



Application Notes

Basics of Color Management



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Introduction

Color management describes a controlled conversion between the colors of various color devices, such as scanners, digital cameras, monitors, printers, and corresponding media.

The primary goal of color management is to obtain a good match across color devices. For instance, imagine an image which should look the same on all media printed with any printer. Color management helps to achieve the same appearance on all media and printers, provided the device is capable of delivering the needed color intensities.

In order to describe the behavior of the various combinations of printer, ink, and media they must be compared (calibrated) in relation to a standard color space. Therefore, pre-defined samples are printed and measured so that an idealized color description of the device is created. This description is called a profile. A profile is created for a certain purpose: either to describe the image color space (input) or to describe the printer color space (output).

The possibilities of the color management for the printout are not only controlled by the printer, ink, and media but also by the data format and color space of the image that is printed. The following chapters explain the supported data formats, color spaces, and the methods for matching the input and the output color spaces.

Color Spaces

Basics

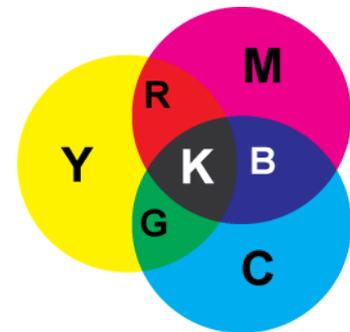
Color models are abstract mathematical figures describing the way colors are represented by numbers, typically with three or four components. When the color model is mapped to a certain device, e.g. a monitor or a printer, a color space with a certain gamut is created as a part of the global color model. For example, Adobe RGB and sRGB are two different color spaces both based on the RGB color model.

In the following, the terms "CMYK color space" (or just "CMYK"), "RGB color space" (or just "RGB"), and "Lab color space" (or just "Lab") are used as generic terms for any RGB, CMYK, or Lab color space.

CMYK

The CMYK model depends of the absorption on the paper. When white light hits color that is permeable to light a part of the color system is absorbed. The other part is reflected to the eye.

Theoretically, a pigment mixture of pure Cyan (C), Magenta (M), and Yellow (Y) absorbs all of the light and creates black; thus, they are called subtractive colors. But, since inks for printing contain also pollution this mixture results in a dirty brown and has to be mixed with black ink (K) to be able to create real black. Mixing the inks for printing for reproducing all other colors is called four-color printing.



Subtractive color mixing

Note: subtractive (CMY) and additive (RGB) colors are complementary colors. Two subtractive colors at a time create an additive color and vice versa.

Normally in CMYK mode, a percentage value for each print color is assigned to each pixel of a CMYK image. The lightest colors (lights) have low percentage values whereas darker colors (depths) have higher percentage values. A bright red e.g. may be build by 2% Cyan, 93% Magenta, 90% Yellow and 0% Black. In CMYK images, pure white is created when all components have a value of 0%.

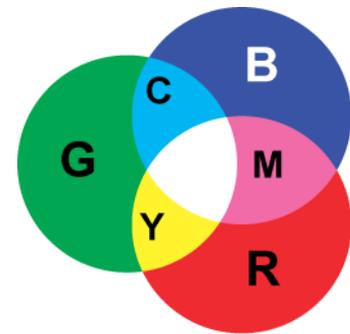
The CMYK mode is used when an image is prepared for four-color printing. The therefore necessary conversion process from RGB to CMYK is called color separation.

Today's large format printers often do not print with CMYK only, but also with lighter dilutions of the basic inks (Light inks) and additional full tone inks such as Orange, Green, Blue, Violet, etc. These additional inks are used to reduce the amount of ink needed (e.g. when using an orange ink instead of mixing magenta and yellow) or to increase the gamut of the printer when the color tone of the additional ink cannot be achieved by just mixing the basic inks.

RGB

The RGB model describes what kind of light needs to be emitted to produce a given color.

A part of the visible color spectrum can be represented by mixing the three basic components of colored light. These components are the primary colors Red, Green and Blue (RGB). Overlapping these three primary colors creates the secondary colors Cyan, Magenta, and Yellow.



Additive color mixing

Because the primary colors together create white, they are called additive colors. When all colors are joined together white will be created – that is, light is completely reflected to the eye. Additive colors are used for illumination, in video technology, for slide exposure, and for monitors. The monitor creates colors by emitting light through red, green, and blue phosphor particles.

In RGB color images, an intensity value between 0 (black) and 255 (white) for each RGB component is adjusted to each pixel. Bright red may have a value of 246 for R, 20 for G and 50 for B. When the value for all components is the same, gray will be created. When the value of all components is 255, pure white is created; black is built by a value of 0 for all components.

RGB images use three colors to represent 16.7 million colors on the monitor. They are 3 channel images; thus they contain 24 (8x3) bit per pixel. RGB is standard for scanners.

sRGB

RGB colors always depend on the device on which they are displayed. The sRGB color space, a standard RGB color space, was created by Hewlett-Packard and Microsoft Corporation for use on (CRT) monitors, RGB printers, and the internet. Since the gamut of the sRGB color space can be displayed with almost all monitors, the sRGB color space is a common color space for the internet and World Wide Web.

Modern non-CRT hardware, such as LCD monitors, digital cameras, and RGB printers, might have a larger gamut but - since sRGB turned out to be a standard for RGB devices - are built to obey the sRGB standard. Just high-end professional equipment might break this rule. For this reason, you may assume that any RGB image you do not have other information for, has been created using the sRGB color space.

Lab

The Lab color model is based on the color model that the "Commission Internationale d'Eclairage" (CIE) declared in 1931 to be the international norm for measuring colors. This model was improved in 1976 and named CIE Lab.

Lab colors are device independent; that is, they create constant colors independently from certain devices like monitors, printers, or computers that are used to create and print images.

Lab colors are built by a luminosity or brightness component (L), and two chromatic components: the a-component ranges from green to red; the b-component from blue to yellow.

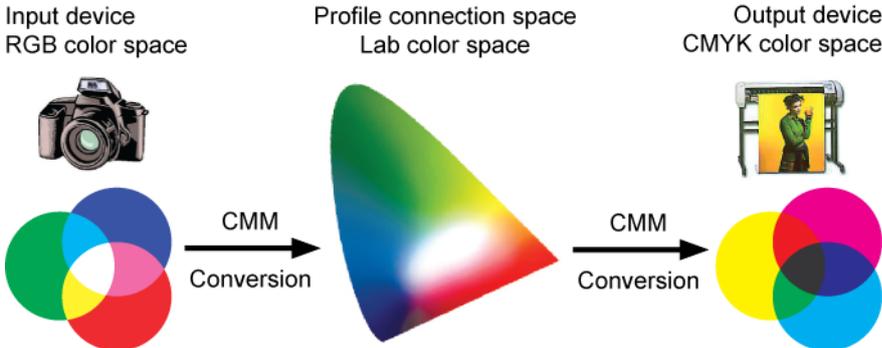
The Lab model is often used when editing Photo CD images or modifying luminosity and color values in an image independently from each other.

Gamut Mapping (Rendering Intents)

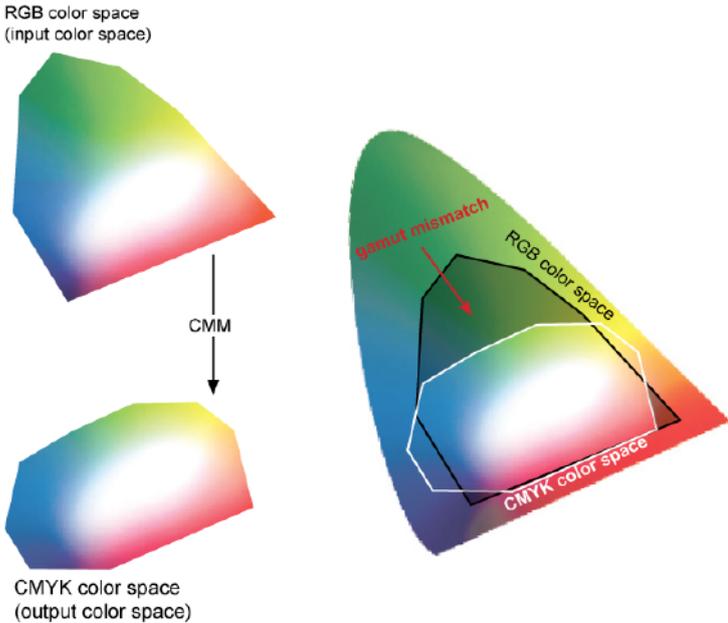
Basics

The rendering intent specifies how out-of-gamut colors of the device-independent Lab color space are to be converted into the printer gamut. This conversion is necessary because the Lab color space holds much more colors than the printer gamut.

A common task for the CMM (color management module) is to convert the image (input) into Lab and then convert it into CMYK (printer):



A closer look to the color spaces will show that the gamut of the RGB input color space and the gamut of the CMYK output color space are both completely covered by the Lab profile connection color space, but the RGB and the CMYK color space cover not completely matching areas. There is a gamut mismatch.



Each time a gamut mismatch occurs, the CMM uses the **rendering intent** to decide how the out-of-gamut colors are converted and which consequences for the image quality are prioritized.

Colorimetric Rendering Intents

The **absolute colorimetric** and **relative colorimetric** rendering intents do not compress the Lab color space to the printer gamut. Thus, colors lying in the printer gamut can be exactly reproduced; all other colors are projected to the printer gamut.

The **relative colorimetric** rendering intent adjusts the Lab white to the white of the media. This means that white in the image will remain white in the output; all other light colors are printed - even when the original color tone is lighter than the output media.

Perceptual Rendering Intent and Saturation

The **perceptual** rendering intent compresses the complete color space so that the color distances survive (adjustment to black and white). The colors themselves are moved so that exact reproduction of colors using Lab values is not possible but the general impression of the image is preserved. Color gradients in the original image will persist as gradient in the output (no abrupt changes in color). The perceptual rendering intent is often used to reproduce images, photos, etc.

Saturation is a modification of the perceptual rendering intent with more weight on the saturation of the colors. Color gradients become less smooth but with higher color intensities. This is useful for vector graphics like diagrams and charts.

Data Formats

Basics

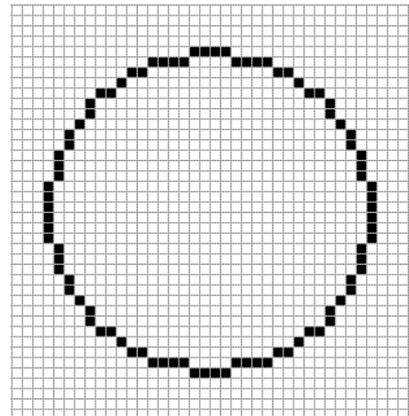
Images are made up of either pixel or vector data, which is rasterized to pixels for the display in most image processing applications. Thus, image files always consist of raster data or vector data or a mixture of vector and raster data.

The following chapters describe the features of the main image data types while the file formats are described later.

Raster Data

A raster image or bitmap is a structure representing a generally rectangular grid of small points of color, so called pixels. Each pixel has a certain position and a certain color value. A bitmap or raster image corresponds bit for bit with an image displayed on the screen. For example, a bicycle tire is built in a bitmap by an accumulation of colored pixels that are located at certain positions. When working with pixel images pixels are edited instead of objects or forms.

A bitmap is characterized by the width and height of the image in pixels and the number of bits per pixel, which determines the numbers of colors it can represent. The quality of a bitmap depends on the total number of pixels, the resolution, and the amount of information in each pixel, the color depth. For example: an image that stores 24 bit of color information per pixel can represent smoother degrees of shading than one that can store only 256 colors. Also, an image sampled with 640 x 480 pixels will look rough and blocky compared to one sampled at 1280 x 1024 pixels.

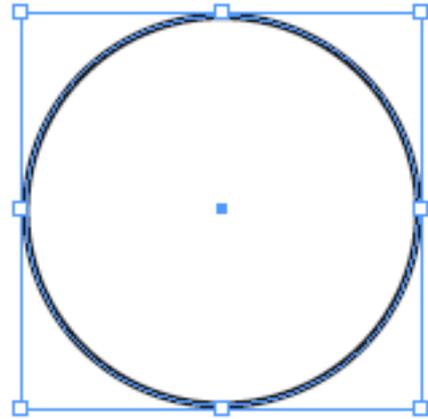


Raster graphics cannot be scaled to a much higher resolution without loss of apparent quality. This is in contrast to vector graphics, which easily scale to any size.

Vector Data

As opposed to the raster image formats above (where the data describes the characteristics of each individual pixel), vector image formats contain a geometric description which can be rendered smoothly at any desired display size.

For example, a bicycle tire is built in a vector graphic by a mathematical definition of a circle that is drawn with a certain radius at a certain location in a certain color. It can be moved, scaled, and its color can be changed without any loss of quality. Vector graphics do not depend on the resolution – that is, they are not determined by a given number of pixels. They are scaled automatically so that they come out very sharp on any output device and in any resolution. Vector images are suitable for text (especially in small sizes) and graphics such as logos that require clear contours in any size.



File Formats and Color Management

Pure Raster Formats

The **ErgoSoft RIP** supports the following raster file formats: TIFF, BMP, JPEG (or JPG).

The **BMP** (Bit Mapped) format is internally used in the Microsoft Windows operating system to handle graphics. These files are typically not compressed resulting in large files. A typical bitmap file uses the RGB color model. Since BMP files do not offer embedded profiles, an external input profile must be selected in order to convert the RGB values into CMYK and being able to print them.

The **TIFF** (Tagged Image File) format is a flexible and adaptable image file format. The ability to store image data in a lossless format makes TIFF files a useful method for archiving images. Unlike standard JPEG, TIFF files can be edited and resaved without suffering a compression loss. TIFF does have an option to use LZW compression, a lossless data compression technique for reducing file size. TIFF files can be saved in RGB, Lab, or CMYK including additional spot color channels. Since they offer the option to embed the used color profile, the **ErgoSoft RIP** offers the possibility to automatically use it. The embedded profile in TIFF files can ensure that the conversion from the original image color space RGB or CMYK to the Lab color space is done correctly (as long as the correct profile is embedded in the image) and thus, helps to ensure the color fidelity of the printout.

The **JPEG** (Joint Photographic Experts Group) image files are a lossy format. The JPEG format supports 8-bit per color - red, green, and blue, for a 24-bit total - and thus, produces relatively small file sizes. Fortunately, the compression in most cases does not detract noticeably from the image. But JPEG files do suffer generational degradation when repeatedly edited and saved. The JPEG compression algorithm is also used for compression in other file formats such as TIFF and PDF, but not recommended to be used because of the loss of data and color information involved. JPEG files use the RGB or CMYK color model. Up to and including version 12, embedded profiles were utilized in the **ErgoSoft RIP** for RGB JPEG files only; CMYK JPEG files needed an external input profile.

Vector Formats

The **ErgoSoft RIP** supports the following vector file formats: EPS, PS, PDF, and AI.

Encapsulated PostScript (EPS) is a graphics file format based on the PostScript language. It can consist of one small vector image up to a complete page of any size and even of several pages. The EPS format is not linked to a certain print driver; it is a common graphics file format that often is used for transferring vector data from one application to another one.

PostScript (PS) is a page description language that is created by PostScript print drivers such as Adobe Generic PostScript. The dimensions of the PS file are limited to the paper sizes provided by the PostScript print driver. It can consist of several pages. When using a PostScript printer to create a PostScript file for printing with the RIP, you have to configure the print driver for highest compatibility or Encapsulated PostScript in order to eliminate print driver specific commands that cannot be processed in the **ErgoSoft RIP**.

Portable Document Format (PDF) is an open file format that is created and controlled by Adobe Systems. PDF files do not encode information that is specific to the application software, hardware, or operating system used to create or view the document. This feature ensures that a valid PDF will render exactly the same regardless of its origin or destination (but depending on font availability when fonts are not encapsulated in the file). PDF files are most appropriately used to encode the exact look of a document in a device-independent way. While the PDF format can describe very simple one page documents, it may also be used for many pages, complex documents that use a variety of different fonts, graphics, colors, and images.

Adobe Illustrator Artwork (AI) is a proprietary file format developed by Adobe Systems for representing vector-based drawings in either the EPS or PDF formats. The .ai filename extension is used by Adobe Illustrator. Up to version Adobe Illustrator version 8, the .ai file format was an EPS like format. The Adobe Illustrator CS versions save the .ai file in a PDF like format. As long as there are no Illustrator specific commands in the .ai file, it can be processed in the **ErgoSoft RIP**.

All supported vector formats have one common property: they can not only consist of pure vector data but also of raster data which leads to the problems with mixed formats that is discussed in the next chapter.

Another property of the supported vector formats is concerning the Color Management: The elements in the vector files may be created in different color spaces and combined in the vector file in the original color spaces. This requires the Color Management to treat the different elements differently, for example: text elements should be treated differently from raster images.

Up to and including version 12, the Color Management was not able to handle this task so that all elements were treated the same and converted into one color space which could be configured to be CMYK or RGB. The usage of embedded profiles could not be configured so that we highly recommended not embedding profiles in vector files.

Now, it is possible to configure the global usage of embedded and external profiles for the three elements text, normal vector images such as logos, and raster images in both color spaces CMYK and RGB.

Problems with Mixed Formats

Apart from the color management problem of mixed color spaces in PostScript files for which the solution is already discussed in the previous chapter, there is another problem resulting from the possibility to mix vector and raster data.

As discussed earlier, raster data saved in pure raster files such as TIFF files are scaled using an interpolation so that the scaled image will still look smooth and only lose contrast when the scaling factor is too high.

On the contrary, vector data are first scaled as vectors and then rasterized (translated into pixels) so that the sharp lines of e.g. a logo or a letter are retained. But exactly this feature is a problem when you have to scale raster data that are part of a vector file: each pixel is interpreted as a tiny square and scaled like a square resulting in more or less visible bricks that now make up the raster image.

In order to avoid this problem you have to separate vector data and raster data and do not have to use both types in the same file. Because this is almost impossible, many image processing applications offer possibility to use the so called OPI functionality when creating EPS files.

OPI Support

What is OPI?

OPI (Open PrePress Interface) is a production tool used to link very large, high resolution image files to PostScript files.

This process automatically or manually creates two versions of the same image: a high resolution version for printing, and a low resolution version that is used for the whole layout process. For printing (final output), the “small” file is either automatically replaced by an OPI server or is manually replaced by the large high resolution image file.

Thus, OPI is a special PostScript file with the raster data not included directly in the file. It is rather organized using links to files with pixel data in addition to the PostScript file.

The **ErgoSoft RIP** supports OPI by replacing while ripping the links in the PostScript file by the raster data in additional files.

Advantages of Using OPI

■ Saving storage space

Fonts and vector graphics need less space because they can be described using mathematical formulas. On the other hand, raster data need very much space (e.g. a page scanned with 300 dpi needs –in uncompressed mode –about 40 MB storage space). The PostScript file will be considerably smaller when placing raster data into the PostScript files using OPI link; space is saved on the hard disk.

■ Saving rasterizing time

The **ErgoSoft RIP** needs considerably less time to rasterize the PostScript document.

■ Scaling

The PostScript file must not be created in the size that it will be printed, for vector graphics are scaled without any loss of quality. When scaling TIFF images the **ErgoSoft RIP** does not use the image size that is noted in the PostScript file, but instead uses the original size of the separate TIFF file.

■ Creating the image

When using very large TIFF images (with long loading time), a low resolution copy of the original image can be worked on, which is replaced by the high resolution original when it is printed.

Limitations of Using OPI

Presently, there are some restrictions to using OPI:

- **Rotated raster data**

Placed TIFF images may only be rotated by 0°, 90°, 180° or 270°. The **ErgoSoft RIP** cannot print images that are rotated by any other degree (for example 45°).

- **Image frames**

Non-rectangular image frames (e.g. oval image frames in QuarkXPress) are not supported, but the images may be cropped.

Creating OPI Images

The following instructions are only meant to be little hints for some design programs. For more information please refer to the help or support of the design program in use.

- **QuarkXPress**

Save the file as EPS and select "Omit TIFF" in the OPI part / menu of the export dialog window. In Version 5, select "OPI active" for TIFF images in the export dialog box.

- **Macromedia Freehand**

From menu File – Output Options select "none" for "image files". Take care that "include OPI comments" is checked. Save the image in EPS format.

- **Adobe Illustrator**

Does not support OPI

- **Adobe Photoshop**

Does not support OPI

- **Adobe InDesign**

Export the file in EPS or PrePress format and omit the proper graphics in the next window "Omit Imported Graphics".

- **Coreldraw**

After having selected the TIFF file in the import dialog box, select "link file with high resolution for OPI output". In the EPS export dialog box, select "keep OPI links".

Fidelity of Colors in the Printing Process

Selecting the Best Rendering Intent

As mentioned earlier in this manual, there are four rendering intents available with different properties. Which rendering intent you choose highly depends on the color space and the creation method of the image you want to print:

■ Rule

When (almost) all colors used in the image are inside the printer gamut, use the Relative Colorimetric rendering intent.

When many (and especially dark) colors used in the image are outside the printer gamut, use the Perceptual rendering intent or Saturation.

■ Finding colors outside the printer gamut

The **ErgoSoft RIP** offers a function to visually display image parts that are outside the printer gamut: Select the image you want to check and launch the Tuning command. Configure the properties of the preview windows (add a new preview window when necessary) so that colors outside the gamut are marked in a certain customizable color. The colors outside the printer gamut do not depend on the selected rendering intent but on the selected input profile.

■ Colors selected from a color book

When all colors in the image have been selected from a color book that was printed with the same printer, printer settings, and ink on the same media as your image should be printed: use the same rendering intent that was used to print the color book.

■ Reproducing colors

As long as the colors to be reproduced are in the printer gamut select the **Absolute Colorimetric** rendering intent.

When the colors are very light so that they are not printed when using the Absolute Colorimetric rendering intent: select the **Relative Colorimetric** rendering intent.

When the Lab values of the colors are outside the printer gamut you have to print a color book and visually select a similar color (with another Lab value) that is in the printer gamut.

Examples:

■ **Lab color space**

When all of the Lab color space is used (from white to black), the color space of the printer is much smaller than the color space of the image. In this situation, the **Perceptual** rendering intent or **Saturation** should be the first choice.

When only the colors are used that are inside the printer gamut (which is a very small part of the Lab gamut), the **Relative Colorimetric** rendering intent is the first choice.

■ **RGB color spaces**

The RGB color spaces are smaller than the Lab color space but still larger than the printer gamut. Thus, the **Perceptual** rendering intent or **Saturation** should be the first choice – except when the file has been created using another rendering intent such as relative colorimetric with black point compensation.

■ **sRGB color space (photos from a digital camera)**

The sRGB color space is smaller than most other RGB color spaces but still larger than the printer gamut. Thus, the **Perceptual** rendering intent or **Saturation** should be the first choice – except when the file has been created using another rendering intent such as relative colorimetric with black point compensation.

■ **CMYK color spaces**

The CMYK color spaces are smaller than the RGB color spaces. Since the printer color space is also (enhanced) CMYK the CMYK color space of the image may be smaller than the printer gamut or almost identical. In this case, almost all colors are inside the printer gamut and you can try the **Relative Colorimetric** rendering intent as first choice.

Controlling the Mixing of the Inks

When using the Color Management (input profile and printer profile), the mixing of the inks is completely controlled by the printer profile. In some cases, this results in unwanted mixings, e.g. Cyan and Magenta dots in a Yellow logo area where the customer does not insist on a certain yellow but on only yellow dots. This requires that the Color Management is (partly) by-passed. The **ErgoSoft RIP** offers two functions for this procedure:

- 1) By-passing the Color Management for the complete image:
Create your image in CMYK and do not attach an input profile (neither embedded nor external input profile).
- 2) By-passing the Color Management for just a certain color:
Use the functions for replacing colors that are described in another manual part.