Color Image Processing

Color models
(also called *color space* or *color system*)

A color model defines a coordinate system,
in which each color is represented by
a single point within the defined space.

- RGB color model
- CMY and CMYK color models
- YIQ color model
- HSI (also called HSV, IHS) color model

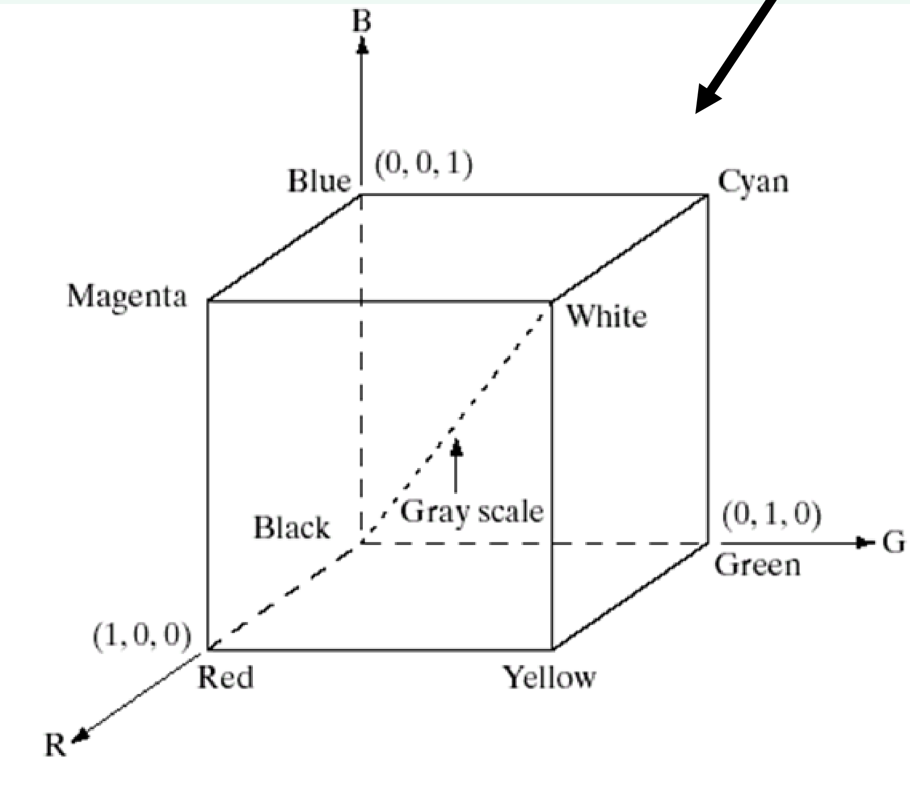
RGB Color Model

The RGB color model is hardware-oriented, and commonly used for image display in color monitors and image acquisition by various types of cameras.

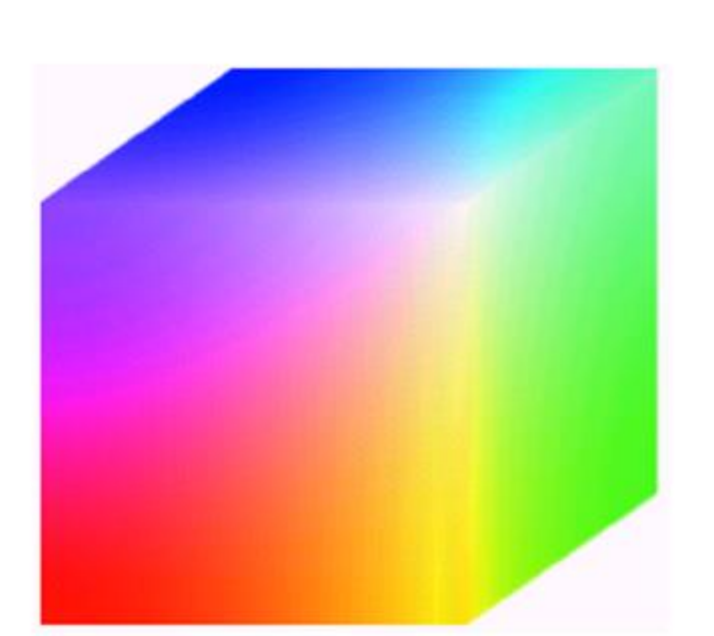
In the RGB model, each color is expressed as a combination of its three primary colors, i.e., *red* (R), *green* (G), and *blue* (B).

Coordinate of the RGB Color Model

All color values are normalized to the range [0,1].

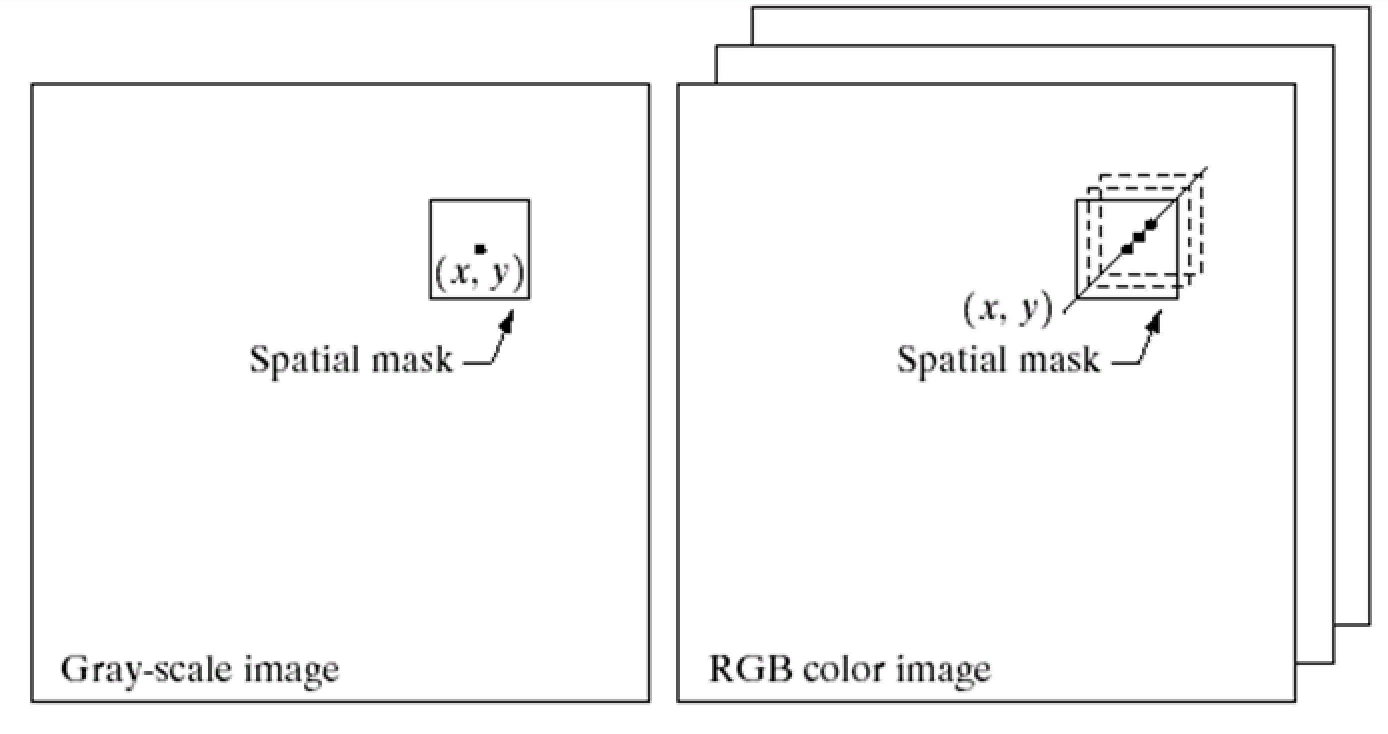


RGB color space



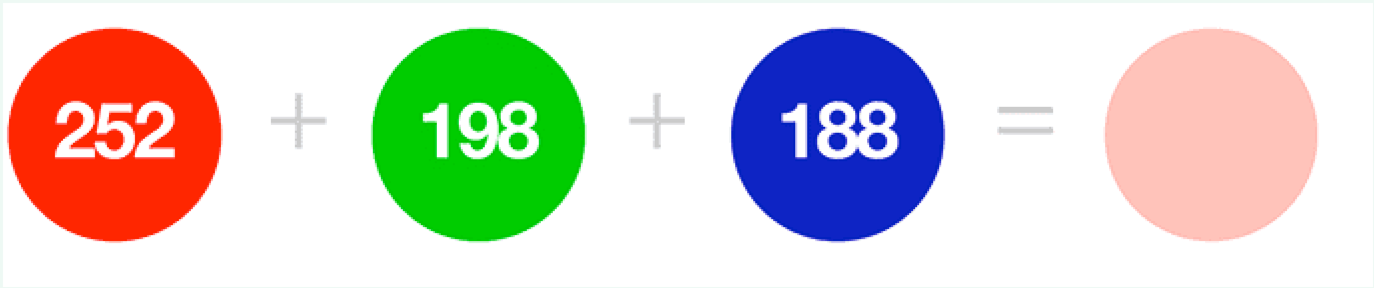
RGB 24-bit color cube

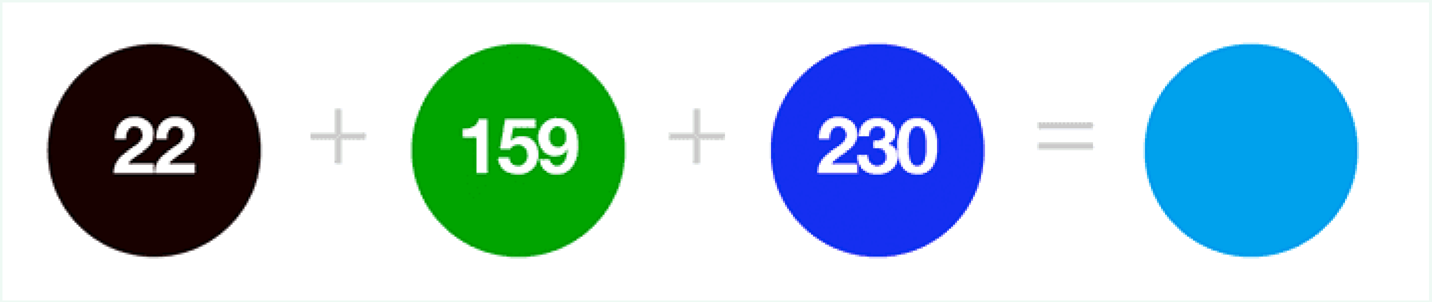
An RGB Image as Three Matrices



An RGB color image can be viewed as three gray-level images, representing, red, green, and blue.

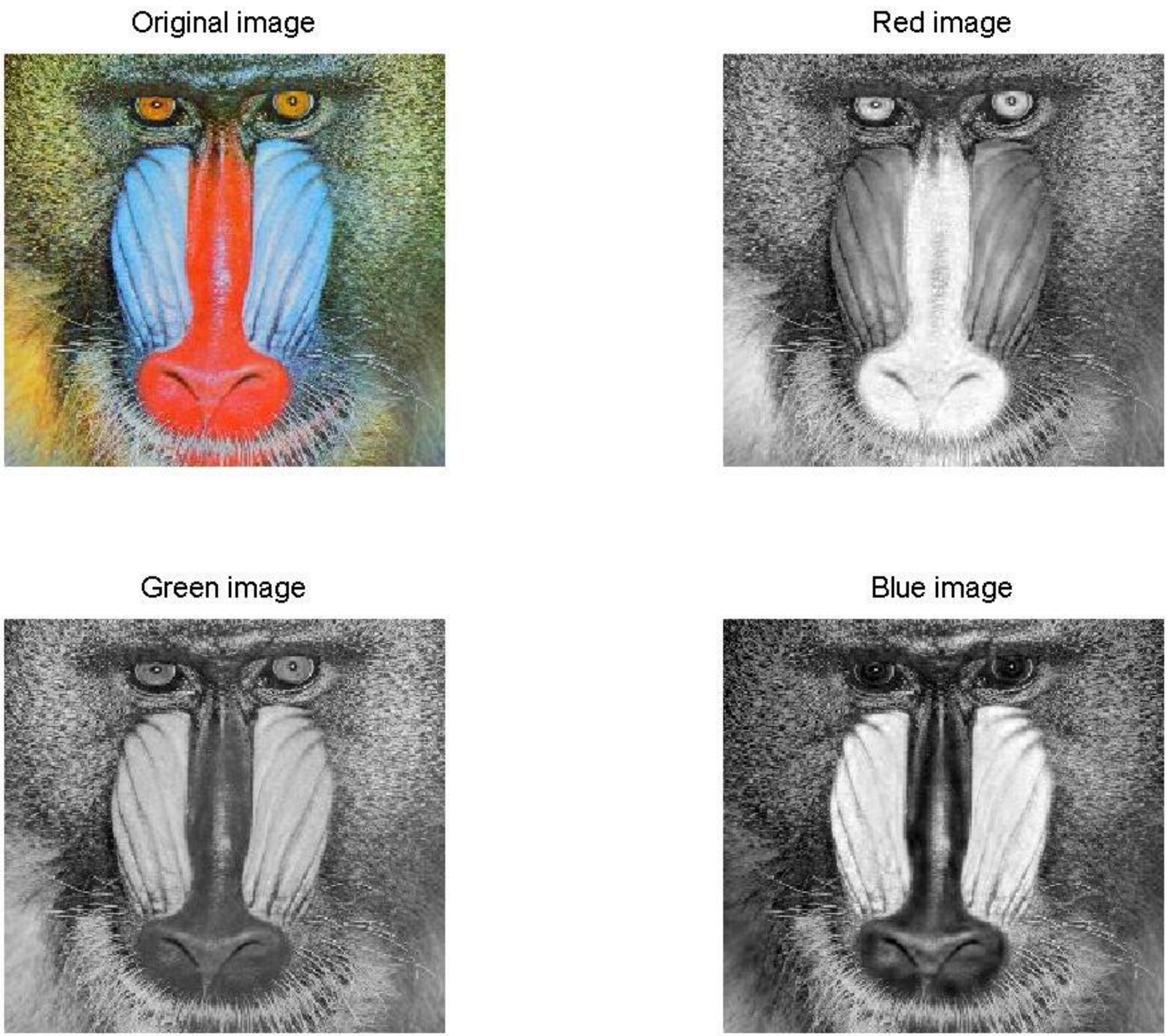
An RGB Image as Three Matrices





An RGB color image can be viewed as three gray-level images, representing, red, green, and blue.

An RGB Color Image



Safe RGB Colors

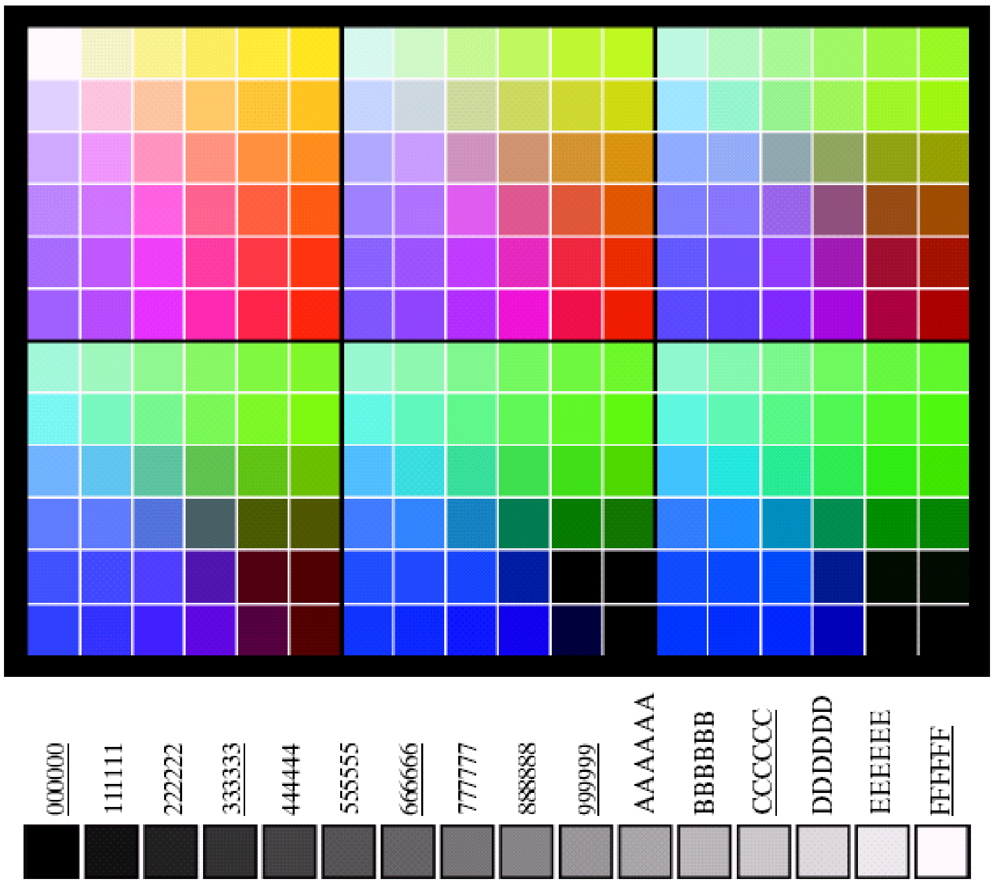
While high-end display cards and monitors provide a reasonable rendition of the colors in a 24-bit RGB image, some systems in use may be limited to 256 colors. Hence, it is convenient to have a subset of colors that can be reproduced faithfully and reasonably independent of viewer hardware capabilities.

This subset of colors is called the set of *safe RGB colors*.

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).

These 216 color have become the de facto standard for safe colors.

RGB 24-bit Colors and Safe Colors

FIGURE 6.8 RGB 24-bit color cube.

2^{24}=16,777,216 colors

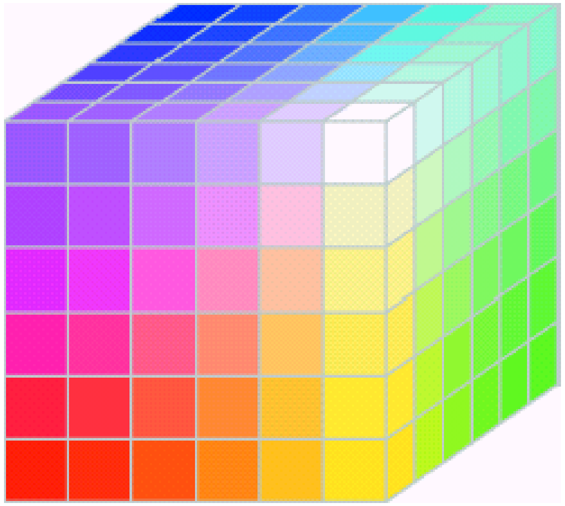


FIGURE 6.11 The RGB safe-color cube.

6^{3}=216 safe colors

+

40 extra colors

(OS dependent)

An Indexed RGB Image

An indexed image consists of an image array and a color map matrix. The pixel values in the array are direct indexes into a color map.

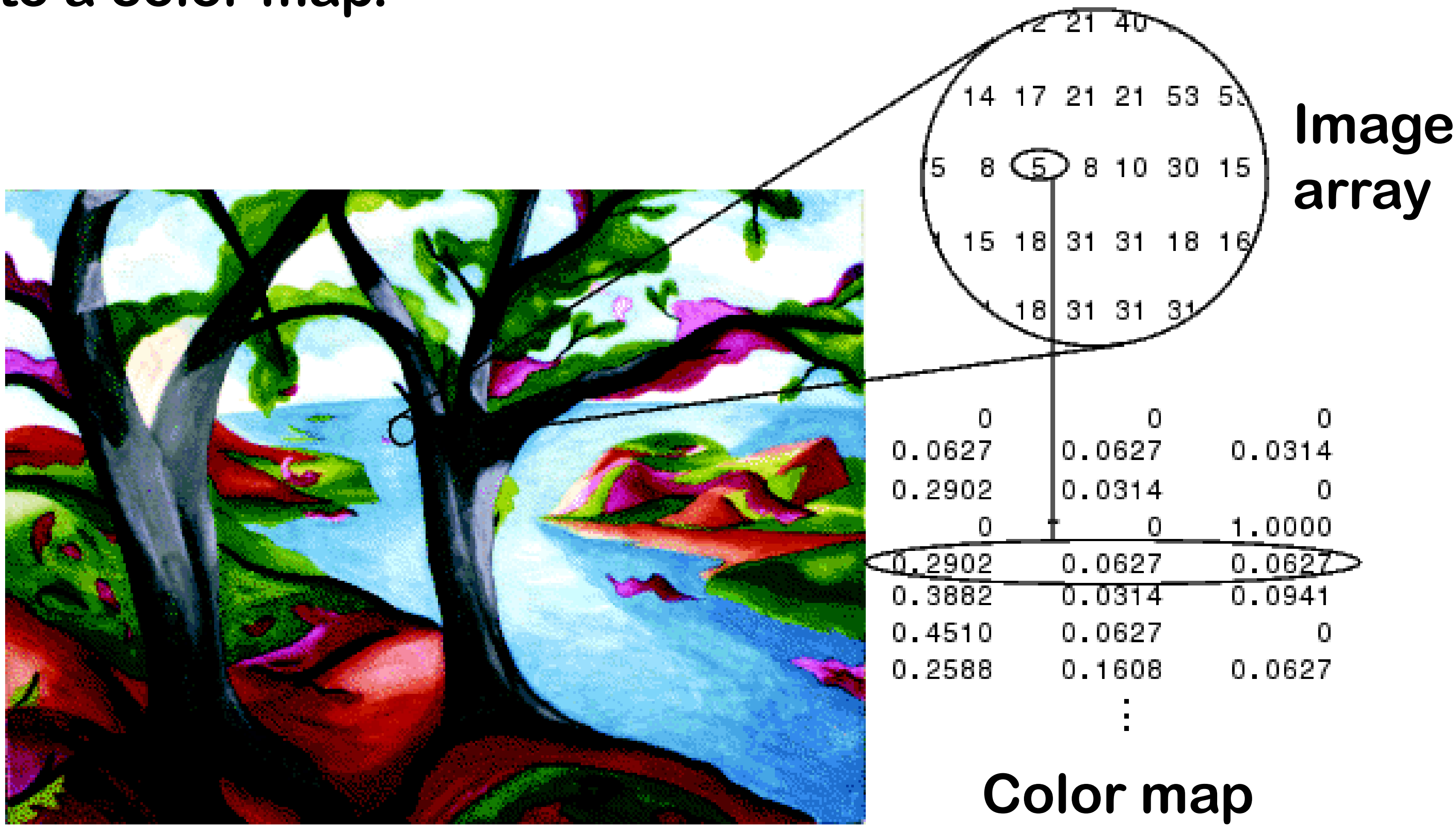


Image Courtesy of Susan Cohen

Indexed RGB Image with MATLAB

```
>> img1=imread('mandril.jpg');
>> [img3,map]=rgb2ind(img1,256);
>> whos

 Name     Size                Bytes   Class

  img1    240x256x3          184320  uint8 array
  img3    240x256             61440  uint8 array
  map       256x3              6144   double array

>> subplot(1,2,1), imshow(img1)
>> subplot(1,2,2), imshow(img3,map)
```

Original and Indexed Color Images

RGB 24-bit colors

RGB 256 colors

Can you see any difference?

CMY and CMYK Color Models

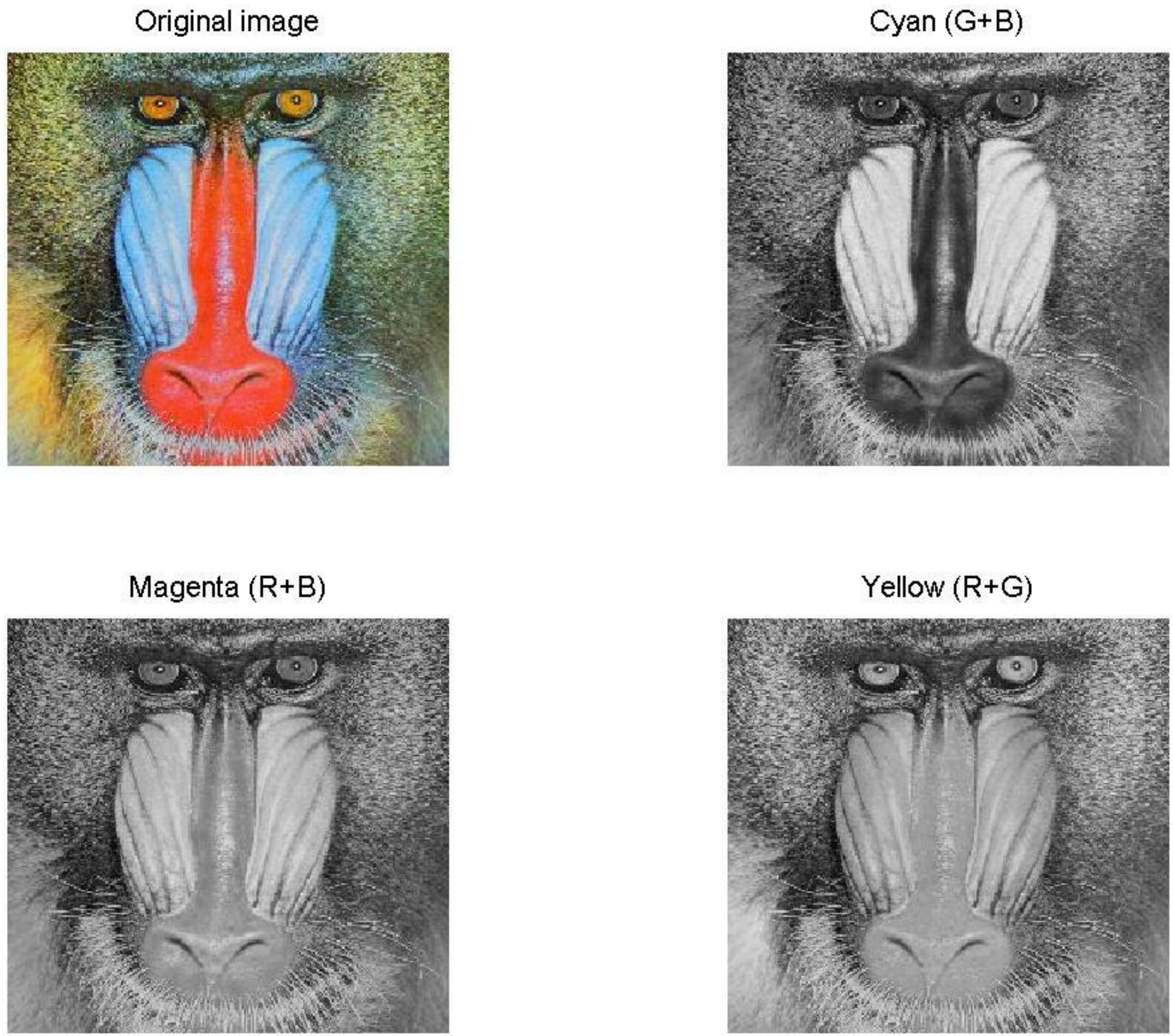
The CMY (*cyan*, *magenta*, *yellow*) model is commonly used for color printing.

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

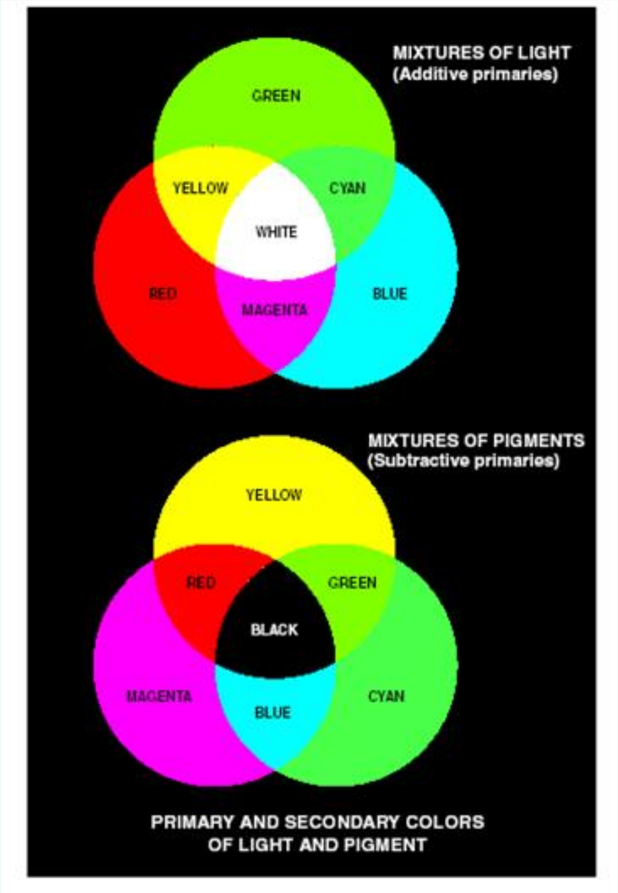
In the CMYK color model, a fourth color, *black*, is added.

```python
rgb_scale = 255
cmyk_scale = 100


def rgb_to_cmyk(r,g,b):
    if (r == 0) and (g == 0) and (b == 0):
        # black
        return 0, 0, 0, cmyk_scale

    # rgb [0,255] -> cmy [0,1]
    c = 1 - r / float(rgb_scale)
    m = 1 - g / float(rgb_scale)
    y = 1 - b / float(rgb_scale)

    # extract out k [0,1]
    min_cmy = min(c, m, y)
    c = (c - min_cmy)
    m = (m - min_cmy)
    y = (y - min_cmy)
    k = min_cmy

    # rescale to the range [0,cmyk_scale]
    return c*cmyk_scale, m*cmyk_scale, y*cmyk_scale, k*cmyk_scale

def cmyk_to_rgb(c,m,y,k):
    """
    """
    r = rgb_scale*(1.0-(c+k)/float(cmyk_scale))
    g = rgb_scale*(1.0-(m+k)/float(cmyk_scale))
    b = rgb_scale*(1.0-(y+k)/float(cmyk_scale))
    return r,g,b
```

A CMY Color Image



Additive and Subtractive Primaries



Red, green, and blue are called *additive primaries*, while cyan, magenta, and yellow are called *subtractive primaries*.

YIQ Color Model

The YIQ model is used in color TV broadcasting. YIQ is a recoding of RGB for transmission efficiency while maintaining compatibility with monochrome TV standards. The RGB to YIQ conversion is defined as

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}.$$

Y **depicts image intensity, while** ***I*** **and** ***Q*** **carry color information.**

HSI Color Model

The HSI (or HSV, IHS) color model represents a color in terms of *hue* (H), *saturation* (S), and *intensity* (I) (or *value* (V)).

- Hue represents a dominant wavelength of a color.
- Saturation refers to the purity of a color.
- Intensity represents the brightness of a color.

Relationship between RGB and HSI

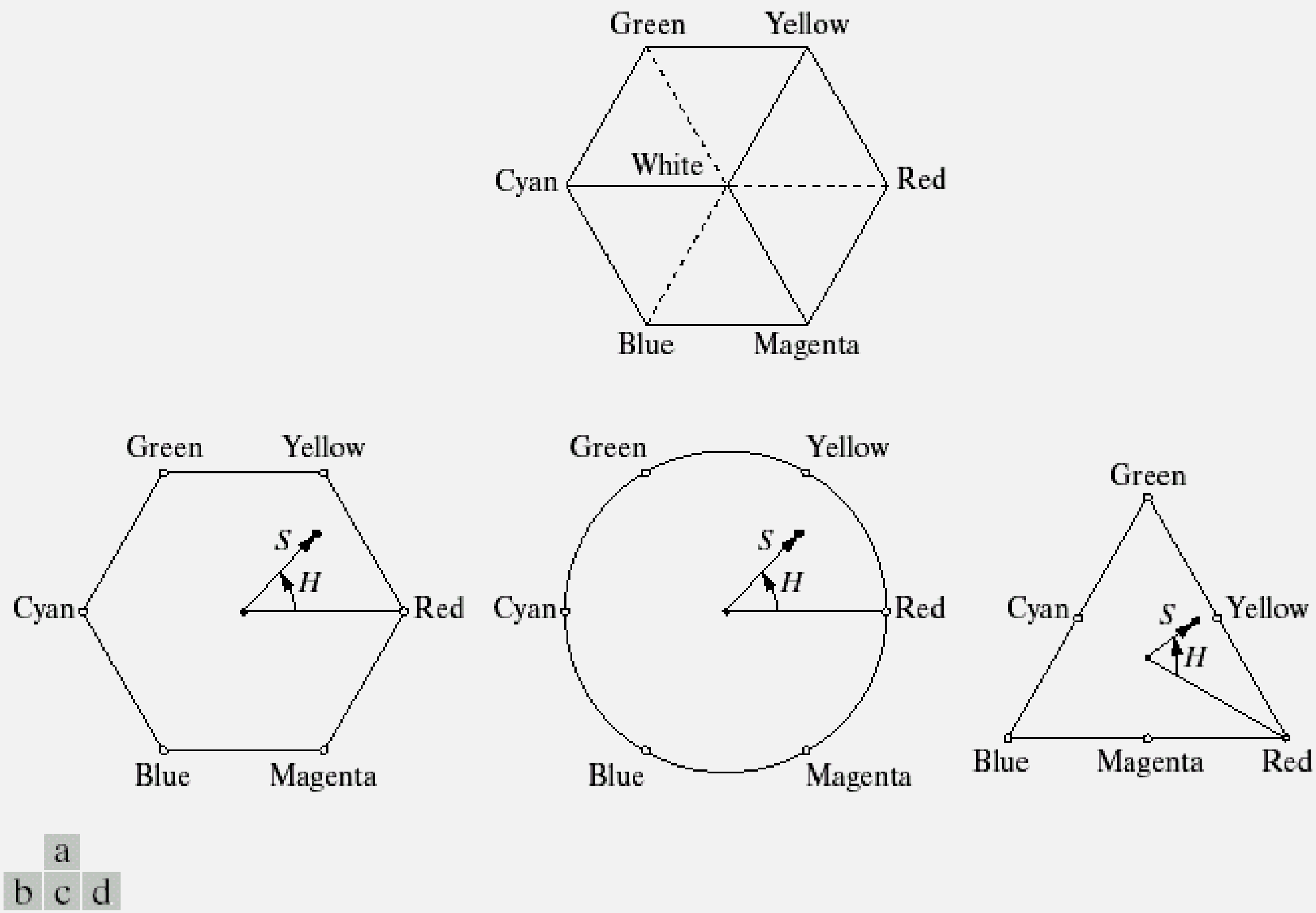
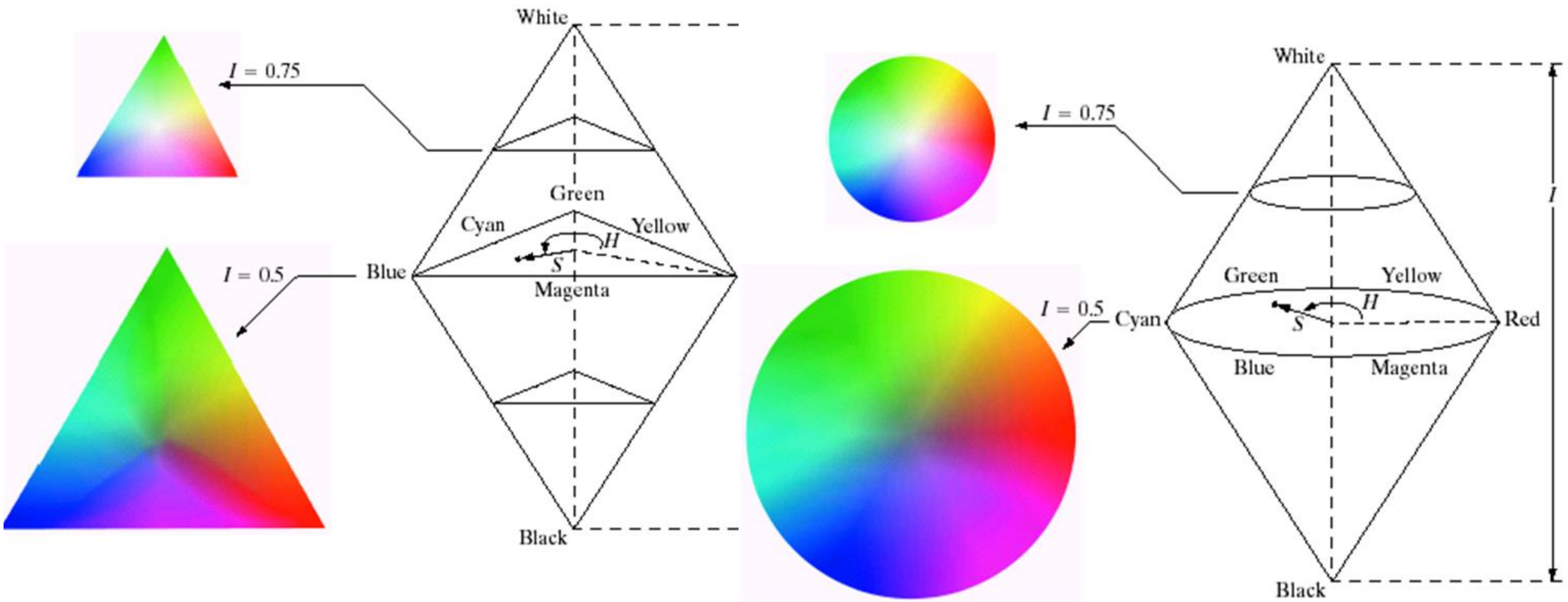


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

HSI Color Circles



HSI Color Triangles

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

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

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

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

Converting Colors from RGB to HSI

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

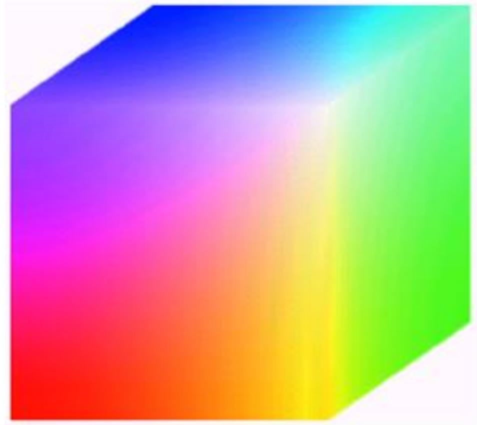
where

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

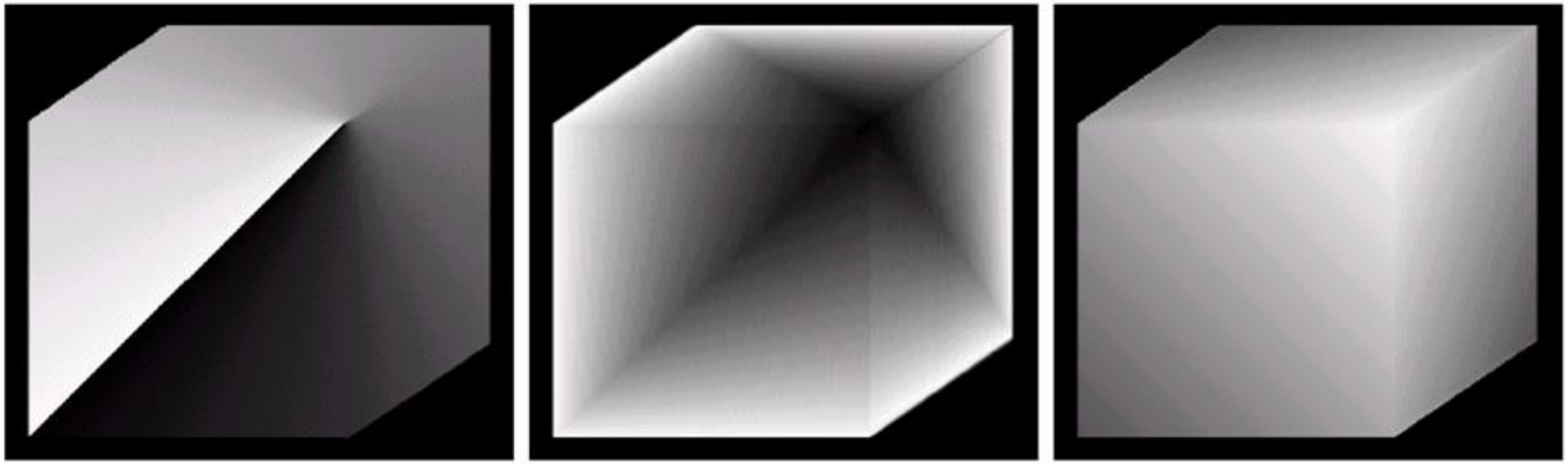
$$S = 1 - \frac{3}{R+G+B}\left[\min(R,G,B)\right]$$

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

HSI Components of the RGB Color Cube

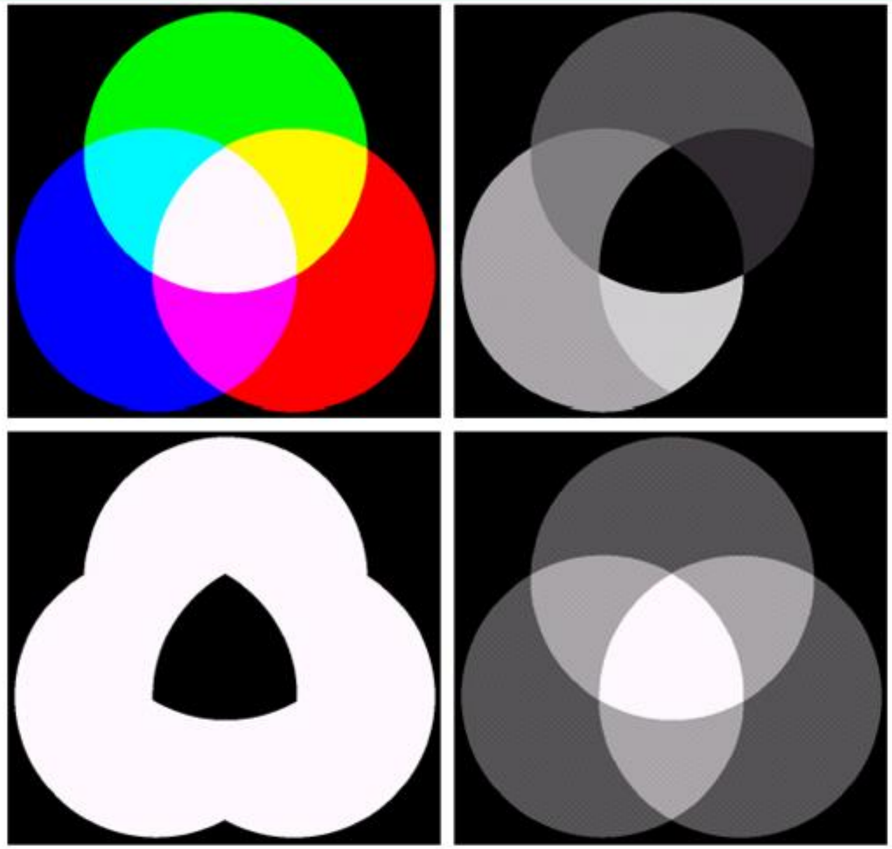


RGB 24-bit color cube.



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

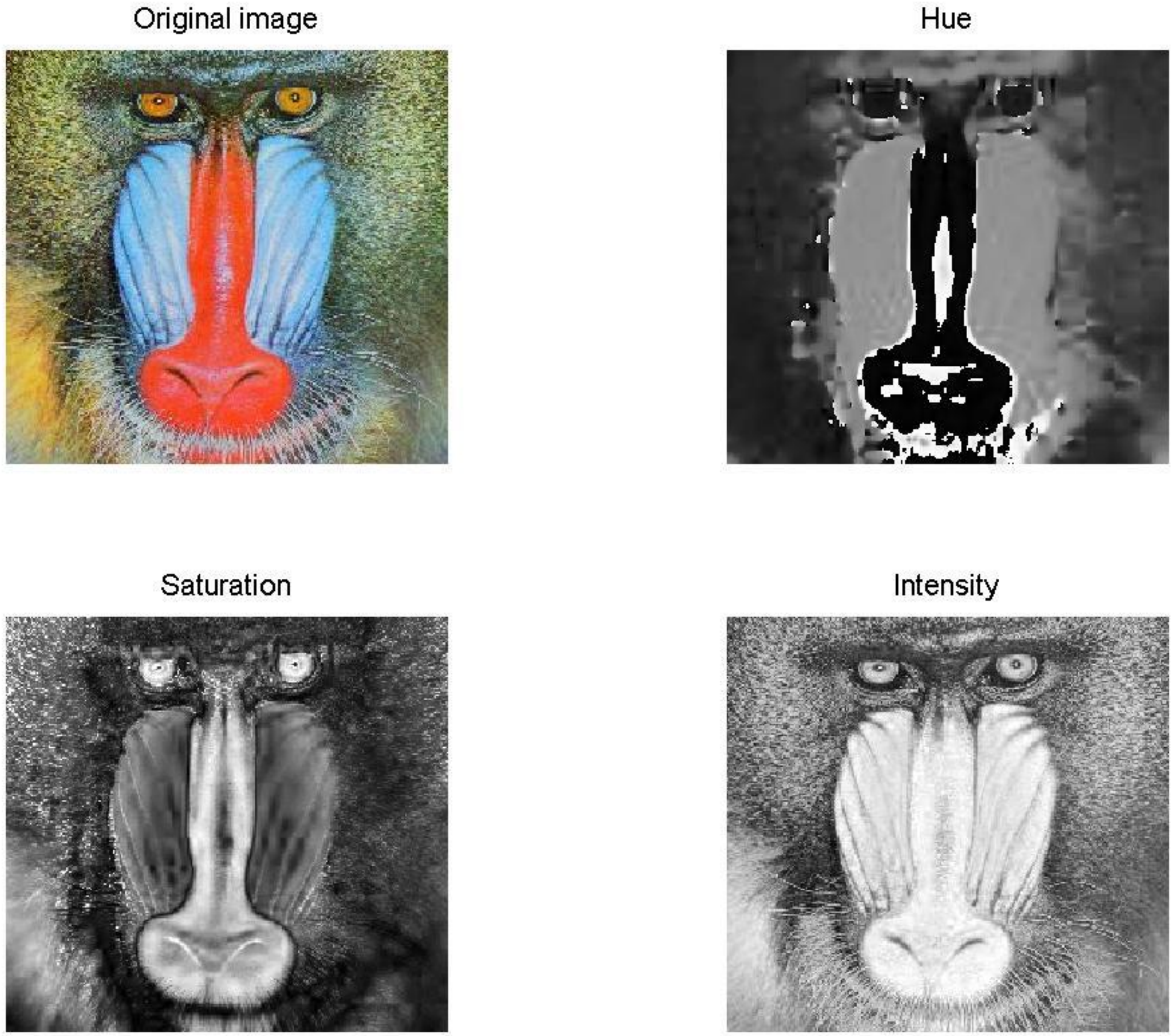
HSI Components of an RGB Image (1)



a b
c d

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

HSI Components of an RGB Image (2)



Features of the HSI Color Model

- The HSI color model decouples the intensity component from the color-carrying information (hue and saturation) in a color image.

- As a result, the HSI model is an ideal tool for developing image processing algorithms based on color descriptions.

- Gray-level algorithms can be performed on the component, whereas segmentation can be performed on the *H* component.

Color Image Smoothing

Image smoothing in RGB and HSV spaces.

a b c Image smoothing with a 5 × 5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

By smoothing only the intensity image, the original color is maintained in (b).

Color Image Sharpening

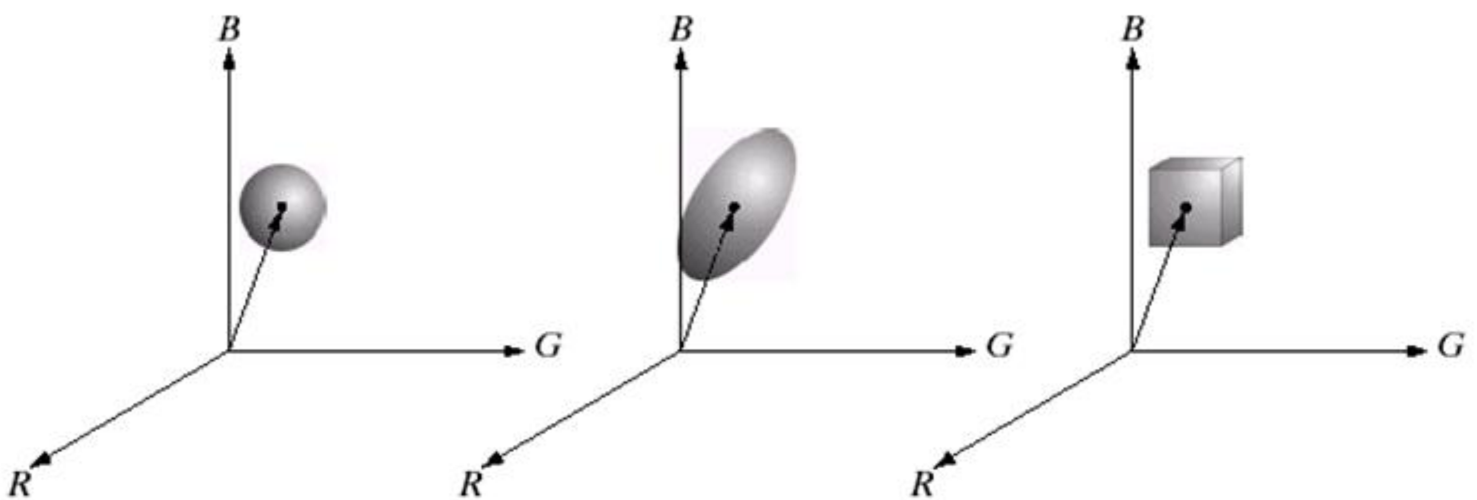
Image sharpening in RGB and HSV spaces.

a b c Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the intensity component and converting to RGB. (c) Difference between the two results.

Euclidean Distance in RGB Space

The Euclidean distance between two colors *p* and *q* is given by

$$D(p,q)=\sqrt{(p_R-q_R)^2+(p_G-q_G)^2+(p_B-q_B)^2}$$



a b c

Three approaches for enclosing data regions for RGB vector segmentation.

Assignment from Color Processing

1. Apply a mean filter to your facial image in both RGB and HSI spaces. Discuss the differences between two resulting images.

2. Segment your face from your image using the Euclidean distance in the RGB space.