Digital Image Processing
CS390S

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2018 Spring

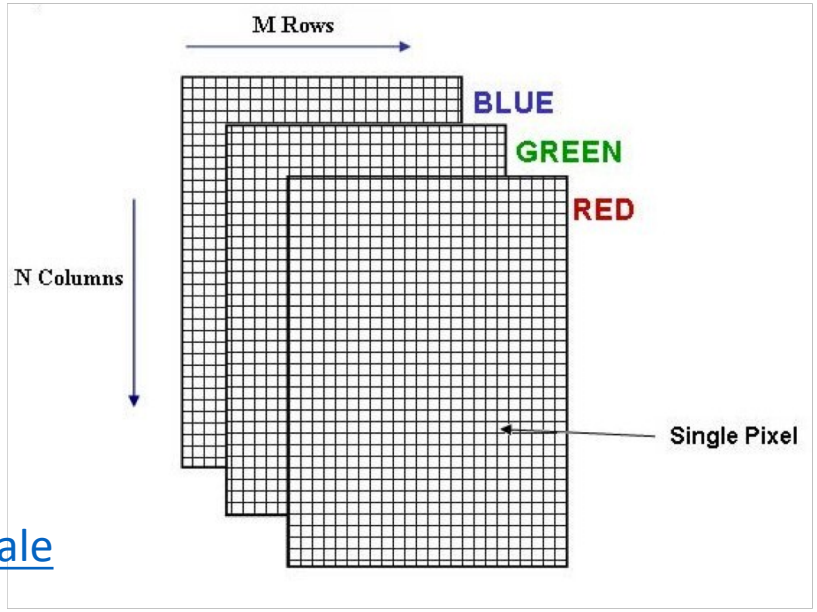
METROPOLITAN STATE UNIVERSITY℠
OF DENVER

Review Day 7

- Edge detection
- Filtering in frequency domain

Day 8 Color Space

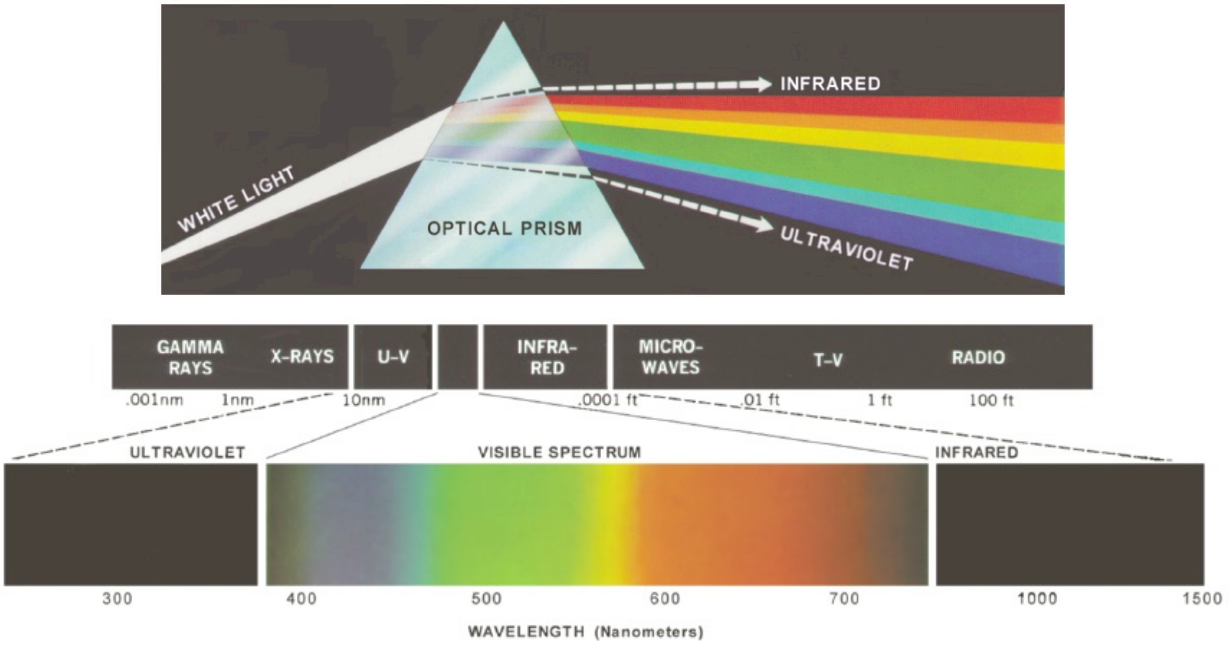
- XYZ CIE standard
- RGB
- HSI (HSV)
- Lab LUV YUV YCrCb



Color image ->grayscale image
https://en.wikipedia.org/wiki/Grayscale

Color space: http://dba.med.sc.edu/price/irf/Adobe_tg/models/ciexyz.html

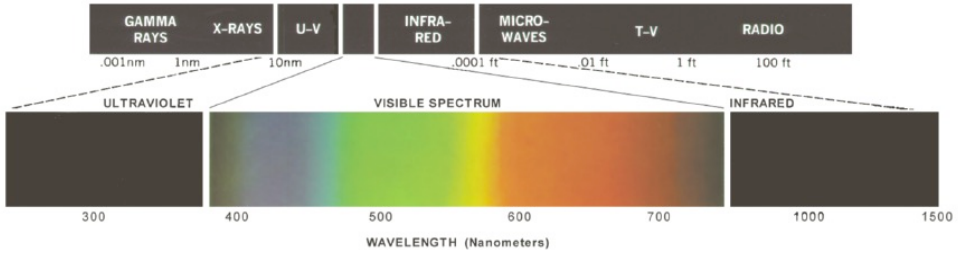
Color Space



- E.g. Green object reflect the light with 500 nm wavelength

Color Space

- Achromatic light (gray level, intensity)
- Chromatic light (400-700 nm)
- luminance, radiance and brightness (subjective, achromatic intensity)



- Human eyes: 6-7 million cones (65% R 33% G 2% B)
- Primary colors (R G B)

Color Space

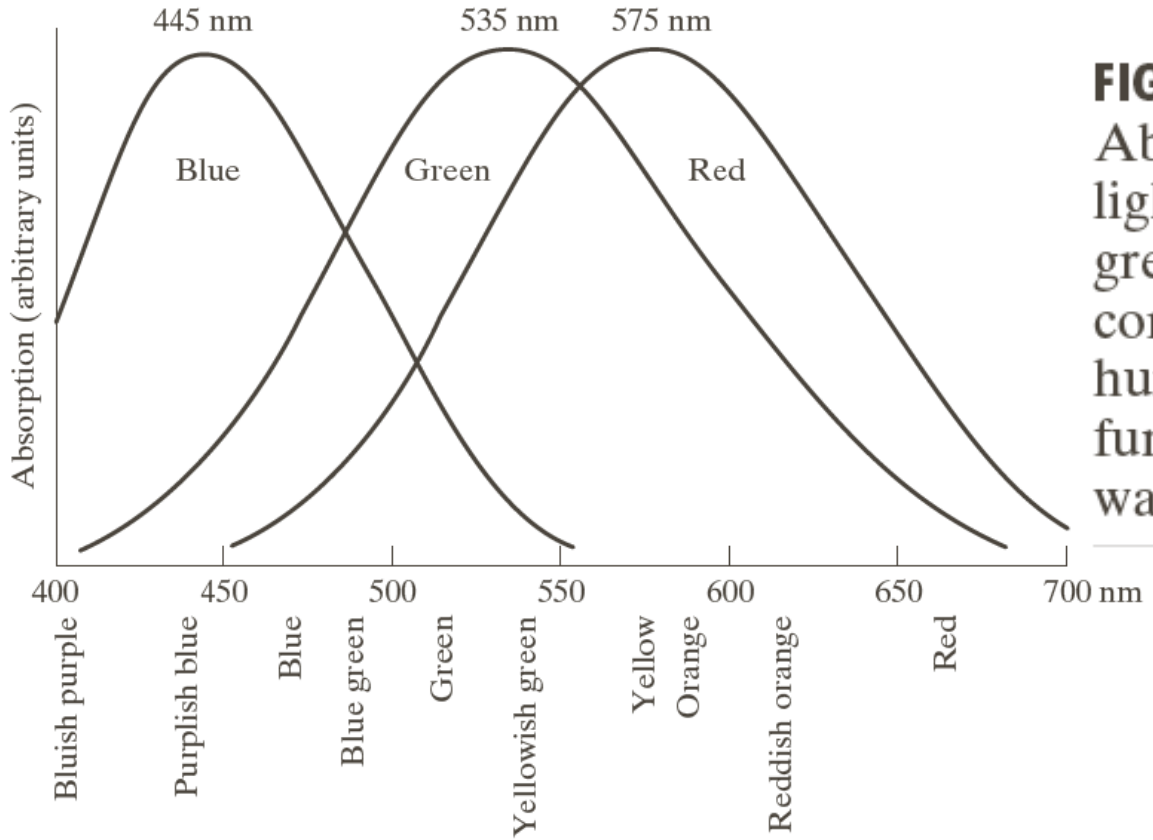
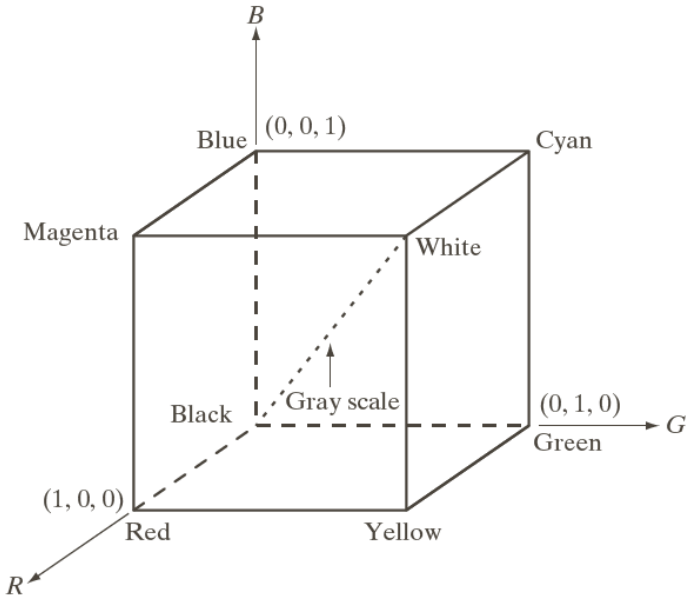
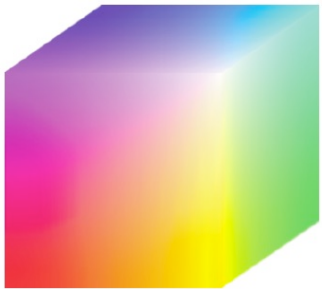


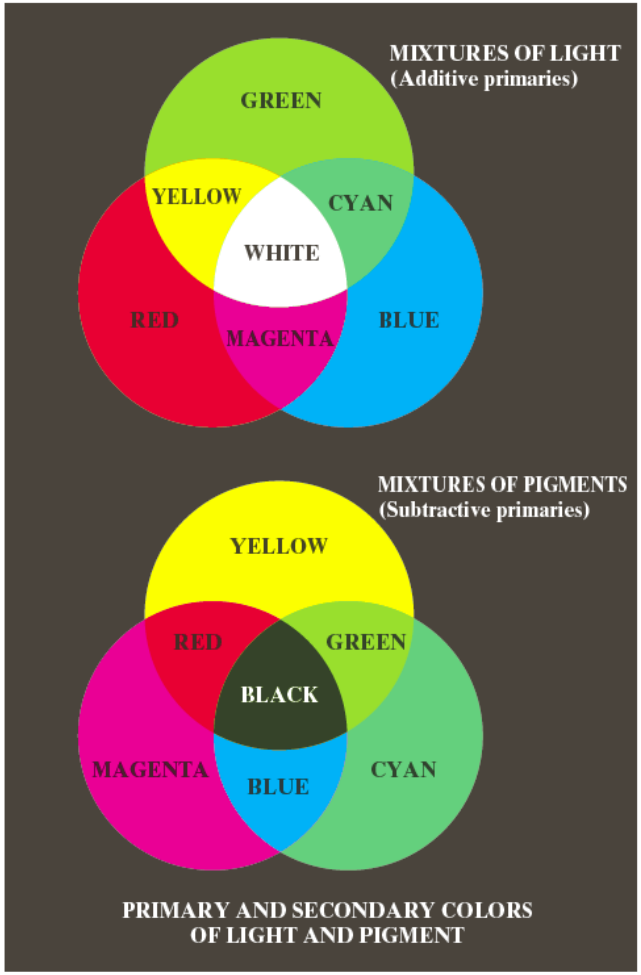
FIGURE 6.3
Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

Color Space

- Primary color
- Secondary color







Color Space

- To distinguish colors :
  - Chromaticity: Hue and Saturation
    - Hue: measures dominant wavelength of light waves
    - Saturation: amount of white light mixed with a hue
    - E.g. pink = red +white
  - Brightness (subjective, impossible to measure, achromatic notion of intensity)

Color Space

- Tristimulus
  - The amount of Red, Green and Blue needed to form a particular color (denoted by X, Y and Z)
  - A color is then specified by its "Tri-chromatic Coefficients"

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \qquad z = \frac{Z}{X+Y+Z}$$

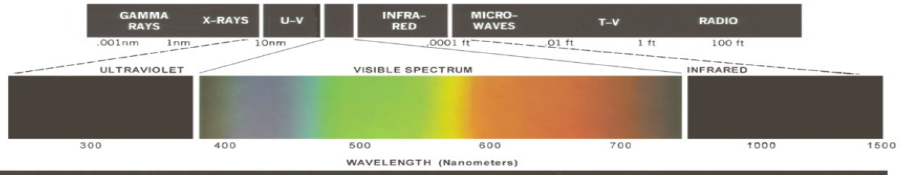
  - Thus $x+y+z=1$

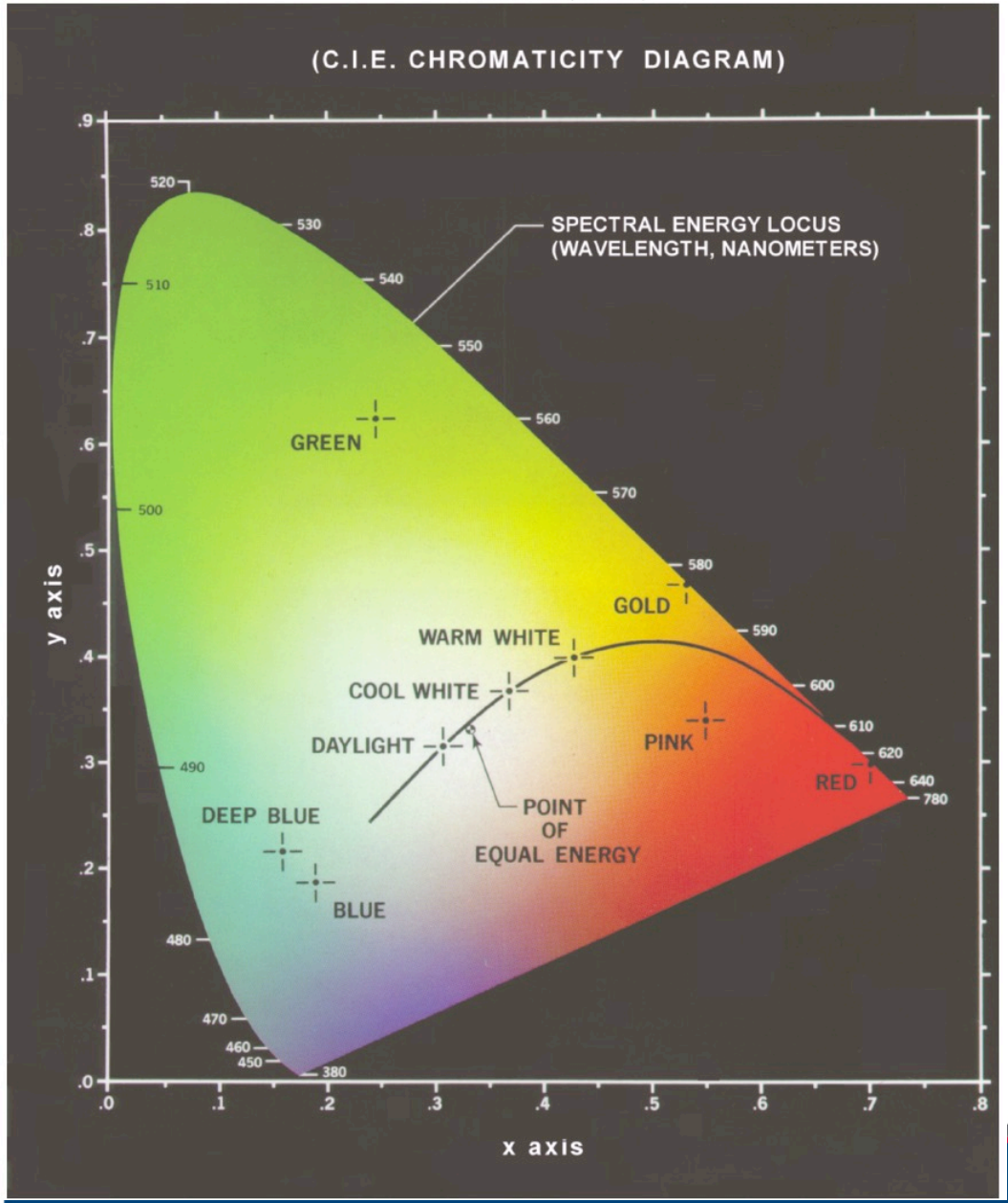
Color Space

- Color gamut

- Boundary saturated
- White point zero saturation

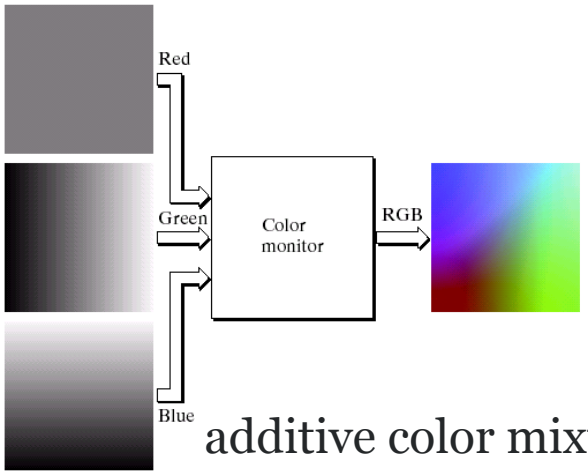
- Not all visible color by RGB
- Just most efficient



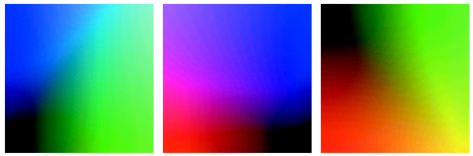


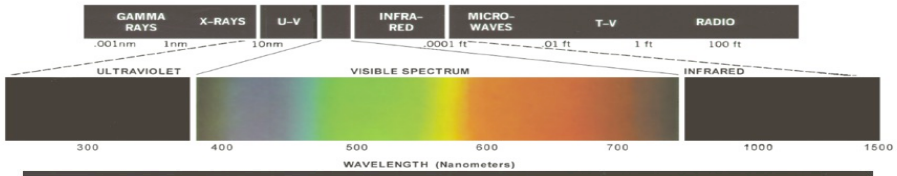
Color Space

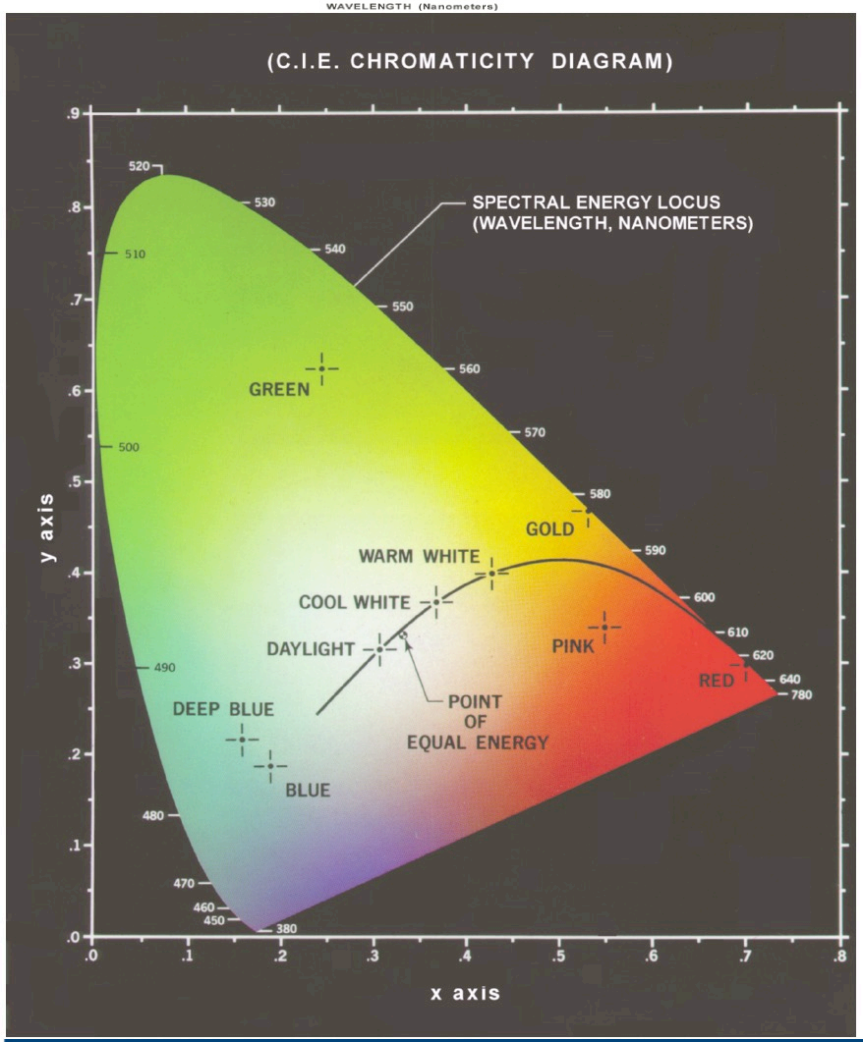
- Color gamut



additive color mixture







Color Space

- RGB – monitor, camera
- CMY, CMYK – printing
- HSI
  - (hue saturation intensity)

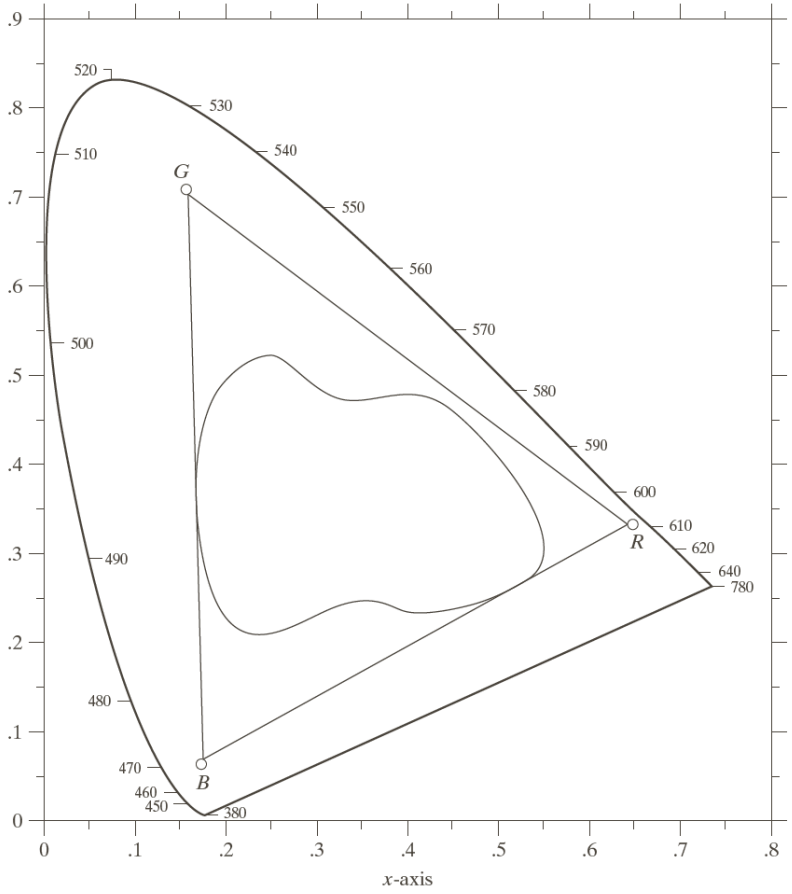


FIGURE 6.6
Typical color gamut of color monitors (triangle) and color printing devices (irregular region).

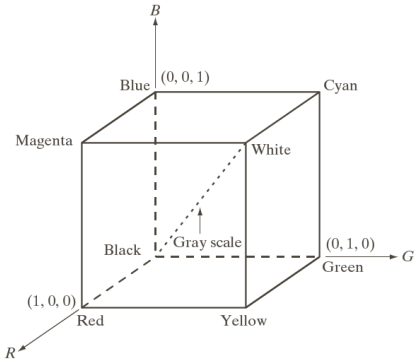
Color Space

- Tristimulus
  - The amount of Red, Green and Blue needed to form a particular color (denoted by X, Y and Z)
  - A color is then specified by its "Tri-chromatic Coefficients"

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \qquad z = \frac{Z}{X+Y+Z}$$

  - Thus $x+y+z=1$

Color Space



- RGB <-> CMY color space conversion

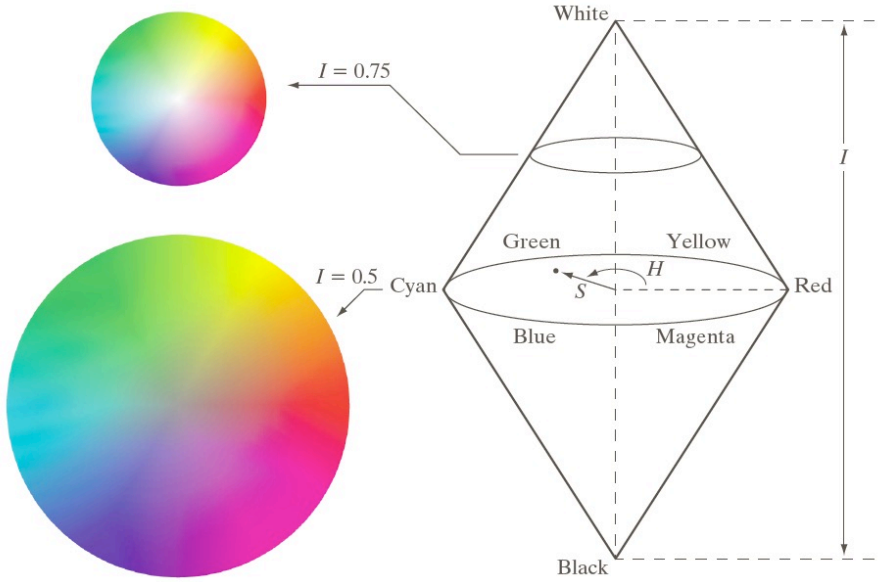
Convert White from (1, 1, 1) in RGB to (0, 0, 0) in CMY:

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

- Sometimes, an alternative CMYK model (K stands for *Black*) is used in color printing (e.g., to produce darker black than simply mixing CMY).

Color Space

- HSI (Hue, Saturation, Intensity)
  - RGB ideal for color generation
  - HSI natural and intuitive to humans



Color Space

- HSI (Hue Saturation Intensity)

  - **RGB → HSI**

$$\theta = \cos^{-1}\left\{\frac{[(R-G)+(R-B)]/2}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\}$$

$$H = \begin{cases} \theta & B \le G \\ 360-\theta & B > G \end{cases}$$

$$S = 1 - \frac{3\cdot\min(R,G,B)}{R+G+B}$$

$$I = (R+G+B)/3$$

Color Space

- HSI (Hue Saturation Intensity)

$$H_n = \begin{cases} 0, & \text{if } 0° \le H \le 120°; \\ H - 120°, & \text{if } 120° < H \le 240°; \\ H - 240°, & \text{if } 240° < H < 360° \end{cases}$$

$$R = \begin{cases} I \cdot \left(1 + \frac{S \cdot \cos(H_n)}{\cos(60° - H_n)}\right), & \text{if } 0° \le H \le 120°; \\ I - I \cdot S, & \text{if } 120° < H \le 240°; \\ 3I - G - B, & \text{if } 240° < H < 360° \end{cases}$$

$$G = \begin{cases} 3I - R - B, & \text{if } 0° \le H \le 120°; \\ I \cdot \left(1 + \frac{S \cdot \cos(H_n)}{\cos(60° - H_n)}\right), & \text{if } 120° < H \le 240°; \\ I - I \cdot S, & \text{if } 240° < H < 360° \end{cases}$$

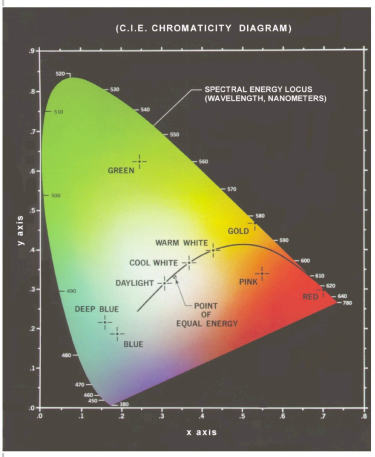
$$B = \begin{cases} I - I \cdot S, & \text{if } 0° \le H \le 120°; \\ 3I - R - G, & \text{if } 120° < H \le 240°; \\ I \cdot \left(1 + \frac{S \cdot \cos(H_n)}{\cos(60° - H_n)}\right), & \text{if } 240° < H < 360° \end{cases}$$

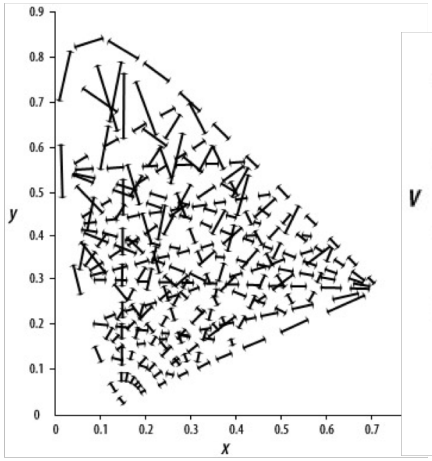
Color Space

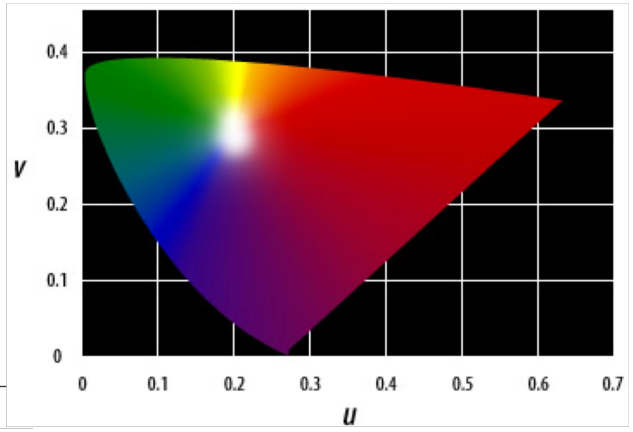
- LUV (CIELUV)

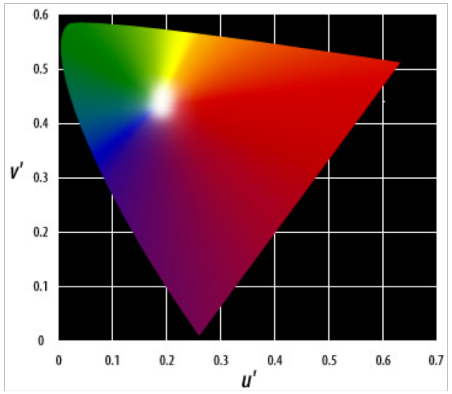
Not uniform ->1960, CIE *u,v* Chrom Diagram.

-> still not satisfied -> 1976 new (*u',v'*) values *L* lightness (0-100)



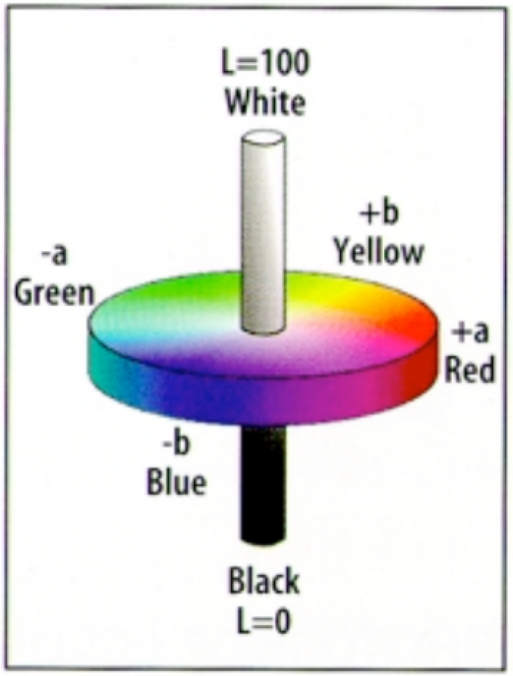






Lab: photoshop

- Photoshop uses this model to get more control over color
- It's named CIE Lab model (refined from the original CIE model
- Liminance: L
- Chrominance: a – ranges from green to red and b ranges from blue to yellow



Lab model

Color Space

Yuv and YCrCb: digital video

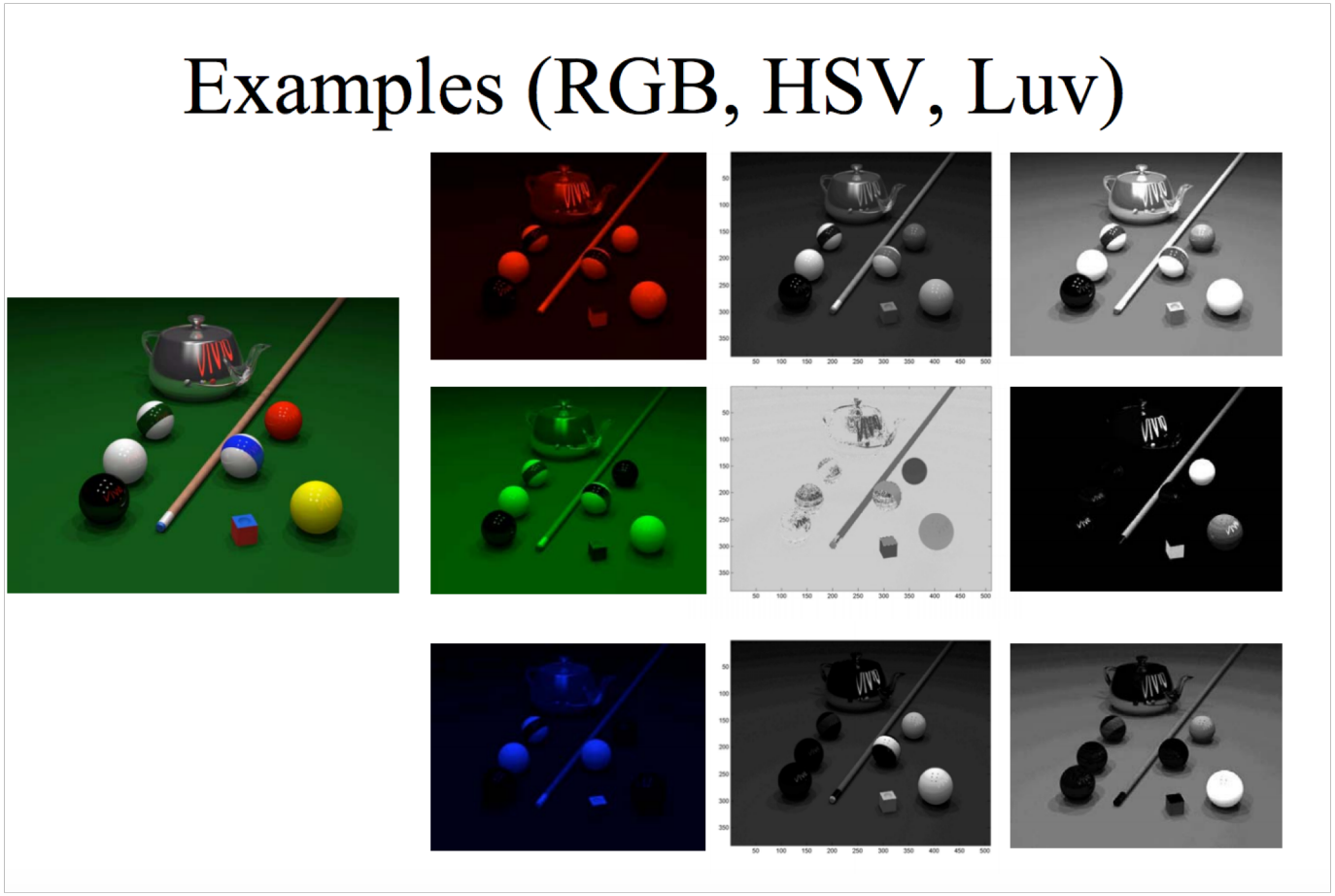
- Initially, for PAL analog video, it is now also used in CCIR 601 standard for digital video
- Y (luminance) is the CIE Y primary.

  $Y = 0.299R + 0.587G + 0.114B$
- *Chrominance* is defined as the difference between a color and a reference white at the same luminance. It can be represented by U and V -- the *color differences*.

  $U = B - Y;\ V = R - Y$
- YCrCb is a scaled and shifted version of YUV and used in JPEG and MPEG (all components are positive)

  $Cb = (B - Y) / 1.772 + 0.5;\ Cr = (R - Y) / 1.402 + 0.5$

Color Space

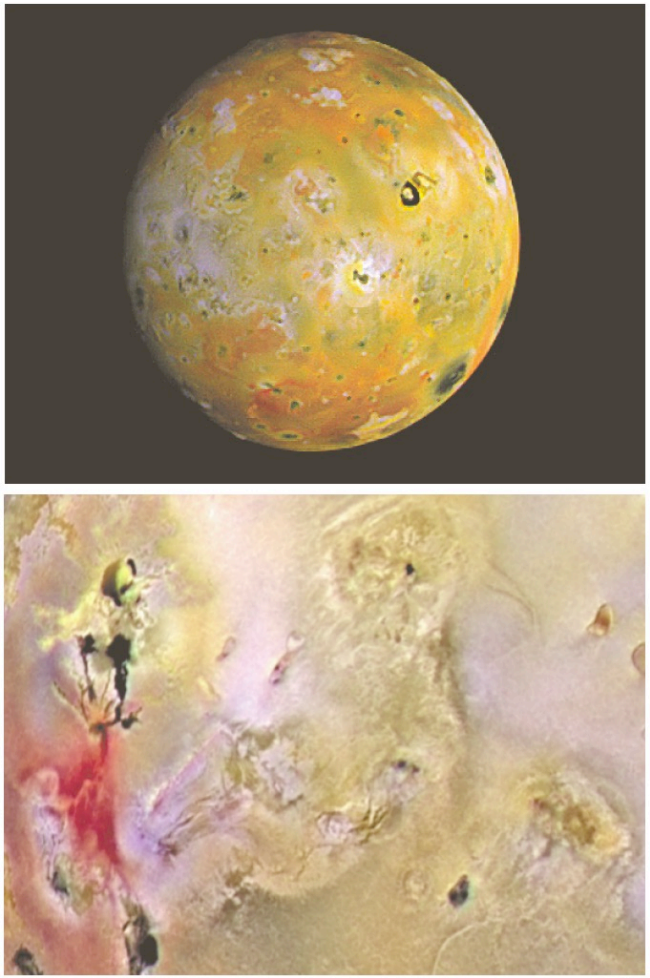


Color Space

- Example
- Applications

Color Space

- Example
- Applications

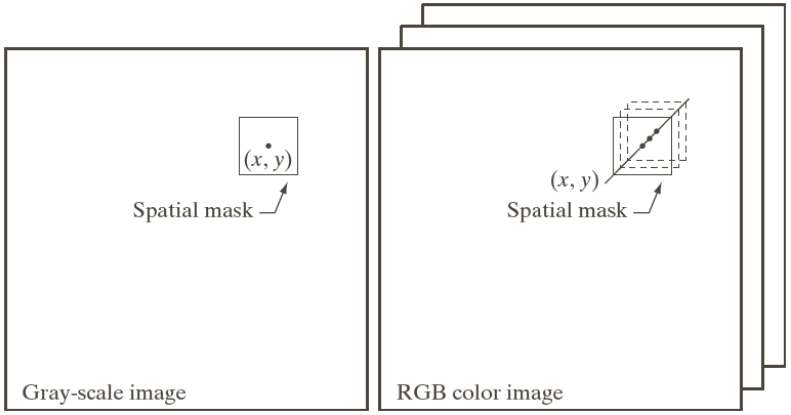


a
b

FIGURE 6.28
(a) Pseudocolor rendition of Jupiter Moon Io. (b) A close-up. (Courtesy of NASA.)

Color Space

- Example
- Applications



a b

FIGURE 6.29 Spatial masks for gray-scale and RGB color images.

Color Space

- Example
- Applications

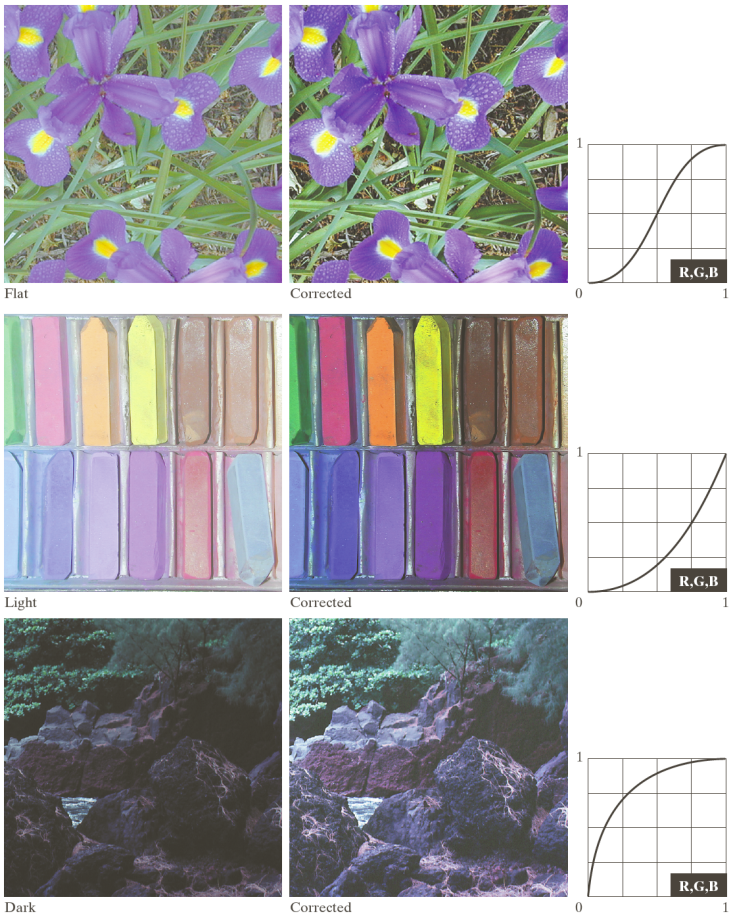


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

Color Space

- Example
- Applications

Original/Corrected

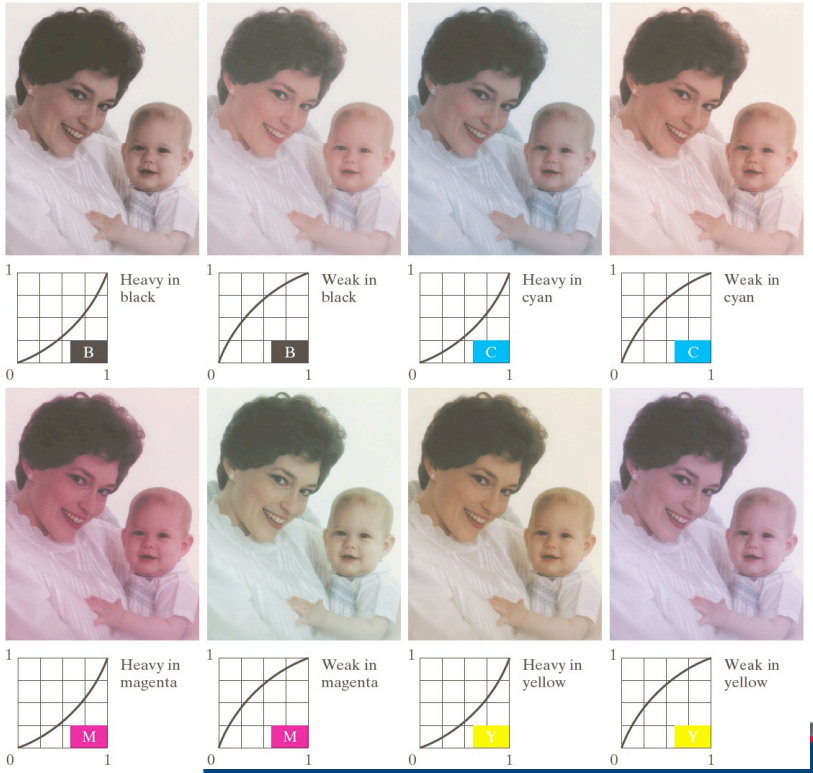
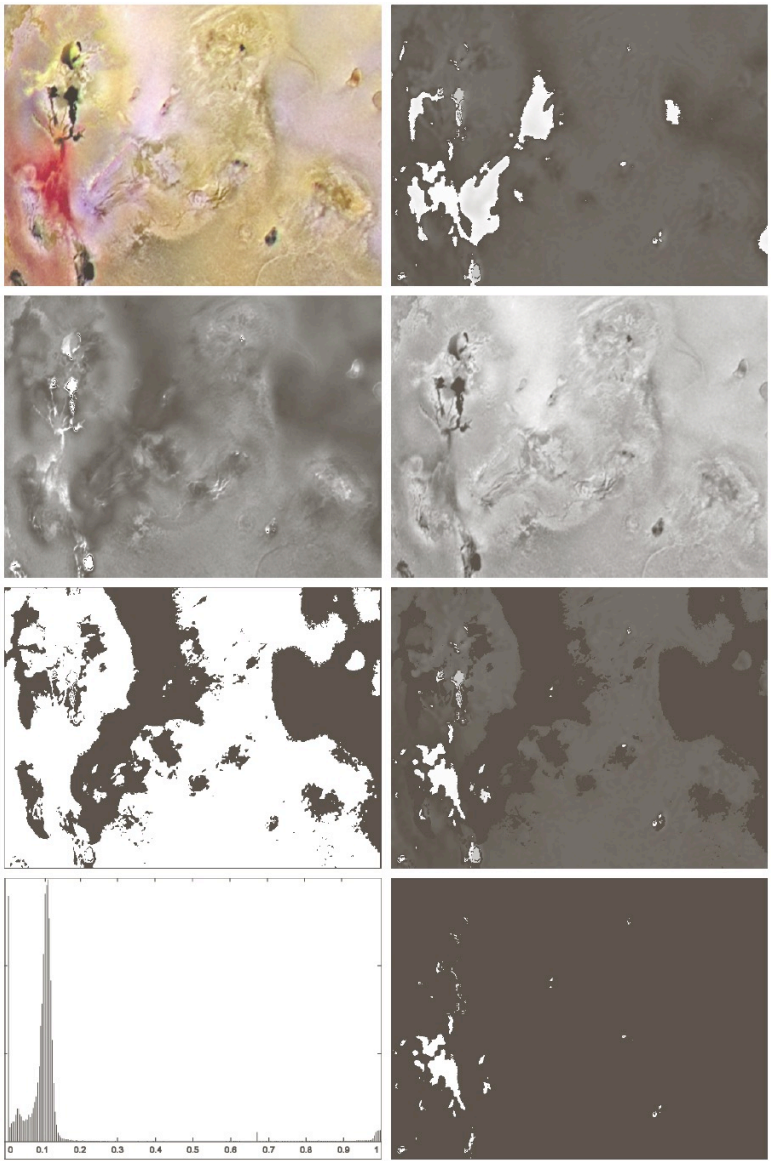


FIGURE 6.36 Color balancing corrections for CMYK color images.

Color Space

- Segmentation in HSI color space (textbook 6.7.1)



a b
c d
e f
g h

FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (e). (g) Histogram of (f). (h) Segmentation of red components in (a).

Color Space

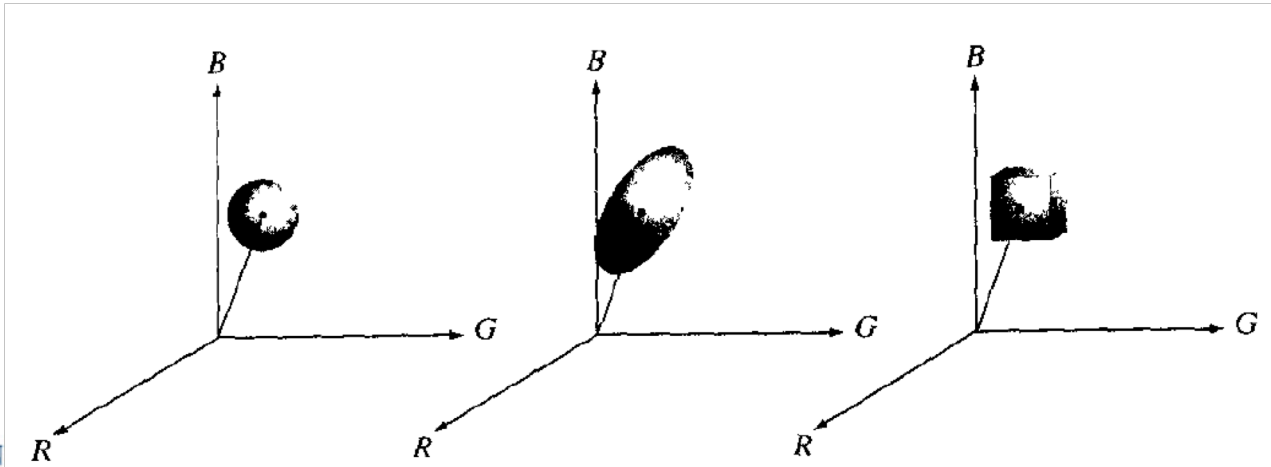
- Segmentation in RGB vector space (textbook 6.7.2)

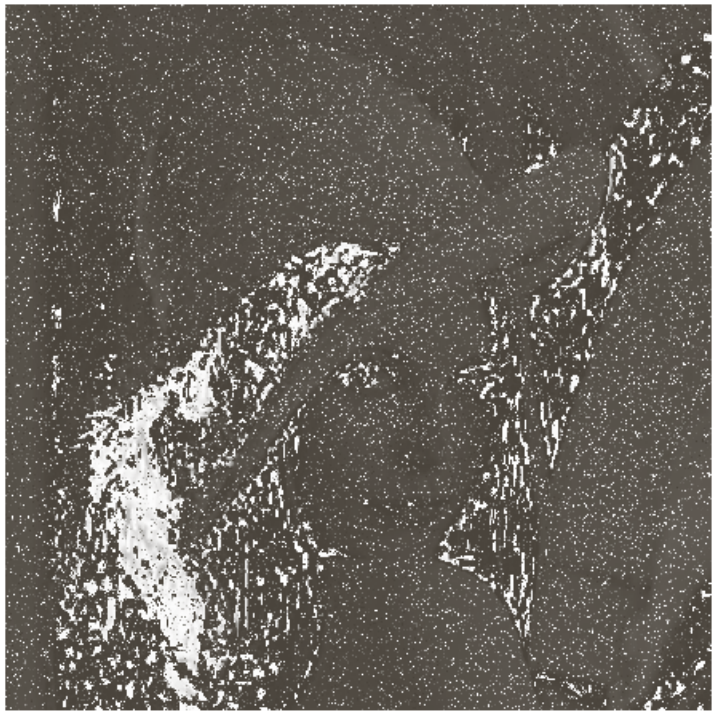
$$D(\mathbf{z}, \mathbf{a}) = \|\mathbf{z} - \mathbf{a}\|$$
$$= [(\mathbf{z} - \mathbf{a})^T(\mathbf{z} - \mathbf{a})]^{\frac{1}{2}}$$
$$= [(z_R - a_R)^2 + (z_G - a_G)^2 + (z_B - a_B)^2]^{\frac{1}{2}}$$

$$D(\mathbf{z}, \mathbf{a}) = [(\mathbf{z} - \mathbf{a})^T\mathbf{C}^{-1}(\mathbf{z} - \mathbf{a})]^{\frac{1}{2}}$$

C is the covariance matrix of the samples reprehensive of the color we wish to segment

$$D(\mathbf{z}, \mathbf{a}) \leq D_0$$



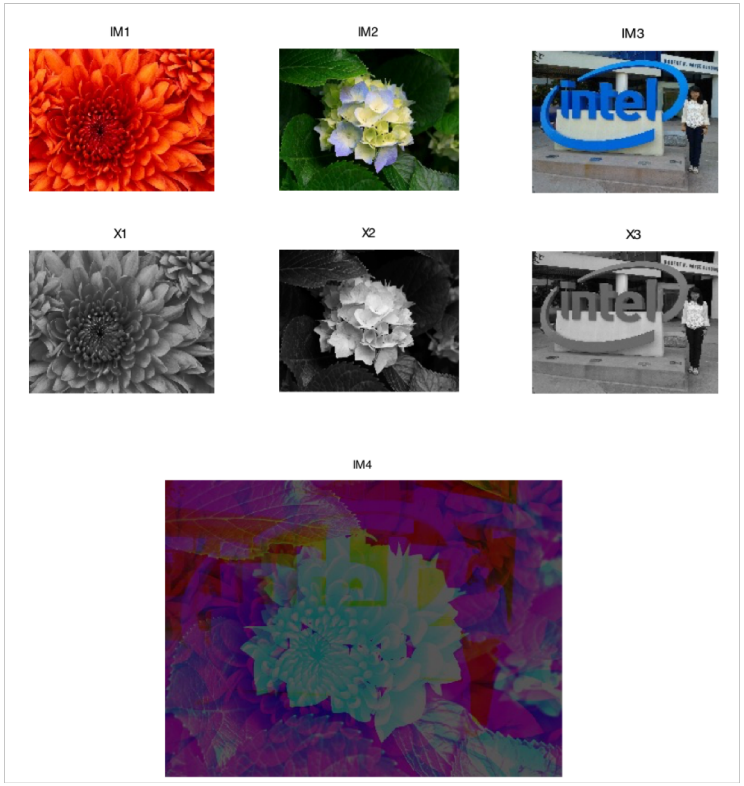


a b
c d

FIGURE 6.50 (a) RGB image with green plane corrupted by salt-and-pepper noise. (b) Hue component of HSI image. (c) Saturation component. (d) Intensity component.

Exercise

- Exercise_ColorSpace.m
- Creating color image by three different images as R G B components




```
im4(:,:,1)=X1;
im4(:,:,2)=X2;
im4(:,:,3)=X3;
```

Exercise

- Exercise_ColorSpace.m
- Perform histogram equalization in R G B component of the image

IM4

im5

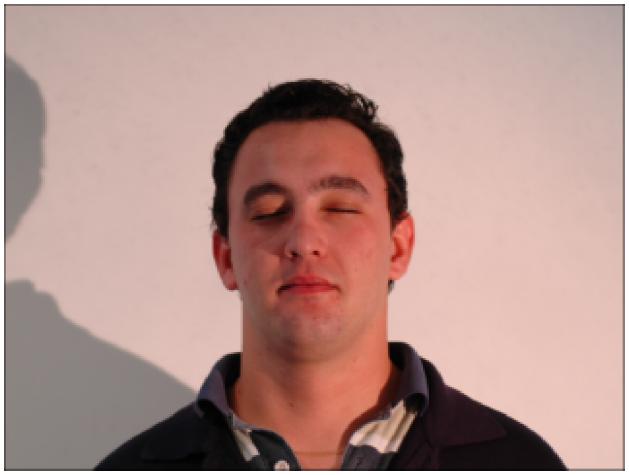
```
Y1=histeq(X1);
Y2=histeq(X2);
Y3=histeq(X3);

im5(:,:,1)=Y1;
im5(:,:,2)=Y2;
im5(:,:,3)=Y3;
```

Exercise – image with bad light condition

- Exercise_ColorSpace_BackgroundLight.m
- Colorspace.m (function you will need)

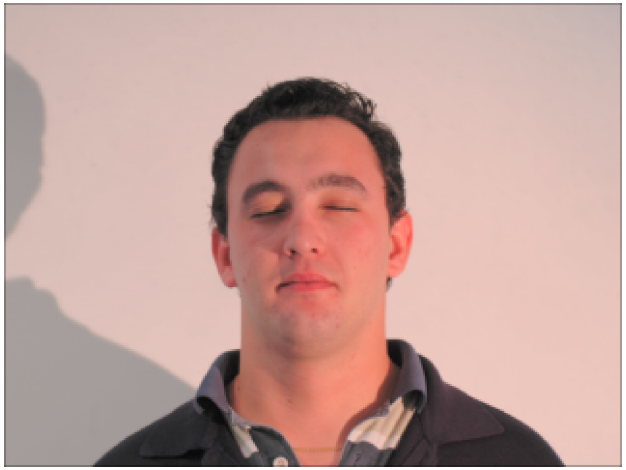
dark face



L

L2

IM7=RGB < L2UV (after gamma correction)



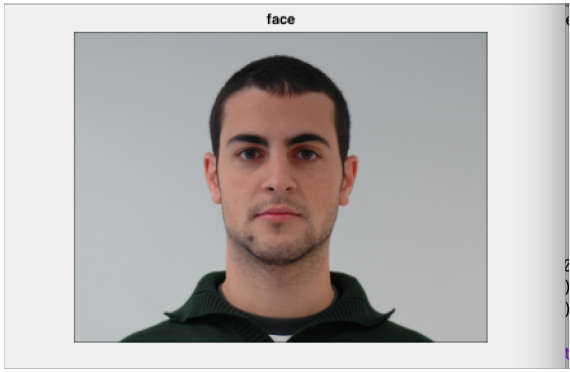
Exercise- skin detection

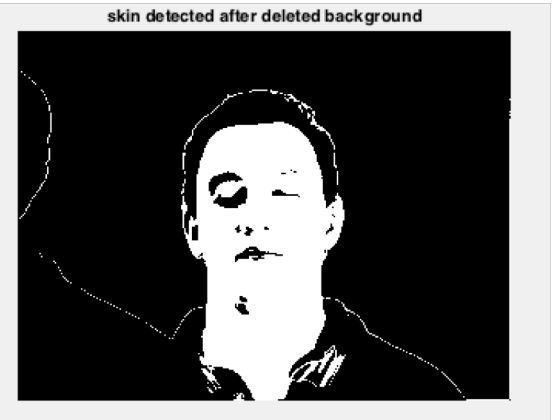
- Paper : Kakumanu, Praveen, Sokratis Makrogiannis, and Nikolaos Bourbakis. "A survey of skin-color modeling and detection methods." *Pattern recognition* 40.3 (2007): 1106-1122.


```
ims1 = (im(:,:,1)>95) & (im(:,:,2)>40) &
(im(:,:,3)>20);
ims2 = (im(:,:,1)-im(:,:,2)>15) |
(im(:,:,1)-im(:,:,3)>15);
ims3 = (im(:,:,1)-im(:,:,2)>15) &
(im(:,:,1)>im(:,:,3));
ims = ims1 & ims2 & ims3;
```

Assignment 3- skin detection

- A good image and a problematic image

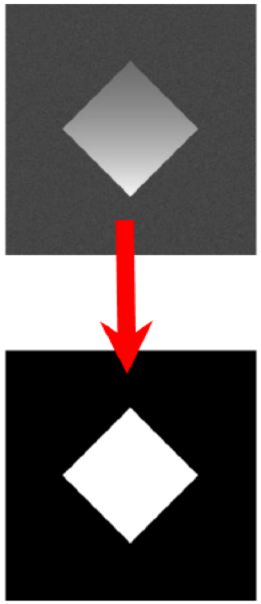


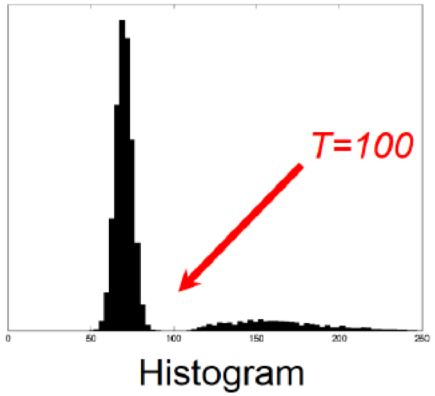


Assignment 3 -review

Histogram Applications

Choosing a threshold

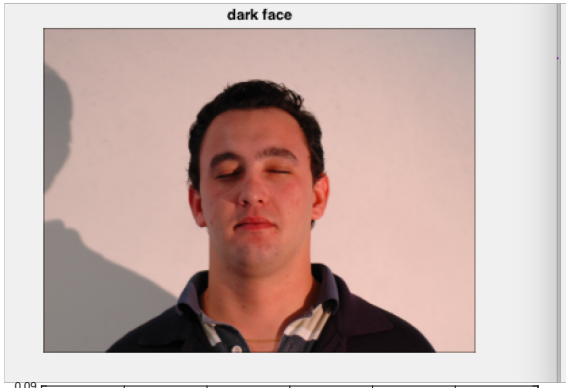


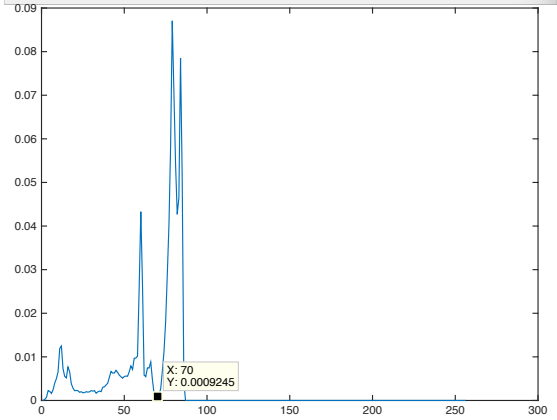


Histogram

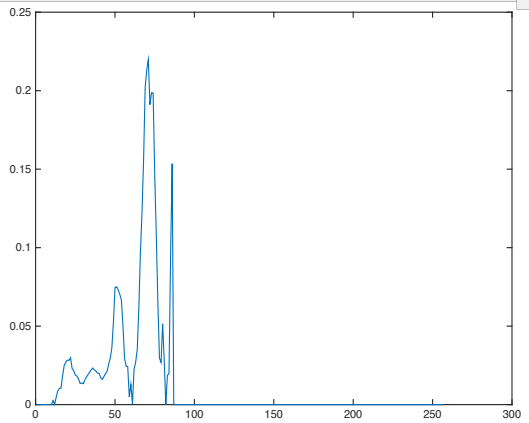
Assignment 3- skin detection

- A good image and a problematic image





Histogram of the luminance component



Variance of the histogram of the luminance component