Color Management White Paper 4

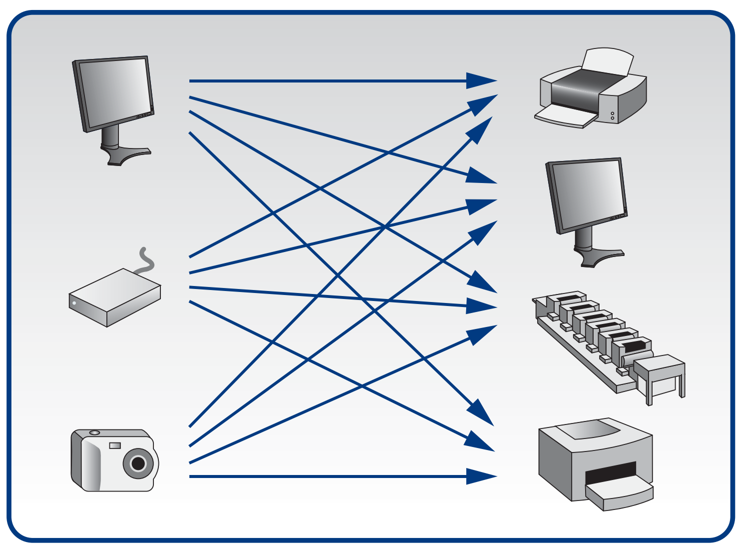
The Basics on ICC Color Management Systems

As mentioned in preceding LaCie White Papers, the wide variety of imaging devices available today makes it very difficult for a document created on one device to be rendered correctly on another. The use of an efficient Color Management System (CMS) is the most accurate answer to this problem.

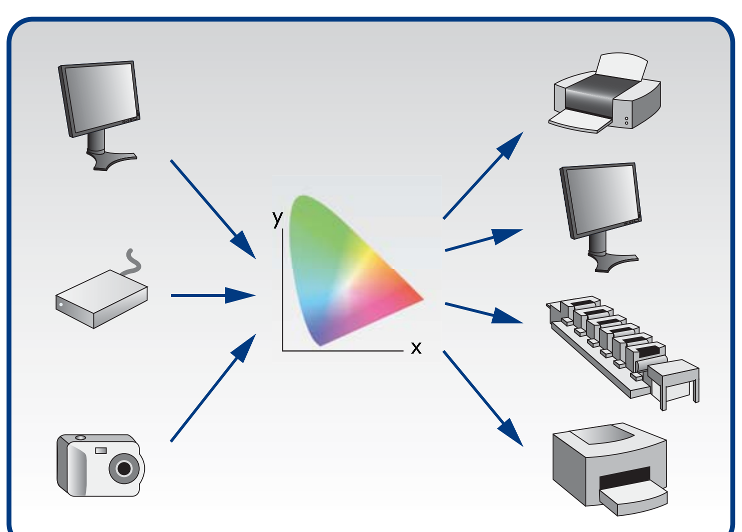
COLOR MANAGEMENT SYSTEM (CMS)

The International Color Consortium (ICC) defines an open standard for a Color Matching Module (CMM) at the operating system level and color profiles (ICC profiles) for devices and working spaces. Operating systems provide a built-in framework—Apple ColorSync on Mac or ICM (Image Color Management) on Windows—for implementing and handling these device profiles. Color measurement instruments are used with CMS and CMS-supported software to gather important data included in device profiles and to periodically monitor and adjust device performance.

Two Color Management Policies



Above: Without CMS; Below: With CMS



The Color Management System as defined by the ICC is based on four main elements:

1. **A Color Matching Module**
2. **A Profile Connection Space**
3. **Color Profiles**
4. **A Rendering Intent**

1. A Color Matching Module (CMM) is a software engine embedded in a graphic application's software, operating system, and hardware driver. The CMM addresses tables within profiles—describing how conversion should occur.Depending on the OS and software used, several CMMs are available. Adobe, Apple, Kodak, Heidelberg and other manufacturers provide their own CMMs. This is due to the fact that ICC is an open standard, which explains why the same transformation can produce different results if carried out by two different CMMs.

2. A Profile Connection Space (PCS) is the device-independent standard reference space into or out of which color data is transformed. It is either L*a*b* or CIE XYZ, and is the universal translator—allowing color space conversion to be carried out from source to destination color spaces. AtoB and BtoA tags (tables) contained in the profiles are used in a PCS to translate source into destination.

3. Color Profiles (ICC Profiles) are small digital files containing a description of how a particular device reproduces color. They also describe the device's color space to the color management system. Profiles are obtained by performing calibration and profiling with ICC-compatible tools (such as LaCie blue eye pro). They also contain other information, such as the preferred CMM, the preferred rendering intent, the PCS used and the version. Multiple tables used for color translation processes are also embedded in the profiles.

The ICC recommends 7 different types of profiles, which are classified into 2 categories.

The first category contains the device profiles:

- Input (scnr) profiles – specially designed for scanners & digital camera
- Display (mntr) profiles – for monitors
- Output (prtr) profiles – for printers & video recorders

The second category gathers profiles designed for special purposes:

- Device Link (link) profiles used for specific direct connection of devices
- Color space conversion (spac) profiles used for conversion between color spaces
- Named color (nmcl) profiles used for specific spot colors such as Pantone
- Abstract (abst) profiles for abstract spaces

All device profiles (except scanner profiles, which only support conversion from device to PCS) are bidirectional: they gather information to convert from device to PCS and vice versa.

Each profile contains multiple tables referred to as "tags". AtoB tags translate from the device space to the PCS; BtoA tags translate from the PCS (L*a*b* or XYZ) to the device space. There is a pair of AtoB and BtoA tags for each rendering intent. These are used by the CMM to set up correspondence between any compatible ICC profiles. As a complete RGB table has more than 16 million rows, a profile containing them all would be too large (several megabytes). Therefore, the CMM performs an interpolation of the table.

Device profile information can be gathered in two ways:

- Using algorithms based on matrices and linearization curves called Matrix Profiles
- Using lookup tables called LUT Profiles (or Table Profiles)

ICC profiles, apart from abstract (abst) and device link profiles (link), can be embedded into images and saved in most image file formats (EPS, TIFF, GIF, etc…) to be easily used in the color management workflow.

4. Rendering Intent refers to the way the CMM (Color Management Module) handles out-of-gamut colors during a conversion from one color space to another.

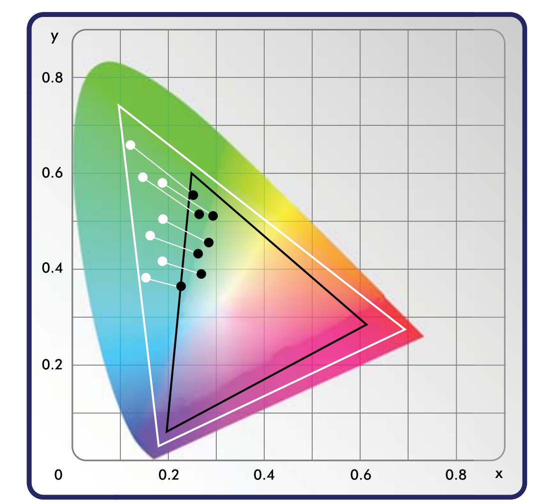
The ICC specification defines four different rendering intents: Perceptual, Relative Colorimetric, Saturation and Absolute Colorimetric.

Because each device can reproduce a certain range of colors, a specific gamut is described in its ICC profile. When printing a document displayed on a monitor, for instance, the gamut of the original file (source) has to fit to the color space of the output device or printer (destination). The rendering intent determines how the CMM will translate colors from one device to another. It is based on the concept of Gamut Mapping.

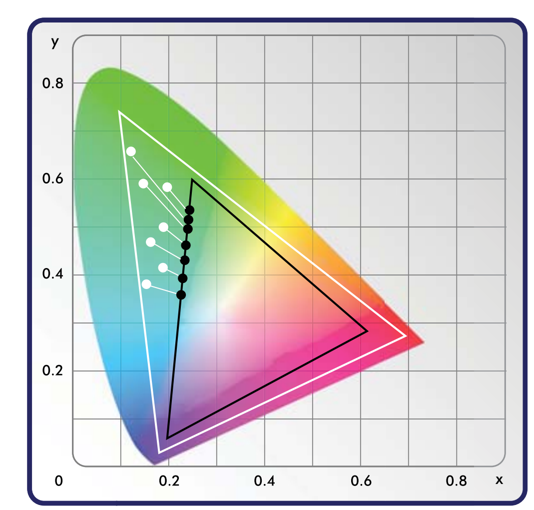
There are two main techniques for mapping out of gamut colors:

- Gamut compression compresses the range of colors that are out-of-gamut into the destination gamut
- Gamut clipping maps all out-of-gamut source colors to the closest colors within the destination

Gamut Mappings methods compared



Gammut Compression



Gammut Clipping

Both techniques are used for calculating rendering intent. The rendering intents below all derive from them. Each ICC profile is tagged with a default (Profiles generated with LaCie blue eye pro use “perceptual rendering intent” by default).
The following four rendering intents are used in accordance with various imaging requirements:

– Perceptual rendering intent preserves color relationships by scaling the entire source space into the destination space, including those colors that were in the source gamut. It produces the most pleasing color results and is generally recommended for continuous-tone images and photographs—when reproducing exact hues is not necessary.

– Saturation intent reproduces the relative saturation of colors from gamut to gamut for the brightest, most vivid results. It is recommended for businesses and vector-based graphics.

– Relative Colorimetric changes only the colors outside the gamut of the destination device. Colors are scaled relative to the destination profile’s white point; the whitest white of the source space is mapped to the whitest white of the destination space. It often produces a more appealing result than the perceptual intent because it preserves colors within gamut.

– Absolute Colorimetric rendering intent matches in-gamut colors exactly, reproducing the white point of the source profile on the destination device, but clipping out-of-gamut colors to the nearest hue. It’s best for signature colors, such as LaCie Blue or Coca-Cola Red, and is most useful for soft-proofing, especially when the proofing device has a larger gamut than the final output.

APPLICATIONS: HOW DOES THIS PROCESS WORK?

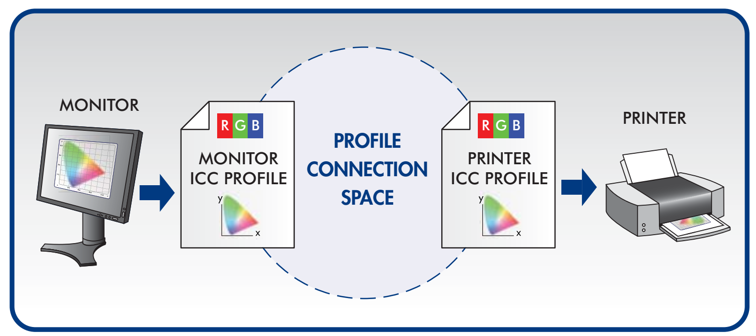
To see how color translation works in practice, suppose a document created in a computer and displayed on a monitor in a particular color space (RGB) must be converted to another (CMYK) in order to be printed.

• The first step is to obtain the two ICC profiles for these devices (printer and monitor). Each RGB triplet is first converted to the PCS using the RGB profile.

A color conversion always occurs between two profiles; the first is the “source” profile and the second is the “destination” profile. In the source profile, the table is always read from RGB to L*a*b*; in the destination profile, the table is read from L*a*b* to CMYK.

• If necessary, the data is converted in the PCS between L*a*b* and CIE XYZ.
• The data is then converted in the PCS to the four C, M, Y, and K values required.

A profile might define several mappings, according to rendering intent. These mappings allow a choice between closest possible color matching, and remapping the entire color range to allow for different gamut.



ICC Profiles form the links in your image chain between device-dependent monitors and the device-independent PCS

The operator will choose in his/her ICC compatible software, Photoshop for instance, the relevant rendering intents to achieve the desired translation when no perfect match can be found. The accuracy of this “approximation” will depend on the rendering intent chosen.

The conversion between two profiles is a general concept, valid for any kind of device. To obtain the same colors on two monitors for instance, the numbers will need to be converted from the profile of the first monitor to that of the second one. There will be a translation from the RGB coordinates of the source monitor to L*a*b* then to the L*a*b* coordinates of the target monitor.

Only the use of an accurate CMS will guarantee a satisfactory color consistency throughout the workflow. In the next LaCie White Paper, we will describe in more detail the CMS Profile creation steps.

“Through a combination of cutting-edge technological engineering and a rich history of unique design aesthetics, LaCie continues as a firm leader in the color display industry. Established in the United States, Europe and Japan, LaCie is a leading worldwide producer of PC and Macintosh compatible peripherals, including a new generation of color LCD monitors. By providing top-of-the line tools for multimedia innovation, LaCie anticipates the needs of creative professionals such as graphic designers, photographers and filmmakers, who require genuine, practical solutions for accurate color management.”

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