4TN3
Image Processing

Chapter 6: Color Image Processing

Color Image Processing

- The use of color in image processing is motivated by:
  1. Color is important in object recognition
  2. Human eyes can discern thousands of colors
- Color image processing:
  1. Full color image processing
  2. Pseudo color processing
- Full color processing: image is acquired by a full-color sensor
- Pseudo color processing: assigning a shade of color to a particular monochrome intensity or range of intensities

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Color Image Processing

- In 1666 Newton discovered that a beam of sunlight passed through a prism will break into a spectrum of colors ranging from violet at one end to red at the other
- Color spectrum: violet, blue, green yellow, orange, and red.
- No color in the spectrum end abruptly

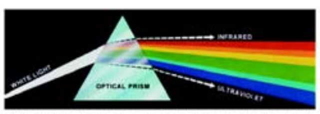


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Color Image Processing

- Color perceived from an object is determined by the nature of light reflected from that object.
- An object reflecting light that is balanced in all visible light appears white.
- An object that favors reflectance in a limited range of the visible spectrum exhibits a specific color

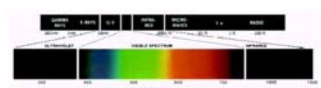


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Color Image Processing

- Achromatic light (without color) is described by intensity (amount)
- Chromatic light is described by 3 quantities:
  1. Radiance
  2. Luminance
  3. Brightness
- Radiance: total amount of energy that flows from the light source
- Luminance: a measure of the amount of energy an observer perceives from a light source
  - Infrared source: zero luminance
- Brightness: a subjective quantity

Color image processing

- Structure of human eye: all colors are seen as variable combinations of 3 primary colors, Red, Green and Blue
- Primary colors can be added to produce secondary colors:
  - Magenta: (red plus blue)
  - Cyan: (green plus blue)
  - Yellow: (red plus green)
- Mixing three primary colors produce white.
- Mixing a secondary color with its opposite primary color produces white

Color image processing

- Cones can be divided into three principal sensing categories: red, green and blue

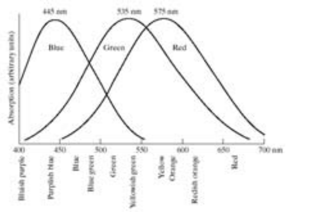


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

Color image processing

- Color TV: an example of the additive nature of light colors
- Interior of TV tube: a large array of triangular dot patterns of electron sensitive phosphor
- Each dot in a triangle produces one of the primary colors
- Intensity of red-emitting phosphor is modulated by an electron gun.
- Similarly for green-emitting and blue-emitting
- Three primary colors are added and received by the eye as a full-color image

Color image processing

- One color from another is distinguished by 3 factors:
  1. Brightness
  2. Hue
  3. Saturation
- Hue: dominant wavelength (color) in a mixture of light waves
- Saturation: relative purity or the amount of white light mixed with a hue
  - Pink is less saturated than red

Color image processing

- The amounts of red, green and blue needed to form a particular color are called tri-stimulus X, Y, Z
- A color is specified by its tri-chromatic coefficients:

  $x= X/(X+Y+Z)$

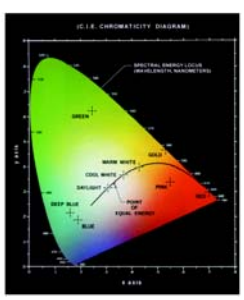
  $y= Y/(X+Y+Z)$

  $z= Z/(X+Y+Z)$

  – $x+y+z=1$

- Another approach for specifying colors is to use CIE chromaticity diagram which shows color composition as a function of x (red) and y (green).
- Various spectrum colors are indicated around the boundary of tongue-shaped diagram (pure colors).

FIGURE 6.5 Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)



- Any point not actually on the boundary represents some mixture of spectrum colors
- Any point on the boundary of chart is fully saturated.
- A straight line segment joining any two points in the diagram defines all different colors that can be obtained by combining these two colors additively.
- A line drawn from the point of equal energy (white) to any point on the boundary will define all the shades on that color
- To determine colors that can be obtained from any three given colors, we draw connecting lines to each of the three color points
- Any color inside the triangle can be produced by various combinations of the three initial colors

Color Models (color space or color system)

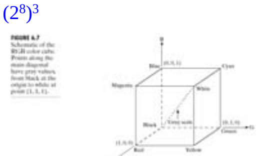
- Color models: used to specify colors in a standard way
- Color model is a coordinate system where each color is represented by a single point
- RGB (red, green, blue)
- CMY (cyan, magenta, yellow)
- HIS (hue, saturation, intensity)

Color image processing

- Each model is oriented toward a hardware or application.
- RGB: color monitors, cameras, color image processing
- CMY: color monitor
- HIS: color image processing
  - HIS has the advantage that it decouples color and gray level information in an image making it suitable for many gray scale techniques discussed before

RGB

- Each color appears in its primary spectral components of red, green and blue
- Different colors in this model are points on or inside the cube
- Number of bits used to represent each pixel in RGB space is called the pixel depth
- If 8 bit is used to represent each color, 24-bit RGB color image is obtained
- Total number of colors: $(2^8)^3$



RGB

- A subset of colors that are likely to be reproduced reasonably independent of viewer hardware is called safe RGB color
- 216 colors have become the de facto standard for safe colors
- Each of 216 safe color is formed from three RGB values but each value can only be 0, 51, 102, 153, 204 or 255.

CMY

- Most devices that deposit colored pigments on paper (color printers and copiers) require CMY data input
- Equal amounts of pigments primaries, cyan, magenta and yellow should produce black
- In practice combing these colors produces a muddy looking black
- In order to produce true black a fourth color black is added (CMYK)
- When publishers are talking about four color printing they are referring to CMY plus black

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

HSI

- RGB and CMY color models are not well suited for describing colors in terms that are practical for human interpretation
- HSI (hue, saturation and intensity) decouples intensity components from the color-carrying information
- Hue: dominant color
- Saturation: relative purity or the amount of white mixed with a hue

HSI

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

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

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

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

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HSI

$0 \le H < 120$

$B = I(1-S)$

$R = I\left[1 + \frac{S\cos H}{\cos(60-H)}\right]$

$G = 1-(R+B)$

$120 \le H < 240$

$H = H - 120$

$R = I(1-S)$

$G = I\left[1 + \frac{S\cos H}{\cos(60-H)}\right]$

$B = 1-(R+G)$

$240 \le H < 360$

$H = H - 240$

$G = I(1-S)$

$B = I\left[1 + \frac{S\cos H}{\cos(60-H)}\right]$

$R = 1-(R+G)$

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Manipulating HSI

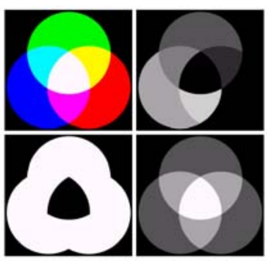

FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

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Manipulating HSI

- We can manipulate H, S and I independently and then convert them back to RGB to see the effects.
- Changing to 0 the blue and green regions in Hue image
- Reduce by half the saturation of the cyan region
- Reduce by half the intensity of central white region

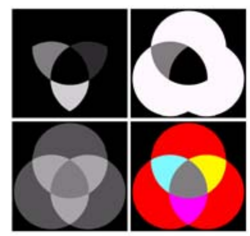

FIGURE 6.17 (a)–(c) Modified HSI component images. (d) Resulting RGB image. (See Fig. 6.16 for the original HSI images.)

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Pseudo-color image processing

- Assigning colors to monochrome images
- Different approaches:
  - Intensity slicing
  - Gray-level to color transformations
  - Filtering approach

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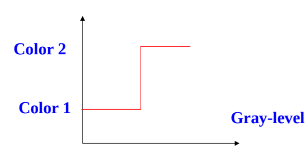
Pseudo-color image processing

Intensity slicing

- The range of gray-levels (black to white) is divided into a number of intervals
- A different color is assigned to each interval



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Pseudo-color image processing

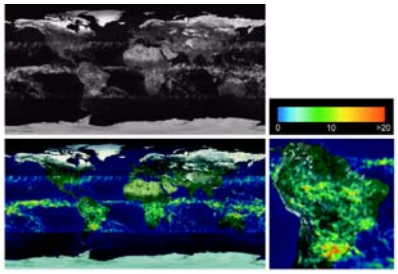

FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South America region. (Courtesy of NASA.)

Pseudo-color image processing

Gray-level to color transformations:

- Three different transformations are performed on the gray-level image
- The results are fed into red, green, and blue guns of a color display

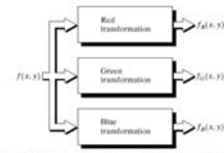

FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

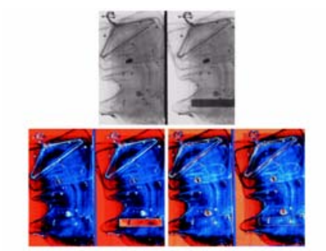

FIGURE 6.24 Pseudocolor enhancement by using the gray-level to color transformations in Fig. 6.25. (Original image courtesy of Dr. Mike Hurwitz, Westinghouse.)

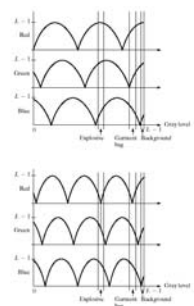

FIGURE 6.25 Transformation functions used to obtain the images in Fig 6.24.

Pseudo-color image processing

Filtering approach

- Similar to the pervious approach.
- Fourier transform of a gray-level image is modified independently by three filter functions
- Three images are generated that are fed into red, green, and blue guns of a color display

Pseudo-color image processing