6.2 Colour Models

Colour model/space/system: coordinate system + subspace within it; each colour = single point

Models:
- **RGB (red, green, blue)**
  - Colour monitors ◦ Colour video cameras
- **CMY (cyan, magenta, yellow)**
  - Colour printing
- **CMYK (cyan, magenta, yellow, black)**
  - Colour printing
- **HSI (hue, saturation, intensity)**
  - Human description/interpretation of colour
  - Decouples colour and gray-scale information
  - Suitable for many gray-scale techniques

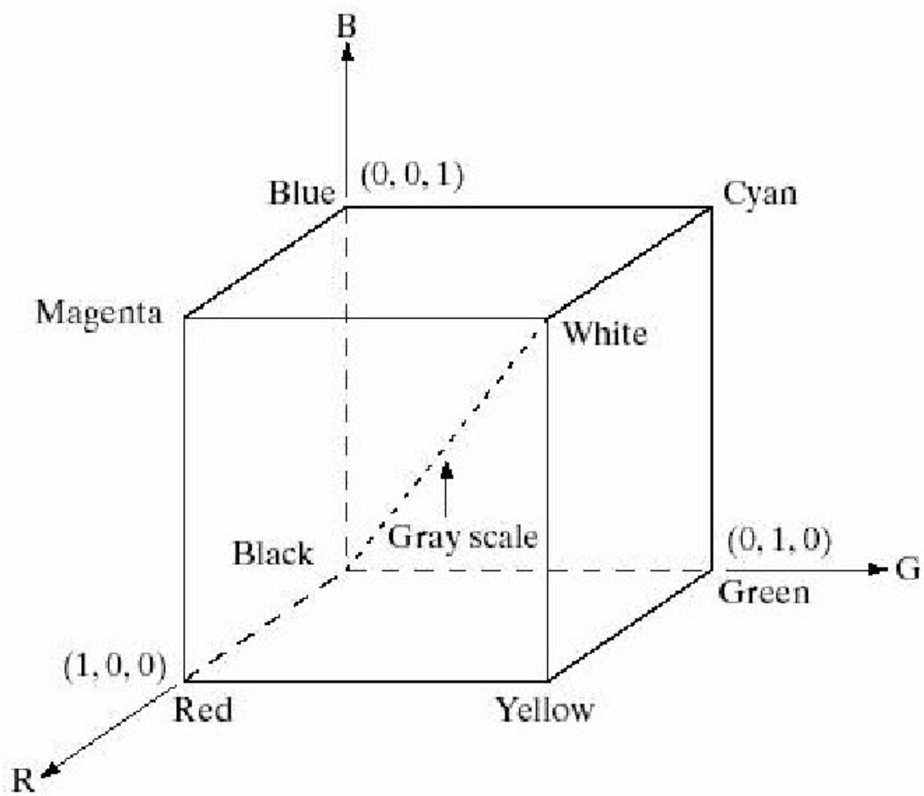
6.2.1 The RGB Colour Model

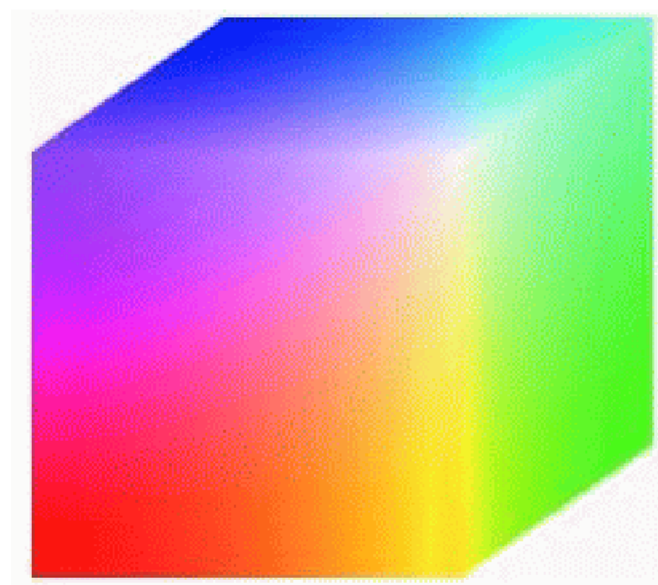
Based on Cartesian coordinate system

Pixel depth: # of bits used to represent a pixel in RGB space

Each R, G, & B image = 8-bit image ⇒ depth = 24 bits ⇒ "full-colour" image ⇒ total # of colours = $(2^8)^3 = 16777216$

Cube with all 16 777 216 colours:



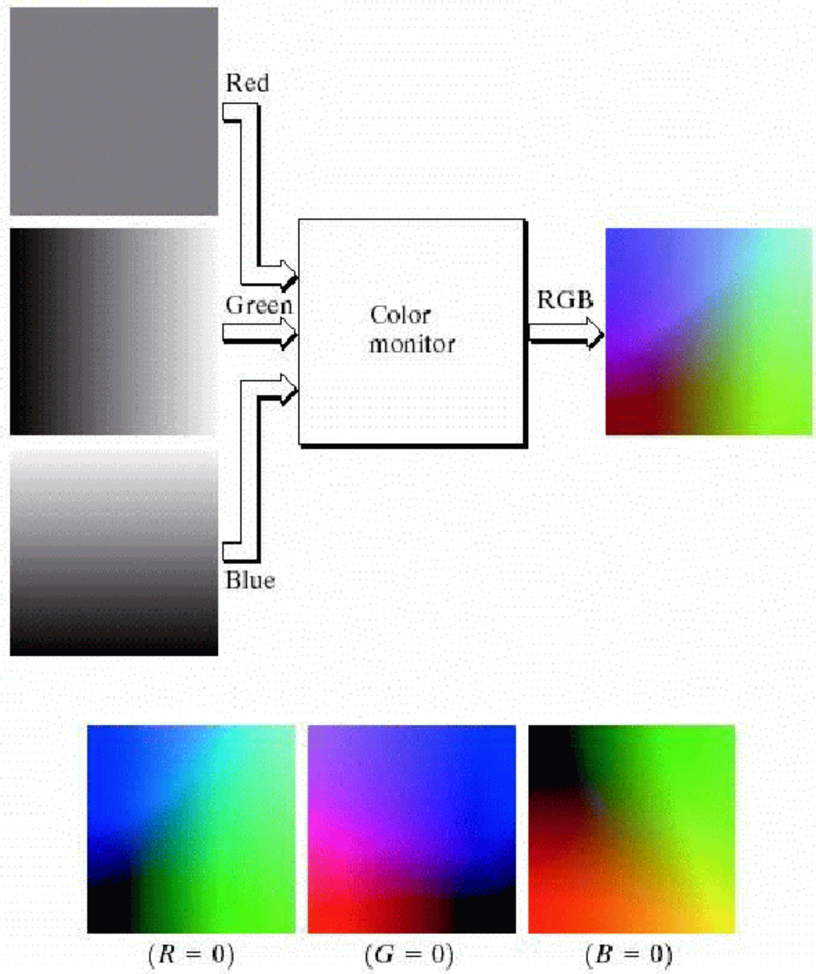


Example 6.1: Hidden face planes and cross section of cube

Mathematically normalized values: $[0, 1]$
Actual pixel values (computer): $0, 1, \ldots, 255$

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.



Many systems limited to 256 colours (or not necessary to use more)

Safe RGB colours: subset of colours likely to be produced faithfully, reasonable independently of hardware capabilities

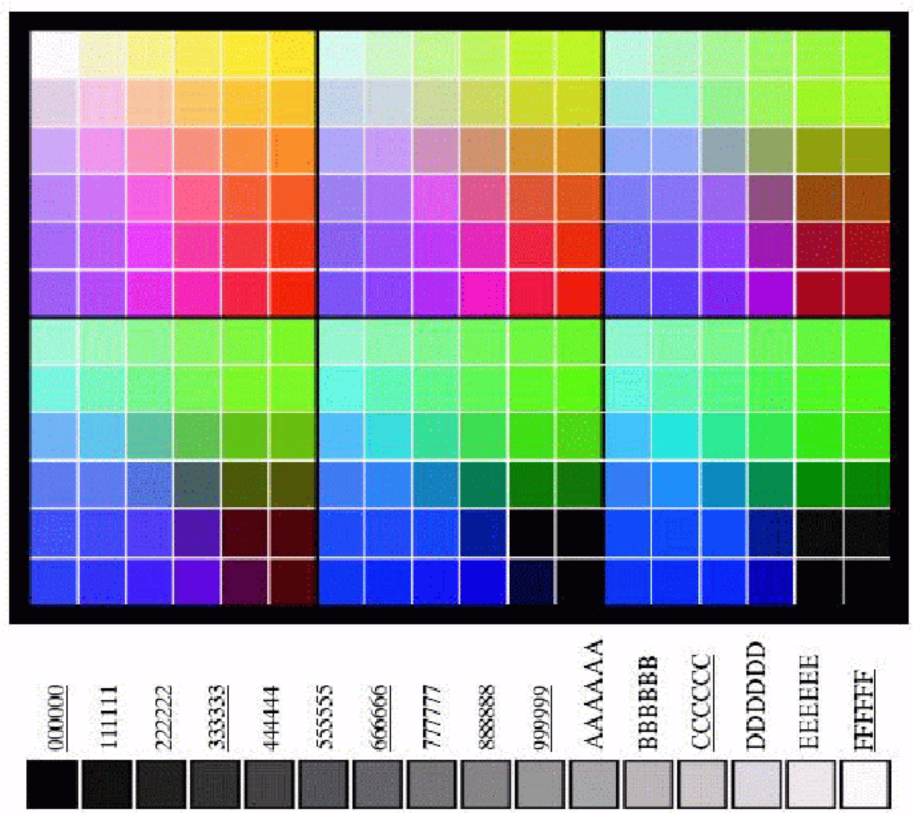
Only 216 colours are common to most systems
$\Rightarrow$ **each RGB value can only be 0, 51, 102, 153, 204, or 255**
$\Rightarrow$ $(6)^3$ **= 216 possible value (all divisible by 3)**
$\Rightarrow$ **hexagonal number system:**

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.

Note: $(33)_{16} = 3 \times 16^1 + 3 \times 16^0 = 48 + 3 = (51)_{10}$
$(\mathrm{CC})_{16} = 12 \times 16^1 + 12 \times 16^0 = 192 + 12 = (204)_{10}$
$(\mathrm{FF})_{16} = (255)_{10} = (11111111)_2$
A grouping of two hex numbers forms an 8-bit byte

Purest red: FF0000
Black: 000000
White: FFFFFF



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).

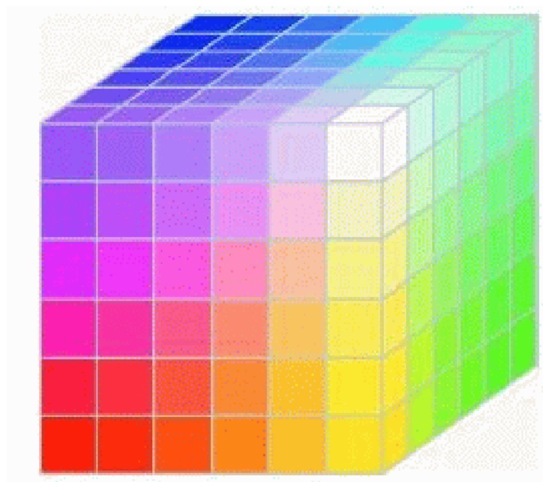
First array (block):

First row	FFFFFF **(white), FFFFCC, FFFF99, etc.**
Second row	FFCCFF, FFCCCC, FFCC99, **etc.**
Final square	FF0000 **(brightest possible red)**

Second array (block) starts with CCCCCC

Final square of last array: 000000 **(black)**

The RGB safe-colour cube (colours only on surface planes)



6.2.2 The CMY and CMYK colour models

- Cyan, magenta, yellow: sec. colours of light / prim. colours of pigment
- For example, when a surface coated with cyan pigment is illuminated with white light, no red light is reflected from the surface, that is, cyan subtracts red light from reflected white light
- Printers/copiers require CMY data input or do conversion:

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

Theoretically equal amounts of the pigment primaries should produce black; in practice a muddy-looking black

To produce true black (predominant in printing), a fourth colour, black is added $\Rightarrow$ CMYK colour model

6.2.3 The HSI colour model

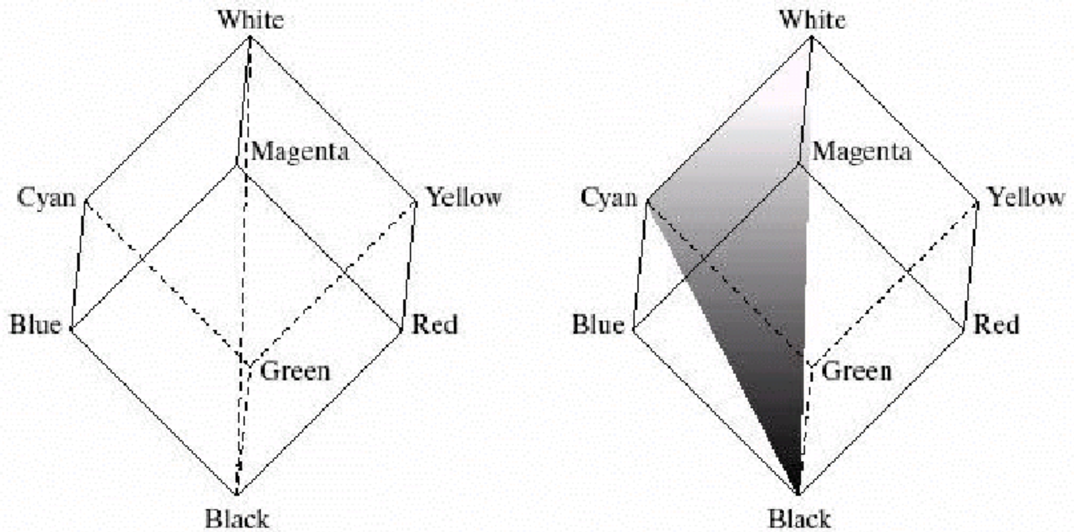
Humans describe a colour object by its hue, saturation and brightness (see previous lecture for definitions)

HSI model decouples intensity component from colour-carrying information $\Rightarrow$ ideal tool for developing IP algorithms

RGB is ideal for colour image generation (camera, monitor)

Relationship between the RGB and HSI models

Figure 6.7: Colour cube on black vertex $(0, 0, 0)$, with white vertex $(1, 1, 1)$ directly above it
Intensity axis (grays) joins white and black vertices



a b

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

Intensity:	**Plane perpendicular to intensity axis containing colour point** **Intensity: intersection of plane with intensity axis**
Saturation:	**Increases as a function of distance from intensity axis (saturation is zero on the axis)**
Hue:	**Consider plane defined by three points: black, white and cyan** **All points in this plane have the same hue, i.e. cyan** **(recall from section 6.1 that all colours generated by three colours lie in the triangle defined by those colours)**

Planes perpendicular to intensity axis...

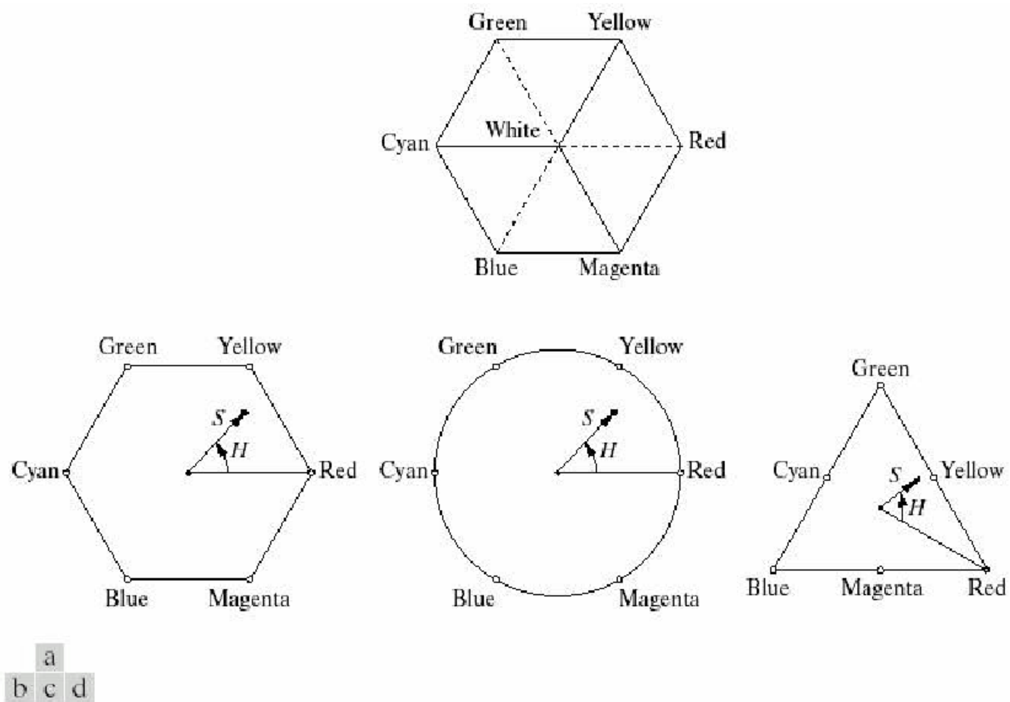
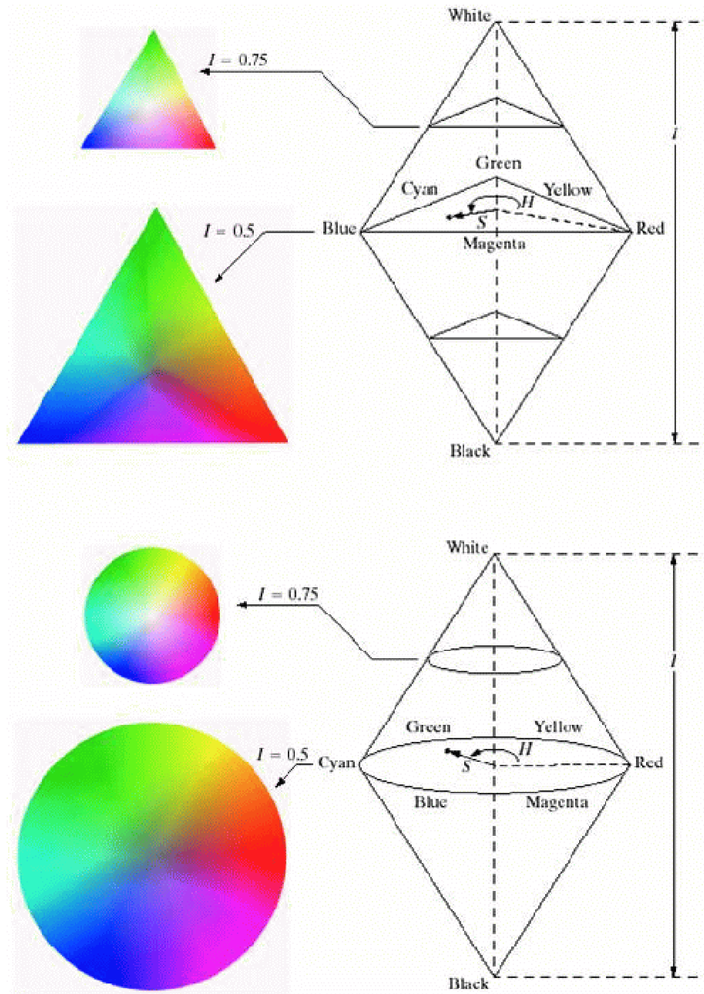


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

- **Angle between primary (or secondary) colours:** 120°
- **Angle between primary and secondary colours:** 60°
- **Hue determined by angle from reference point (usually red)**
- **Saturation is length of vector from origin to point**
- **Shape (hexagon, circle, triangle) does not matter**



Converting colours from RGB to HSI: $H = \begin{cases} \theta & \textbf{if } B \le G \\ 360 - \theta & \textbf{if } B > G \end{cases}$

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

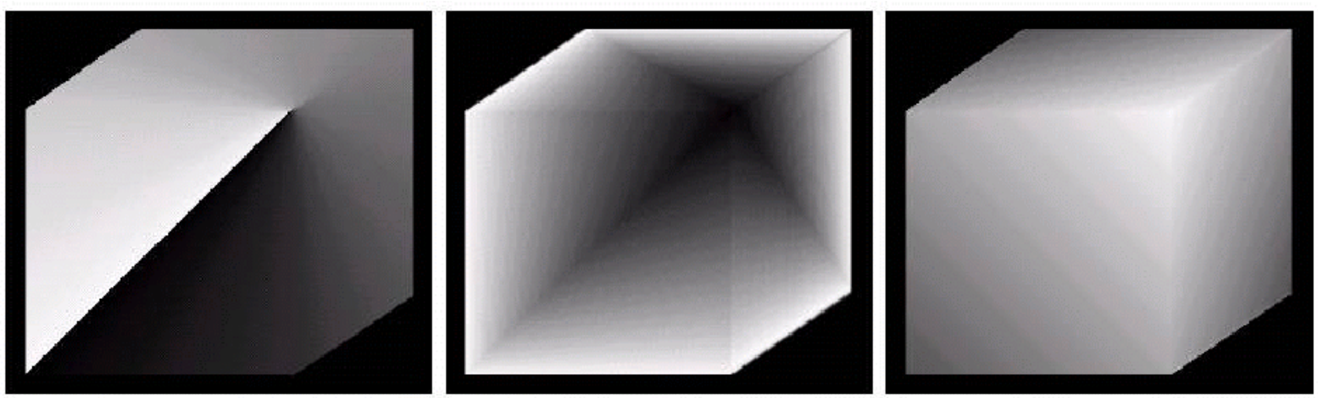
$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)]$$
$$I = \frac{1}{3}(R+G+B)$$

Derivation of these formulas is tedious and is not discussed

Converting colours from HSI to RGB

See G&W: page 433/434

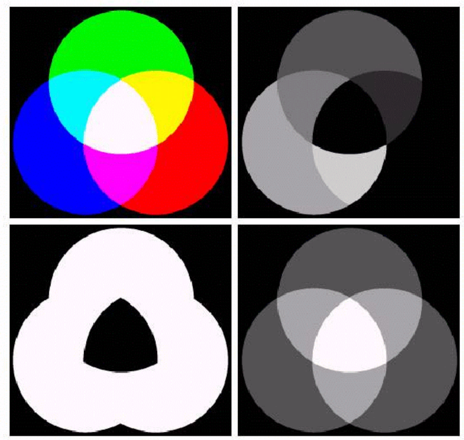
Example 6.2: HSI values of RGB colour cube (figure 6.8)



a b c

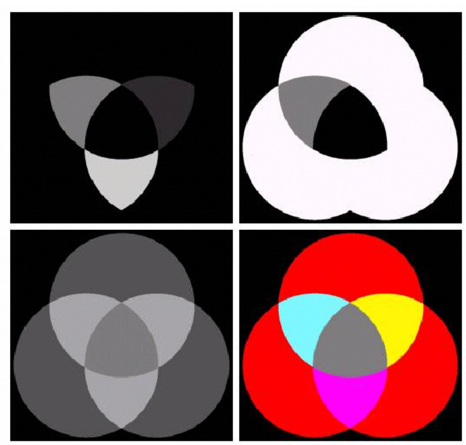
FIGURE 6.15 HSI components of the image in Fig. 6.8. (a) Hue, (b) saturation, and (c) intensity images.

Manipulating HSI component images



a b
c d

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



a b
c d

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