Lecture1

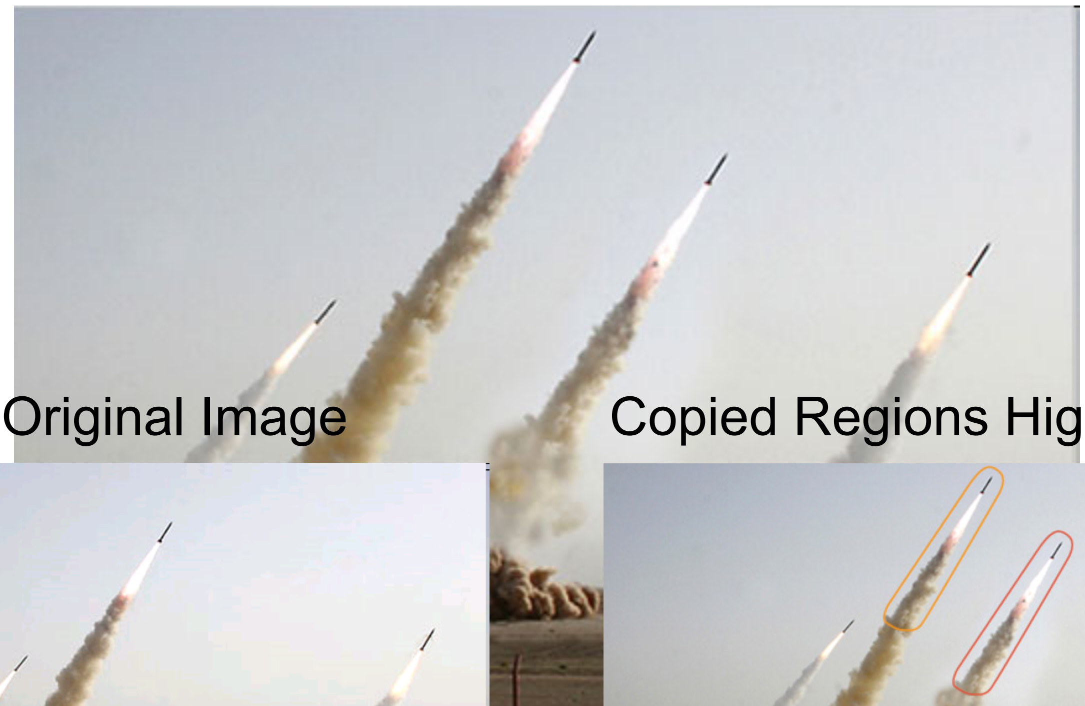
ECES 435

Multimedia Forensics & Security

☞ *Slides adapted with permission from ENEE408G course developed @ ECE Department, University of Maryland, College Park by Profs. Ray Liu (kjrliu@umd.edu) and Min Wu (minwu@umd.edu).*

Digital Multimedia Tampering

- Editing software can create *perceptually realistic* digital multimedia forgeries



Original Image

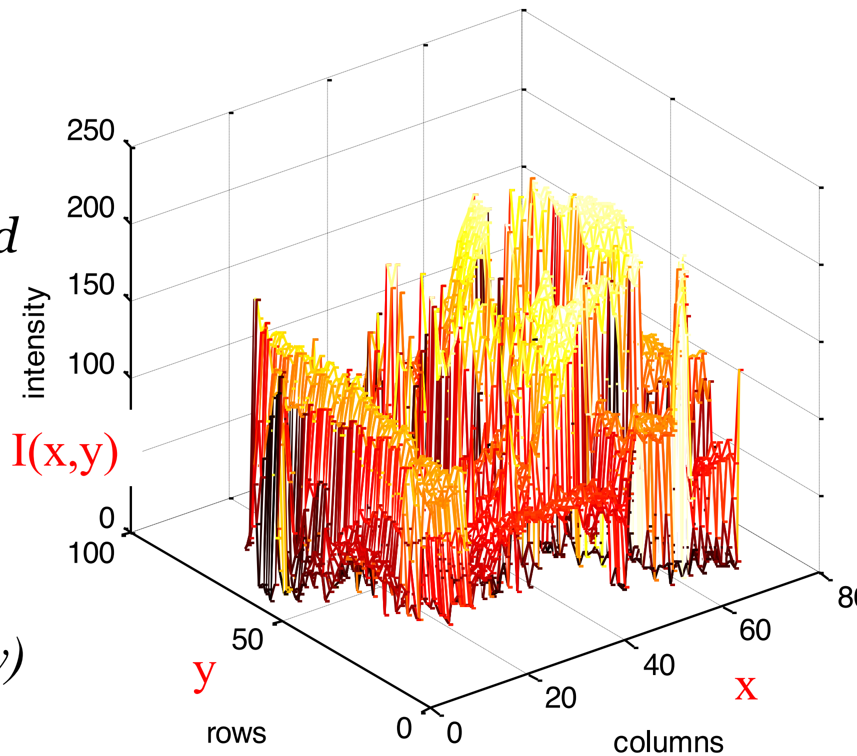
Copied Regions Highlighted

Introduction to Digital Image Processing

What is An Image?

- What we perceive as a grayscale image is a pattern of light intensity over a 2-D plane ("image plane")
  - A function *I(x,y)* of the two spatial coordinates, describing the intensity at the point *(x,y)* on the image plane.
  - I(x,y) takes non-negative values
    - *Often consider an image is bounded by a rectangle* [0,a]×[0,b]

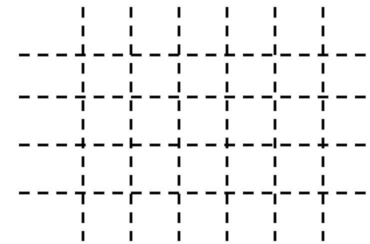
$$I: [0, a] \times [0, b] \to [0, inf)$$



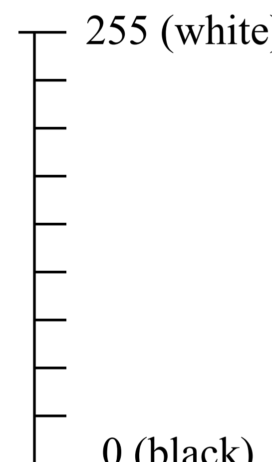
- Color image
  - Can be represented by three functions, *R(x,y)* for red, *G(x,y)* for green, and *B(x,y)* for blue.

Sampling and Quantization

- Computer handles "discrete" data
- Sampling
  - Sample the value of the image at the nodes of a rectangular grid on the image plane.
  - A pixel (picture element) at (i, j) is the image intensity value at grid point indexed by the integer coordinate (i, j)
  - How dense should we sample?
    => extend 1-D sampling theorem to 2-D



- Quantization
  - Is a process of transforming a real valued sampled image to one taking only a finite number of distinct values
  - Each sampled value in a 256-level grayscale image is represented by 8 bits
  - How many levels should we choose?



Examples of Sampling

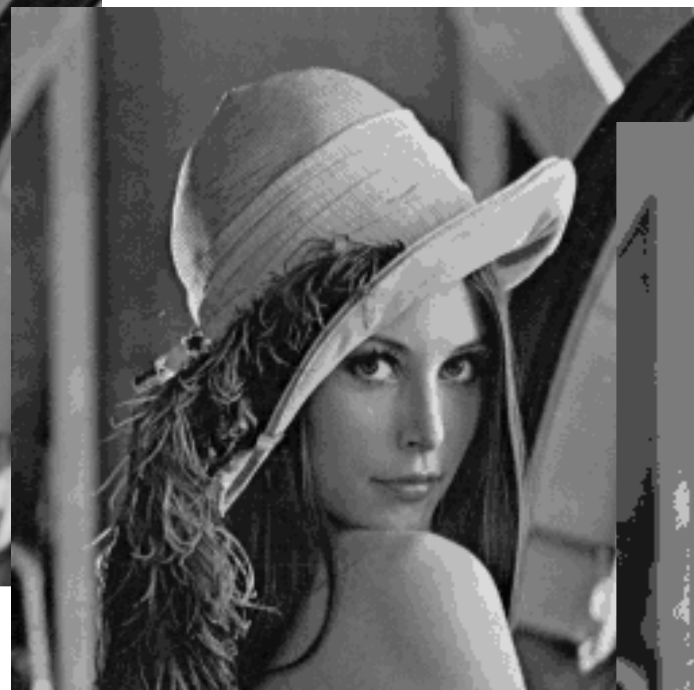
256x256

64x64

16x16

Examples of Quantizaion

8 bits / pixel



4 bits / pixel

2 bits / pixel

Huge Data Volume of Multimedia

- Color image of 600x800 pixels
  - 600*800 * 24 bits/pixel
    = 1.44M bytes
  - After JPEG compression
    - *only 89K bytes*
    - *compression ratio ~ 16:1*
- Video
  - 720x480 per frame, 30 frames/sec, 24 bits/pixel ~ 243M bits/sec
  - DVD ~ about 5M bits/sec
    - *Compression ratio ~ 48:1*
- Audio
  - 44.1KHz * 16bit * 2 ch. = 1.4 Mbps
  - MP3 ~ about 64K – 256 Kbps

“Library of Congress” by M.Wu (600x800)

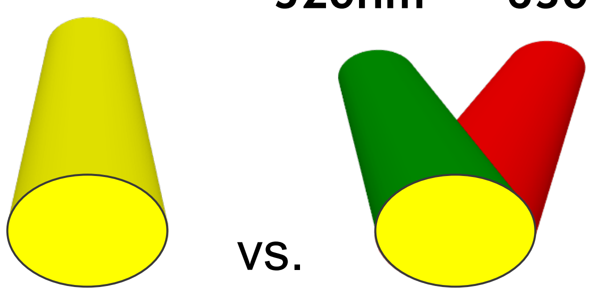
Color of Light

- Perceived color depends on spectral content
  (wavelength composition)
  - e.g., 700nm ~ red.
  - "spectral color"
    - *A light with very narrow bandwidth*

"Spectrum" from http://www.physics.sfasu.edu/astro/color.html

- A light with equal energy in all visible bands appears white

Example: Seeing Yellow Without Yellow



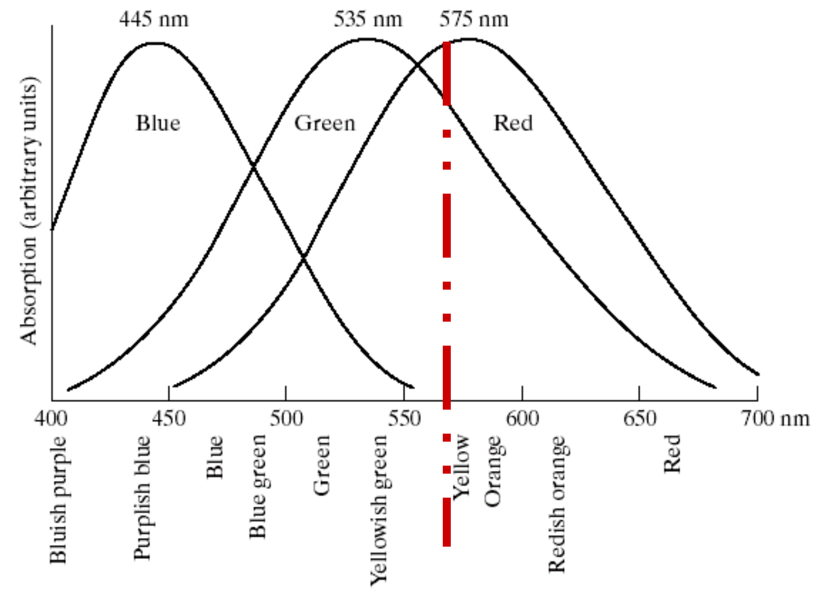


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

mix <u>green and red</u> light to obtain perception of <u>yellow</u>, without shining a single yellow photon

=> human eyes are not a precise spectrum analyzer

"Seeing Yellow" figure is from B.Liu ELE330 S'01 lecture notes @ Princeton; R/G/B cone response is from slides at Gonzalez/ Woods DIP book website

Color Perception

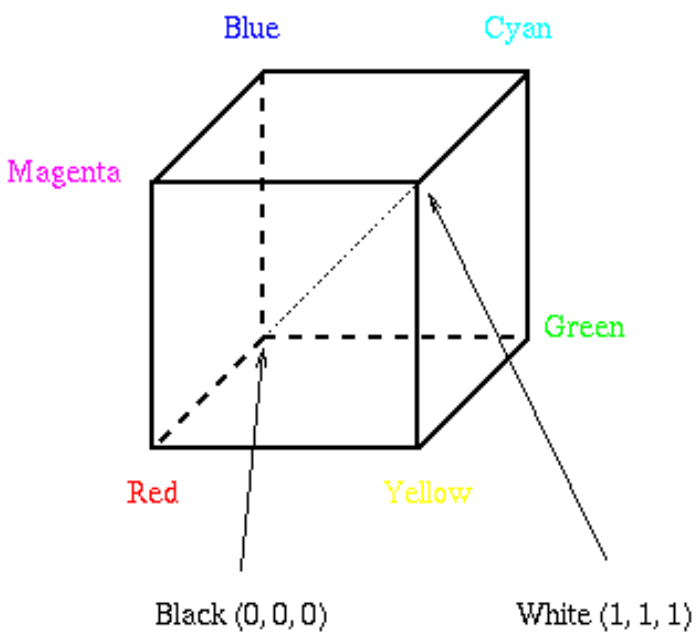
- Three kinds of photoreceptors in human retina for perception of color under bright light
  - Their sensitivity has peaks around 450nm (blue), 550nm (green), 600nm (yellow-green)

- Three Color Theory (Thomas Young, 1802)
  - Any color can be reproduced by mixing an appropriate set of three primary colors

- RGB primaries
  - red (700nm), green (546nm), blue (436nm)

RGB Primaries and Color Representation

- Use red, green, blue light to represent a large number of visible colors
- The contribution from each primary is normalized to [0, 1]



The RGB Cube

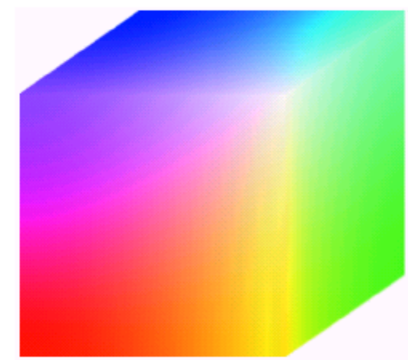


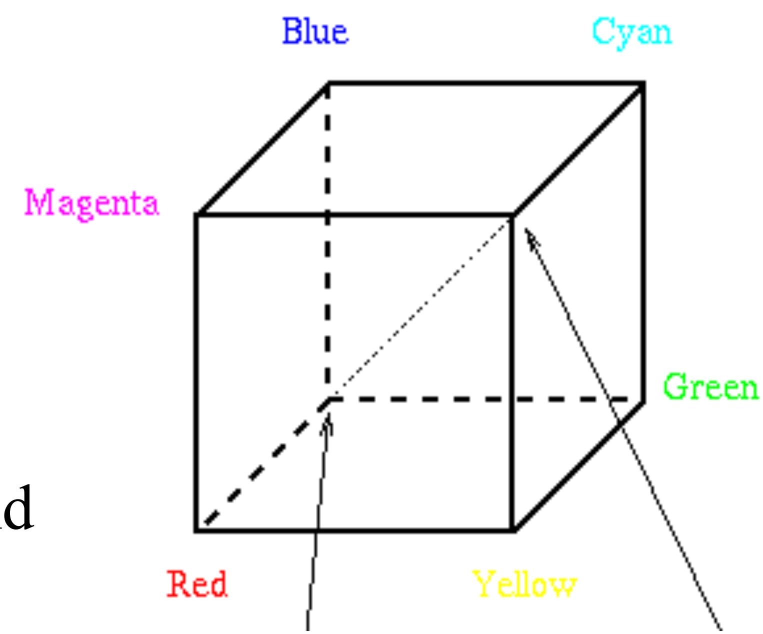
FIGURE 6.8 RGB 24-bit color cube.

Color-cube figures: left figure is from B.Liu ELE330 S'01 lecture notes @ Princeton, right figure is from slides at Gonzalez/ Woods DIP book website

Color Coordinate for Printing ("subtractive")

- CMY pigment primaries for printing
  - Cyan, Magenta, Yellow: complementary to RGB
  - Pigment's color depends on the light reflected

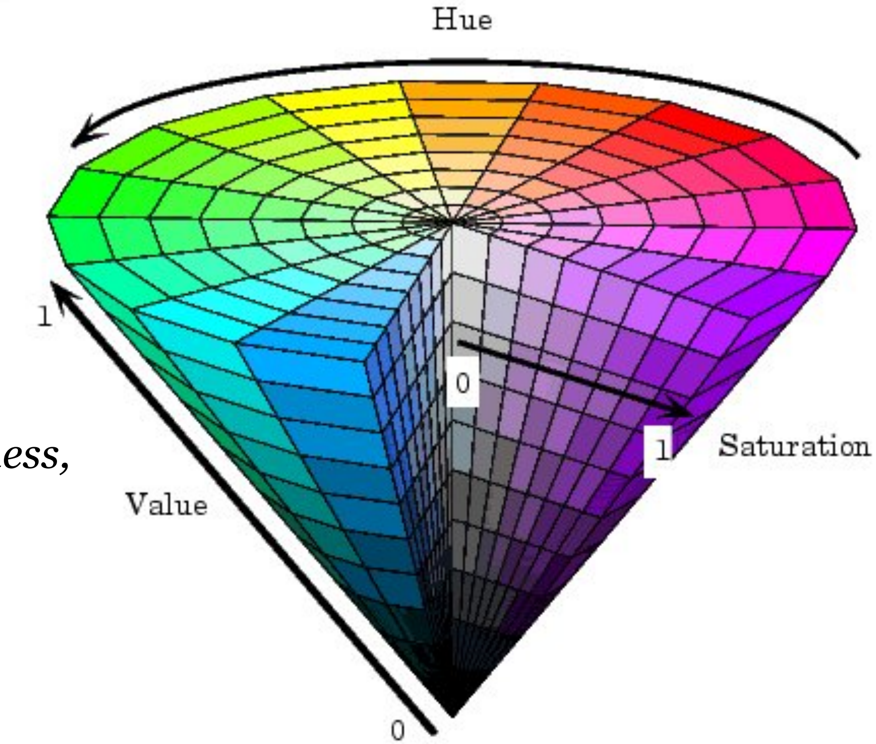
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}.$$



E.g. to paint blue, we'll put cyan and magenta pigment.

Perceptual Attributes of Color

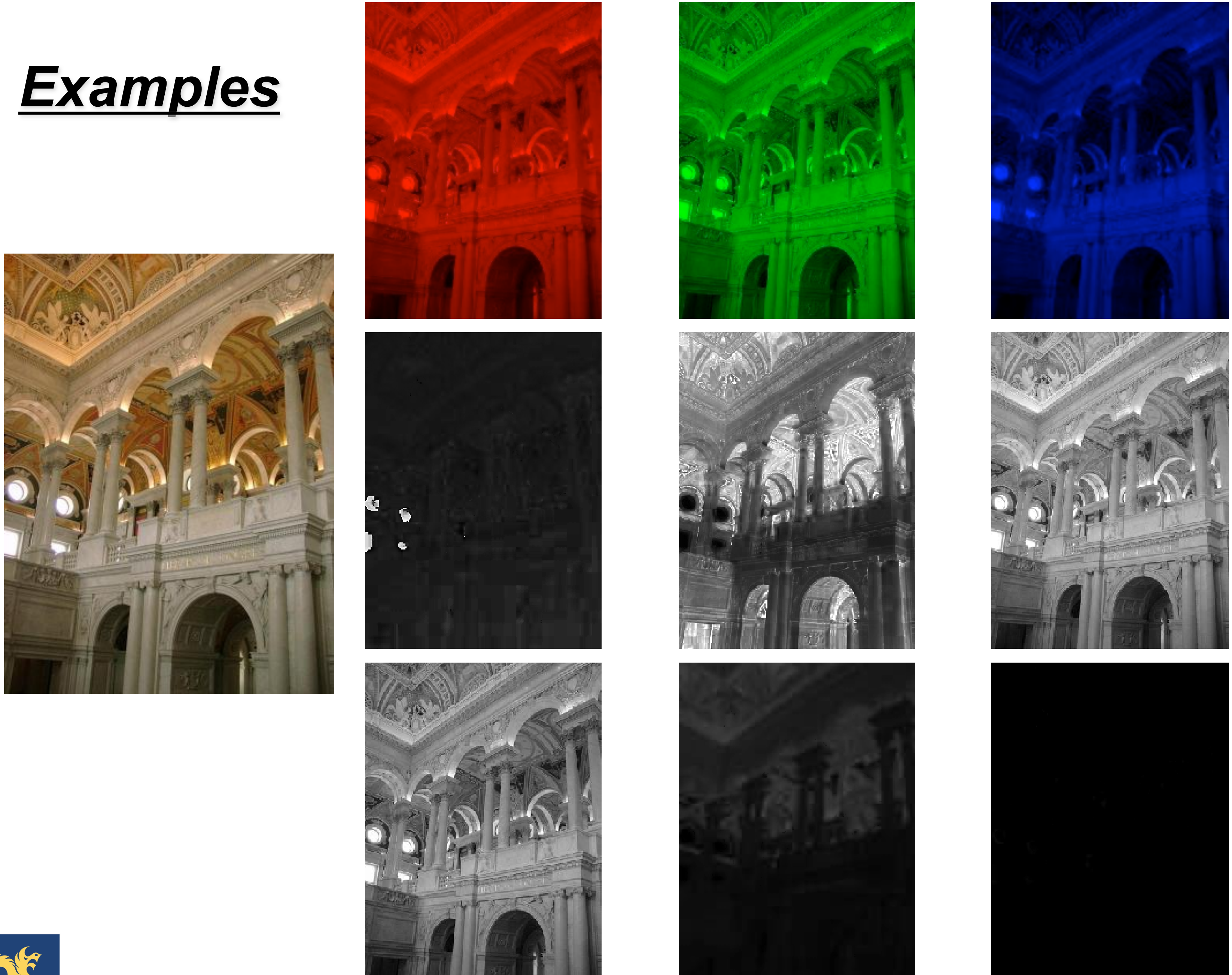
- Value of Brightness (perceived luminance)
- Chrominance
  - **Hue**
    - *specify color tone (redness, greenness, etc.)*
    - *depend on peak wavelength*
  - **Saturation**
    - *describe how pure the color is*
    - *depend on the spread (bandwidth) of light spectrum*
    - *reflect how much white light is added*
- RGB ⇔ HSV Conversion ~ *nonlinear*



HSV circular cone is from online documentation of Matlab image processing toolbox

http://www.mathworks.com/access/helpdesk/help/toolbox/images/color10.shtml

Examples



RGB

HSV

YUV

Color Coordinates Used in TV Transmission

- Facilitate sending color video via 6MHz mono TV channel
- YIQ for NTSC (National Television Systems Committee) transmission system
  - Use receiver primary system (R_N, G_N, B_N) as TV receivers standard
  - Transmission system use (Y, I, Q) color coordinate
    - *Y ~ luminance, I & Q ~ chrominance*
    - *I & Q are transmitted in through orthogonal carriers at the same freq.*

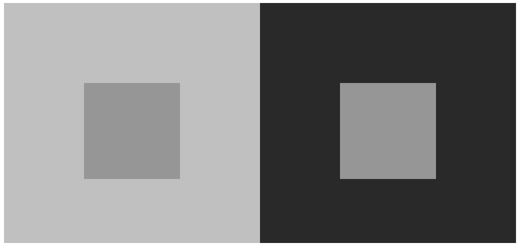
$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R_N \\ G_N \\ B_N \end{bmatrix}. \qquad \begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R_P \\ G_P \\ B_P \end{bmatrix}.$$

- YUV (YCbCr) for PAL and digital video
  - Y ~ luminance, Cb and Cr ~ chrominance

“Spectrum” from http://www.physics.sfasu.edu/astro/color.html

Luminance vs. Brightness

Same lum.
Different
brightness



Different lum.
Similar
brightness

- Luminance (or intensity)
  - Independent of the luminance of surroundings

$$L(x,y) = \int_0^{inf} I(x,y,\lambda)V(\lambda)d\lambda$$

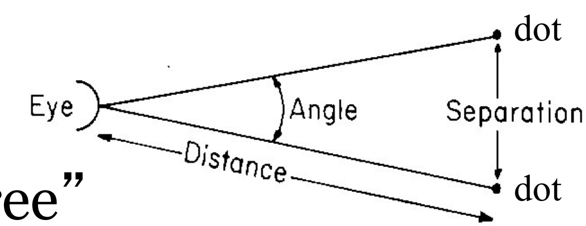
$I(x,y,\lambda)$ -- spatial light distribution

$V(\lambda)$ -- relative luminous efficiency func. of visual system
(bell-shaped, higher efficiency in middle wavelength range)

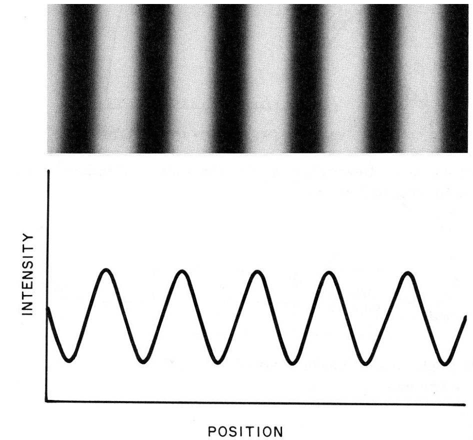
- Brightness
  - Perceived luminance
  - Depends on surrounding luminance

Visual Angle and Spatial Frequency

- Visual angle matters more than absolute distance
  - Smaller but closer object vs. larger but farther object
  - Eyes can distinguish about 30 lines per degree in bright illumination
    - *25 lines per degree translate to 500 lines if distance=4 × screenheight*



- Spatial Frequency
  - In unit of "cycles per visual degree"
  - Measures the extent of spatial transition



- Visibility threshold at different spatial frequency
  - Eyes are most sensitive to medium spatial freq. and least sensitive to high freq.
    ~ similar to a band-pass filter
  - More sensitive to horizontal and vertical changes than other orientations