated job is proofed on a proofing system such as Dupont Chromalin™ or Imation Matchprint™. These systems use the same or similar colorants as the final output devices and can use the final separations as their input. When the designer is satisfied with the proof, the job is sent to the print shop, where printing plates are produced and mounted on a press – a time consuming and costly task. A press check is done to ensure that the color is correct on press, relative to the proof. If not, the press operator tries to fix color problems on press, rather than going through the very costly process of producing new separations. When the press check is complete, the final print run is made. The print run generally needs to be long in order to amortize the high fixed costs.

Digital printing presses do not require printing plates or a long and tedious set-up process and thus don't have to amortize the costs through long runs. Likewise, individual color proofing and adjustment of each printing job is not acceptable in digital color production printing. The cost of a press operator adjusting color on press can not be amortized assuming a long print run. The press check must be replaced by stable, digital printers, reliable digital color management, and accurate digital proofing devices.

Another observable trend is that the set of devices on which digital data can be generated or consumed is increasing rapidly. Conventional color reproduction systems were closed systems. Color television cameras produced signals ready to be displayed on color television sets with very specific characteristics. Graphic arts scanners produced standard print CMYK data, which was matched to particular inks and transfer characteristics. Traditional color films and photographic papers were designed to work together, with no option but to print the negative on the intended photographic medium. Today, just about any capture device may act as the "on ramp" for graphic content to an all inclusive digital system. Devices have a very wide range of characteristics and capabilities. In an open system, any input device's data may flow to any output device. Likewise, output devices are based on a variety of different technologies, have a wide range of characteristics and capabilities, and the manufacturer and end customers generally want their devices to be used to their maximum potential. One specific example are displays, which moved from one type (CRT) to a whole set of different technologies (LCD, plasma, projection) resulting in a much broader range of color reproduction capabilities.

The industry is still adapting to the changes from a set of closed systems to open systems with a wide variety of input and output devices that are all supposed to work together. In addition, the expectations of users have also changed. Often they don't care about the specific reproduction technology that is used, but they do care about a consistent look and feel across different devices. All these trends present interesting technical challenges for comprehensive, high quality digital color management.

Core Concepts of the ICC Color Management System

The International Color Consortium (ICC) was formed in the early 1990s to develop commercial printing industry standards for the management of digital color data. Broadly speaking, the ICC system uses color profiles to provide transforms between various color encodings (such as exchange color encodings, working spaces, and device specific values) and a common interface called the Profile Connection Space (PCS). The transforms are applied using a Color Management Module (CMM). The ICC profile format is a data structure that contains the information necessary to perform the transformations. For example, an input profile will convert data from a capture device's native color encoding to the PCS, and likewise an output profile will convert data from the PCS to the output device's native encoding. Standard color encodings such as sRGB, Adobe RGB (1998)™, and Standard Web Offset CMYKs are also supported using profiles to convert between these encodings and the PCS.

Recognizing that color reproduction objectives vary, ICC profiles contain four rendering intents: Perceptual, Saturation, Media-relative Colorimetric, and ICC-absolute Colorimetric. The Perceptual Intent (PI) transform maps color data from one encoding to another such that a pleasing reproduction which maintains the artistic intent of the source data is obtained at the destination. For example, the PI transform for a printer would take data in the PCS and transform it to the printer's color encoding such that an image in the PCS would look pleasing on the printer. The transform must take into account both the PCS Perceptual Intent Reference Medium (PRM) and the actual print medium's dynamic range, color gamut, and viewing environment.

The colorimetric intents transform colors between the PCS and a device or standard color encoding such that colorimetry, either relative to the media white or to a hypothetical perfect reflecting diffuser, is preserved. For example, an ICC-absolute colorimetric transform will take colorimetry (CIEL*a*b* or CIEXYZ) in the PCS and transform it to printer coordinates such that when those device coordinates are actually printed (and measured), the colorimetry in the PCS is obtained (within the print medium gamut). Media-relative colorimetric transforms perform this in such a way that all measurements are with respect to the device-side media white.

In the most recent version of the ICC specification, ICC version 4 (v4), profiles are recommended to be bi-directional. In most cases the transforms go both to and from the PCS. This allows profiles to be used as both source and destination profiles as desired. For example, a standard CMYK printing condition profile that was the destination in the creation of original printed content can be used as the source profile in a conversion to sRGB for web viewing.

Issue with ICCv2 Specification and Implementations

One way to design a color management system with perceptual color rendering is to use an intermediate reproduction description. As an example, baseline color management for consumer digital photography uses an intermediate reproduction description approach. Digital cameras produce sRGB data and printers consume sRGB data. Cameras are responsible for color rendering scene data such that it looks pleasing on an sRGB display in the viewing conditions specified by the sRGB standard (IEC 61966-2-1). Printers assume the image looks pleasing on an sRGB display in the sRGB viewing conditions and color re-render it for the actual print gamut, viewing environment, etc. An sRGB display provides an intermediate color rendering target for image data exchange.

The ICC system also uses an intermediate reproduction description approach for the PI, using the PRM. Input profiles convert from the input encoding to a colorimetric encoding that would look pleasing if it were printed on the ICC PI PRM. Conversely, PI output transforms assume image data appears pleasing on the PRM and color re-render the data for the actual output medium and viewing conditions. The PRM is the intermediate rendering target.

An issue with ICCv2, the previous version of the ICC specification, was an under-specification of the PRM and ambiguity in how to use it. Different profiling software vendors and equipment manufacturers made different assumptions about the rendering target in the PCS. Some vendors rendered the entire encoding range of the PCS to the gamut of a printer or display. This led to quality issues and distrust of the PI, as it is not possible to color render and re-render to and from a reference medium gamut that cannot be viewed (to check the quality of the rendering). The quality issues led some to assume sRGB or other display-like colorimetry in the PCS. This led to interoperability problems with profiles from different vendors, and a confounding of rendering intent selection and source profile type. The rendering intent selection became dependent on the source and destination profiles to be used. This is contrary to the ICC design goal that rendering intent selection depends solely on the reproduction objective, and makes workflows considerably more complicated. It also tends to produce poor results when the PI is used and the source is not display-like. Furthermore, since this ad-hoc workflow is not standardised or documented, users cannot assume that all profiles have been constructed accordingly. During the development of v4, there was a thorough review of the ICC specification to remove all known ambiguities, and address interoperability and workflow complexity problems.

The ICCv4 Perceptual Intent Reference Medium

The v4 PRM has a reference viewing condition based on the P2 viewing condition for appraisal of hard copy prints in ISO 36643, with an illuminance of 500 lux and a neutral surround reflectance of 20%. The PRM is based on a high quality virtual photo print with a 288:1 dynamic range, having a neutral media white reflectance of 89% and a darkest printable colour with a neutral reflectance of 0.30911%. In addition a viewing flare of 0.75% of the luminance of the reference medium in the reference viewing environment (i.e. 1.06 cd/m2) is assumed relative to the prescribed 45/0 reflection measurement geometry.

The dynamic range of the Perceptual Reference Medium was defined in the ICC v4 specification, but not the target gamut. The PRMG amendment4 adopted the gamut from ISO 12640-35 as the PRM gamut, thus for the first time providing a necessary and sufficient definition of the PRM. (It should be noted that the PRMG is intended as a 'fuzzy' gamut; it is not necessary to map exactly to and from this gamut.) The PRMG amendment provides optional tags for the perceptual and saturation rendering intents that identify whether the PRMG was used in rendering to or from the PCS.

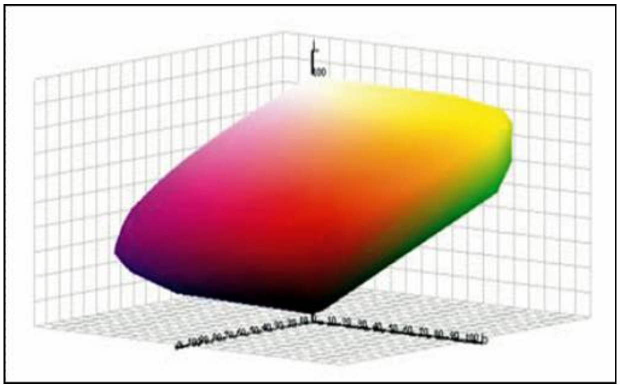

Fig. 1 Perceptual Reference Medium Gamut.

The PRMG completes the definition of the PRM. It approximates the gamut of commonly occurring surface colours, and few reproducible colours will be found to lie outside the PRMG. A full specification, including data on the gamut surface and primaries is given in ISO 12640-35,6.

Most input and colour space profiles in circulation are ICC v2 profiles, and do not have perceptual intents that render to the PRMG, or even to the v4 PRM. ICC is addressing this through white papers available through the ICC web site, and by providing a default ICC v4 sRGB profile whose PI renders bi-directionally between the sRGB color encoding and the PRM. This profile is available for download from http://www.color.org/srgbprofiles.xalter.

Similarly, most existing printer profiles are v2 profiles, or, if they are v4 profiles, they most probably have a v2 type perceptual transform which does not consider the v4 PRM. ICC is communicating to vendors that the use of the PRM is required with v4 profiles, and recommends that the PRMG be considered the gamut of the PRM. Current work in the ICC includes the development of profile assessment tools and methods to check whether v4 profiles are correctly constructed.

How to Use the ICC sRGB v4 Default Profile

The sRGB_v4_ICC_preference.icc profile (as it is officially called) is a v4 replacement for commonly used v2 sRGB profiles. It gives better results in workflows that implement the ICC v4 specification. It is intended to be used in combination with other ICC v4 profiles. The advantages of the new profile are: 1) More pleasing results for most images when combined with any correctly-constructed v4 output profile using the perceptual rendering intent. 2) More consistently correct results among different CMMs using the ICC-absolute colorimetric rendering intent. 3) Higher color accuracy using the media-relative colorimetric intent.

A typical use case would be to print sRGB images captured with a digital still camera. In this case a user could open the image in Adobe Photoshop™ and assign the sRGB v4 profile. The user would then convert the data to printer specific values with the sRGB v4 profile as source, the v4 printer profile as destination, and select the perceptual rendering intent,. The three available rendering intents of the sRGB v4 profile should normally be used as follows: 1) The ICC-absolute colorimetric rendering intent should be used when the goal is to maintain the colors of the original on the reproduction, 2) The media-relative colorimetric intent should be used when the goal is to map the source medium white to the destination medium white, 3) The perceptual intent should be used when the goal is to re-optimize the source colors for the destination medium while approximately maintaining the "look" of the source image Overall users can expect to get better and more consistent results using the sRGB v4 profile versus the sRGB v2 profiles. More details are available through the ICC web page www.color.org.

Conclusion

In today's world, both consumers and professionals have moved from using a set of closed specialized systems to using and taking advantage of open digital system and expect that all the pieces work together and provide quality results. The ICC color management architecture and profile data structure is well suited for the needs of the 21st century. However, a full implementation of the ICC v4 specification and the newest amendments is needed by companies, who provide profiling software, by companies who provide ICC profiles to the end customer, and by application vendors who use ICC color management.

The transition to ICC v4 can be achieved if some companies play a leadership role for the benefit of the industry and their customers. The ICC, as an industry consortium is committed to helping the industry make the switch from ICC v2 to ICC v4 by providing educational materials on its web page and through events like the ICC Developers Conferences, as well as a through the distribution of default profiles that are needed for typical workflows and can be used by everyone.

References

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Author Biography

Gary Dispoto is a department manager for the Color and Precision Imaging Department at Hewlett-Packard Laboratories in Palo Alto, California, USA. He has been at HP Labs for over 22 years, first working as a researcher on the area of color reproduction, and later managing color reproduction at HP Labs. He currently manages research on color reproduction and other elements of print production. He holds B.S. and M.S. degrees from Stanford University and an M.B.A. from the University of Santa Clara.