Color Management: What's Needed for Printing and Publishing

by David Q. McDowell

Color management has been the subject of numerous articles, test reports, tutorials, and evaluations. While many have addressed graphic arts applications, they have focused primarily on applications within a single site. In order to understand its potential benefits and impact, I would like to try to see where color management fits within the larger printing and publishing industry workflow.

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

Where to Start?

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

1. Where users typically are today, i.e., baseline ICC (International Color Consortium) color management use;
2. A typical single-vendor solution, i.e., a closed, in-house color-managed workflow; and
3. An industrywide, multi-vendor, interoperable color-managed workflow for process color data.

In all three scenarios, I have made some fundamental assumptions about the basic operating methodology of the printing and publishing industry. In some ways this methodology 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: These scenarios have a principally North American focus and may not fit workflows in other parts of the world quite as well. In addition, they are aimed at four-color, process-color printing. Important issues such as duotones, Hi-Fi color, package printing, and others, are not included but are relatively straightforward extrapolations.

Assumptions

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 designer, the preparatory shop, and the printer. Each has a role to play and each needs to verify that its part was done correctly.

When something goes wrong in the advertising world there is a "make-good." One of the participants must "make good" the cost of the failed advertisement. This requirement becomes a driving force when new technologies or options may put at risk the ability to clearly identify the quality of image information being exchanged among 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 printing operation is expected to match the proof using whatever capability it 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 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.

In the publication workflow, this is further complicated by the many-to-many relationship that exists between advertisers and publications. The same ad is sent to many publications, and each publication receives ads from many customers (and prep shops). Therefore, the color management tools used among the participants cannot be common (unless there is a single dominant color management vendor) but must still behave in a consistent (standard) fashion.

Publication advertising is what drives much of the industry expenditures on new tools like color management. 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

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requirements are the advertising work, and the rest of the work rides along using the same capability.

Let's consider the three reference scenarios in more detail.

Scenario 1: Baseline ICC Color Management Use

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. The CMYK data aims may be based on either local shop requirements or industry standard printing conditions. Data are edited, merged, and color corrected in CMYK. Because all the data exchanged is CMYK, interoperability 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, as it becomes part of the proofing device. Use of color management as the control and matching tool for non-halftone proofing systems is common practice. 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, remember that any repurposing or retargeting of data via color management in this scenario must accept the already gamut-limited CMYK data as input.

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

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Scenario 1 allows an organization to begin using 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 "get your feet wet" step.

Scenario 2: Closed, In-house Color-Managed Workflow

In Scenario 2 all work within a shop is color-managed. Input data are tagged with the appropriate input profiles or pointers into a profile library. Data are edited, merged, and color corrected as raw data, as RGB 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 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 is sometimes called an RGB workflow.

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). This places minimal restrictions on the color management system because there are no interoperability requirements. However, none of the advantages of using color-managed data to receive input from other sources or exchange of final work are easily available. This approach works especially well for printing operations where creative, prepress, and printing are all done within a well-controlled environment, typically by a single organization. Some catalog work, much promotional material, some commercial printing, and most specialty printing fall in this category.

This second scenario can be viewed as a more sophisticated version of Scenario 1. Scenario 2 still uses CMYK data for exchange but uses color-managed data for all intermediate processing. Scenario 2 may use a custom, intermediate color space for image editing, assembly, and correction, and/or non-ICC color management techniques and procedures.

Although multi-vendor compatibility and interoperability is not felt to be an issue in Scenario 2, usually envisioned as a single-vendor solution with CMYK output, the lack of interoperability is its biggest drawback. An individual shop may fully embrace a particular vendor's brand of color management and achieve significant productivity improvements. However, when the shop tries to interact with partners 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: Industrywide, Multi-vendor, Interoperable Color-Managed Workflow

Scenario 3 embodies an industrywide, multi-vendor, interoperable color-managed workflow (using four-color process color) involving multiple organizations. A partial model for this is the "blind" exchange concept that drove many of the features of PDF/X1 (*ANSI/CGATS.12/1, Graphic technology — Prepress digital data exchange — Use of PDF for composite data— Part 1: Complete exchange*).

The key element is that senders and receivers should not have to communicate with each other about the particular characteristics of their systems to successfully and correctly exchange color-managed data. Source data (e.g., scanner code values, monitor values, CMYK source data), accompanied by appropriate input and output profiles, would be used for editing, merging, color correcting, and exchanging data. Such data would be temporarily converted to CMYK for proofing and output; any device link profiles needed for proofing devices or press retargeting would be added as necessary. This workflow would preserve the data's full repurposing capability and also minimize any data loss due to conversion to CMYK and subsequent transformations to an alternate CMYK for proofing. 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 typical publication workflow model offers a useful example of the requirements for the Scenario 3 workflow: Advertisements are prepared at several locations using the appropriate input and output profiles for the equipment at that site and the reference printing condition expected. Each preparation site would process the image data to CMYK for proofing and customer approval using its vendor-supplied CMM (color management module, which is the software color computing engine in a color management system). The edited source data would then be forwarded to the publisher accompanied by the input and output profiles used to gain customer approval. The publisher would then assemble the inputs as source data plus profiles and process the composite data files through a single CMM to create CMYK data for imaging to film or plates. Where appropriate, the publisher might add device link profiles to adjust the data for a particular printing process (e.g., gravure vs. offset) or printing press.

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 all profile vendors use a common definition of the profile connection space (PCS).

Systems Issues

Inherently conflicting goals make it difficult to draw clear conclusions about the needs and opportunities for color management in printing and publishing. From an industry point of view, the conflict is between interoperability and proprietary systems. For color management system vendors, it

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 only that the transform linking the device to the common reference be created.

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

The PCS is nominally the CIELAB color space associated with a reflection print with a very large color gamut. (Many other details are required by the color scientist to build profiles but they do not impact our general understanding.)

Profiles are based on 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, making any appearance transforms needed to convert from original to PCS color definitions. The classic example 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, 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 with a Web RGB output profile to go to the World Wide Web. This flexibility and versatility is the attractiveness of color management.

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is interoperability vs. unique system features. For vendors, any strategy that does not foster interoperability sacrifices potential market size. A strategy that does not foster unique features, however, sacrifices potential product advantage and market share. In some instances, this places vendor interests in conflict with industry interests. With these perspectives in mind, I would like to address some issues related to each scenario. In all cases, issues that affect Scenario 1 will affect Scenario 2 and 3, etc.

Scenario 1

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

CMM definition: There isn't enough data to verify that the current level of CMM compatibility will allow consistent processing of profiles by CMMs from different vendors. Given the need to match proof to print, this has wide impact in the graphic arts. It also impacts Scenario 1, where CMMs from different vendors become part of output devices such as proofers, film imagesetters, and CTP devices.

Some CMMs dynamically concatenate input and output profiles before processing to reduce processing time, essentially creating a device-ink profile. It has been suggested that variations in this concatenation process may be a source of some of the variability 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 the 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 newer CMMs are producing more consistent results.

Reference printing conditions: CMYK output profiles require characterization data for the expected printing process. Too often users characterize a local press even though they intend to exchange the data with someone else or use it in a publication. This practice introduces profile proliferation and makes it difficult to associate meaning to any particular set of CMYK data. It also encourages widespread "tuning" of profiles or color management workflows to produce CMYK results unique to local conditions, including positive vs. negative film, CTP, 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. The only standardized printing characterization data that exist are SWOP (Specifications for Web Offset Publications) with SNAP (Specifications for NonHeat Advertising Printing) in preparation.

Characterization data for SWOP are contained in *ANSI/CGATS Technical Report 001 (TR001)*, which lists the relationship between CMYK data and the CIELAB values of the printed color at what is nominally the SWOP aim. Using this as the characterization data for CMYK output profiles can assure 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 getting experience in color management. Current graphic arts data exchange standards, which are largely publication-driven, specify CMYK data only and will probably 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 exchange standards concentrate on CMYK data, this will inhibit adoption of open fully color-managed workflows, even where it may otherwise be practical. However, it also means that proprietary and single-vendor solutions will have a reasonable life expectancy. This will allow users to integrate color management into many of their workflow areas without it affecting data exchange.

Data editing and quantizing: One issue that may interfere with adopting Scenario 2 workflows is 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) or some intermediate space to which all data are converted (PCS, sRGB, large-gamut RGB). This requires that editing and image assembly tools be available to work in these spaces. In addition, these tools must have the ability to dynamically display the results of the expected color management data processing. Alternatively, edits in output space must be capable of being projected backward 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 films, plates, or data files are, therefore, more prone to show artifacts than composite color images. It is these individual separations that are exchanged, 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 meet the quality needs of the printing and publishing industry but also avoid the need for more than 8-bit-per-channel data.

Mixed work environment: Scenario 2's fully color-managed workflow in a closed environment is possible and attractive. It offers opportunities for vendors to present unique features such as a custom color data editing space. However, many shops operate with a combination of both in-house (closed) work and advertising or open exchange, so 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 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 to color management vendors to maintain unique capabilities and offer an appropriate level of interoperability.

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

PCS: In the workflows described, the compatibility of PCS definitions is of secondary importance. In all the scenarios, 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 where PCS definition will be important is in a particular shop's initial setup and the tuning of its suite of profiles to produce the desired results.

Profile exchange: Scenario 3 proposes that all necessary profiles be sent with the data; therefore all profile licenses need to provide 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

Strong leadership from the printing and publishing industry will be required to reduce confusion about the benefits or impact of color management. Two critical needs are (1) education to help create reasonable expectations and (2) an organized identification of industry needs.

The ICC's fundamental approach 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 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.

Today, however, the ICC architecture, our data exchange standards, and thus vendor products cannot support Scenario 3. Thus, an industry-wide, multi-vendor, interoperable color managed workflow (using four-color, process color) is not possible. This is changing and adequate support from the printing and publishing industry will accelerate the rate of change.

Even without the capability for Scenario 3, our industry has much to gain by using color management. The key implication is that CMYK will continue to be the primary data used for open exchange. Using baseline ICC color management to improve the efficiency of individual workflow steps or adopting 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 the inputs into the data needed 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 Web. 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.

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