

- COLOR MANAGEMENT: COLOR SPACES -

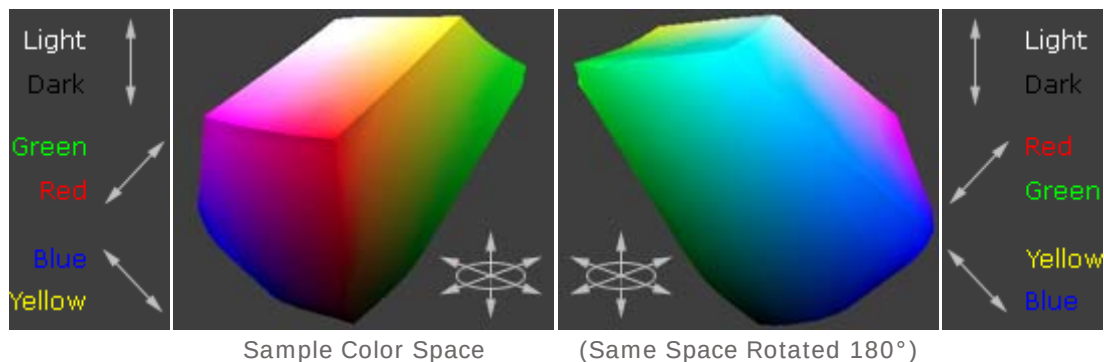
A color space relates numbers to actual colors, and is a three-dimensional object which contains all realizable color combinations. When trying to reproduce color on another device, color spaces can show whether you will be able to retain shadow/highlight detail, color saturation, and by how much either will be compromised.

TYPES

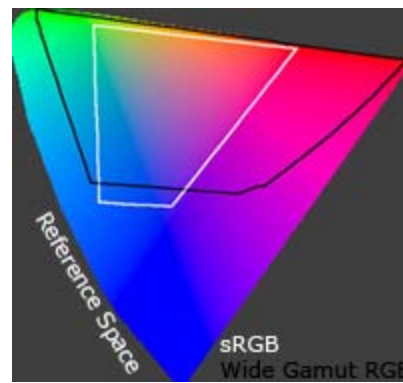
Color spaces can be either dependent to or independent of a given device. Device-dependent spaces express color relative to some other color space, while device-independent color spaces express color in absolute terms. Device-dependent color spaces can tell you valuable information by describing the subset of colors which can be shown with a monitor or printer, or can be captured with a camera or scanner. Devices with a large color space, or "wide gamut," can realize more extreme colors, whereas the opposite is true for a device with a narrow gamut color space.

VISUALIZING COLOR SPACES

Each dimension in "color space" represents some aspect of color, such as lightness, saturation or hue, depending on the type of space. The two diagrams below show the outer surface of a sample color space from two different viewing angles; its surface includes the most extreme colors of the space. The vertical dimension represents luminosity, whereas the two horizontal dimensions represent the red-green and yellow-blue shift. These dimensions could also be described using other color properties.



The above color space is intended to help you qualitatively understand and visualize a color space, however it would not be very useful for real-world color management. This is because a color space almost always needs to be compared to another space. In order to visualize this, color spaces are often represented by two-dimensional regions. These are more useful for everyday purposes since they allow you to quickly see the entire boundary of a given cross-section. Unless specified otherwise, two-dimensional diagrams usually show the cross-section containing all colors which are at 50% luminance (a horizontal slice at the vertical midpoint for the color space shown above). The following diagram shows three example color spaces: sRGB, Wide Gamut RGB, and a device-independent reference space. sRGB and Wide Gamut RGB are two working spaces sometimes used for image editing.



2D Color Space Comparison
(Colors at 50% Luminance)

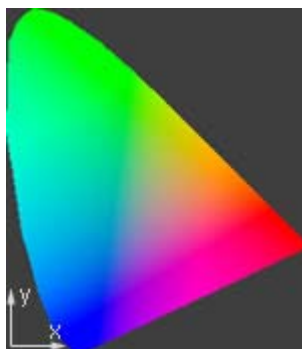
What can we infer from a 2D color space comparison? Both the black and white outlines show the subset of colors which are reproducible by each color space, as a fraction of some device-independent reference space. Colors shown in the reference color space are only for qualitative visualization, as these depend on how your display device renders color. In addition, the reference space almost always contains more colors than can be shown on a computer display.

For this particular diagram, we see that the "Wide Gamut RGB" color space contains more extreme reds, purples, and greens, whereas the "sRGB" color space contains slightly more blues. Keep in mind that this analysis only applies for colors at 50% luminance, which is what occupies the midtones of an image histogram. If we were interested in the color gamut for the shadows or highlights, we could look at a similar 2D cross-section of the color space at roughly 25% and 75% luminance, respectively.

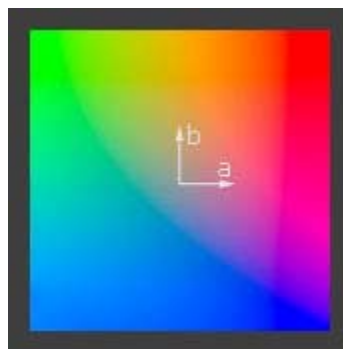
REFERENCE SPACES

What is the device-independent reference space shown above? Nearly all color management software today uses a device-independent space defined by the Commission International de l'éclairage (CIE) in 1931. This space aims to describe all colors visible to the human eye based upon the average response from a set of people with no vision problems (termed a "standard colorimetric observer"). Nearly all devices are subsets of the visible colors specified by the CIE (including your display device), and so any representation of this space on a monitor should be taken as qualitative and highly inaccurate.

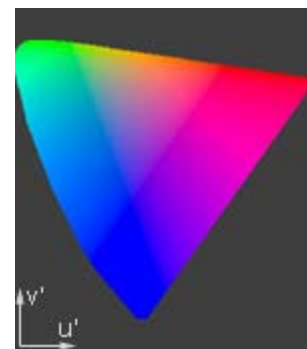
The CIE space of visible color is expressed in several common forms: CIE xyz (1931), CIE $L^*a^*b^*$, and CIE $L^*u^*v^*$ (1976). Each contains the same colors, however they differ in how they distribute color onto a two-dimensional space:



CIE xy



CIE a^*b^*



CIE u^*v^*

(All color spaces shown are 2D cross-sections at 50% Luminance)

CIE xyz is based on a direct graph of the original X, Y and Z tristimulus functions created in 1931. The problem with this representation is that it allocates too much area to the greens. CIE $L^*u^*v^*$ was created to correct for this distortion by distributing colors roughly proportional to their perceived color difference. Finally, CIE $L^*a^*b^*$ transforms the CIE colors so that they extend equally on two axes-- conveniently filling a square. Furthermore, each axis in $L^*a^*b^*$ color space represents an easily recognizable property of color, such as the red-green and blue-yellow shifts used in the 3D visualization above.

WORKING SPACES

A working space is used in image editing programs (such as Adobe Photoshop), and defines the set of colors available to work with when performing any image editing. Two of the most commonly used working spaces in digital photography are Adobe RGB 1998 and sRGB IEC61966-2.1. For an in-depth comparison for each of these color spaces, please see [sRGB vs. Adobe RGB 1998](#).

Why not use a working space with the widest gamut possible? It is generally best to use a color space which contains all colors which your final output device can render (usually the printer), but no more. Using a color space with an excessively wide gamut can increase the susceptibility of your image to [posterization](#). This is because the [bit depth](#) is stretched over a greater area of colors, and so fewer bits are available to encode a given color gradation.

For further reading, please visit:

[Color Management, Part 1](#)

[Color Management: Color Space Conversion \(Part 3\)](#)

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