Digital Imaging and Color Management

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Introduction
The advent of the desktop prepress technology in the 1990s had changed the prepress infrastructure, including equipment, materials, manpower, and workflows. Capturing digital images and preparing them for print via ICC-based color management is a part of the new imaging paradigm. It requires a whole new set of understanding and skill sets. This article, a revision of a similar article published by the *Instant & Small Commercial Printer* (Chung, 2002), provides a basic understanding of digital imaging and the ICC-based color management.

Pixel describes a picture element
A pixel is the contraction of two words, picture and element. It is the fundamental element an input device can assign a digital value to. An example of an input device is a digital camera or a flatbed scanner. Pixel-based images can be edited by software, such as Adobe Photoshop.

When we capture an image with a digital camera with 1,000 pixels across its width and 1,000 pixels down its length, the image is said to have 1,000 x 1,000 or 1,000,000 pixels. Since the number, 1,000,000 is a million, we call the digital camera an one-mega pixel camera. The more pixels a digital camera can pack in a given dimension, the greater the spatial resolution, e.g., 300 pixels per inch, the device is capable of.

Pixel has bit depth
A pixel, like a pigeon hole in a roll-top desk, is used to store data. A pixel with one-bit depth can store either a ‘zero’ or ‘one.’ So, a bitmap image is suitable for representing a line art image, e.g., a cartoon drawing, at high spatial resolution.

A pixel with 8-bit depth is necessary to represent visual information with sufficient gray levels, e.g., a black-and-white photograph. In other words, an image will appear to be photograph-like when any one of the pixels in the image can be represented by 256 (2 to the 8th power) possible gray values (Figure 1).

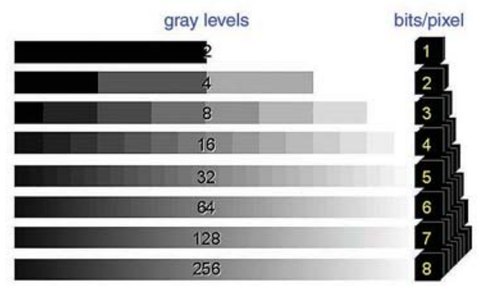

Figure 1. Gray levels as a function of bit depth.

When capturing a color image, a pixel typically contains 24 bits in three channels. One-third of the bit depths (8 bits) is assigned to the red channel, the other one-third is assigned to the green channel, and another one-third is assigned to the blue channel. Eight bits is equal to one byte in the world of computers. So, a mega-pixel input device will produce a three megabyte uncompressed color image data file.

Rendering pixels as visual signals
Understanding human color vision facilitates the understanding of how digital image rendering works. Color is a visual sensation which is the result of detecting light, that has been modified by an object, as color signals (Figure 2).

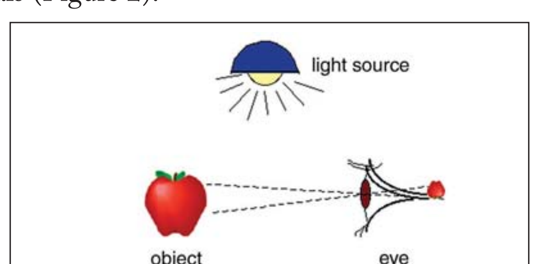

Figure 2. The human visual system.

The color signals are detected by light sensitive cells in the eye, and interpreted by the brain. For example, the red of an apple is seen as the result of having white light falling on to the apple whereby long wavelength energies are reflected from the apple’s surface, entering into the eye and detected by red light sensitive cells. The color signals, then, pass through the optical nerves and to the brain. It is the brain that interprets the visual signals as a sensation. In short, the more energy the eye detects, the brighter or the more colorful the object is.

A color monitor emits tiny red, green, and blue light. This is why a three-channel RGB image is essential for displaying a digital image on a monitor. A press prints cyan, magenta, yellow, and black dots of varying sizes to absorb lights that are not in the image. Thus, a four-channel CMYK file is essential for output to a digital image to a desktop digital printer or a web press. In addition, there are a number of issues involved in the digital image rendering process, e.g., spatial resolution, device color space, and color conversion. Let’s explore these topics further.

RGB drives monitor display
A color monitor has a finite number of addressable spots. Each spot is coated with either red, green, or blue phosphor. The collection of all the spots in a linear array is called a raster. Red, green, and blue raster lines are interlaced in the monitor. The total number of raster lines makes up the monitor matrix or display area. The higher the monitor matrix, e.g., 1280 x 1024 as opposed to 640 x 480, the greater details the monitor can render an image with. The larger the phosphor chromaticities are, the more colorful the monitor can display a color image.

A color monitor uses RGB data for display and behaves according to the additive color mixing principle. For example, when a pixel contains high digital values for red, green, and blue channel, more electrons bombard the phosphors which cause the spot on the monitor to emit more energies. The spot would look bright to the viewer (Figure 3). If a pixel represents the red of an apple in the source image, only high digital counts, up to 255, are stored in the red channel of that pixel, and the spot would appear red on the monitor. If a pixel represents a dark element in the source image, low RGB values are stored in that pixel, and the spot would appear dark to the viewer.

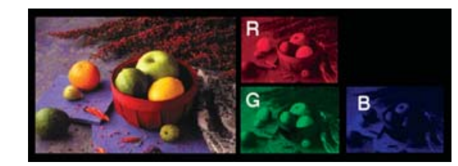

Figure 3. RGB and additive color mixing principle.

CMYK for color printing
A color printer consists of a marking engine with CMYK colorants, and a paper transport sub-system. The marking engine, whether it’s a laser, an inkjet head, a dye diffusion thermo transfer head, is driven by the rasterized version of the image data. The smallest mark an output device can produce is called a spot. The number of spots per linear distance, e.g., 2,400 spots per inch (spi) is a measure of the addressability of the output device. The higher the addressability, the greater potential for the device to render fine image details.

We rely on the subtractive color mixing principle to render tone and color in a hard copy (Figure 4). When white paper is used for hard copy output, the specular highlight in an image requires little or no colorants at the pixel. The more colorants are laid down, the more light are absorbed (or subtracted). Thus, the area that is occupied by heavy ink coverage appears dark.

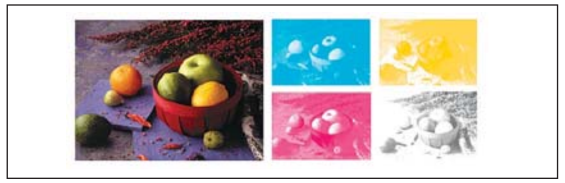

Figure 4. Subtractive color mixing principle.

There is a resolution limit in the human visual system. An unaided eye can resolve fine details around 100-150 line pairs per inch (lpi). Beyond that, it sees fine line markings as gray. This is why we are able to perceive printed color reproduction, at the screen rulings of 100-150 lpi, resembling the source image closely.

When a hard copy is printed with dots of different sizes but with the same screen frequency, e.g., 150 lpi, we call this type of tonal rendering, conventional halftoning or amplitude modulated (AM) screening. When a hard copy is printed with microdots of equal sizes but with different frequency, we call this type of tonal rendering, error diffusion or frequency modulated (FM) screening. One of the test targets, TF_04, in this publication shows the effect of both AM and FM screening on tone reproduction.

Pair-wise color management

Just as color perception varies from one person to the other, an imaging device—input, display, or output—relies on a different mechanism to capture or reproduce colors. For example, as an image moves from scan to proof to final print, each device, along the workflow, introduces its own subtle changes in color.

In the past, when organizations purchased all equipment from one manufacturer, e.g., Scitex, Hell, or Crosfield, that manufacturer would develop proprietary technologies to ensure color quality and consistency from a specific brand of input device to a specific brand of output device. The pair-wise color management solution is a close system for color management. In other words, the image, prepared for one imaging device, can not be easily repurposed for another device, not to mention another device of a different manufacturer.

ICC-based color management

Today, many companies use an open system approach to implement digital workflow that calls for devices and software supplied by a range of manufacturers. To ensure color quality and consistency in the digital workflow, an open system solution is based on the methodology developed by the International Color Consortium (ICC). The goal of ICC is to create and promote the standardization of an open, vendor-neutral, cross-platform color management system (CMS) architecture.

Color can be specified in a device-independent manner and coded in a color imaging software. Not all colors can be reproduced accurately. The range of colors an imaging device can render is called color gamut. The color gamut of an output device can be expressed in the CIELAB color space.

If a pixel in the source file is an in-gamut color of the destination device, then CMS is used to match the color in the destination device by means of absolute colorimetric rendering. If a pixel in the source file is an out-of-gamut color of the destination device, then CMS is used to manage the color of the pixel according to other rendering intents. In either case, ICC-based CMS offers a solution whereby the color management module (CMM) alters the data from the source device, via the profile connection space (PCS), to achieve the color agreement as judged from the destination device output (Figure 5).

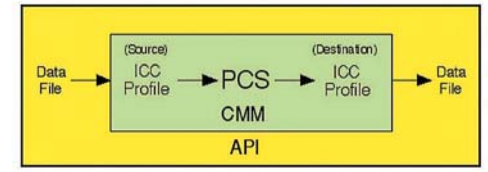

Figure 5. ICC-based CMS infrastructure.

For example, presses using cyan, magenta, yellow, and black inks cannot match deep blues and deep reds, as seen in photographic media or on color monitors, because these colors are outside of the printer color gamut. For scan-to-print workflow, the color rendering intent used is called perceptual rendering.

Implementing color management

To achieve color portability in an open system environment, CMS begins with device calibration, i.e., adjusting the amplitude of solids and tonal values to known values. After the device is calibrated, an ICC profile of the device is then generated with the use of profiling software packages, such as Kodak ColorFlow ProfileEditor (Figure 6a), GretagMacbeth ProfileMaker (Figure 6b), or Monaco Profiler (Figure 6c). This publication includes a collection of profiling targets and a total area coverage (TAC) chart for profiling uses.

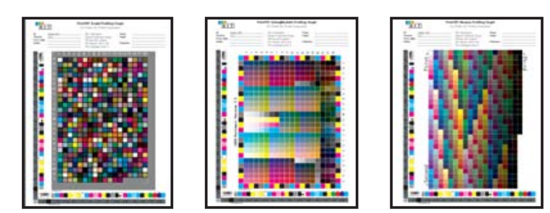

Figure 6. Printer profiling targets from Kodak (a, left), GretagMacbeth (b, center), and right (c, Monaco)

To convert images from the source device to the destination device, a combination of software at the OS level and the application level are essential. Today, Adobe Photoshop 7, running on Mac OS X, has the most complete application programming interface (API) for ICC CMS implementation. But Photoshop is limited to handling only one image at a time. Color management solution must be document based. In addition, color conversions from RGB-to-CMYK are likely to take place later in the workflow as in the pagination, PDF, or RIP stage.

Summary

Digital imaging and printing is an emerging and fast maturing technology. Digital imaging fundamentals are further covered by books such as *Pocket Guide to Digital Printing* (Cost, 1997). CMS, as a body of knowledge, encompasses from design to prepress to printing. CMS software and hardware vendors now provide easy-to-use and affordable products (Fraser, et al., 2003). The creative community and publishers now have greater access to color management. Print buyers are often the suppliers of digital files for print. They need to know what quality color is and how to start the color management chain. Printers ultimately find themselves responsible for color quality at the end of an imaging and print production workflow.

Literature Cited

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