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IT4130 – Image Understanding and Processing

Lecture 08 – Color Image Processing

Color Fundamentals

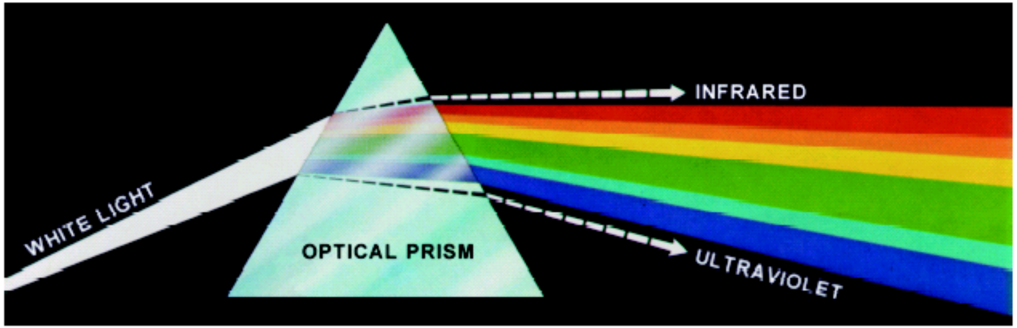


FIGURE 6.1 Color spectrum seen by passing white light through a prism. (Courtesy of the General Electric Co., Lamp Business Division.)

Color Fundamentals

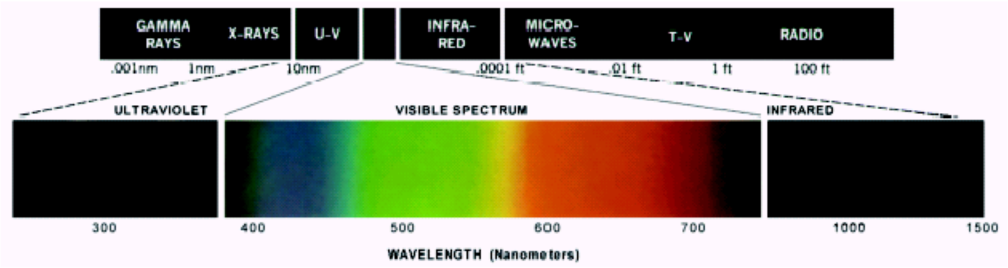


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Characteristics of light

- Achromatic
  - Intensity
- Chromatic
  - Radiance
    - Total energy (W)
  - Luminance
    - Perceived energy (lm)
  - Brightness
    - subjective

Light absorption in the eye

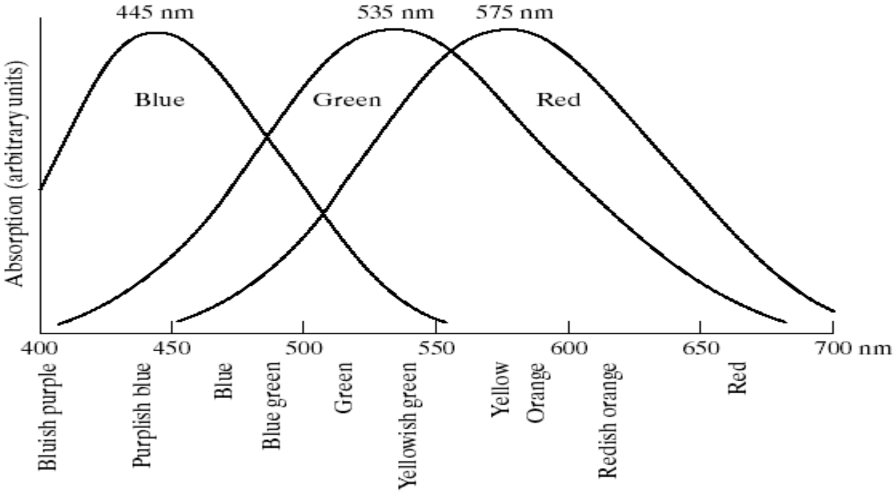
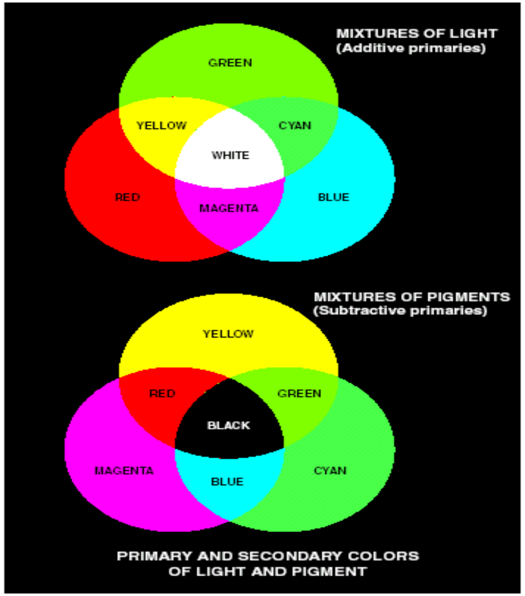


FIGURE 6.3 Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

Color combinations



a
b

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

Distinguish color

- Brightness
    - Subjective
- chromaticity
    - Hue
        - Dominant wavelength
    - Saturation
        - Degree of saturation and amount of added white light are inversely proportional.

Color specification

1. Trichromatic coefficients

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

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

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

Color specification

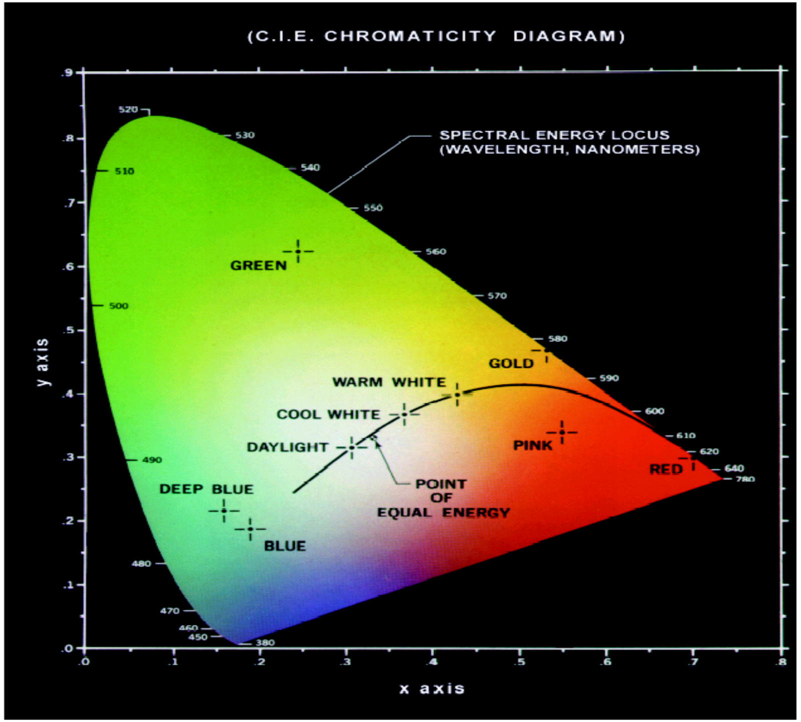
2.

Chromaticity Diagram

Based on

$x + y + z = 1$

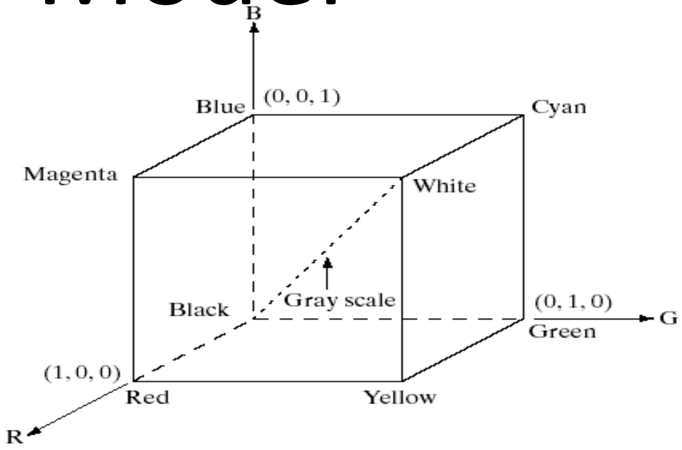
FIGURE 6.5 Chromaticity diagram. (Courtesy of the General Electric Co., Lamp Business Division.)



Color Models

1. RGB Color Model

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).



- Pixel depth – number of bits used to represent a pixel
- Full color image – 24-bit RGB color image

RGB Color Model

How many colors are represented by the cube which has a pixel depth of 24 bits?

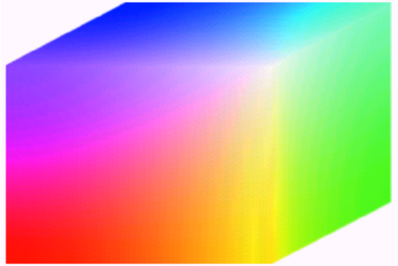
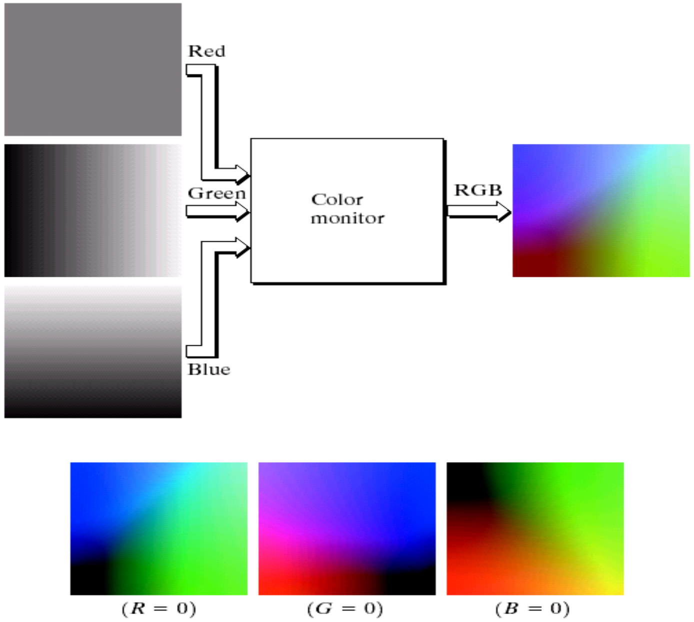


FIGURE 6.8 RGB 24-bit color cube.

RGB Color Model

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.



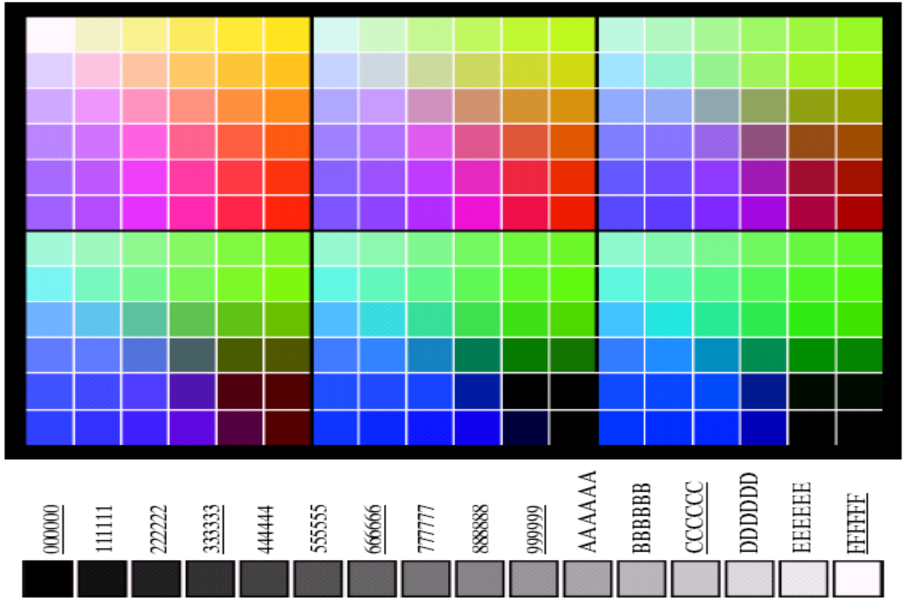
Safe RGB Colors

- **Safe RGB colors** are reproduced faithfully, reasonably independently of viewer hardware capabilities
- Formation of 216 safe colors
  - 0, 51, 102, 153, 204, 255
  - $(6)^3 = 216$
- Decimal to hex and binary
  - White
    - $FFFFFF_{16}$
    - $111111111111111111111111_2$
  - Pure red
    - $FF0000_{16}$
    - $111111110000000000000000_2$

Safe RGB Colors

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
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).

Safe RGB Colors

Each plane has a total of 36 colors

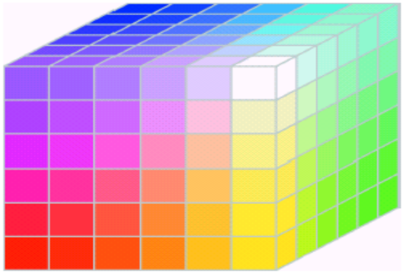


FIGURE 6.11 The RGB safe-color cube.

2. CMY and CMYK color model

- Secondary colors
  - Cyan = G + B
  - Yellow = R + G
  - Magenta = R + B
- RGB to CMY

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

- CMYK (Four-color printing)
  - CMY and black

CMY

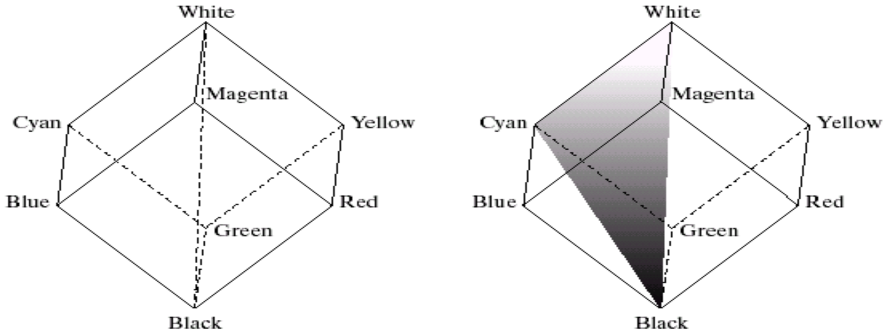
CMYK

http://en.wikipedia.org/wiki/CMYK

3. HSI color model

- Natural and intuitive to humans while RGB is ideal for color generation
- Three parameters
  - Hue
    - Describes a pure color
  - Saturation
    - Gives a measure of the degree to which a pure color is diluted by white light.
  - Brightness (Intensity)
    - Subjective and impossible to measure

HSI color model



a b

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

HSI color model

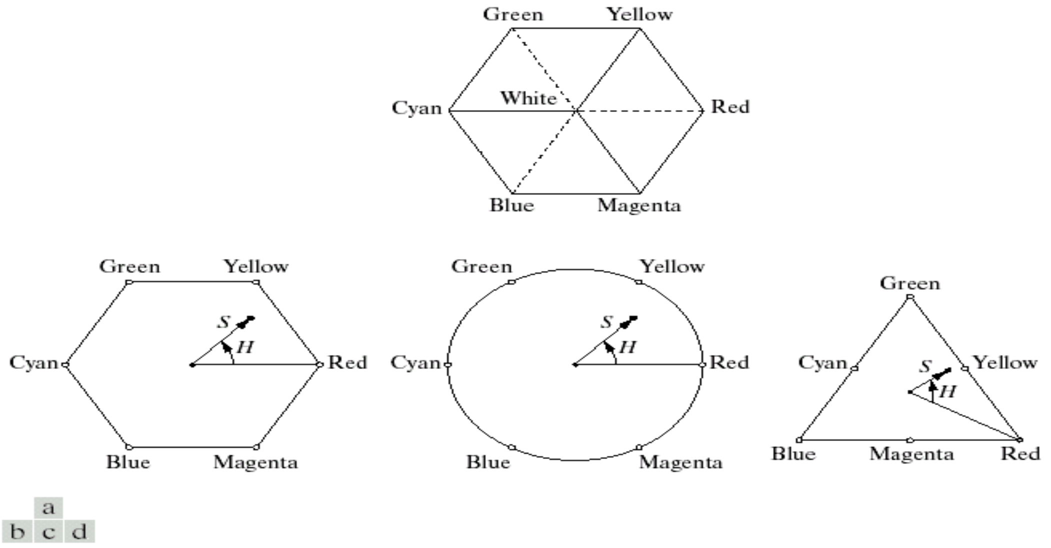
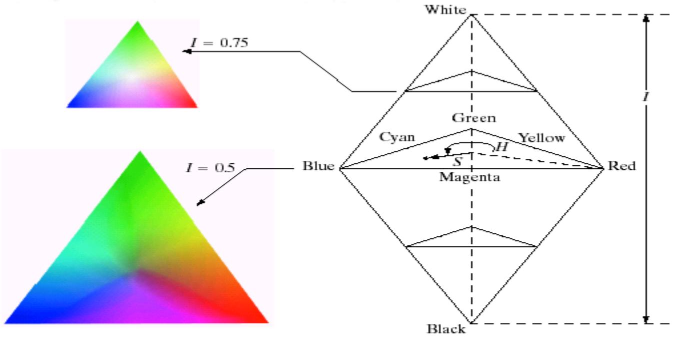


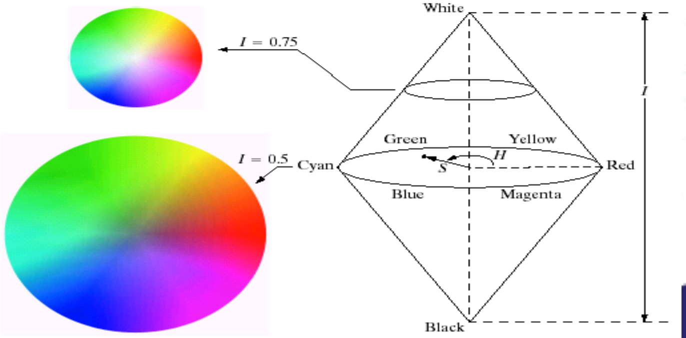
FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

HSI color model

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.





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HSI color model

- Converting RGB to HSI
  - Hue

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

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

  - Assumptions
    - RGB values are normalized in the range [0,1]
    - Angle is measured w.r.t. the red axis of the HSI space.

HSI color model

- Converting RGB to HSI
  - Saturation

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

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

HSI color model

- Converting HSI to RGB
  - RG sector $(0^\circ \leq H < 120^\circ)$

$$B = I(1 - S)$$

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

and

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

HSI color model

- Converting HSI to RGB
  - GB sector $(120^\circ \le H < 240^\circ)$

$$H = H - 120^\circ$$

$$R = I(1 - S)$$

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

and

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

HSI color model

- Converting HSI to RGB
  - BR sector $(240^\circ \le H \le 360^\circ)$

$$H = H - 240^\circ$$

$$G = I(1 - S)$$

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

and

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

HSI color model

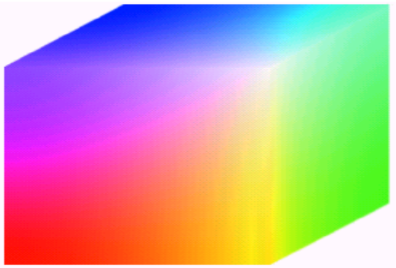
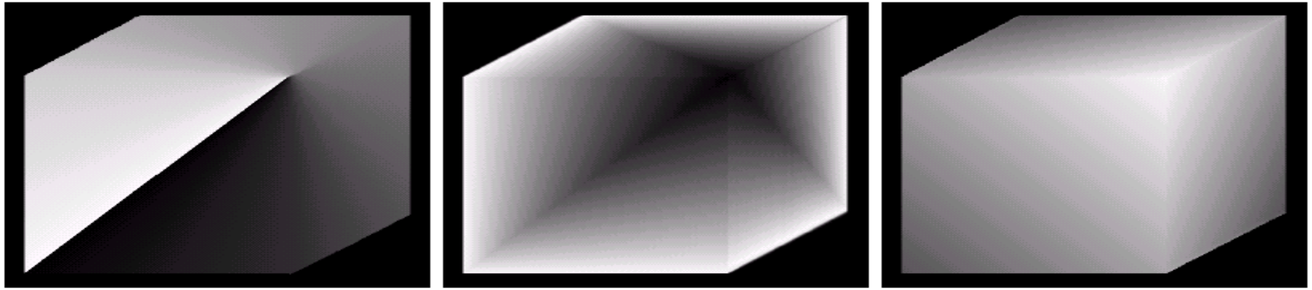


FIGURE 6.8 RGB 24-bit color cube.



a b c

FIGURE 6.15 HSI components of the image in Fig. 6.8. (a) Hue, (b) saturation, and (c) intensity images.

HSI color model

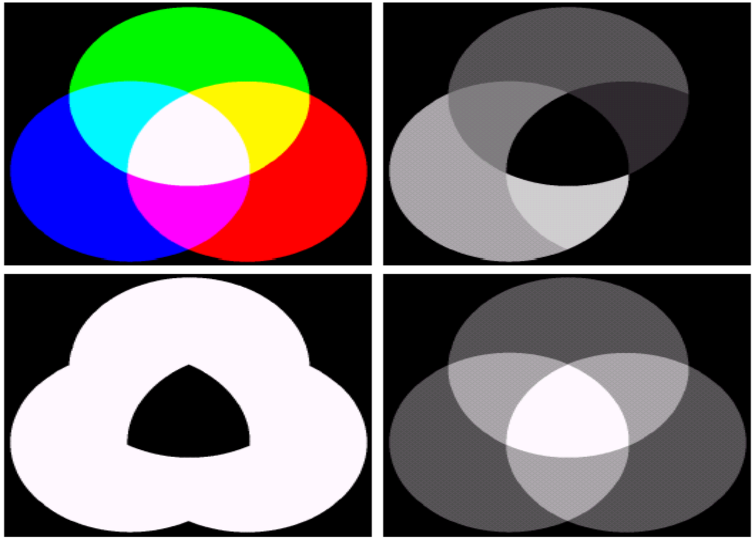


FIGURE 6.16 (a) RGB image and the components of its corresponding HSI image: (b) hue, (c) saturation, and (d) intensity.

Gray level to color transformations

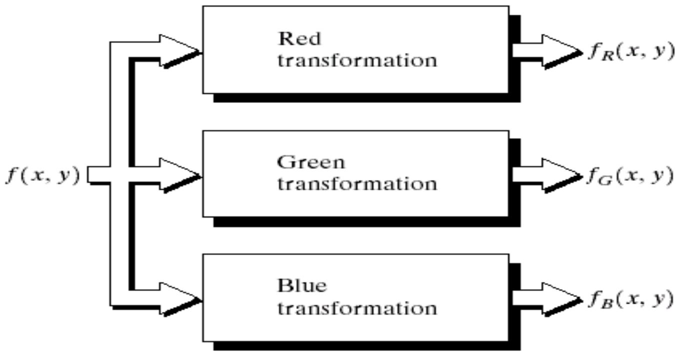
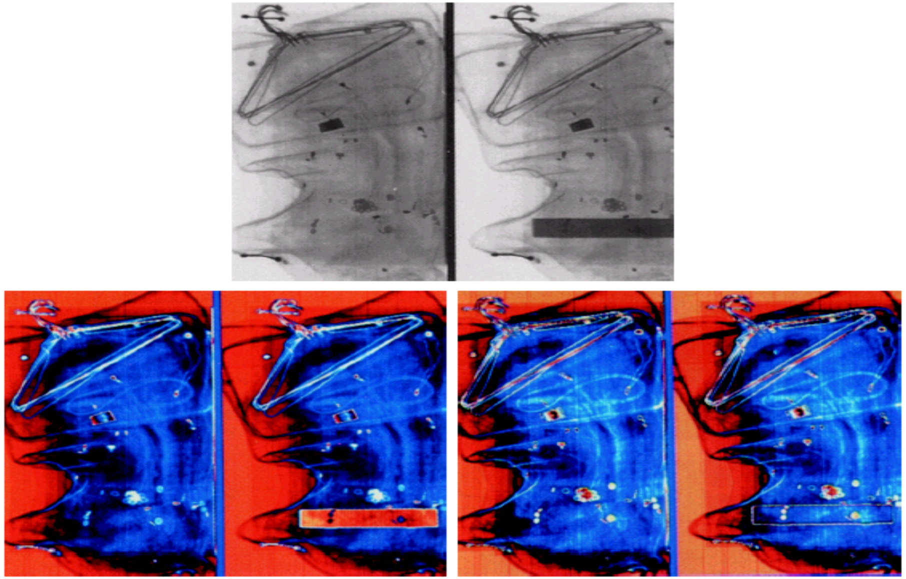


FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

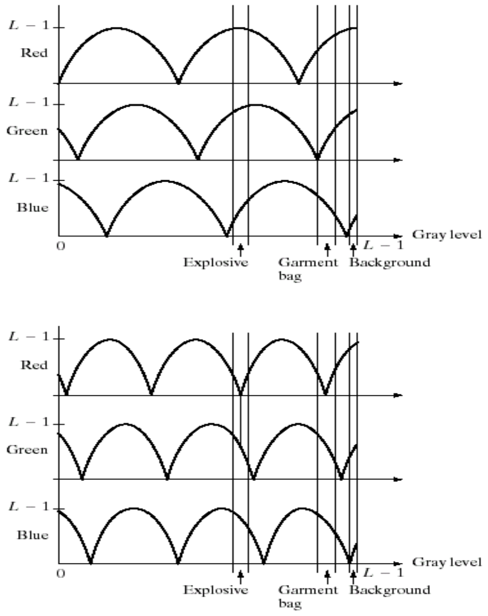
Gray level to color transformations



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.)

Gray level to color transformations



a
b

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