Color Management

What's Needed for Printing & Publishing?

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Color management has been the subject of numerous articles, test reports, "how to" tutorials, and evaluations over the last few years. While many of these have addressed graphic arts applications, they have focused primarily on applications within a single site. I would like to step back and look at color management and try to see where it fits within the larger printing and publishing industry workflow to understand its potential benefits and/or impact.

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Part of the problem is that because we have so many different workflows, it is difficult to describe the role or benefit of color management for any specific user, much less the industry in general. Thus, there has been a lack of any clear definition of features and requirements color management tools need to have to meet the needs of the printing and publishing industry, as contrasted to the many other applications for color management.

Where to Start

In an attempt to reach some level of agreement in discussions, to quantify requirements and concerns, and to provide recommendations, I have chosen to use three color management workflow scenarios to characterize the application of color management within the industry. While many other possibilities exist, these scenarios are sufficiently representative that they can provide a realistic basis for discussion of capabilities and requirements.

The three scenarios I have chosen to use as references represent:

¶ Where users typically are today, i.e., baseline ICC (International Color Consortium) color management (see sidebar on page 10) use;

• A typical single vendor solution, i.e., a closed, in-house color managed workflow; and

, An industry-wide, multi-vendor, interoperable color managed workflow for process-color data.

In all three scenarios there are some fundamental assumptions I have made concerning the basic operating methodology of the printing and publishing industry. This methodology in some ways sets printing and publishing apart from other applications of color management, and it is also not likely to change in the near future. One caution is that these scenarios have a principally North American focus and these may not fit the workflows in other parts of the world quite as well. In addition, they are aimed at four-color, process-color printing. Other important issues such as duotones, Hi-Fi color, package printing, etc., are not included but are relatively straightforward extrapolations. These assumptions are:

•A key element in the printing and publishing workflow is that several different organizations (companies) are involved in the workflow. Typically, they are the customer, the

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designer, the preparatory shop, and the printer. Each has a role to play and each needs to verify that their part was done correctly. In the advertising world when something goes wrong there is something called a *makegood*. That is, one of the participants must make good the cost of the failed advertisement. This requirement becomes a driving force when new technology or options are being considered that may put at risk the ability to clearly identify the quality of image information being exchanged between the participants.

•From the color management point of view, a key issue is that the preparatory shop gets color image approval from the designer and the customer relatively early in the process, usually based on a hard copy proof. This proof and the data files are then shipped to the printer for reproduction. The printer is expected to match the proof using whatever capability he has. Matching the proof involves not only getting the color correct but often also matching the image structure that creates the color. At the high end, the black-to-color relationship (UCR, GCR, and separation aims) is also expected to match.

•This means that if data other than CMYK are shipped between the preparatory shop and the printer, the printer must be able to reconstruct the CMYK that was used as input to the proofing process that produced the customer approved proof. This would seem to apply even though both proofing and printing may use additional color management manipulations of the CMYK data to account for individual device characteristics.

•This is further complicated, in the publication workflow, by the many-to-many relationship that exists between advertisers and publications. The same ad is sent to many

What Is a Color Management System?

A color management system, as described by the current International Color Consortium (ICC) architecture, is a method by which the color characteristics of all input and output devices are related to a common reference. Using this approach, instead of requiring individual transforms for every combination of devices, pairs of transforms may be combined to link devices. To add a new device requires that only the transform linking the device to the common reference be created.

The key parts of such a color management system therefore are: the common reference or profile connection space (PCS), the transforms between the devices and the PCS (Profiles), and the color computing software that processes the image data through the profile transformations (color management module, CMM).

The PCS is nominally the CIELAB color space associated with a reflection print with a very large color gamut. (There are many additional details that are required by the color scientist in building profiles but those do not have an impact on our general understanding.)

Profiles are based upon device characterization data, that is the relationship between color data values (either in an original being viewed or scanned or produced by an output or display device) and the device code values that correspond to that particular part of the image. These may be scanner code values (RGB), the output of a digital camera, the RGB values that feed a monitor, or the CMYK or RGB values that drive printers.

Profiles may have several flavors or intents. The two of most interest to the graphic arts are perceptual and colorimetric. Perceptual preserves the appearance of an image while colorimetric preserves the color of an image.

Input profiles (device to PCS) generally attempt to maintain the full range of color data available, simply making any appearance transforms necessary to convert from original to PCS color definitions. The classic example of this is the color transparency which is intended for viewing in a darkened room and must have contrast and color balance adjusted to accommodate the “ideal reflection print” PCS. Output profiles, on the other hand, have several choices. If they are perceptual, they must accomplish the gamut and tone scale compression necessary to fit the color of the original, as reflected in the PCS color space, into the available range of the output device. If they are colorimetric, they must simply reproduce what is in gamut and gracefully do something with the out-of-gamut colors. In both cases the output profile also accomplishes the color separation task including UCR, GCR, UCA, etc.

The same source data and input profile could be used with a CMYK output profile to go to print and a web RGB output profile to go to the World Wide Web (WWW). This flexibility and versatility is the attractiveness of color management.

publications and each publication receives ads from many customers (and therefore preparatory shops). Therefore, the color management tools used between the various participants in the workflow cannot be common (unless there were a single dominant color management vendor) but must behave in a consistent (standard) fashion.

• Publication advertising is what drives much of the industry expenditures on new tools like color management, etc. In most publications advertising drives the process and editorial goes along for the ride. By the same token, in the typical preparatory shop or printer the most demanding requirements are the advertising work and the rest of the work rides along using the same capability.

Workflow Scenarios

Let's look in more detail at the three scenarios we have chosen to use as reference: (1) baseline ICC color management use; (2) a closed, in-house color managed workflow; and (3) an industry-wide, multi-vendor, interoperable color managed workflow.

Scenario 1

Today, color management is most often used to import data from scanners, cameras, and other sources and convert it directly to press-ready CMYK data. These CMYK data aims may be based either on local shop requirements or industry standard printing conditions. Data are edited, merged, and color corrected in CMYK. In this scenario, because all data exchanged is CMYK, inter-operability between color management systems at the data interchange level is not an issue and no color management information is carried with the CMYK data being exchanged.

Color management may also be used later in the workflow to allow proofing devices to emulate a given printing condition. This use of color management is often invisible to the user, as it becomes part of the proofing device. The use of color management as the control and matching tool for use with non-halftone proofing systems is common practice. The use of color management to retarget data, between CMYK and other applications (e.g. web publishing) or devices, is also becoming more widely used. However, it must be remembered that any repurposing or retargeting of data, via color management, in scenario 1 must accept the already gamut limited CMYK data as input.

Even in scenario 1, it may not always be possible to have all color management elements provided by a single vendor. Editing tools, device specific profiles, CMMs, etc., may, of necessity or practicality, be provided by different vendors. This intermixing of different vendors' products may present problems of compatibility, and consistency within the individual shop. However, once initial issues of compatibility are solved the same tools are used over and over again as a routine part of the local shop workflow, which is primarily CMYK based.

Scenario 1 allows an organization to begin to use color management incrementally. It can be phased into parts of the workflow in parallel with existing practices. While to many, the advantages are not significant, neither are the risks. It is the typical first "get your feet wet" step.

Scenario 2

In scenario 2 all work within a shop is color managed. Here, input data are tagged with the appropriate input profile, or a pointer into a profile library. Data are edited, merged, and color corrected as raw data, as PCS (profile connection space) data, or in whatever color space the color management system vendor finds convenient. When the final page (or job element) is ready to be output it is converted to CMYK, possibly even in the output device RIP. Data to be exchanged are also converted to CMYK appropriate to the intended application. The advantages of color management are achieved within the shop, but data exchange and interoperability are still tied to traditional CMYK techniques and limitations.

This approach to color management is optimized when all corresponding parts of the system are provided by a single vendor (e.g., all profiles from same vendor, only one vendor's CMM, etc.). This places minimal restrictions on the color management system as there are no interoperability requirements. However, none of the advantages of using color managed data for receipt of input from other sources or exchange of final work are easily available.

This approach works especially well for those printing operations where creative, prepress, and printing are all done within a well controlled environment, typically controlled by a single organization. Some catalogue work, much promotional material, some commercial printing, and most specialty printing fall in this category.

Scenario 2 can be viewed as a more sophisticated version of scenario 1 which still uses CMYK data for exchange but uses color managed data for all intermediate processing. A particular feature that is available within this scenario is the use of a custom intermediate color space for image editing, assembly, and correction and/or the use of non-ICC compliant color management techniques and procedures. Because scenario 2 is usually envisioned as a single vendor solution with CMYK

output, multi-vendor compatibility and interoperability is not felt to be an issue.

This lack of interoperability is the biggest drawback of scenario 2. An individual shop may fully embrace a particular vendor's brand of color management and achieve significant improvements in productivity within their shop. However, when they try to interact with partners in the printing chain who are not using color management or are using some other "brand," the need to use CMYK for data exchange can become a real roadblock. This is particularly true when the interaction requires sequential editing, correction, and proofing—for example between a design house and a prepress service provider.

Scenario 3

An industry-wide, multi-vendor, interoperable color managed workflow (using four-color, process color) involving multiple organizations is embodied in scenario 3. A partial model for this is the "blind" exchange concept that drove many of the features of PDF/X-1 (*ANSI/CGATS.12/1, Graphic technology—Prepress digital data exchange—Use of PDF for composite data—Part 1: Complete exchange (PDF/X-1)*) The key element is that the sender and receiver should not have to communicate with each other concerning the particular characteristics of their systems to be able to successfully and correctly exchange color managed data.

Source data (scanner code values, monitor values, CMYK source data, etc.), accompanied by appropriate input and output profiles, would be used for editing, merging, color correcting, and data exchange. Such data would be temporarily converted to CMYK for proofing and or output, and any device link profiles needed for proofing devices or press retargeting would be added as necessary. This workflow would preserve full repurposing capability of the data as well as minimizing any data loss due to conversion to CMYK and subsequent transformations to an alternate CMYK for proofing, etc. This can be thought of as a "virtual CMYK" workflow (source data of any type **plus** all necessary profiles to get to a specific CMYK data set).

A useful example of some of the requirements of the scenario 3 workflow is a typical publication workflow model. In this model advertisements are prepared at a variety of locations and each would be assumed to have appropriate input and output profiles from their favorite vendors. Each preparation site would process the image data to CMYK for proofing and customer approval using their vendor supplied CMM (the color management module—the software color computing engine in a color management system). It is assumed that the actual profiles used to obtain customer approval would then accompany the source data when it is sent to the publisher. The publisher would then assemble the various inputs as source data plus profiles and then process these composite data files through a single CMM to create CMYK data for imaging to plates or film. Where appropriate, the publisher might add device link profiles to properly adjust the data for the particular printing process (e.g., gravure vs. offset) or printing presses to be used.

Scenario 3, therefore, places the maximum demand for interoperability and compatibility on color management systems. It requires that all CMMs process profiles consistently and, to a lesser extent, that a common definition of the PCS be used by all profile vendors.

Systems Issues

In attempting to evaluate the needs and opportunities in color management, as it applies in the printing and publishing industry, there are inherently conflicting goals that make it difficult to draw clear conclusions. From an industry point of view, these goals are interoperability vs proprietary systems. From the point of view of a color management system vendor, these are interoperability vs unique system features.

For any particular systems vendor, a strategy that does not foster interoperability sacrifices potential industry market size. A strategy that does not foster unique system features sacrifices potential product advantage and thus market share. In some instances, this places the interests of vendors in conflict with the interests of the industry.

With this perspective, some issues relating to each scenario follow. In all cases, issues that affect scenario 1 will affect scenario 2 and 3, etc.

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Scenario 1

This is the most common situation today. It is also the workflow where there is the greatest competition in standalone and/or niche products. Currently, it is the scenario into which the vast majority of printing and publishing color management product offerings fit. Where color management tools from one vendor must interact with other manufacturer's products, such as CMMs and/or profiles, incompatibilities between tools may present problems.

CMM definition: There is insufficient data to verify that the current level of CMM compatibility will allow consistent processing of profiles by CMMs provided by different vendors. This has wide impact in the graphic arts given the need to match proof to print but also has an impact in scenario 1 where the CMMs from different vendors become part of output devices such as proofers, CTP and film imagesetters.

Some CMMs dynamically concatenate input and output profiles before processing to reduce processing time. They essentially create what is referred to as a device-link profile. It has been suggested that variations in this concatenation process may be a source of some of the variability seen between different CMMs. One option to reduce variability might be to always concatenate the input and output profiles to create a device-link profile and use this in place of the individual profiles throughout the workflow. Another option might be to enable all CMMs (and controlling applications) to allow serial processing of profile pairs for critical graphic arts applications. However, this will increase processing time required to color manage data with some CMMs.

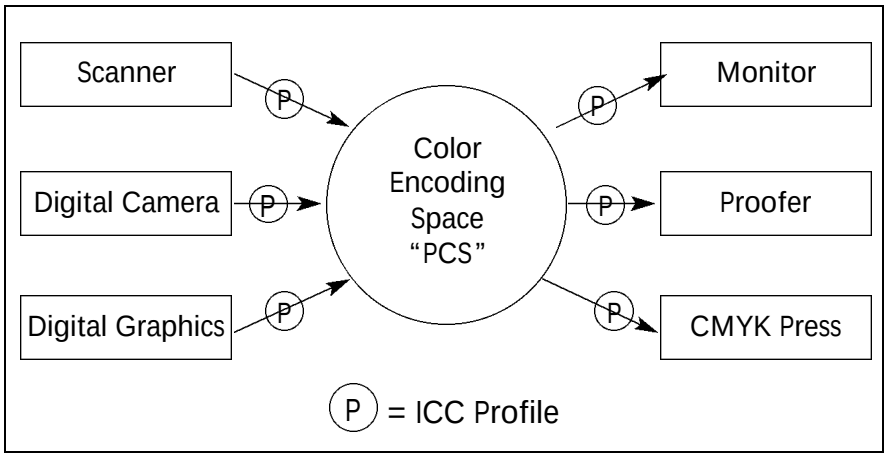
The ICC currently has no specifications or test procedures in place for CMMs. However, informal testing does indicate that the various CMMs available are becoming more consistent in the results they produce.

Reference printing conditions: CMYK output profiles require characterization data for the expected printing process. Too often users characterize a local press even though they are intending to exchange the data with someone else or to use the data in a publication. This practice introduces profile proliferation and makes it very difficult to associate meaning to any particular set of CMYK data. It also encourages widespread "tuning" of profiles and/or color management workflows to produce CMYK results unique to local conditions including positive vs. negative film, computer-to-plate, etc. It also complicates exchange of CMYK data.

For most applications an output profile based on industry-developed reference printing conditions is far better. Unfortunately, a complete set of reference printing conditions is not yet available. Today the only printing process characterization data that exist are SWOP (Specifications for Web Offset Publications) with SNAP (Specifications for Non-Heat Advertising Printing) in preparation. Fortunately for the publication market characterization data for SWOP are contained in *ANSI/CGATS Technical Report 001 (TR001)*. This lists the relationship between CMYK data and the CIELAB values of the printed color at what is nominally the SWOP aim. By using this as the characterization data for CMYK output profiles, users can be assured that images from different sources using profiles from different vendors will print together.

Scenario 2

Scenario 2 may offer one of the best short-term opportunities for people to begin getting experience in color management. Current graphic arts data exchange standards, which are largely publication driven, specify CMYK data only and probably will continue to do so until significant progress is made in the acceptance of virtual CMYK data and the compatibility of CMMs across vendors. As long as the data exchange standards concentrate on CMYK data, this will inhibit adoption of open fully color managed workflows, even in those areas where it may be practical. However, it also means that proprietary and/or single vendor solutions will have a reason-



able life expectancy. This will allow users to integrate color management into many of their workflow areas without having an impact on the issues of data exchange.

Data editing and data quantizing: One issue that may interfere in the adoption of scenario 2 workflows is the issue of data editing. From a color management perspective, all data are ideally edited in either native color space (e.g., scanner code values, monitor data values, etc.) or some intermediate space to which all data are converted (PCS, sRGB, large gamut RGB, etc.). This requires that editing and image assembly tools be available to work in these spaces. In addition, these tools must have the capability to dynamically display the results of the expected color management data processing. Alternatively, edits in output space must be capable of being projected backwards into the initial data space.

One of the key goals of a color managed workflow is to preserve the full range of the input data. In addition, any additional transforms to an intermediate work space and, in particular, any additional quantification into 8-bit-per-channel data files introduces information loss. This information loss may show up as contouring or other artifacts when converted to individual separated planes of CMYK data.

Individual separations, either as halftone film, plates, or data files are much more prone to show artifacts than composite color images. Unfortunately, in the printing and publishing workflow individual separations are often visible and if they show artifacts the exchange and/or responsibility between participants becomes an issue. This means that color editing data spaces and tools need to be chosen carefully to both meet the quality needs of the printing and publishing industry and also avoid the need for more that 8-bit per channel data.

Mixed work environment: A fully color managed workflow in a closed environment (scenario 2) is possible and attractive. It offers opportunities for vendors to present unique features and capabilities such as a unique color data editing space. However, because so many shops represent a combination of both in-house (closed) work and advertising or open exchange, it is not clear how these two requirements will interact if there is an industry-wide move to open color managed data exchange. Many shops will require a single color management solution that will satisfy all of their work requirements. This will require a unique balancing of scenario 2 and scenario 3 concepts.

Scenario 3

Scenario 3 offers the greatest potential for color management and at the same time presents the greatest challenge for color management vendors to maintain unique capabilities and offer an appropriate level of interoperability.

CMM: In an industry-wide color managed printing and publishing workflow the compatibility of CMMs is a key requirement. This is based on the assumption, described earlier, that a user will edit data or tune profiles to get the results desired and will then expect that the same results will be obtained elsewhere in the process.

PCS: In the printing and publishing workflows described, the compatibility of PCS definitions is of secondary importance. In all of the scenarios described, any initial incompatibilities in PCS definitions will have been tuned out by the time a proof is made and customer approval obtained. The key area in which PCS definition will be important is in initial setup of a particular shop and the tuning of their suite of profiles to produce the desired results.

Profile exchange: Scenario 3 proposes that all necessary profiles be sent with the data; therefore all profiles licenses need to make provision for open use at least for display and printing. The situation is not clear across the industry and there appears to be a need for either a profile tag to indicate such status and/or a registration authority to maintain status information.

Summary and Conclusions

Strong leadership from the printing and publishing industry will be required to reduce the confusion concerning the benefits and/or impact of color management on the printing and publishing industry. Two critical needs are education to help create reasonable expectations and an organized identification of industry needs.

The fundamental approach of the ICC has been, and in many ways continues to be, one in which the sender and receiver are only loosely coupled. The sender sends as much information as possible about the color of the original image (without any restrictions on gamut, etc.). And the receiver is responsible for providing the best reproduction possible within the constraints of the output device (even to the extent of a black- and-white reproduction if that is all that is available). This must be, and is being, expanded to provide capabilities to meet the needs of the printing and publishing industry.

However, today the ICC architecture, our data exchange standards, and thus vendor's products cannot support what we have identified as scenario 3. Thus an industry-wide, multi-vendor, interoperable color managed workflow (using four-color, process color) is not possible. This is changing and with adequate support (push) from the printing and publishing industry the rate of change will accelerate.

Even in the absence of the capability for scenario 3, the printing and publishing industry has much to gain through the use of color management. The key implication is that CMYK will continue to be the primary data used for open exchange.

Use of either the baseline ICC color management to improve the efficiency of individual steps in the workflow or the adoption of a complete internal color managed workflow, will not only provide immediate benefits but also prepare users to be the leaders when a full industry wide color managed workflow is available. An important step in that preparatory process is the adoption of industry reference printing conditions, such as TR001, and the use of color management procedures to transform these inputs into the data need by individual printing and proofing equipment.

Color management provides many immediate benefits for the printing and publishing industry, as well as the possibility of future workflow changes that offer exciting possibilities for full data integration across archive, traditional printing, and the WWW. Realistic expectations on the part of knowledgeable users, coupled with ongoing support from industry organizations and standards committees represent the best path to follow at this time. IPA

NPES serves as secretariat for CGATS and ISO TC130 activities. Information is available from the NPES Standards Department at (703)264-7200.