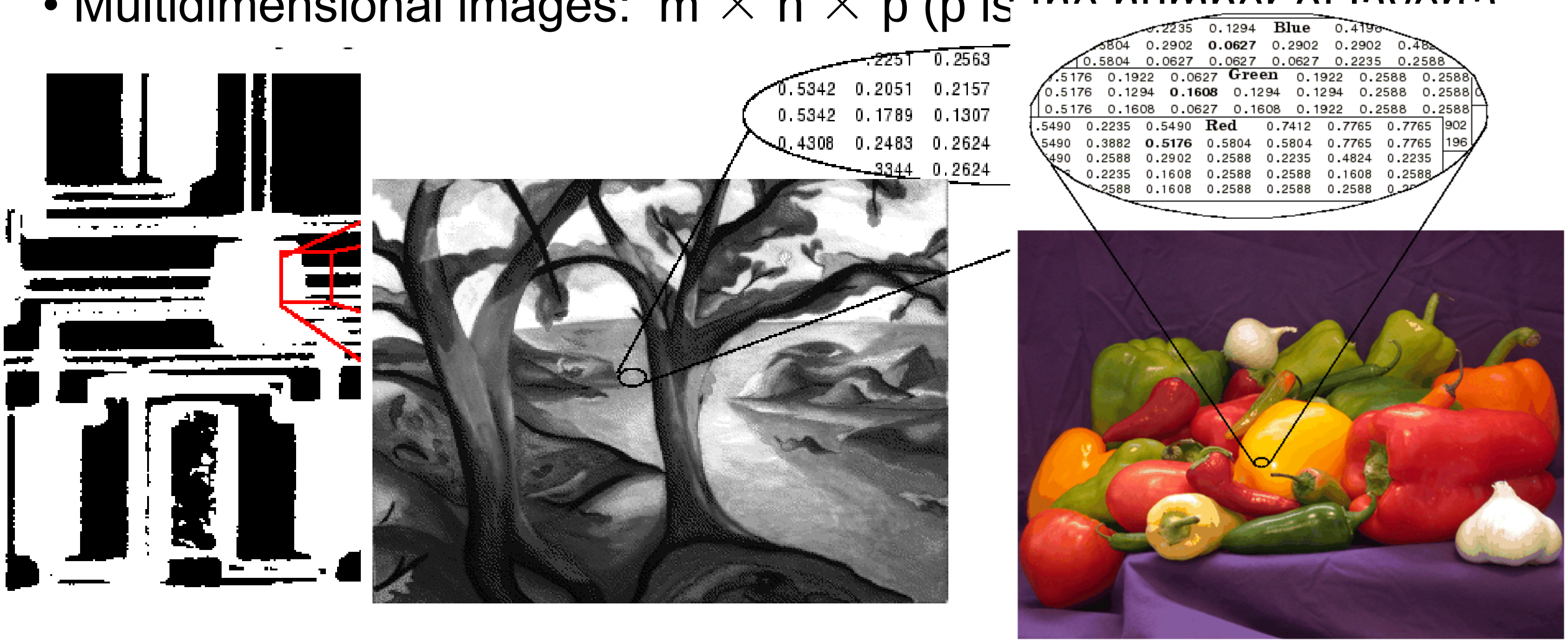
Color Theory

Prog3 (Update)

- “Negative Image” means reverse black and white. i.e. grayscale value of each pixel become: 255-original_value
- Test image and result examples are under course website’s testimages/prog3/

Images in MATLAB

- Binary/1-bit images : {0,1}
- Intensity/8-bit grayscale images : value ranged from [0,1] in double or [0,255] in `uint8`.
- 24-bit colored images(3 channels) : m $\times$ n $\times$ 3
- Multidimensional images: m $\times$ n $\times$ p (p is the number of layers)



1-bit Image

- Each pixel is stored as a single bit (0 or 1), so also referred to as **binary image**.

- Such an image is also called a 1-bit **monochrome** image or a pure black/white image since it contains no color.

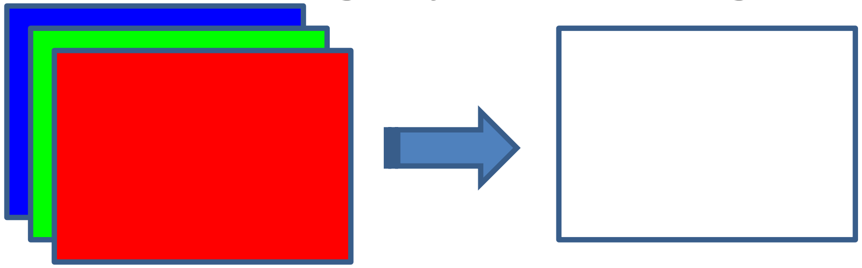
- We show a sample 1-bit monochrome image "Lena"
  - A standard image used to illustrate many algorithms

8-bit Grayscale Image

- Each pixel has a gray-value between 0 and 255.
  - A dark pixel might have a value of 10, and a bright one might be 230.
- Each pixel is represented by a single byte;
- **Image resolution** refers to the number of pixels in a digital image
  - Higher resolution always yields better quality
  - Fairly high resolution for such an image might be 1600x1200, whereas lower resolution might be 640x480.
- Without any compression, a raw image's size = # of pixels x byte per pixel

24-bit Colored Image

- You can image them as three 8-bit grayscale images layered together



  - Each pixel is represented by three bytes, usually representing RGB
  - one byte for each R, G, B component
  - 256x256x256 possible combined colors, or a total of 16,777,216 possible colors.
- In matlab, you can get R channel image by access I(:,:,1), similarly, G is the 2nd layer, B is the 3rd.

24-bit Colored Image-Example

imshow(I);

Original Image (RGB)

imshow(I(:,:,1));

Intensity Image: Red Layer

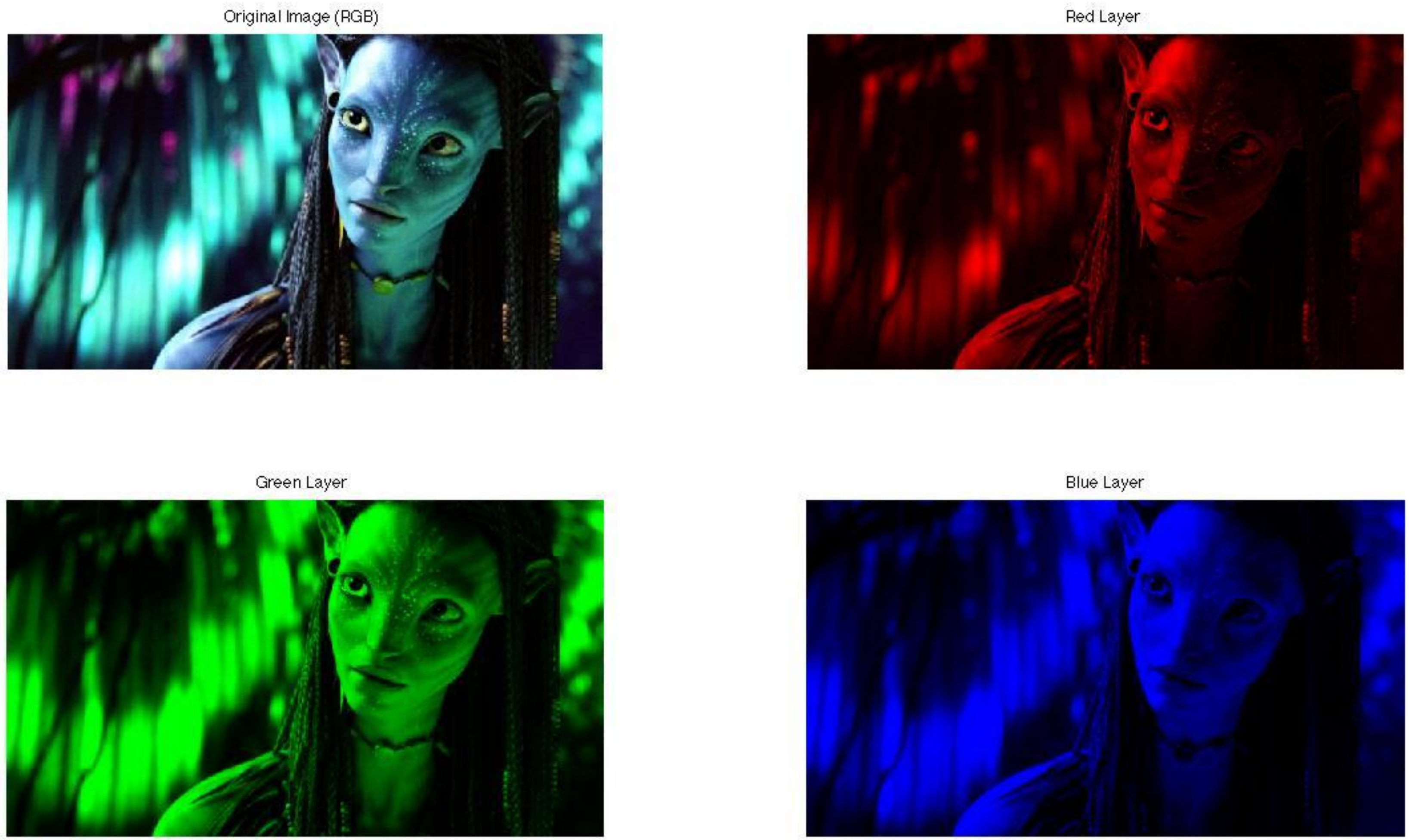
imshow(I(:,:,2));

Intensity Image: Green Layer

imshow(I(:,:,3));

Intensity Image: Blue Layer

24-bit Colored Image-Example



Color = EM Waves

- Light is an **electromagnetic wave**. Its color is characterized by the **wavelength** content of the light.
  - Most light sources produce contributions over many wavelengths.
  - Laser light consists of a single wavelength
  - Short wavelengths produce a blue sensation, long wavelengths produce a red one
- Human can not detect light, but its contributions that fall in the visible wavelengths (**400—700nm**)
  - Nanometer: $1nm=10^{-9}$ meter

color	wavelength interval
red	~ 700–635 nm
orange	~ 635–590 nm
yellow	~ 590–560 nm
green	~ 560–490 nm
blue	~ 490–450 nm
violet	~ 450–400 nm

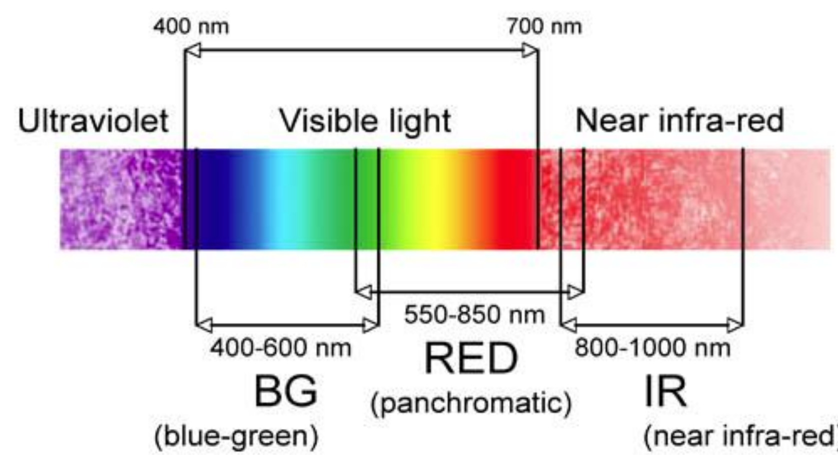
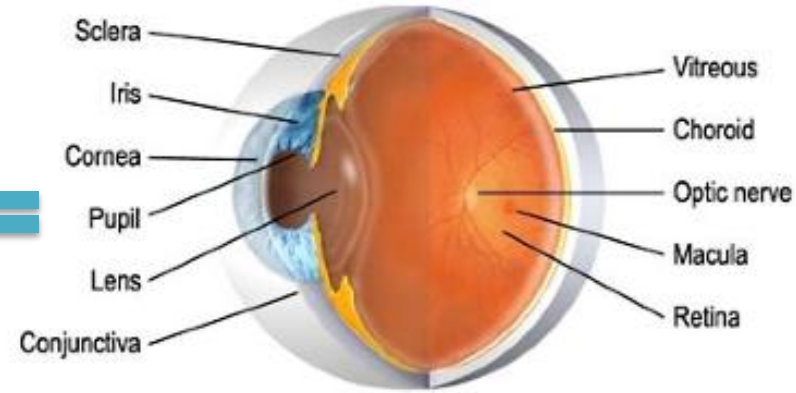


Image from http://hirise.lpl.arizona.edu/HiBlog/tag/color/

Human Vision

Like a Camera



Mapping camera components to the eyes

Lens → Lens, cornea

Shutter → Iris, pupil

Film/Sensor → Retina/Optic Nerve

Retina: a light sensitive tissue lining the inner surface of the eye.
The optics of the eye create an image of the visual world on the retina.

Human Perception of Colors

- Retina contains photo receptors
  - Cones: day vision, can perceive color tone
    - **Red**, **green**, and **blue** cones
    - cones have different frequency responses
    - Tri-receptor theory of color vision
  - Rods: night vision, perceive brightness only
    - produce a image in shades of gray (“all cats are gray at night!”)

color	wavelength interval
red	~ 700–635 nm
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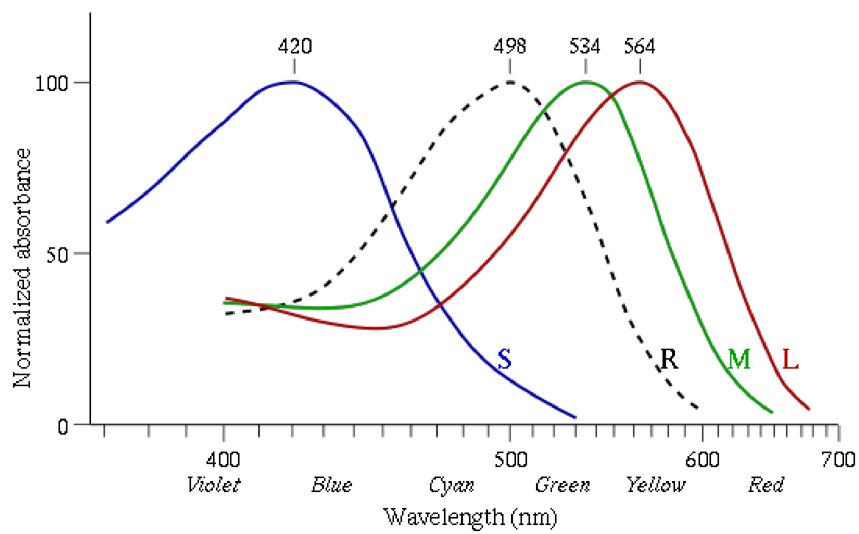
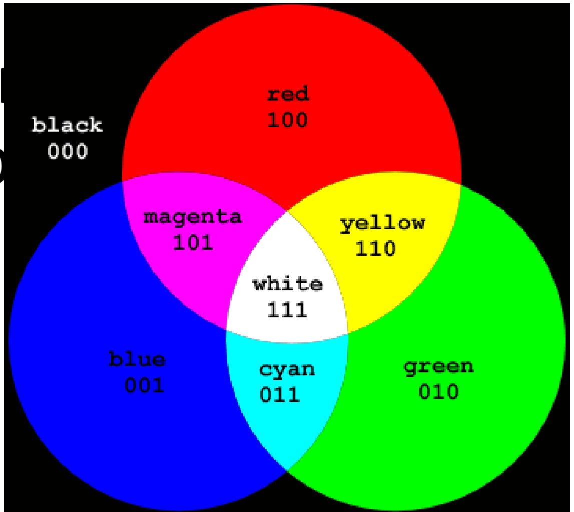


Define Colors via RGB

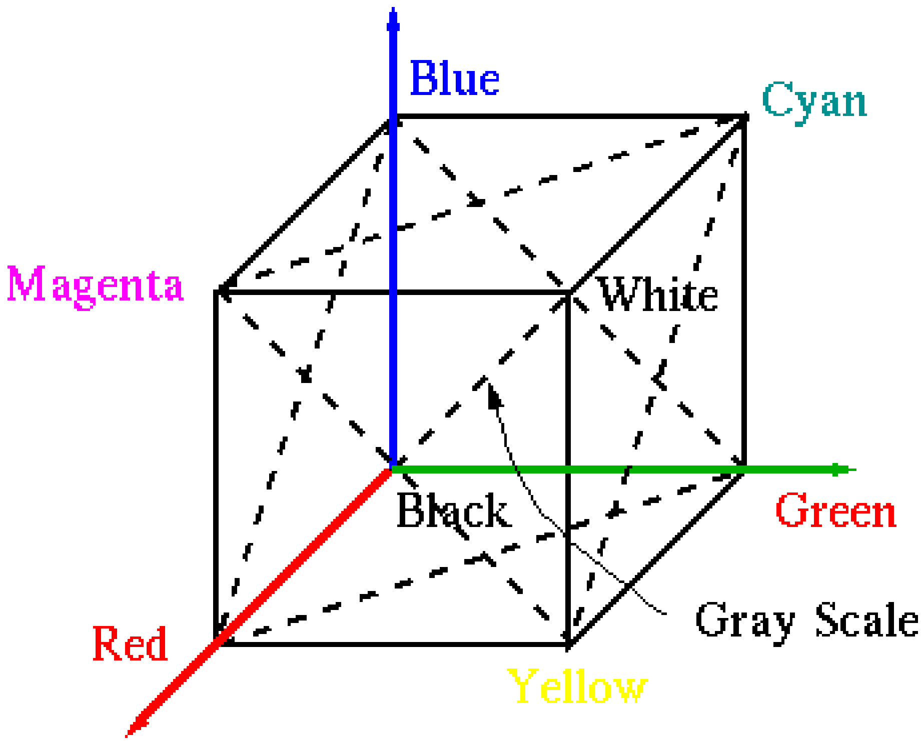
- **Trichromatic** color mixing theory
  - Any color can be obtained by mixing three primary colors with a right proportion

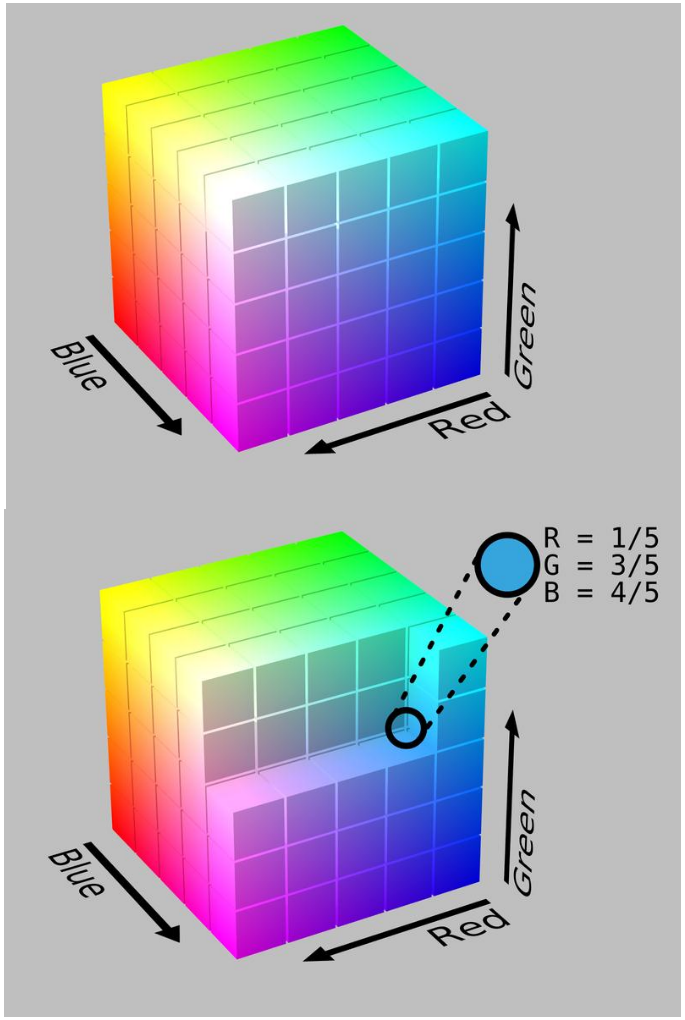
- Primary colors for illuminating sources:
  - Red, Green, Blue (RGB)
  - CRT works by exciting r
    e phosphors using sep
    gu
    hite

Used in digital images



RGB Coordinate

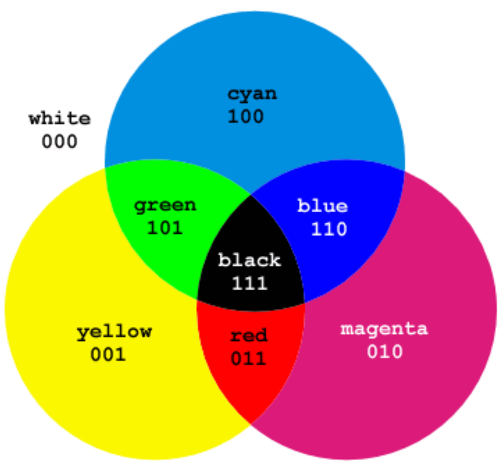




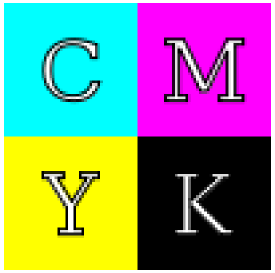
http://en.wikipedia.org/wiki/HSL_and_HSV

Define Colors vs. CMY

- Primary colors for reflecting sources (also known as secondary colors):
  - Cyan, Magenta, Yellow (CMY)
  - Example: Color printer works by using cyan, magenta, yellow and black (CMYK) dyes
  - Subtractive rule: R+G+B=Black



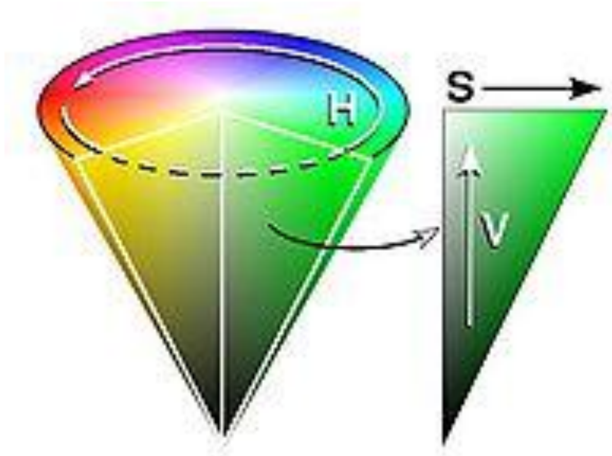
Used in printing



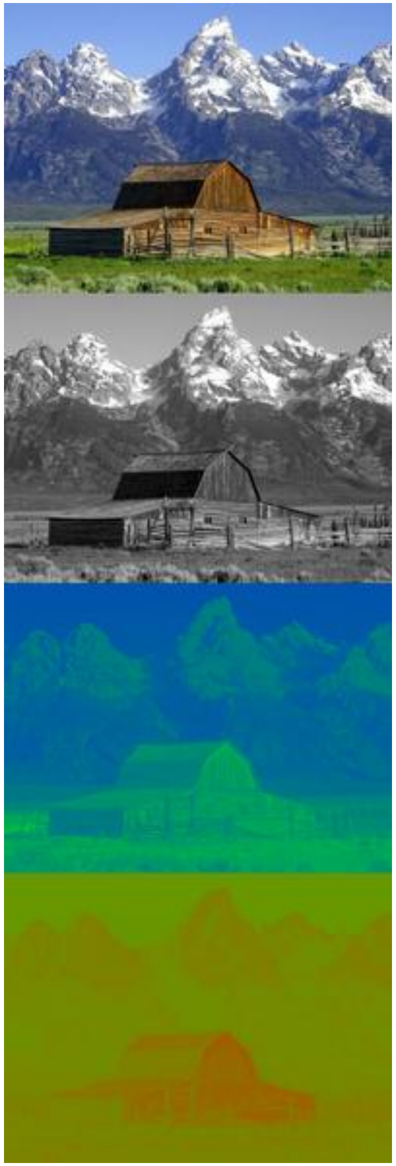
Luminance & Chrominance

- Color sensation can also be characterized by
  - Luminance (brightness)
  - Chrominance
    - Hue (color tone)
    - Saturation (color purity)
- Hue, saturation, and intensity
  - typically used by artists.
  - HSB/HSV (brightness/value), HSL(light)
- Intensity-chromaticity color spaces, YUV and YIQ,
  - Used for television broadcast.

HSB/HSV



Intensity-chromaticity based

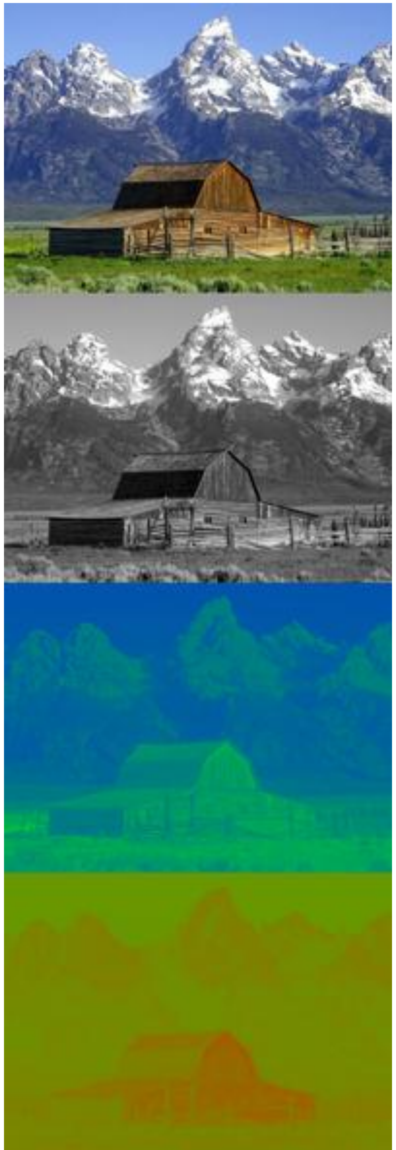


- **YUV (PAL TV broadcast, Europe & Asia, and some forms of NTSC)**
  - Code a **luminance** signal in **Y' channel**, the "luma".
  - **Chrominance** refers to the difference between a color and a reference white at the same luminance. –> use color differences **U, V**
  - **Human eyes are more sensitive to changes in luminance than in chrominance (for compression purpose)**

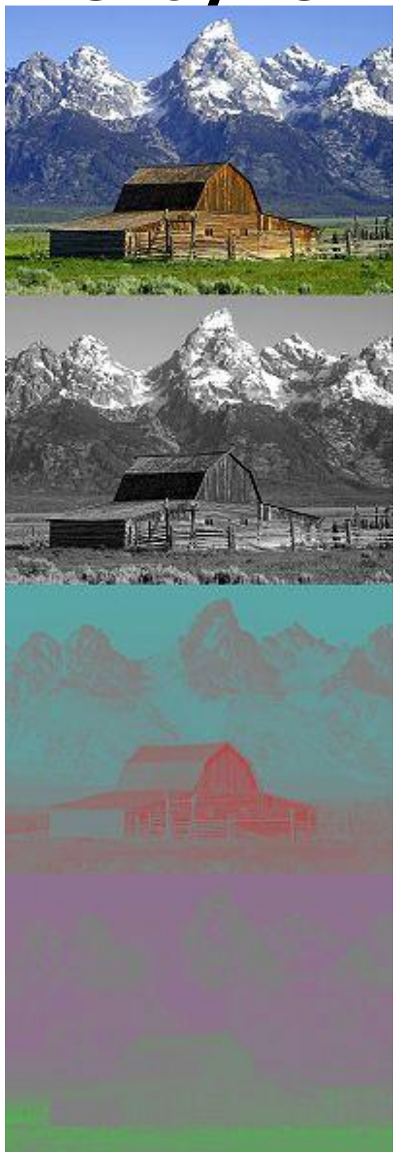
$$Y = 0.299R + 0.587G + 0.114B$$
$$U = -0.147R - 0.289G + 0.437B$$
$$V = 0.615R - 0.515G - 0.100B$$

http://commons.wikimedia.org/wiki/File:Barn-yuv.png

Intensity-chromaticity based



YUV



YIQ

- **YIQ (NTSC TV broadcast, north America)**
  - *I : in-phase*
  - *Q: quadrature*

RGB-to-YIQ

Y = 0.299R +0 .587G +0.114B
I = 0.596R - 0.274G - 0.322B
Q = 0.211R - 0.523G - 0.312B

RGB –YUV & YIQ

- ***RGB-to-YUV***

  Y = .299R + .587G + .114B
  U = -.147R - .289G + .437B=0.492(B-Y)
  V = .615R - .515G - .100B=0.877 (R-Y)

- ***RGB-to-YIQ***

  Y = .299R + .587G + .114B
  I = .596R - .274G - .322B
  Q = .211R - .523G - .312B

- ***YUV-to-RGB***

  R = 1.00Y + .000U + 1.403V
  G = 1.00Y - .344U - .714V
  B = 1.00Y + 1.773U + .000V

- ***YIQ-to-RGB***

  R = -1.129Y + 3.306I - 3.000Q
  G = 1.607Y - .934I + .386Q
  B = 3.458Y - 3.817I + 5.881Q