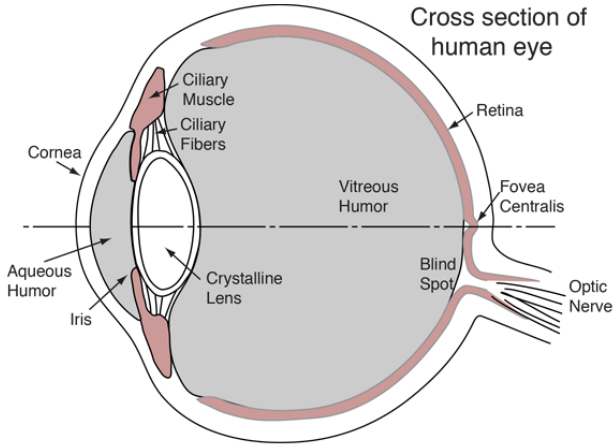
Color Images

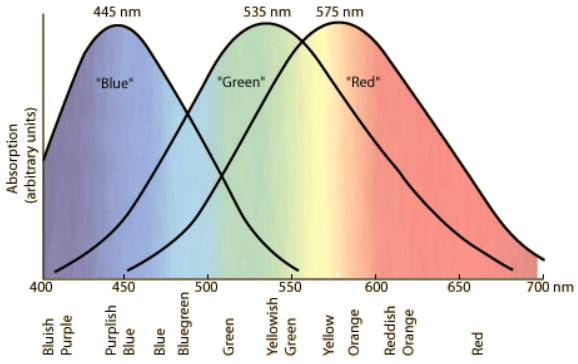
We have seen that photographs and images can be in grayscale or in color. We utilize color in many contexts to convey information that is in addition to intensity.

The retina is a light-sensitive layer at the back of the eye that covers about 65 percent of its interior surface. The human eye contains two different kinds of photosensitive receptor cells called rods and cones in the retina that convert incident light energy into signals that are carried to the brain by the optic nerve.



(http://hyperphysics.phy-astr.gsu.edu/hbase/vision/eye.html)

Rods are used for night vision and are mostly color independent. Cones mediate color vision. There are three types of cones and their color sensitivity are shown in the figure below. The range on the horizontal axis corresponds to the wavelength of visible light that is between 400 nm and 700 nm.



(http://hyperphysics.phy-astr.gsu.edu/hbase/vision/colcon.html)

Color Theory

Pure colors have a single wavelength. The tristimulus theory states that any color can be specified by a weighted combination of three (primary) colors. Red, green and blue are one set of additive primary colors. Additive colors are defined as the three colors of light that when mixed can produce white.

Color depth in digital representations

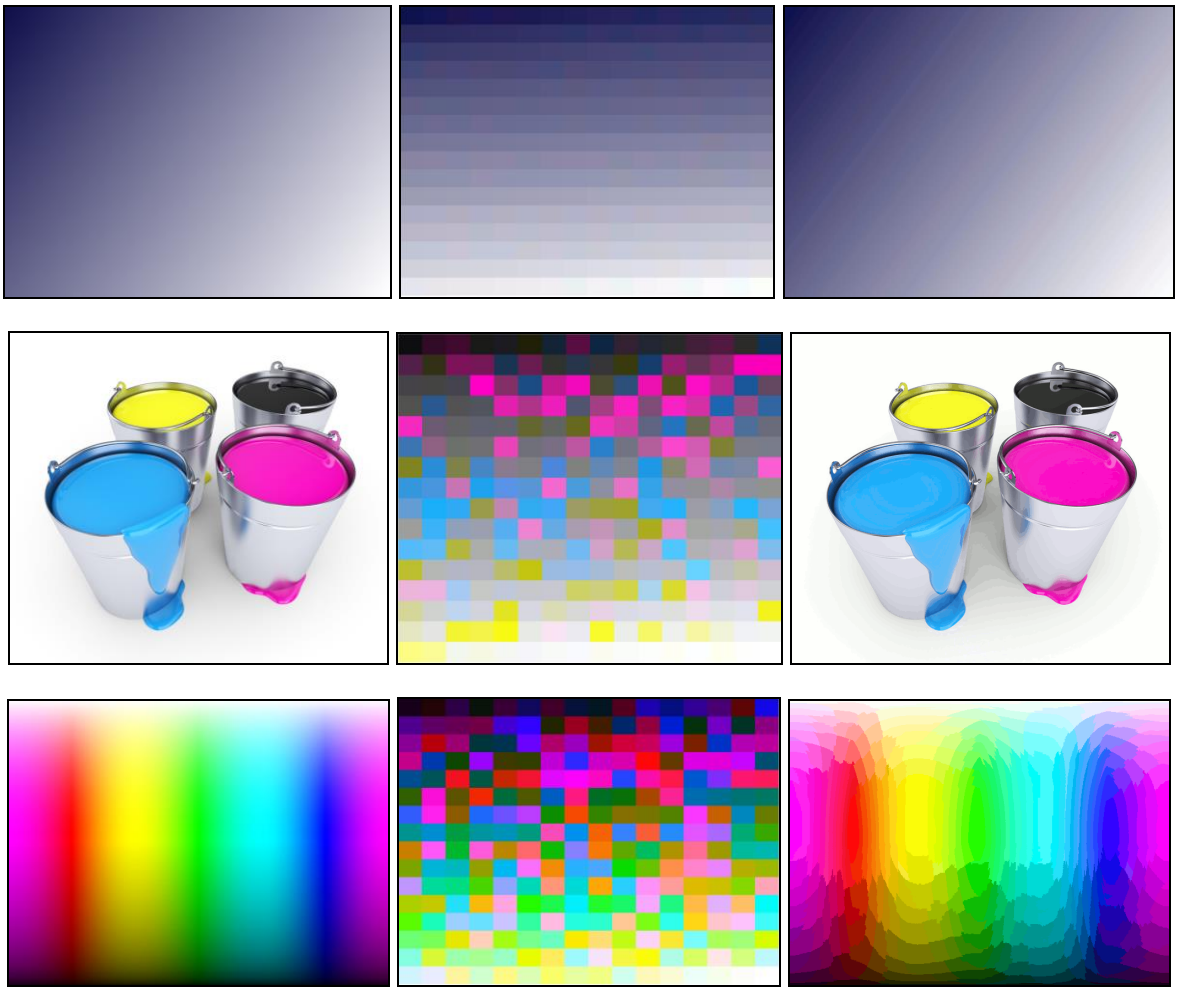
The total number of bits over all primary colors used to represent a color is called the color depth. When we refer to a 24-bit color depth with a tristimulus color model we mean each color is represented with 8 bits and hence can have one of 256 different intensities for each color. The total number of colors is 2^24; approximately 16.7 million colors.

Indexed color

Not all images need to have 16 million different colors. The image itself can have a limited number of colors or an approximation could be tolerated in exchange for file size. Indexed color uses a table to store the colors and stores the index of a color in the table instead of the full color for each pixel. For example, a 1024x1024 image with 256 colors would need 3x1024x1024 = 3 Megabytes using a 24-bit color representation and only need 3x256+1024x1024 ~= 1 Megabyte with an indexed color format; almost 3 fold smaller. The figure below shows the palette and images in two formats.

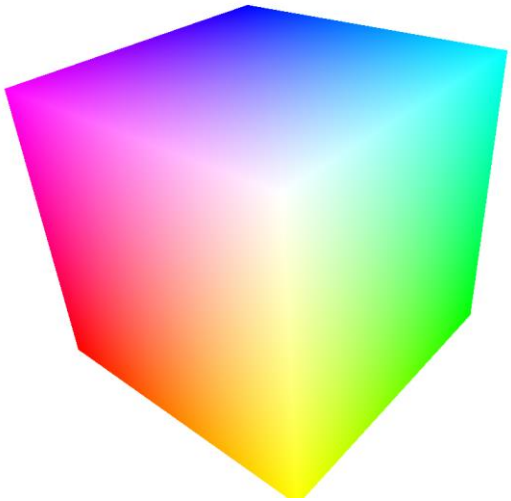
The figures below show the 256-element palettes (left) corresponding to the indexed color images (right) obtained from the original color images (middle).

(Original) (Palette) (Indexed)

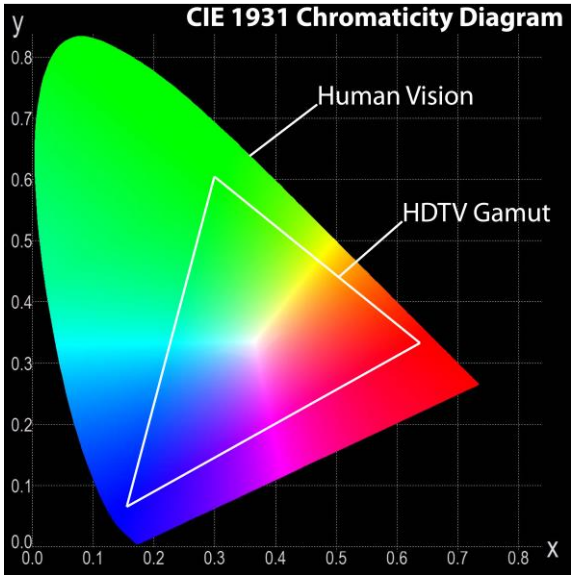


The RGB color model

Uses the three primary colors RGB to construct colors. The RGB color space is shown below. It is a cube with red, green and blue as the intensities on the principal axes (X, Y and Z).

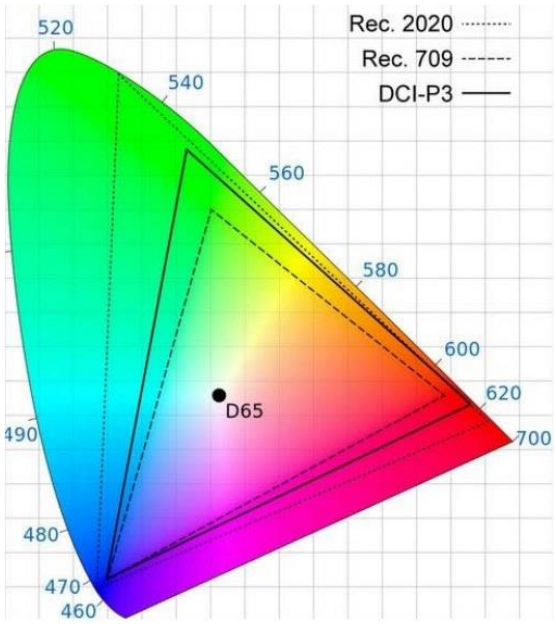


This, however, only produces a subset of actual colors seen by humans. The triangle in the figure below shows the limits of the RGB model compared to human vision. Nevertheless, this model is useful because TV and computer monitor manufacturers use these three colors to produce an approximation to the color spectrum in an affordable way.



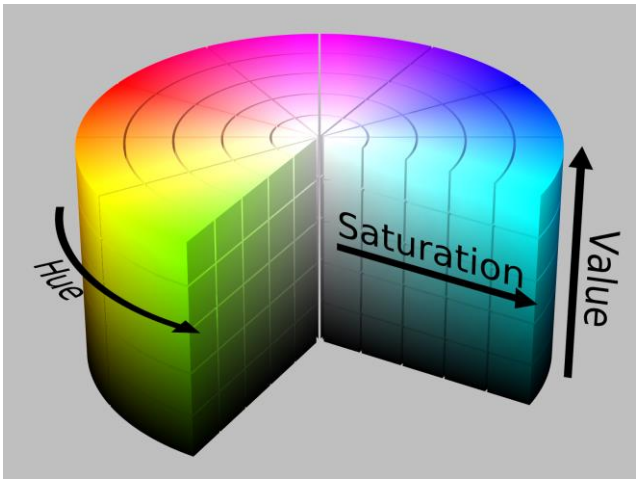
(http://dot-color.com/)
(CIE: International Commission on Illumination)

Rec. 709: HDTV – 1080p
DCI-P3: theatrical monition picture distribution
Rec. 2020: ultra-high-definition television (UHDTV - 4K UHD and 8K UHD, 16:9)



The HSV color model

Another way to describe color is through its hue, saturation and value (brightness). Hue is defined as the wavelength at which most of the energy is concentrated. Brightness or value is a measure of how light or dark the color is. Saturation refers to the color's purity or colorfulness. There is a direct conversion between the RGB color representation and the HSV representation.



(https://en.wikipedia.org/wiki/HSL_and_HSV)

MATLAB has two functions to convert between the RGB and HSV representations. The functions are called **hsv2rgb** and **rgb2hsv**. See the help pages for their use. Remember that MATLAB will only display RGB images, so if you are working with an HSV representation you need to convert it to RGB before using imshow.

CMYK color model

Is a subtractive color model. It is usually used for printing. Mixtures of cyan, magenta and yellow are used to produce colors and black (K) is used to produce pure black.