Color Management on the Desktop

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Introduction

As color input, display and output devices become more and more common the need for managing color becomes greater and greater. Color management refers to tools that support color matching, editing, preservation and storage. Color management offers the means of transmitting color images and documents containing color across local and wide area networks while maintaining the fidelity of the colors of the original image or document.

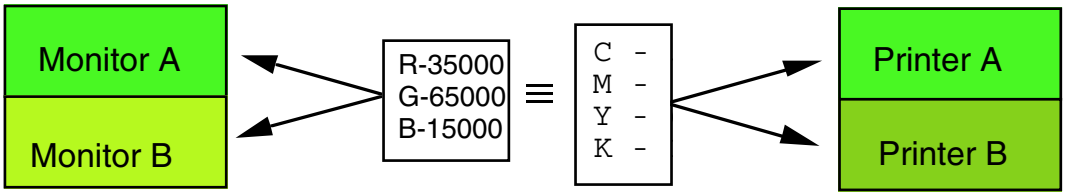
The fundamental problem to be solved lies in the device dependent nature of color devices. That is, color is specified in RGB or CMYK without a standardized reference point to define the objective meaning of RGB or CMYK. This presentation will review the background problem of device dependence and the options to create device independent color images. Color management systems as application level solutions and as embedded aspects of operating sytems will be described. Apple's new ColorSync color extensions will be described as operating system level utilities to support color management.

The Problem with Color

While most people want color, actually using color with desktop computers is a real challenge today because achieving WYSIWYG (What you see is what you get) in color is much more difficult than in black and white. The physics of color means that Color WYSIWYG is in the best case difficult; in the worst case, impossible. Some specific tools can be built into desktop operating systems which will help solve the mismatch of colors between devices. We must be aware, however, that the solution will only be an approximation. Several problems dictate that color matching solutions will never be exact.

1. The first problem is due to the way in which colors are sampled by scanners and output on displays and printers. Typically colors are created and described in device dependent terms (RGB - Red, Green, Blue) for monitors and most scanners, and (CMYK - Cyan, Magenta, Yellow, and Black) for most printers. The mechanism of color capture and output to a display follows the laws of additive color mixture while printers subscribe to the laws of subtractive color mixture since delivering colored light is very different from delivering colored ink. Device dependent descriptions cause the same blend of RGB on one monitor to display a very different color from the same blend on a different monitor. The result is that if you try to simply translate RGB to CMYK you get different and unexpected results and poor color fidelity.

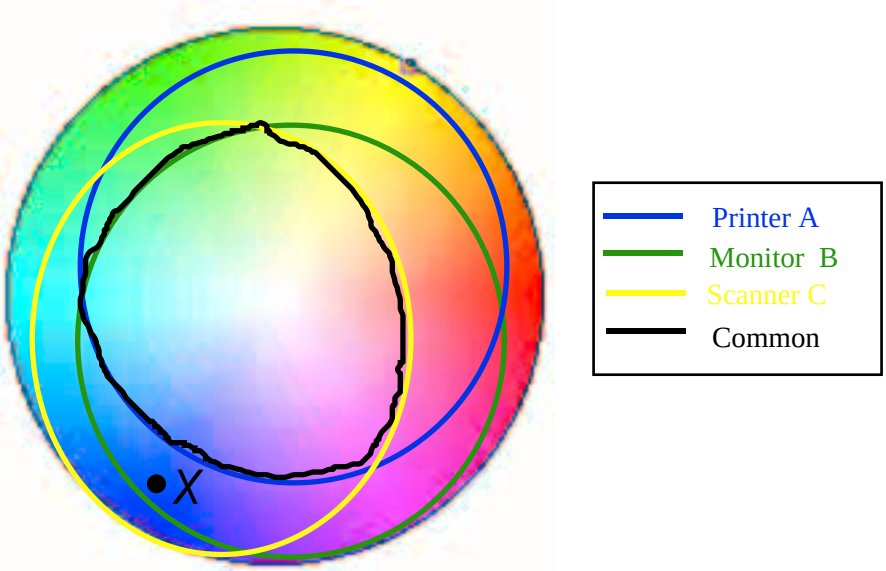
This problem is illustrated below:



A single RGB or CMYK value can lead to different colors on different monitors and printers. While an RGB value can be mapped to a CMYK value for a given pair, changing the devices changes that mapping and, therefore, the result.

2. The second problem with achieving color matches between devices is that different devices (scanner, monitor, printer) not only describe colors differently but actually have different capabilities in terms of delivering color. That is, a color that is possible on one device may not be possible on another. This is described as a mismatch in the device color gamut.

The chart below illustrates this point. The total circle represents all visible colors. The printer, monitor and scanner are each capable of capturing a subset of that color space as represented by the colored lines. The black line designates the common colors, those colors within the capabilities of all three devices. As long as the color is within this area, there are no problems. But if we scan a photograph and display it on the monitor and it contains some blue elements (as in point X), the printer cannot print that color blue. This illustrates the barrier to achieve WYSIWYG; a requested color is outside the color gamut of one of the devices.



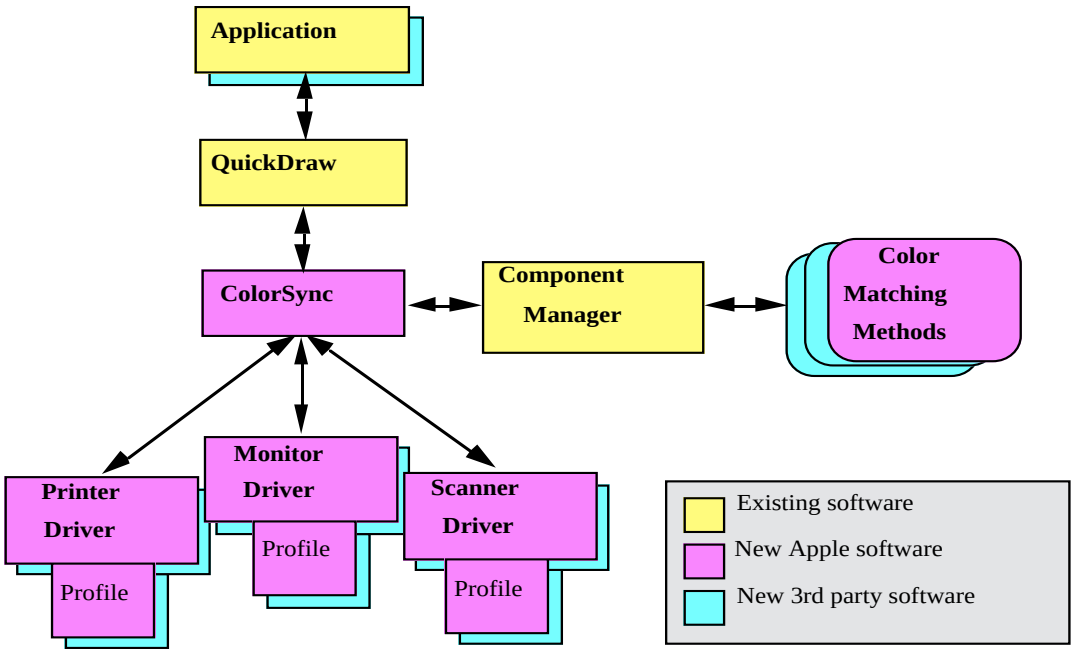
3) The third problem is that the perceived color given by a specific value of RGB for an individual monitor can vary. This means that any RGB to CMYK mapping will not be accurate over time. The solution for this problem is commonly called calibration. Actually, calibration goes hand in hand with a companion process known as device characterization. That is, device characterization describes in objective terms the color gamut of a given class of devices such as a monitor from a specific manufacturer. Calibration is a process by which the output values of a specific device are mapped to an objective standard.

A Color Matching Solution—ColorSync™

As an example of providing system level color management solutions, Apple has designed a series of extensions to the QuickDraw and QuickDraw GX graphics architectures of the Macintosh Operating System. These extensions are known as ColorSync. ColorSync attempts to provide an architecture which deals with all three of the color problems outlined above. We will first discuss the ColorSync architecture and then how it provides answers for each of these problems.

The Architecture of ColorSync

ColorSync is a system extension that provides color matching capabilities to the existing QuickDraw graphics model. ColorSync color matching is just one of the new capabilities that will be part of Apple's new imaging platform - GX. ColorSync adds the capability to define colors independently of the device creating the colors, and to initiate matches of colors on different devices. Because Apple wanted to provide an architecture where third party developers could add value, ColorSync utilizes the Component Manager. This was developed in conjunction with QuickTime™ to link a series of Apple or third party color management resources and utilities.



The architecture of ColorSync in the existing QuickDraw world provides three important features;

1. System level support for color matching
2. Support for existing applications
3. Opportunities for third parties to add value

1. System level color matching: The only way that color matching can be truly pervasive and not just a high-end add-on is when it is offered as a system resource. Then all applications and peripherals can take advantage of it. By integrating ColorSync with the QuickDraw graphics model, we make color matching a central part of the Macintosh system. This means that all applications and imaging peripherals will use the same scheme for color matching; this allows a user to scan, display, manipulate, and print with matched colors.

2. ColorSync was designed to allow some existing applications to get color matched printing so users won't have to wait for revised applications to get one of the benefits of ColorSync. ColorSync also provides some new calls that enable applications to match to the display. These new calls will complete the entire picture–matched input, display and output.

3. ColorSync uses the Component Manager, which allows third parties to add value to the color matching system. Apple will provide base level functionality to all users but recognizes the importance of third party products that will offer additional functionality for specific solutions. This enables companies like Kodak, EFI, and others to bring their expertise to the ColorSync architecture rather than to offer replacement solutions.

ColorSync Offers Device Independent Color

As was mentioned before, ColorSync was developed to solve the problems related to device-dependent color such as RGB and CMYK. ColorSync is founded on a device-independent and human perception based color space called CIE XYZ. In 1931 the Commission International De I'Eclairage (The International Commission on Illumination) surveyed the color data that was available and developed a space for color.

To create a device-independent color definition while maintaining compatibility with QuickDraw (which is RGB based), we use Apple's Color High-Resolution RGB monitor as the default system profile or space (the user can define the system profile by selecting the monitor he is using assuming a profile for that monitor is installed). The source RGB data can be converted to CIE XYZ based on the source profile to provide a device-independent definition of color on the Macintosh. Once there is a device-independent description of a device, we can translate the capabilities of any input device to those of any output device.

Applications and ColorSync

ColorSync was designed to provide color matching services to existing applications and provide opportunities for adding more value in the future. There will three levels of ColorSync application support.

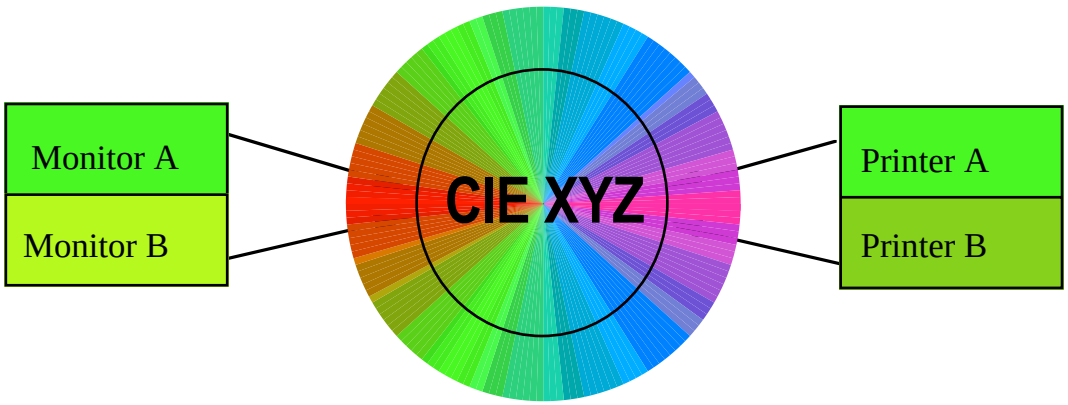
1. Printing fidelity – simply making the standard Macintosh call – DrawPicture – will enable the source image to be matched to the printer. Applications that support this call will provide printing functionality without revision. We are working through Evangelism to get non-compliant applications to support at least this base functionality.

2. Display fidelity – matching to the display as well as source and printer. ColorSync can correct for the display if the source is a scanner or a different monitor. With the new ColorPicker, you will see two gamuts, thus enabling the user to pick those available on both the monitor and printer/ or other display.

3. ColorSync also allows applications to offer a preview function by indicating those colors that are not possible on a particular device. This would save a great deal of time and money by giving the user of a high-end color printer the ability to check the document before it is ever printed.

Device Profiles and Drivers

Because ColorSync uses CIE XYZ, we can characterize each device in terms of that color space. These characterizations are called profiles. They are essentially a description of the color capabilities of a specific device in terms of the CIE XYZ color space. Since all devices are described in terms of a common space, comparisons can be made between any pair of ColorSync devices without having to be compared to each other.



Color Matching with ColorSync
Color Matching Methods

The final key to color matching is converting from one color space to another and giving the best possible match when the exact match is not possible. For example, a scanner and a monitor may display a very vivid red, but a given printer may only provide a pinkish red. When a color is not available, a method can be used to determine the "next best" color. The schemes for determining the best approximation are called the CMMs.

Apple is providing a default method that uses an algorithmic approach to give the next best match. The default, Apple developed CMM, was designed to provide good matching results, yet have a small memory footprint so mainstream users can take advantage of color matching. There are four options for this matching calculation; Perceptual, Colorimetric, and Saturation, and Faster.

• Perceptual - maintains perceptual differences. Colors are interpreted relative to the destination device's white point. This option is usually best for photographic scanned images.

• Colorimetric - maintains individual colors at the expense of their relative values. This option is usually best for spot colors.

• Saturation - maintains the levels of color saturation. Contrast is sacrificed to maintain color saturation. This option is usually best for computer generated graphics.

• Faster matching - offers a good compromise between photographs and computer generated images and takes less time.

Other companies such as EFI and Kodak are developing other CMMs that are table driven. This means that they have large color look-up tables that provide the next best color. These tables can give superior results and can be faster but require much more memory and a separate table for each scanner, display and printer combination. If users require better color matching capabilities and have additional RAM/disk space, these alternative CMMs can be purchased from these third parties.

Color Calibration

The third problem, color consistency, is accommodated by the ColorSync architecture. Because all input and output devices can vary over time and between different units of the same model, high-end users often want to calibrate a device to a known state. The ColorSync Color Management extensions support the calibration systems currently available from third party developers such as SuperMac, Radius, and Raster Ops, which will allow a user to periodically update their profile to compensate for differences from the standard profile.

Adobe PostScript Level 2

Apple and Adobe have worked to coordinate their color management efforts. The basic tools provided by Apple are compatible with the PostScript level II color extensions and are designed to facilitate color exchanges on the Macintosh platform for PostScript files. Future PostScript drivers will incorporate the capability to include device profiles so that color matching can occur. Of course, the utilities are designed in such a way that PostScript is not a requirement for use of the new Color Sync extensions. A PostScript driver is available from Phoenix Technologies which supports ColorSync for PostScript printers.

Color Standards

In developing ColorSync, Apple has attempted to incorporate suggestions from standards developing groups as well as from key third party Mac developers. Most notably Apple has tried, as much as possible, to be sensitive to the recommendations of the Association of Color Developers (ACD), which has put great effort into improving the Macintosh platform for device independent color. Additionally, we have incorporated many of the notions offered in the draft standard ISO 8613 Open Document Architecture. This last year a group of color developers has been meeting periodically under the sponsorship of FOGRA in Germany to agree upon standards for color management on the desktop using ColorSync as the base model.

Using ColorSync

The Color Management extensions are toolbox level extensions. That is, Apple does not expect users to access the extensions directly. Rather, the goal is to make color matching and color handling capabilities transparent to the user. In fact, existing SW, as indicated above, can perform color matching with a simple change of device driver.

Apple has characterized it's own color monitors (RGB 13",16" and 21"). These device profiles, accessible as a CDEV, will be made available with the extensions. The facility to create device profiles for other monitors will be made available to third party developers as well as the process for characterizing color devices. While Apple does not intend to offer a specific color calibration facility, the ColorSync Color Management extensions support the calibration systems currently available from third party developers such as SuperMac, Radius, Raster Ops and Barco.

Because Apple's Color Management extensions are toolbox-level features, no human interface specific to color management will be offered by Apple. While guidelines for consistent user interface will be issued, Apple feels that developers will be able to add value by developing creative human interfaces for color management.

Finally Apple is interested in seeing ColorSync used on platforms other than the Macintosh. Discussions are underway with a number of computer HW and SW manufacturers to make ColorSync and industry standard.

The tables below list a few of the specific features of ColorSync from both the perspective of the developer and end user.

ColorSync Provides

- Device Independent Color Support
- System Level Color Management
- Open Architecture for 3rd Party Solutions
- Device Profiling Methodology
- Default Color Matching Method

End User Benefits

- Automatic Color Matching
- Color Matching for all Color Devices
- Gamut Checking
- Preview before Printing
- Multiple Color Matching Methods

Summary

While true WYSIWYG color is not a real possibility in the strictest sense, it can be approximated by extensions to desktop operating systems. These extensions must provide a means of defining and nomenclating colors independently of the device used to create the colors. Apple is currently developing a set of Color Management extensions to the Quickdraw Graphics Model. These extensions will permit device-independent color definition and handling on the Macintosh platform. Additionally, utilities for color matching will be included as well as the capability of accessing third party color matching and management solutions.