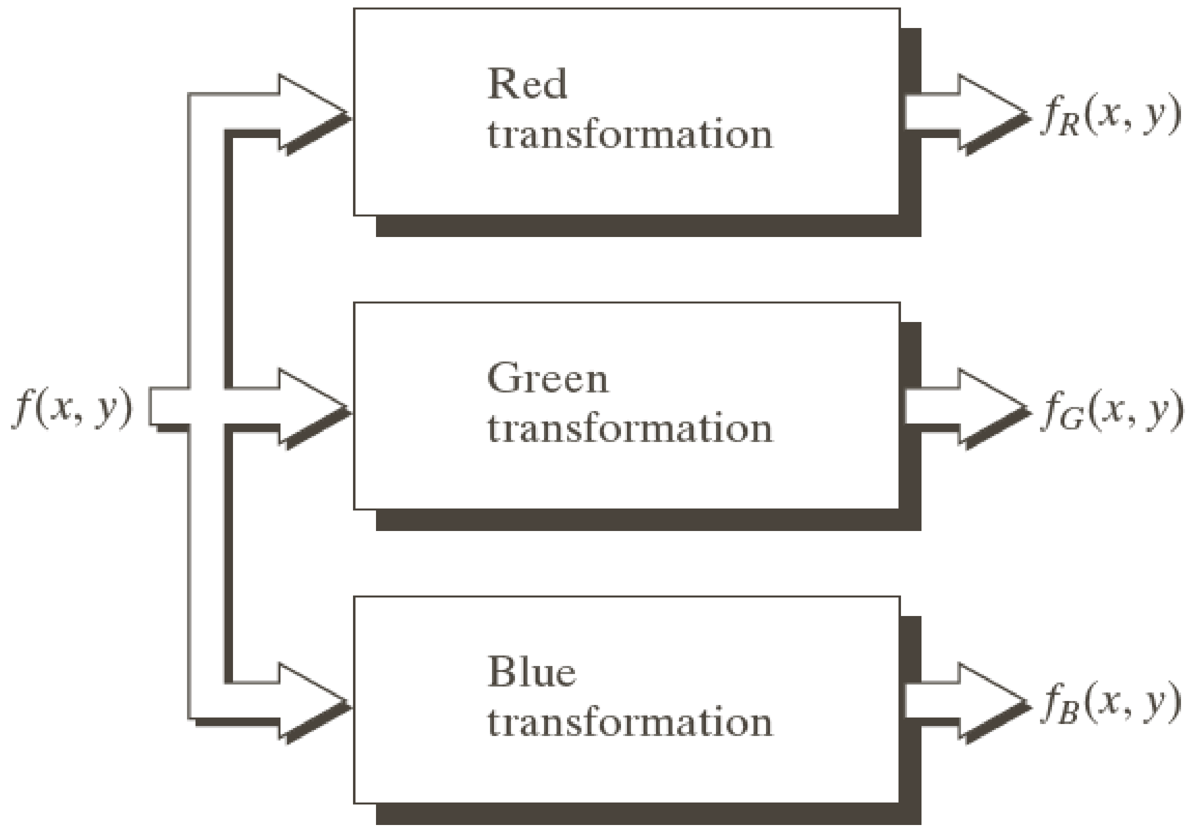
Today’s Agenda

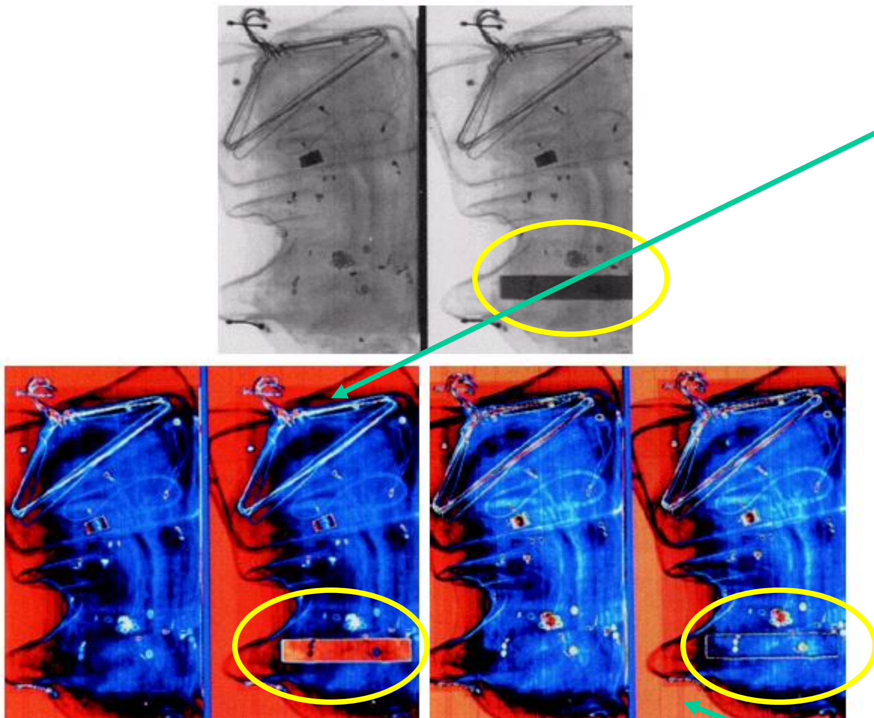
- Color image processing
- Review for Midterm

Intensity to Color Transformation

FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

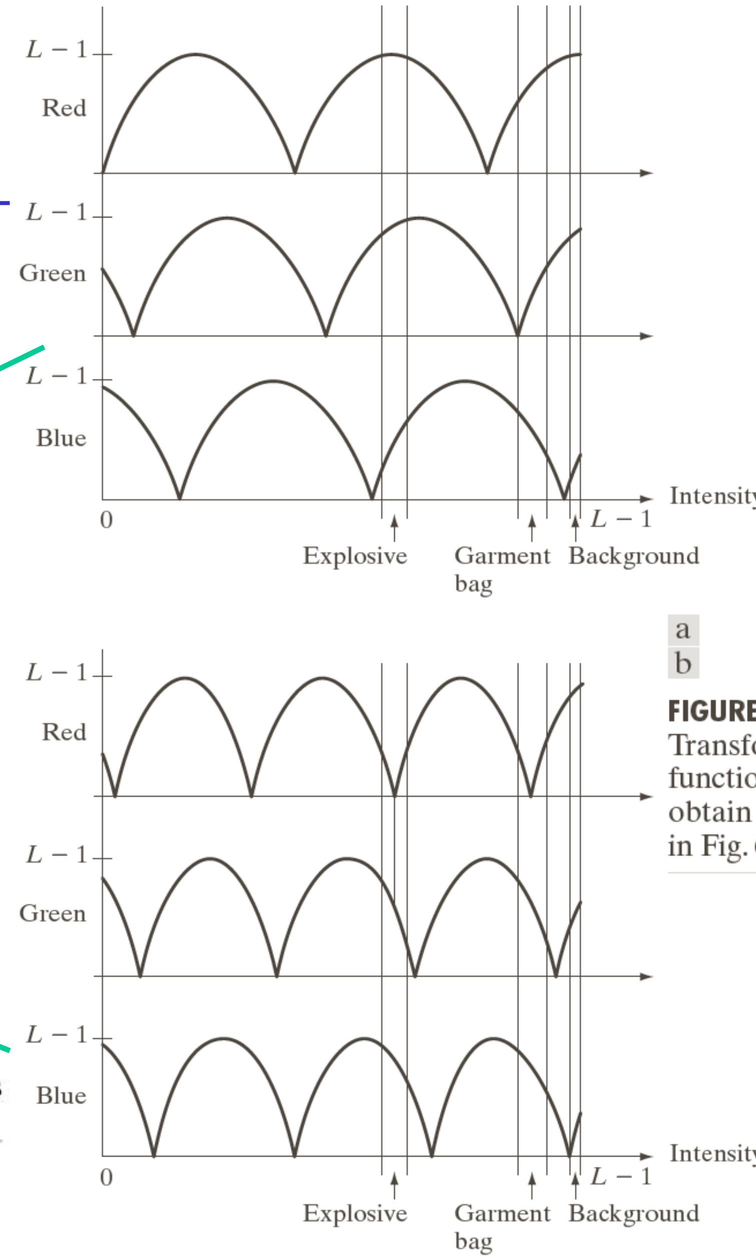


Example



a
b c

FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)



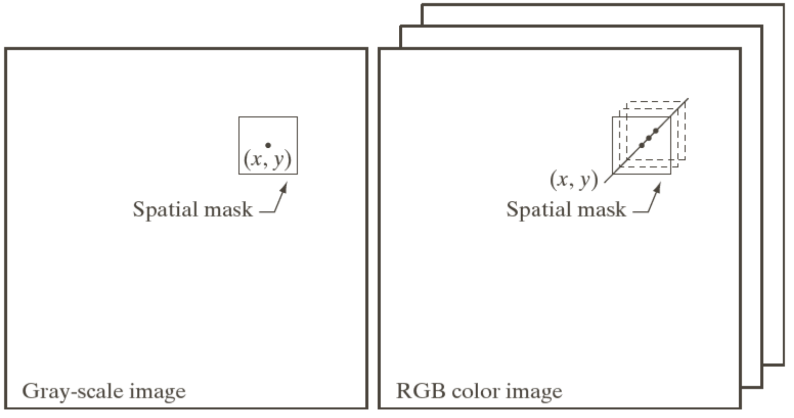
a
b

FIGURE 6.25 Transformation functions used to obtain the images in Fig. 6.24.

Full-color Image Processing

Pixel in color image $\mathbf{p}(x,y)=\begin{bmatrix} p_r(x,y) \\ p_g(x,y) \\ p_b(x,y) \end{bmatrix}$

- **Process each component/channel individually, then generate the composite image**
- **Work on each pixel individually**



Color Transformation

For a color image with n components

$$s_i = T_i(\overbrace{r_1, r_2, \cdots, r_n}^{\text{input values for all components}}), \qquad i = 1, 2, \cdots, n$$

Output value for i^th component   Transformation functions

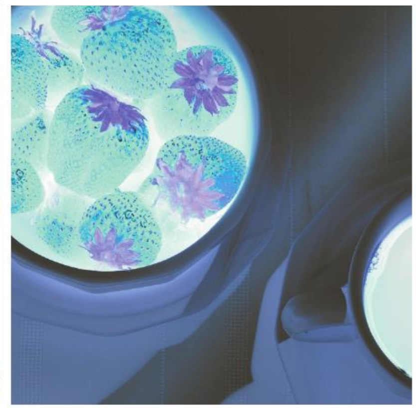
- Modify intensity
- Color complement ("negative" color image)
- Color slicing
- Tonal correction
- Color balancing
- Histogram processing

Examples of Color Image Transformation

Original image

Intensity modification

HSI



Complement color

RGB

Color slicing

RGB

Tonal Correction

Correct the tonal range (distribution of color intensities)

- Recall the intensity transformation in the gray level images
- For RGB model, each component has the same transformation function
- For HSI model, the transformation is applied on the intensity component only

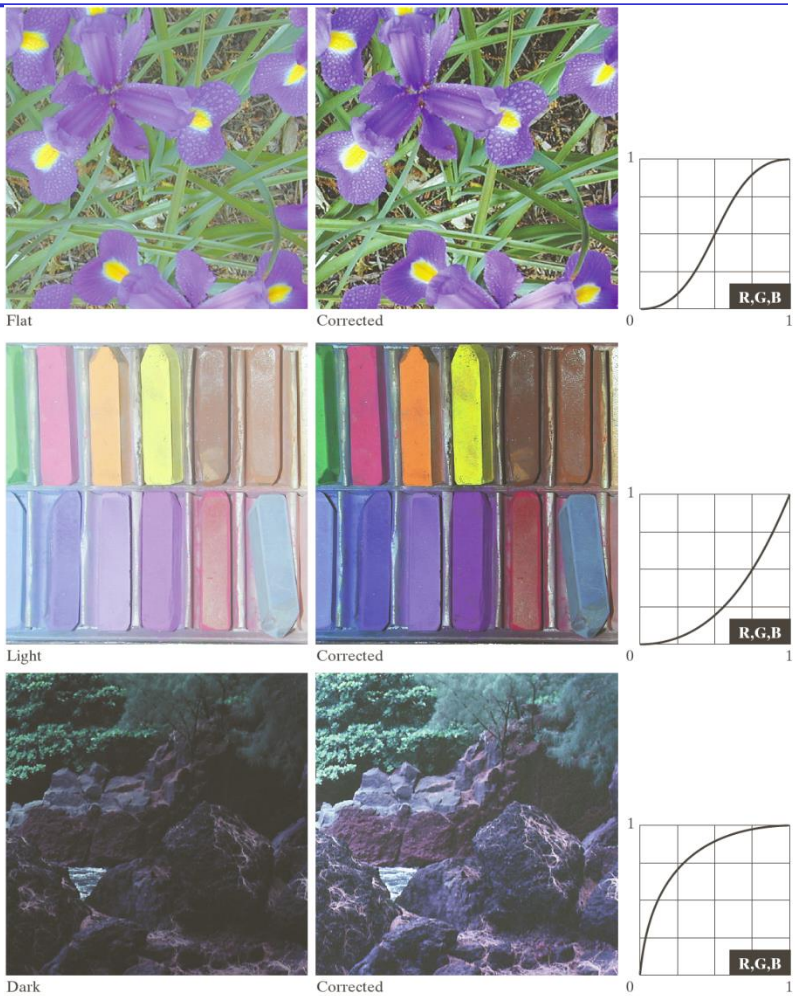
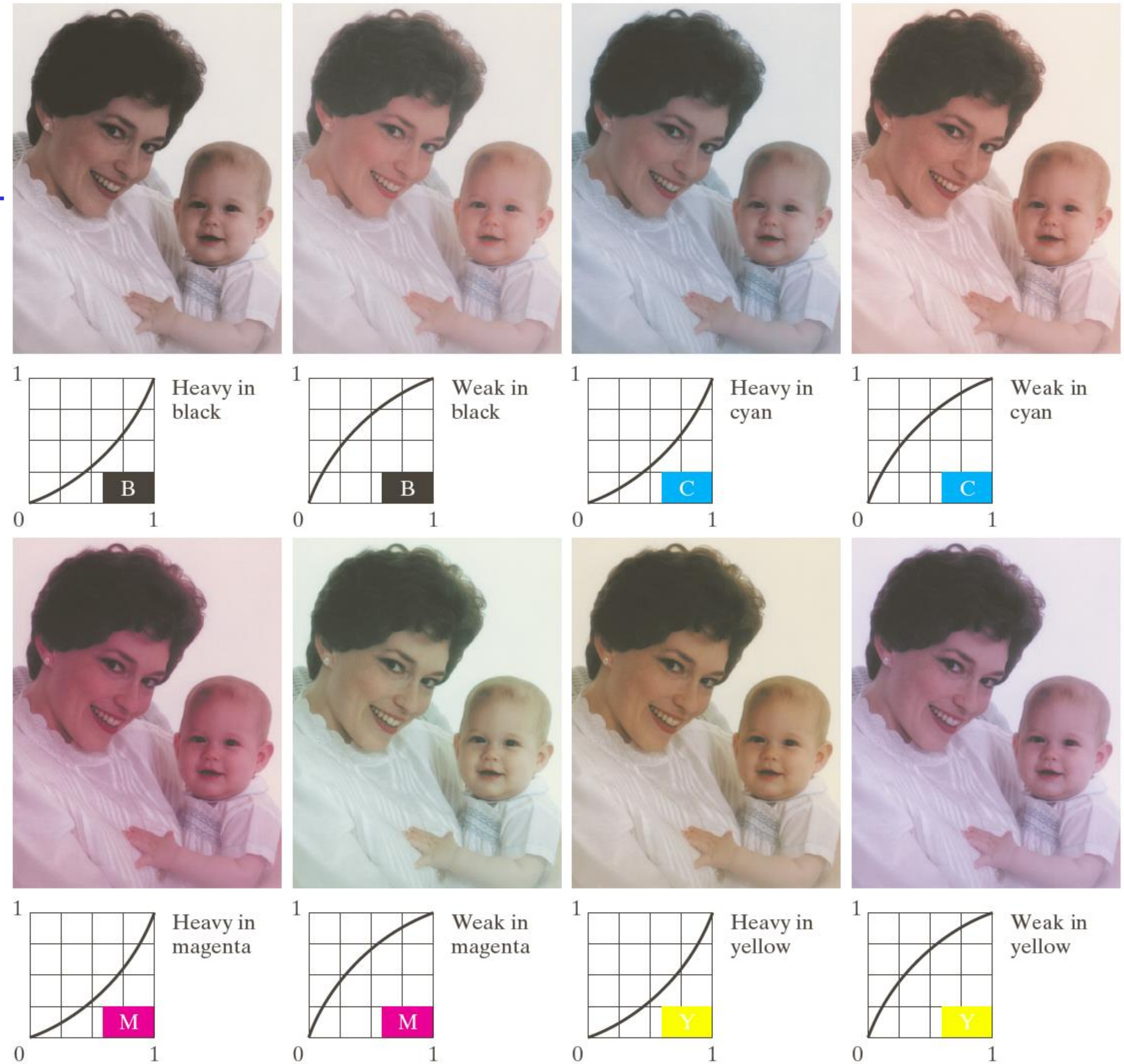


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

Color Balancing

Correct color unbalance by analyzing a known color in image

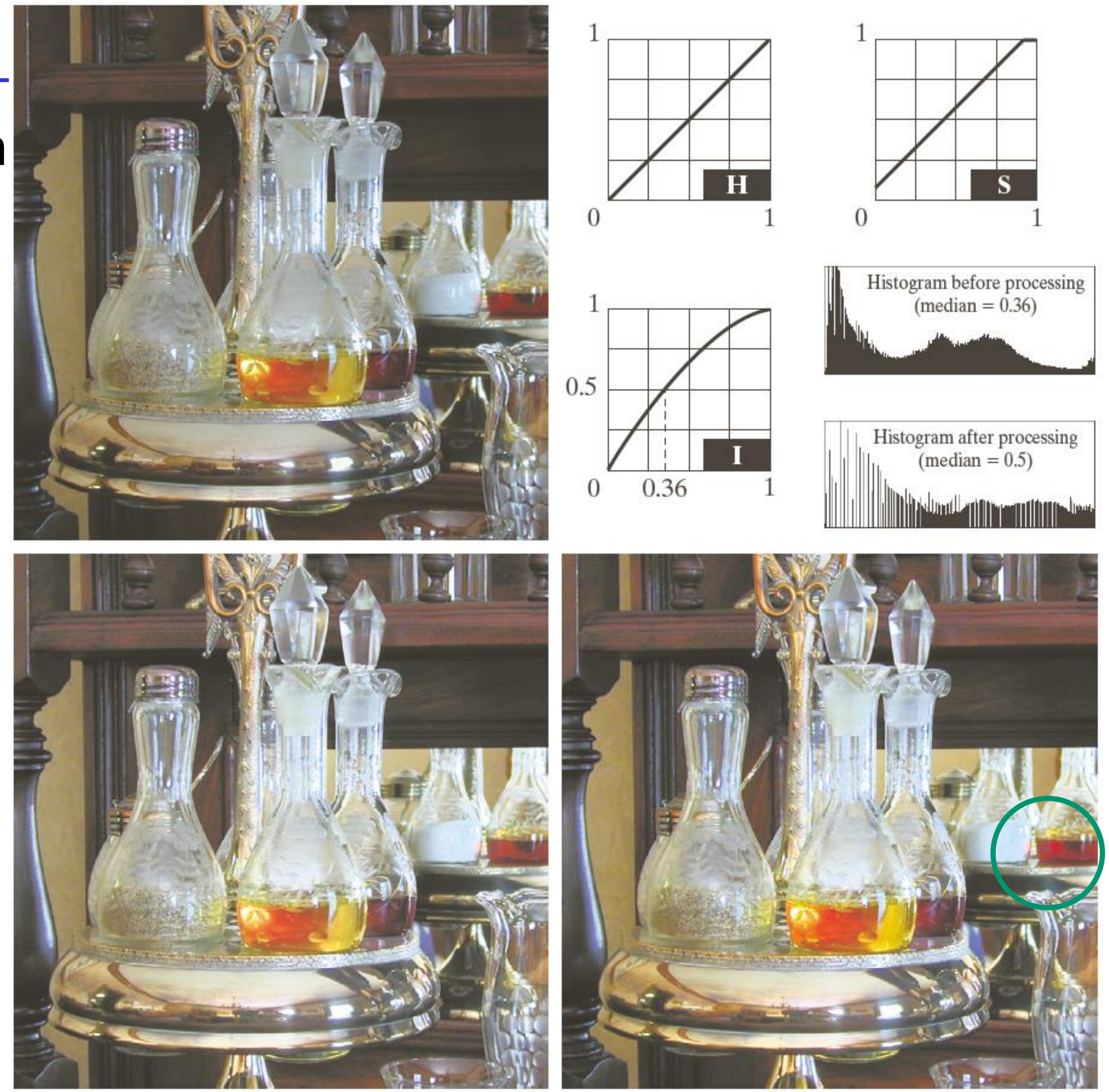
Original/Corrected



Histogram Processing

Step 1: Histogram equalization

Step 2: Saturation adjustment



a b
c d

FIGURE 6.37 Histogram equalization (followed by saturation adjustment) in the HSI color space.

Reading Assignment

- Reading Chapter 6.6, 6.7, 6.8
- Read Chapter 7 (Wavelets and Multiresolution Processing)

Review of Chapter 2- Chapter 5

Chapter 2

- Human vision system
- Basics of image processing

Chapter 3

- Intensity transformation
- Spatial filtering

Chapter 4

- Fourier transform
- Image convolution in frequency domain

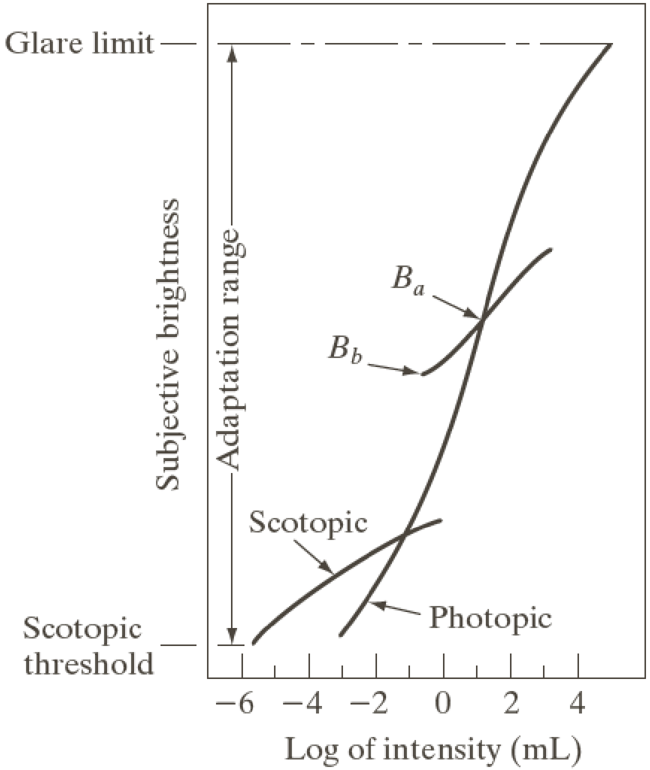
Chapter 5

- Image denoise
- Image degradation
- Image restoration

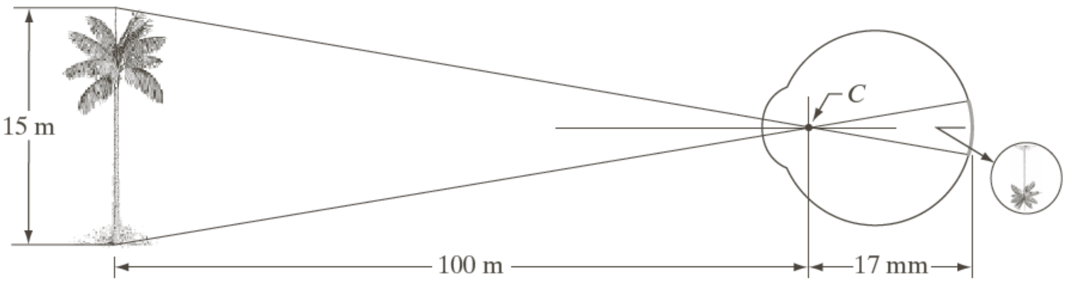
Chapter 6

- Fundamentals of color image processing
- Color transformation

Human Vision System



Brightness adaption



- Geometrical relationship between the real object and the image of the object
- The minimum size of the object you can "see"

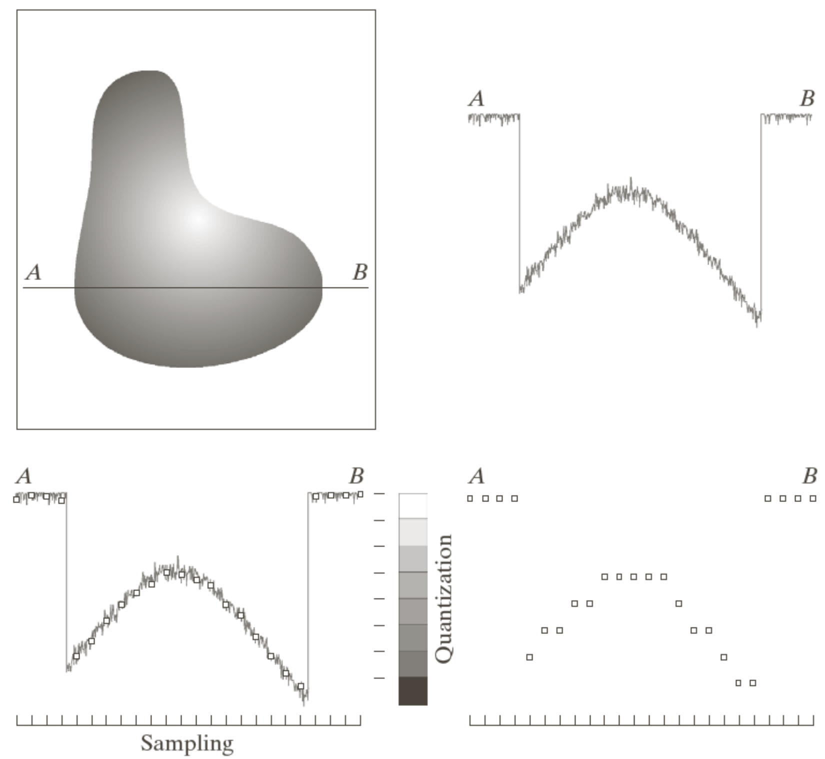
Basics of Image Processing

$$f(x,y) = i(x,y) \cdot r(x,y)$$

- **Image sampling and quantization**
  - Spatial/intensity resolution
- **Dynamic range of the image**

$$I_{\max} / I_{\min}$$

- **Image representation and storing**
- **Image interpolation**
  - Nearest neighbor and bilinear
- **Set operations**



Basics of Image Processing (Cont.)

Basic relationships between pixels

- Adjacency
- Connectivity
- Path

Basic relationships between regions

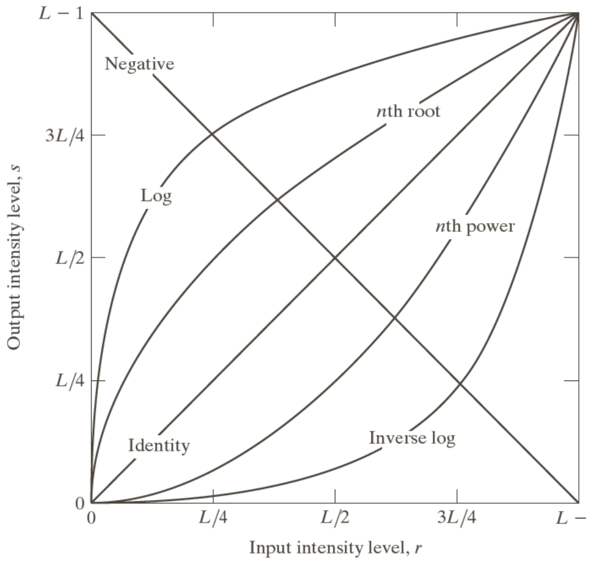
- Adjacency
- boundary

Distance measurement

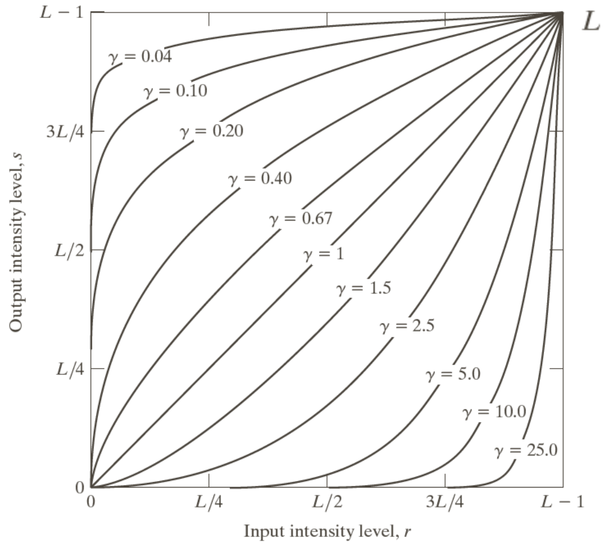
Mathematical tools

- Difference between matrix and array operation
- Linear/nonlinear operation
- Applications of image averaging, subtraction, and multiplication

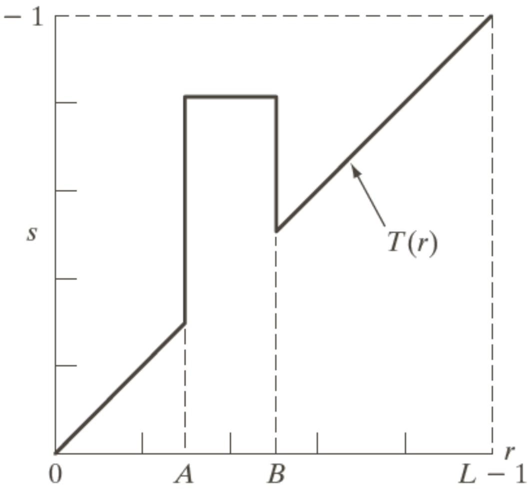
Intensity Transformation



Log transformation



Power-law (gamma) transformation



Intensity level slicing

Applications and working conditions using these transformations

Histogram Processing

What is a histogram of an image?

Histogram equalization

Histogram matching

Spatial Filtering

Image convolution in spatial domain and has properties of

- Commutativity, Associativity, distributivity

Image correlation in spatial domain

Spatial filters

- Smoothing filter
  - Average filter
- Sharpening filter
  - Laplacian filter
  - Unsharp masking
  - Sobel operator
- Order-statistic filter
  - Median filter
  - Min/max filter

Fourier Transform

Fourier series

$$f(t) = \sum_{n=-\infty}^{+\infty} c_n e^{\frac{j2\pi nt}{T}}$$

Unit impulse and its sifting property

$$\int_{-\infty}^{\infty} f(t)\delta(t - t_0)dt = f(t_0)$$

Fourier transform

$$F(\mu) = \int_{-\infty}^{\infty} f(t)e^{-j2\pi\mu t}dt \quad \Longleftrightarrow \quad f(t) = \int_{-\infty}^{\infty} F(\mu)e^{j2\pi\mu t}d\mu$$

Image convolution in frequency domain

Basic Properties of FT

Linearity $h(t) = af(t) + bg(t) \leftrightarrow H(u) = aF(u) + bG(u)$

Translation $h(t) = f(t - t_0) \leftrightarrow H(u) = e^{-j2\pi t_0 u} F(u)$

Modulation $h(t) = e^{j2\pi u_0 t} f(t) \leftrightarrow H(u) = F(u - u_0)$

Scaling $h(t) = f(at) \leftrightarrow H(u) = \frac{1}{|a|} F(\frac{u}{a})$

Conjugation $h(t) = f^*(t) \leftrightarrow H(u) = F^*(-u)$

Symmetry $f(t) \leftrightarrow F(\mu) \Rightarrow F(t) \leftrightarrow f(-u)$

Image Degradation

$$g(x,y) = h(x,y) \otimes f(x,y) + \eta(x,y)$$

$$G(u,v) = H(u,v)F(u,v) + N(u,v)$$

Important noise models

- Gaussian noise model
- Impulse noise model

Image denoise

- Various mean filters and their applications
- Order-statistic filters and their applications

Image restoration

- Inverse filtering, Wiener filtering, and Constrained Least Square filtering
  - Working conditions

Fundamentals of color image processing

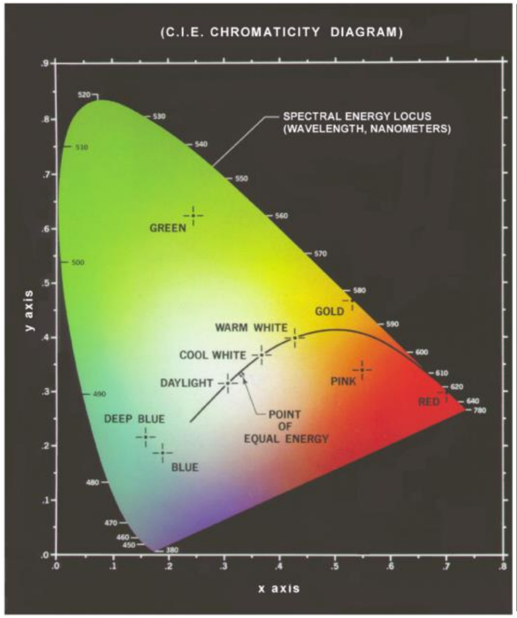
Primary/secondary colors

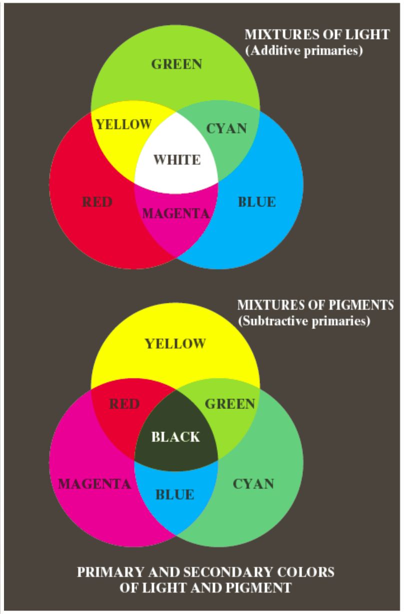
Primary/secondary pigments

What's the difference between them?

Chromaticity: hue and saturation

Color gamut: any color on a line segment can be generated by two ending points; the same color can be generated by different combinations



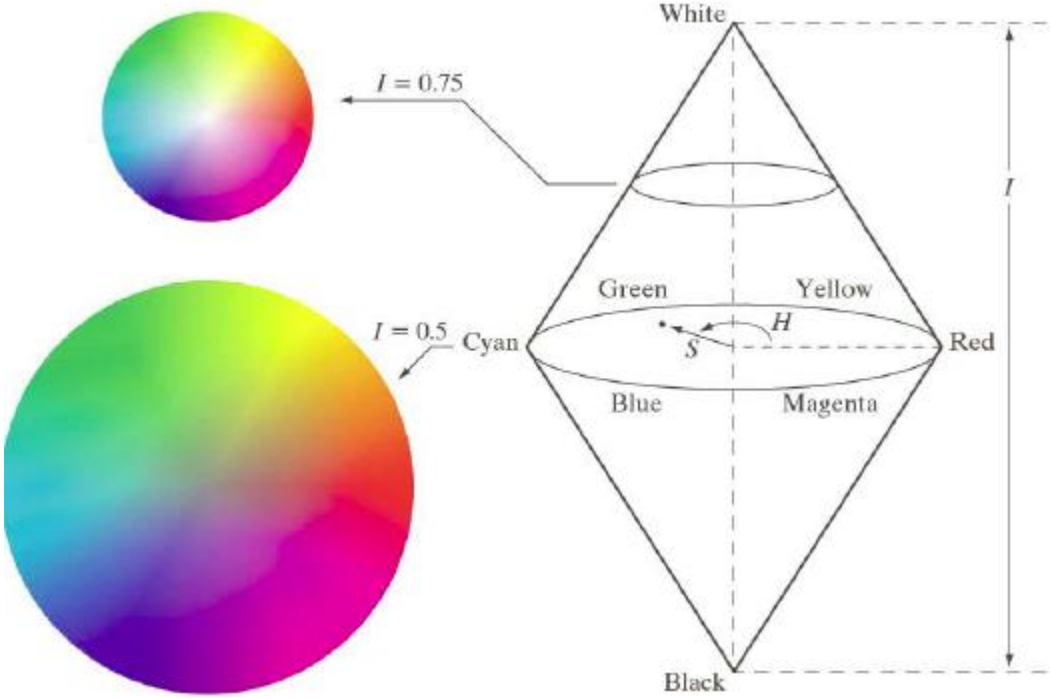


Fundamentals of color image processing (Cont'd)

RGB model

CMYK model

HSI model



Requirement: how to represent a color in a specific model?

Color Transformation

For a color image with n components

$$\underbrace{s_i}_{\text{Output value for ith component}} = \underbrace{T_i}_{\text{Transformation functions}}(\overbrace{r_1, r_2, \cdots, r_n}^{\text{input values for all components}}), \qquad i = 1,2,\cdots,n$$

Intensity modification	HSI model
Color complement	RGB model
Tonal correction	HSI model
Color balancing	The choice of color model varies for a specific image
Histogram processing	HSI model

Which model is the most effective to perform a specific transformation?