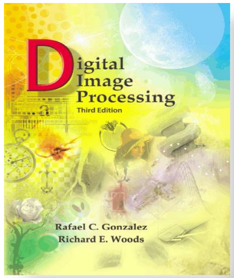
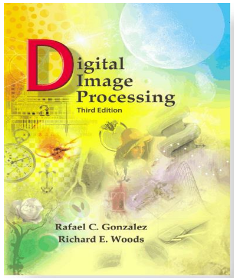


- *Color Fundamentals and models*
- *Pseudo-Color Image Processing*
- *Full-color Image processing*



- *Color is a powerful descriptor that often simplifies object identification and extraction from a scene*
- *Humans can discern thousands of color shades and intensities, compared to about only two dozen shades of gray*

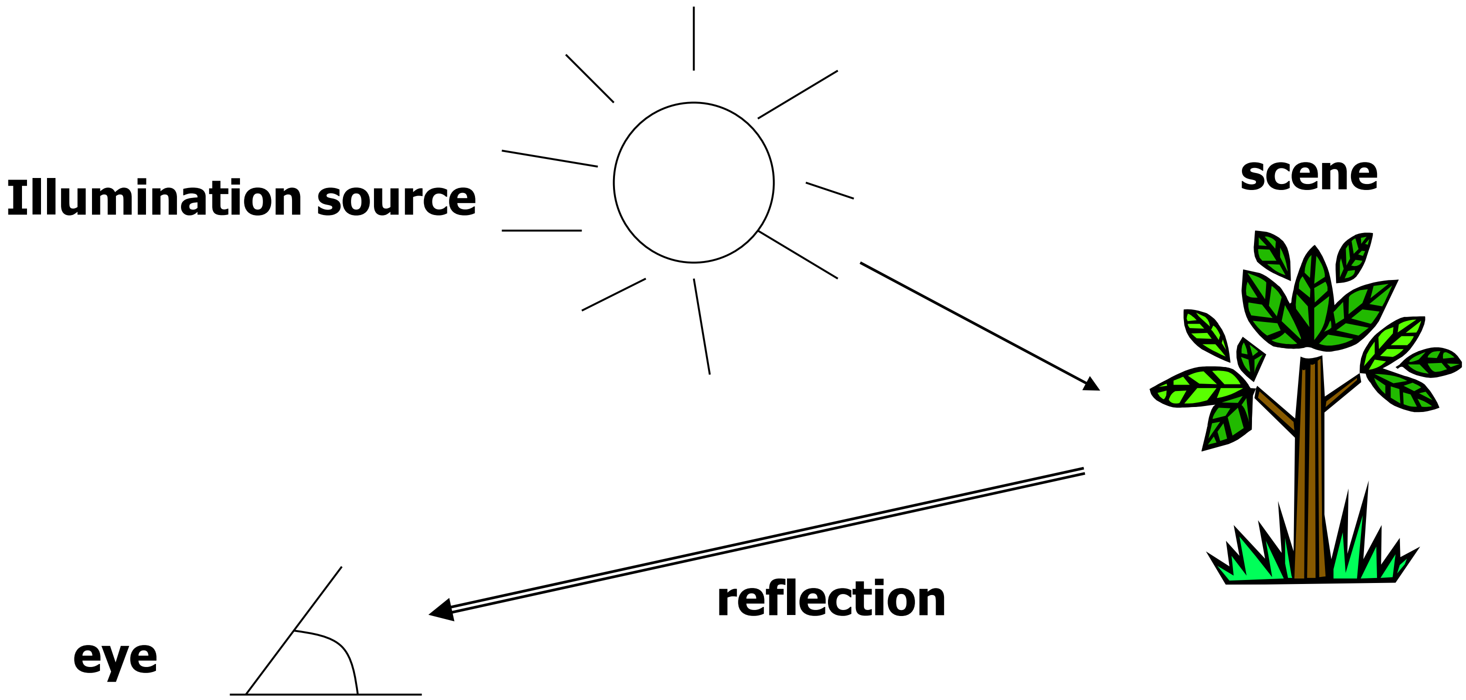
- *Color image processing is divide into two major area:*
  - *Full-Color Processing*

    The images in question typically are acquired with a full-color sensor

  - *Pseudo-Color Processing*

    The problem is one of assigning a color to a particular monochrome intensity or range of intensities

- *The color that human perceive in an object = the light reflected from the object*



Color Fundamentals

- *When a beam of sunlight passes through a glass prism, the emerging beam of light is not white but consists instead of a continuous spectrum of colors ranging from violet at one end to red at the other.*

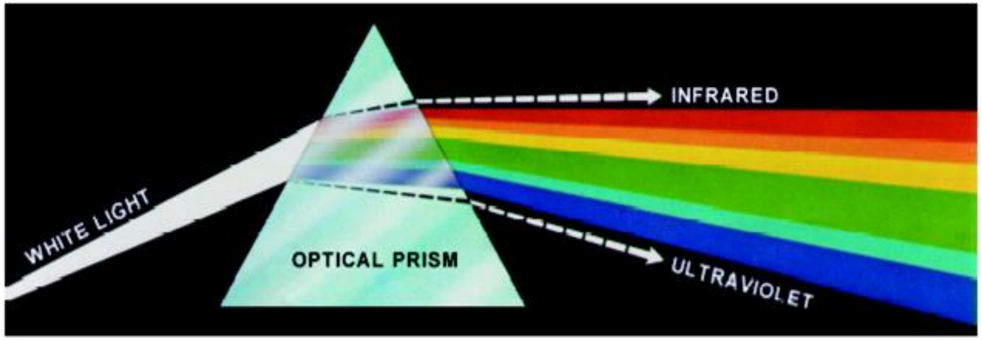


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Chapter 6

Color Image Processing

- *Chromatic light spans the electromagnetic spectrum from approximately 400 to 700 nm.*
- *No color in the spectrum ends abruptly, but rather each color blends smoothly into the next.*

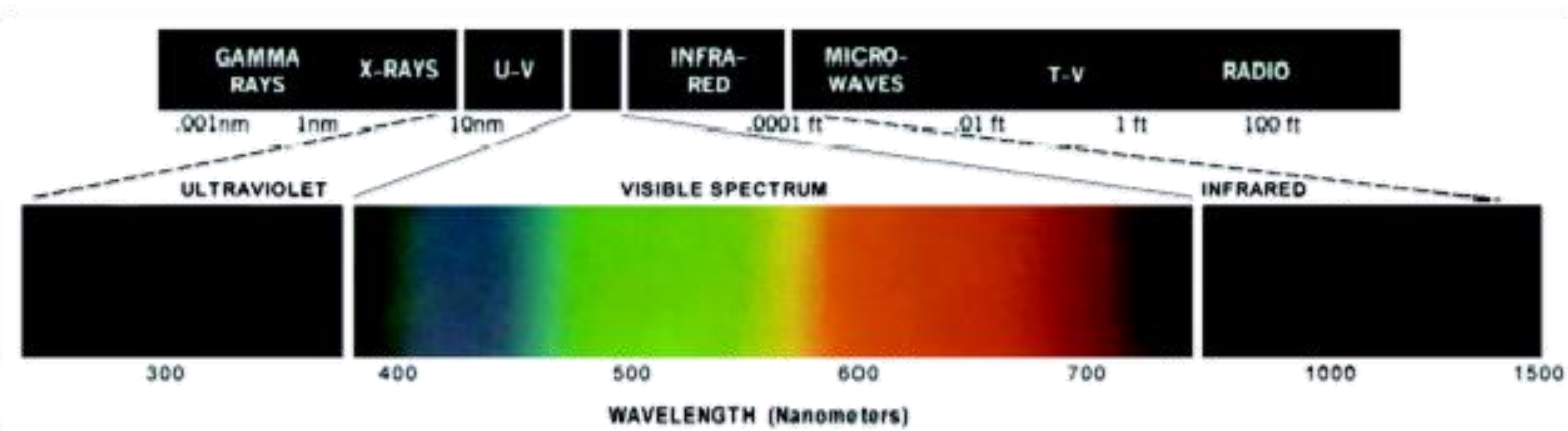
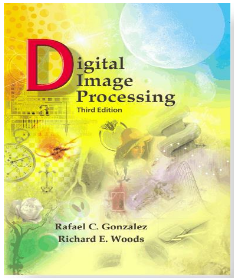


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

- *Basic quantities to describe the quality of light source:*
  - *Radiance: Total amount of energy that flows from the light source (in W).*
  - *Luminance: A measure of the amount of energy an observer perceives from the light source (in lm)*
  - *Brightness: A subjective descriptor that embodies the achromatic notion of intensity and is practical impossible to measure.*



- *Primary colors: red(R), green(G), blue(B).*

Blue: 435.8nm; Green: 546.1nm; Red: 700nm

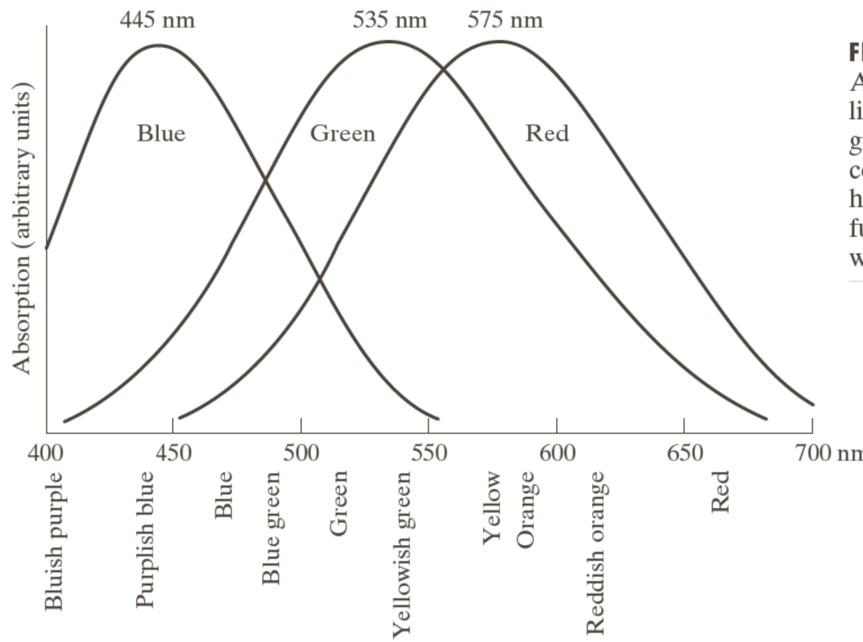
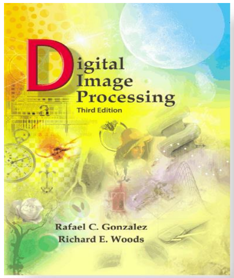
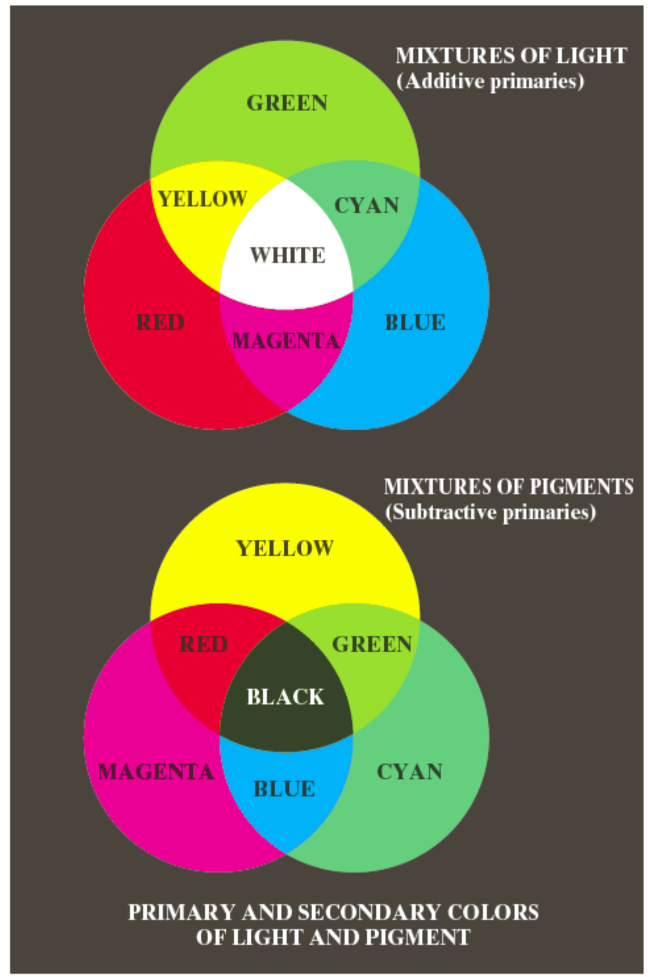


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.



- *The primary colors can be added to produce the secondary colors of light.*

- *A primary color of colorants is defined as one that subtracts or absorbs a primary color of light and reflects or transmits the other two.*



a
b

FIGURE 6.4 Primary and secondary colors of light and pigments. (Courtesy of the General Electric Co., Lamp Business Division.)

- *The characteristics generally used to distinguish one color from another are Brightness, Hue, and Saturation.*
  - *Hue: Represents dominant color as perceive by an observer.*
  - *Saturation: Relative purity or the amount of white light mixed with a hue*

- *Hue and saturation taken together are called chromaticity, and therefore, a color may be characterized by its brightness and chromaticity.*

- *First approach for specifying colors:*
  - *The amounts of red, green and blue needed to form any particular color are called the tristimulus values and are denoted X, Y and Z, respectively.*
  - *A color is then specified by its trichromatic coefficients, defined as*

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

From these equations that $x+y+z=1$

- *Another approach for specifying colors:*
  - *use the CIE chromaticity diagram which shows color composition as a function of x(red) and y(green).*
  - *The chromaticity diagram is useful for color mixing.*

Green Point = 62% green, 25% red, 13% blue.

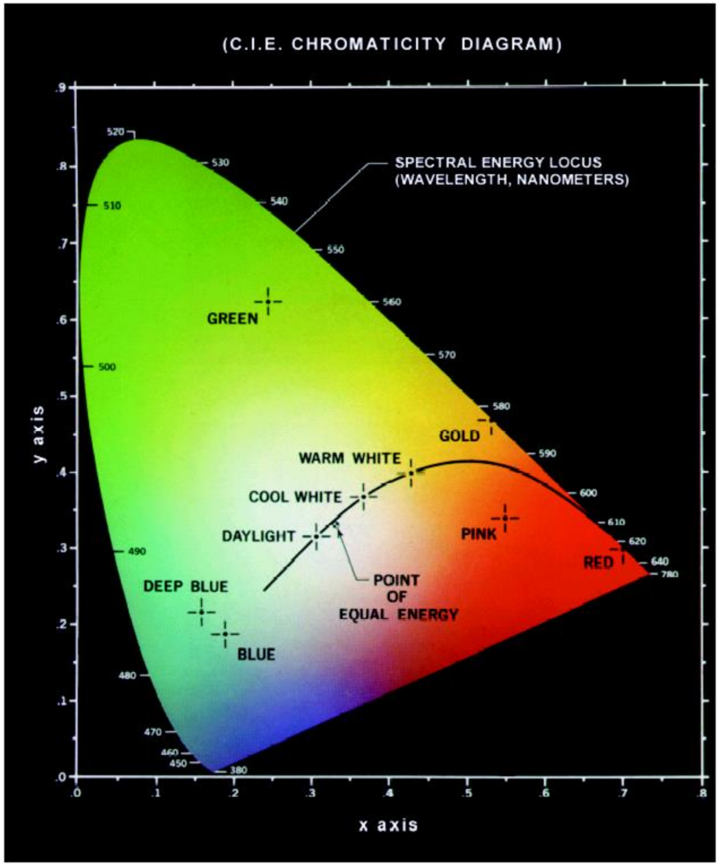
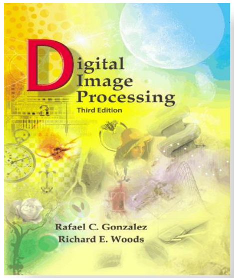


FIGURE 6.5 Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)



Color Models

- *The purpose of a color model (also called color space or color system) is to facilitate the specification of colors in some standard, generally accept way.*
- *RGB (red, green, blue) : monitor, video camera.*
- *CMY(cyan, magenta, yellow),CMYK (CMY, black) model for color printing.*
- *HSI model, which corresponds closely with the way humans describe and interpret color.*

The RGB Color Model

- *In the RGB model, each color appears in its primary spectral components of red, green, and blue.*

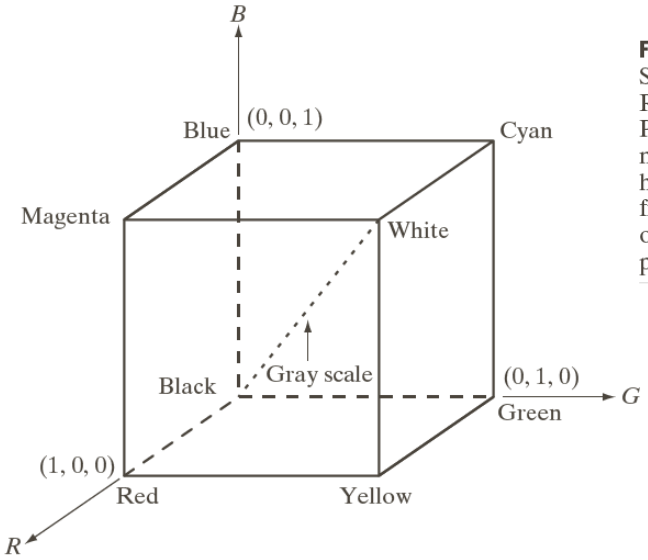
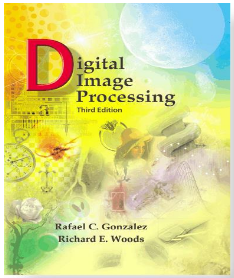


FIGURE 6.7 Schematic of the RGB color cube. Points along the main diagonal have gray values, from black at the origin to white at point (1, 1, 1).



- *The number of bits used to represent each pixel in RGB space is called the pixel depth.*

- *Consider an RGB image in which each of the red, green, and blue images is 8-bit image. Under these conditions each RGB color pixel is said to have a depth of 24bits.*

- *The total number of colors in a 24-bit RGB image is* $(2^8)^3 = 16{,}777{,}216$.

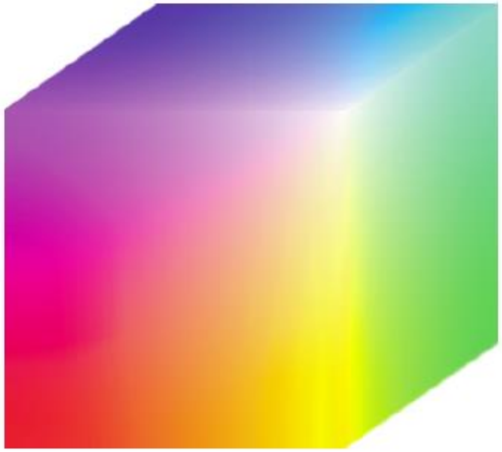


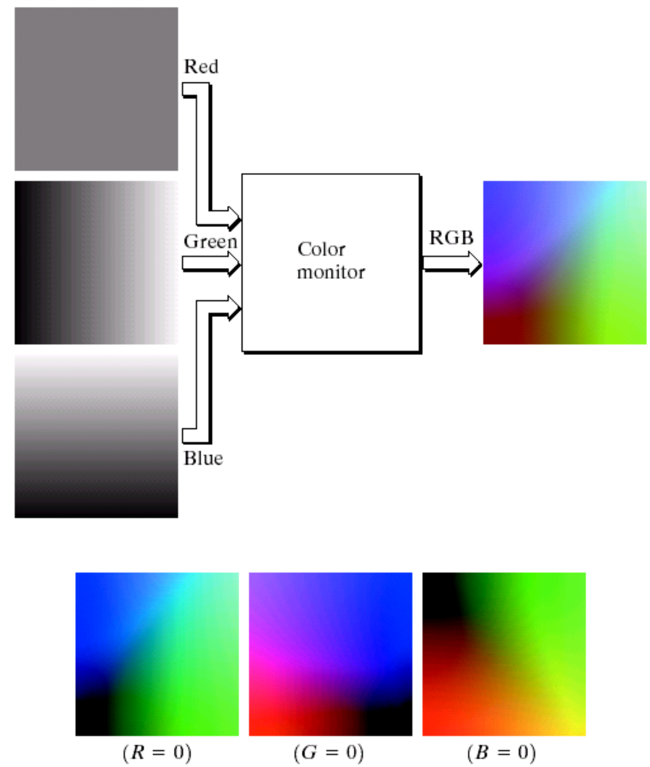
FIGURE 6.8 RGB 24-bit color cube.

- *A convenient way to view these colors is to generator color planes(faces or cross sections of the cube).*

- *Figure 6.9(a) shows that an image of the cross-sectional plane is viewed simply by feeding the three individual component images into a color monitor.*

a
b

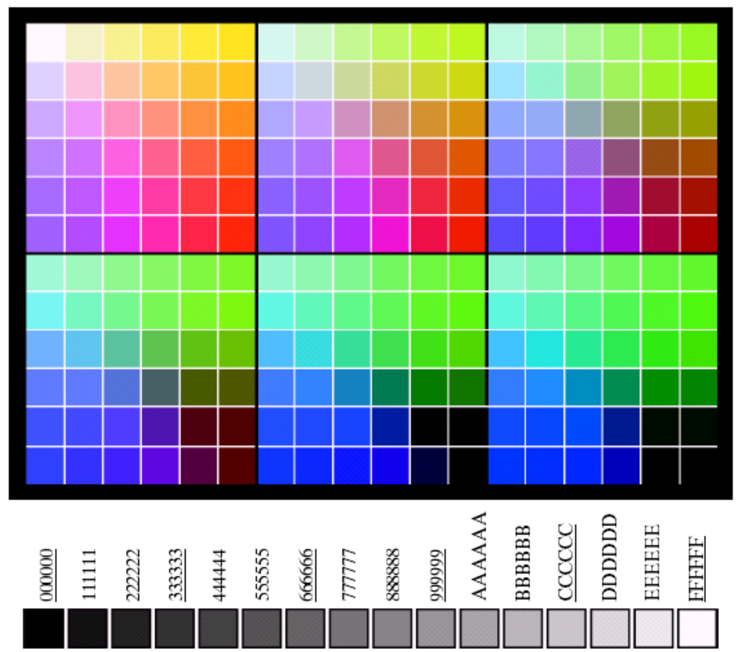
FIGURE 6.9 (a) Generating the RGB image of the cross-sectional color plane $(127, G, B)$. (b) The three hidden surface planes in the color cube of Fig. 6.8.



Number System	Color Equivalents					
Hex	00	33	66	99	CC	FF
Decimal	0	51	102	153	204	255

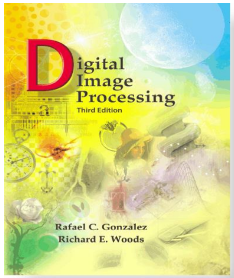
TABLE 6.1 Valid values of each RGB component in a safe color.

- *A subset of colors that are likely to be reproduced faithfully, reasonably independently of viewer hardware capabilities is called the set of safe RGB colors.*



a
b

FIGURE 6.10 (a) The 216 safe RGB colors. (b) All the grays in the 256-color RGB system (grays that are part of the safe color group are shown underlined).



- *The cube has valid colors only on the surface planes.*
- *The entire surface of the safe-color cube is covered by* $6^3 = 216$ *different colors.*

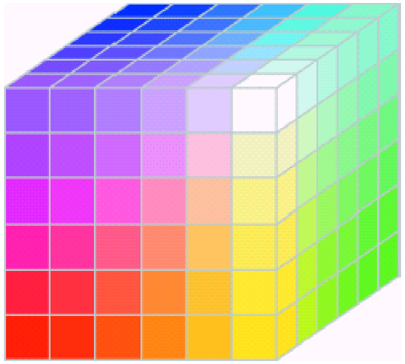
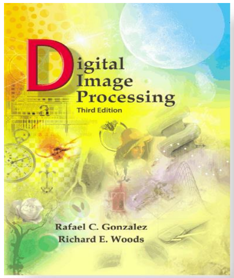


FIGURE 6.11 The RGB safe-color cube.



The CMY and CMYK Color Models

- *Cyan, Magenta and Yellow are the secondary colors of light*
- *Most devices that deposit colored pigments on paper, such as color printers and copiers, require CMY data input.*

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

The HSI Color Model

- *Hue is a color attribute that describes a pure color, saturation gives a measure of the degree to which a pure color is diluted by white light.*
- *Brightness is a subjective descriptor that is practically impossible to measure.*

Intensity

How to extract intensity and saturation

An RGB color image can be viewed as three monochrome intensity images, so it should come as no surprise that we should be able to extract intensity from an RGB image.

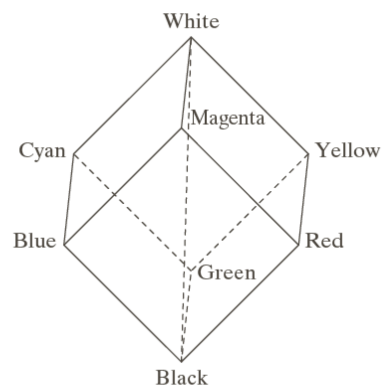


FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.

How to define hue

From Fig.6.12(b), we can see that all points contained in the plane segment defined by the intensity axis and the boundaries of the cube have the same hue.

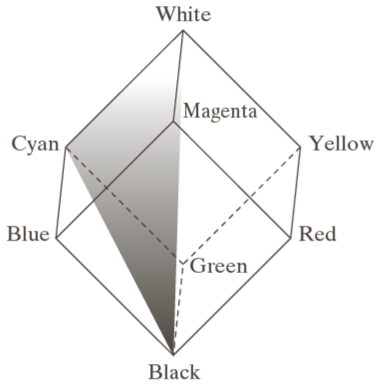


FIGURE 6.12 Conceptual relationships between the RGB and HSI color models.

- *The key point is that the HIS space is represented by a vertical intensity axis and the locus of color points that lie on planes perpendicular to this axis.*

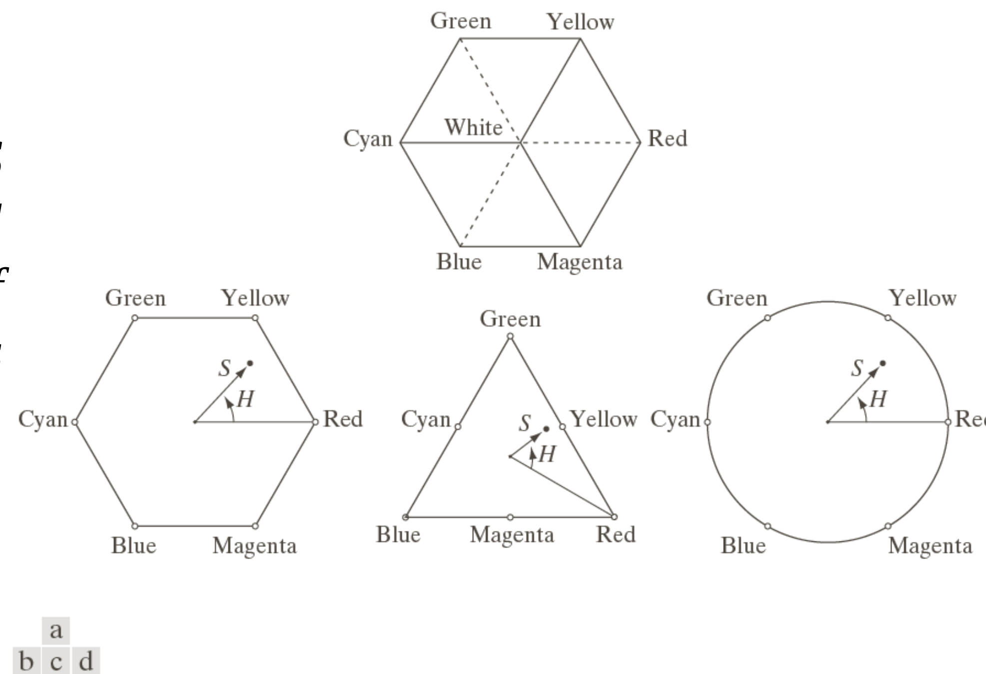
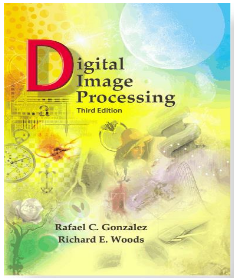


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.



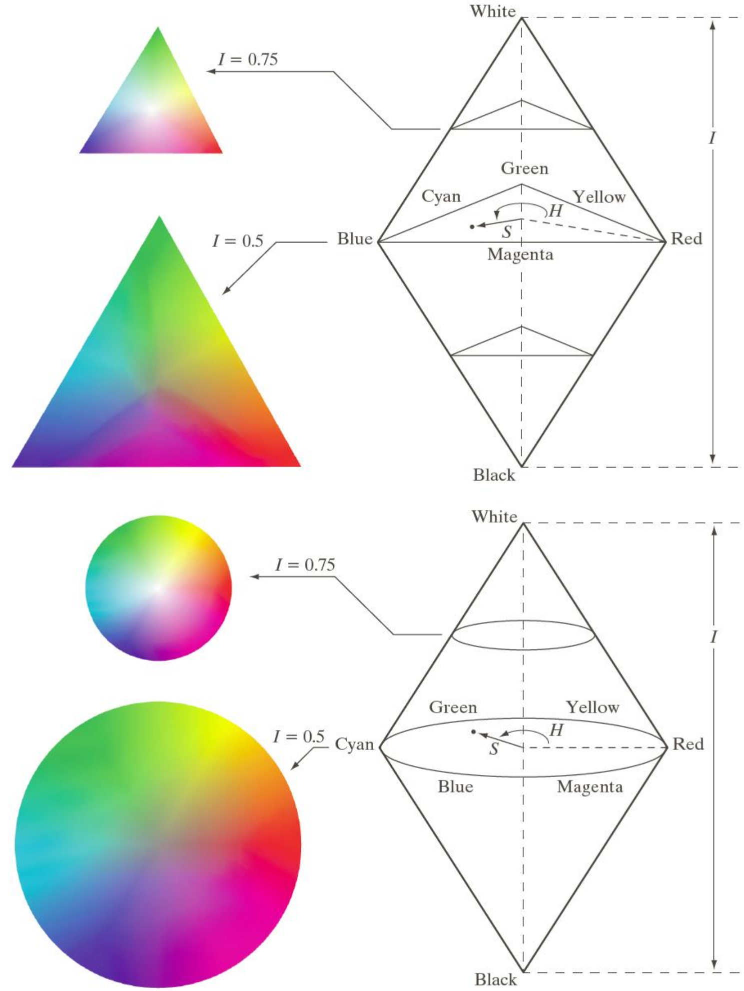
- *Converting colors from RGB to HSI*

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

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

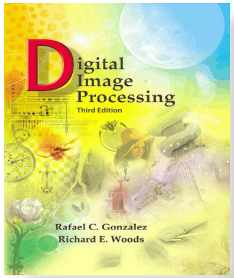
$$S = 1 - \frac{3}{(R+G+B)}[min(R,G,B)]$$

$$I = \frac{1}{3}(R+G+B)$$



a
b

FIGURE 6.14 The HSI color model based on (a) triangular and (b) circular color planes. The triangles and circles are perpendicular to the vertical intensity axis.



- *Converting colors from HSI to RGB*

RG sector$(0^\circ \leq H < 120^\circ)$:

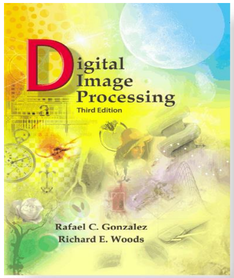
$$B = I(1-S) \qquad R = I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right] \qquad G = 3I - (\mathrm{R} + \mathrm{B})$$

GB sector$(120^\circ \leq H < 240^\circ)$:

$$H = H - 120^\circ \qquad R = I(1-S) \qquad G = I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right] \qquad B = 3I - (\mathrm{R} + G)$$

BR sector$(240^\circ \leq H < 360^\circ)$:

$$H = H - 240^\circ \qquad G = I(1-S) \qquad B = I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right] \qquad R = 3I - (G + B)$$



summary

Color fundamentals

- *Spectrum of colors, three standard primaries*
- *brightness, hue, saturation*
- *CIE chromaticity diagram*

Color models

- *RGB*
- *CMY*
- *HSI*