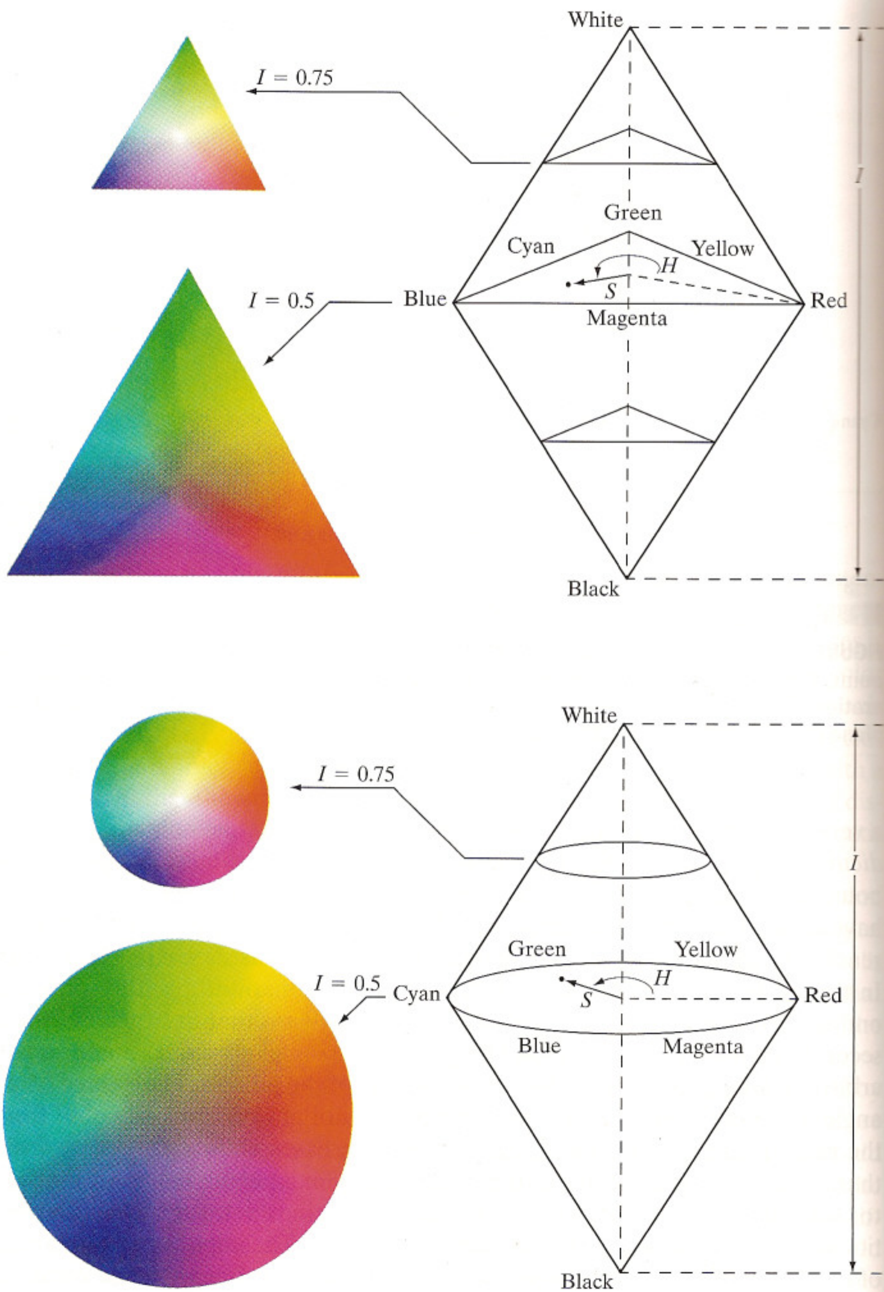

a
b

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 RGB to HSI

Given an image in RGB color format, the H component of each RGB pixel is obtained using the equation

$$H = \begin{cases} \theta & \text{if } B \leq G \\ 360 - \theta & \text{if } B > G \end{cases} \tag{6.2-2}$$

with

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

The saturation component is given by

$$S = 1 - \frac{3}{(R + G + B)}\left[\min(R, G, B)\right]. \tag{6.2-3}$$

Finally, the intensity component is given by

$$I = \frac{1}{3}(R + G + B). \tag{6.2-4}$$

It is assumed that the RGB values have been normalized to the range $[0, 1]$ and that angle θ is measured with respect to the red axis of the HSI space, as indicated in Fig. 6.13. Hue can be normalized to the range $[0, 1]$ by dividing by 360° all values resulting from Eq. (6.2-2). The other two HSI components already are in this range if the given RGB values are in the interval $[0, 1]$.

The results in Eqs. (6.2-2) through (6.2-4) can be derived from the geometry shown in Figs. 6.12 and 6.13. The derivation is tedious and would not add significantly to the present discussion. The interested reader can consult the book's references or web site for a proof of these equations, as well as for the following HSI to RGB conversion results.

See inside front cover

Consult the book web site for a detailed derivation of the conversion equations between RGB and HSI, and vice versa.

Converting colors from HSI to RGB

Given values of HSI in the interval $[0, 1]$, we now want to find the corresponding RGB values in the same range. The applicable equations depend on the values of H. There are three sectors of interest, corresponding to the 120° intervals in the separation of primaries (see Fig. 6.13). We begin by multiplying H by 360°, which returns the hue to its original range of $[0°, 360°]$.

RG sector $(0° \leq H < 120°)$: When H is in this sector, the RGB components are given by the equations

$$B = I(1 - S) \tag{6.2-5}$$

$$R = I\left[1 + \frac{S \cos H}{\cos(60° - H)}\right] \tag{6.2-6}$$

and

$$G = 3I - (R + B). \tag{6.2-7}$$

GB sector $(120° \leq H < 240°)$: If the given value of H is in this sector, we first subtract 120° from it:

$$H = H - 120°. \tag{6.2-8}$$

Then the RGB components are

$$R = I(1 - S) \tag{6.2-9}$$

$$G = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right] \tag{6.2-10}$$

and

$$B = 3I - (R + G). \tag{6.2-11}$$

BR sector $(240° \leq H \leq 360°)$: Finally, if H is in this range, we subtract 240° from it:

$$H = H - 240°. \tag{6.2-12}$$

Then the RGB components are

$$G = I(1 - S) \tag{6.2-13}$$

$$B = I\left[1 + \frac{S\cos H}{\cos(60° - H)}\right] \tag{6.2-14}$$

and

$$R = 3I - (G + B). \tag{6.2-15}$$

Uses of these equations for image processing are discussed in several of the following sections.

EXAMPLE 6.2: The HSI values corresponding to the image of the RGB color cube.

■ Figure 6.15 shows the hue, saturation, and intensity images for the RGB values shown in Fig. 6.8. Figure 6.15(a) is the hue image. Its most distinguishing feature is the discontinuity in value along a 45° line in the front (red) plane of the cube. To understand the reason for this discontinuity, refer to Fig. 6.8, draw a line from the red to the white vertices of the cube, and select a point in the middle of this line. Starting at that point, draw a path to the right, following the cube around until you return to the starting point. The major colors encountered in this path are yellow, green, cyan, blue, magenta, and back to red. According to Fig. 6.13, the values of hue along this path should increase from 0° to 360° (i.e., from the lowest to highest possible values of hue). This is precisely what Fig. 6.15(a) shows because the lowest value is represented as black and the highest value as white in the gray scale. In fact, the hue image was originally normalized to the range $[0, 1]$ and then scaled to 8 bits; that is, it was converted to the range $[0, 255]$, for display.

The saturation image in Fig. 6.15(b) shows progressively darker values toward the white vertex of the RGB cube, indicating that colors become less and less