



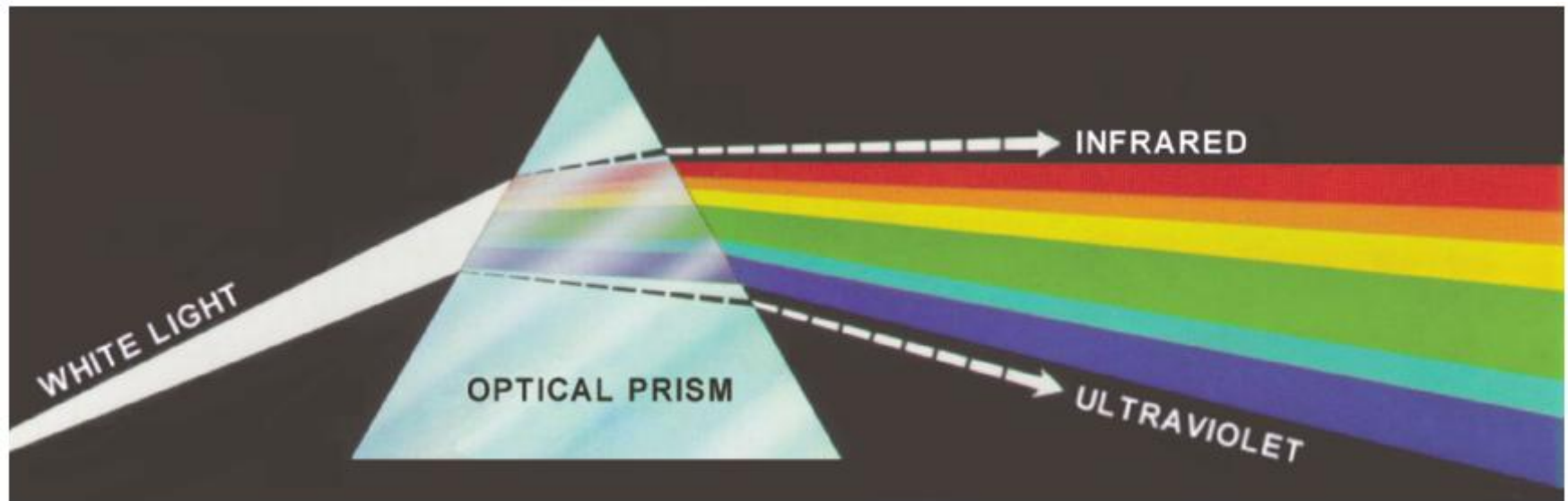
Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

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





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

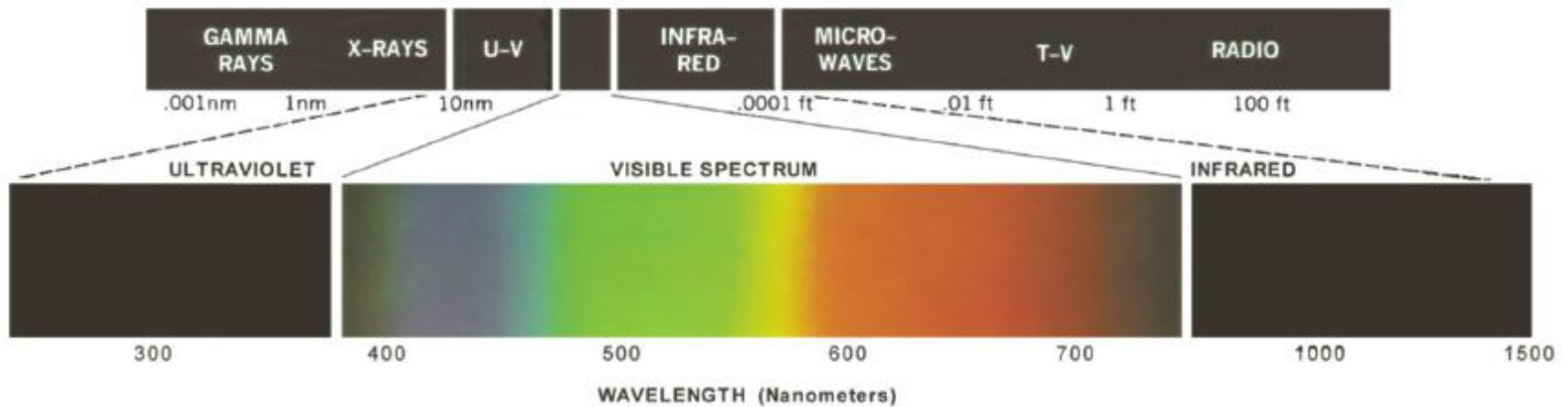


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

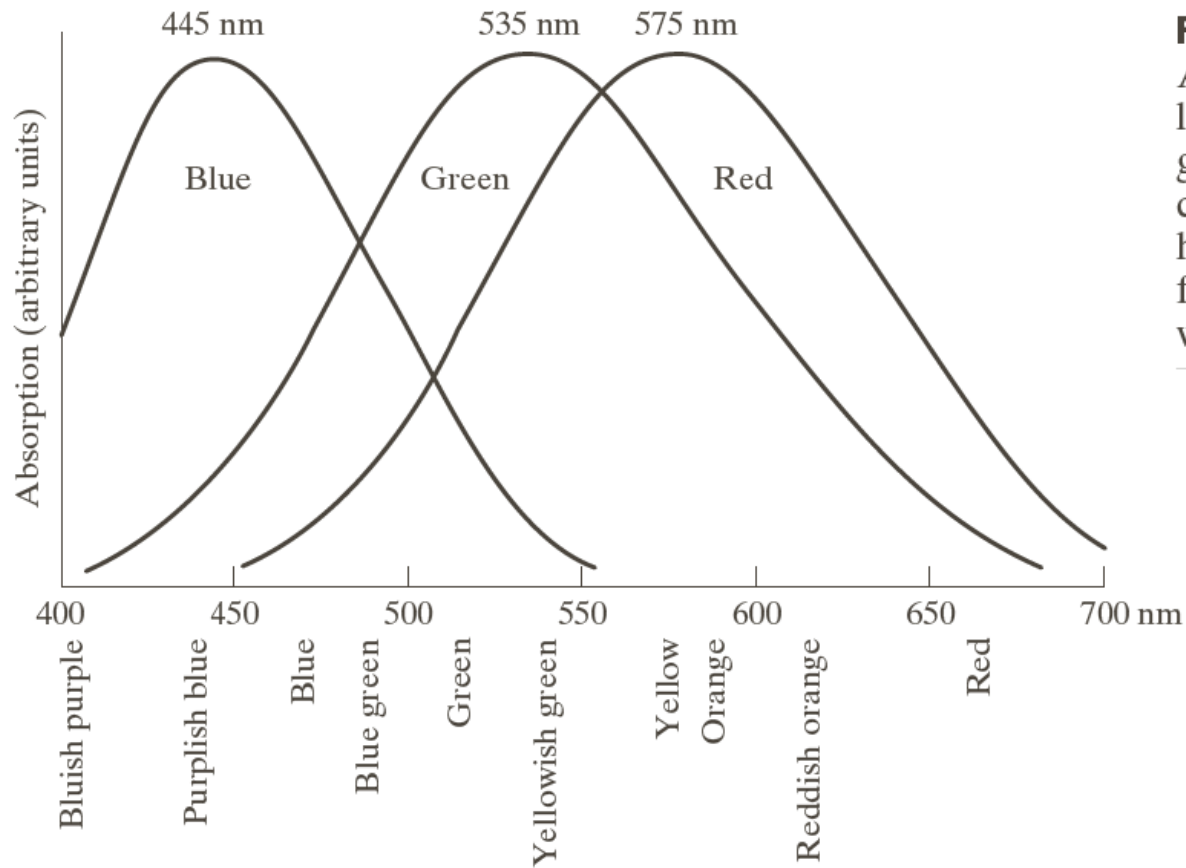


FIGURE 6.3
Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.

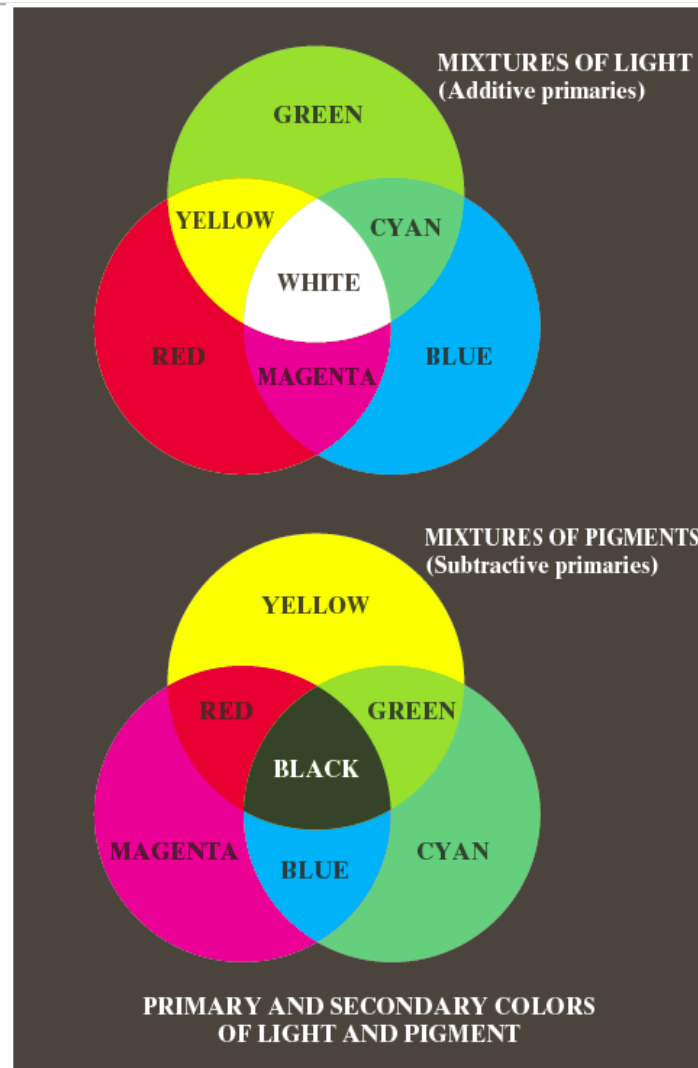


Digital Image Processing, 3rd ed.

Gonzalez & Woods

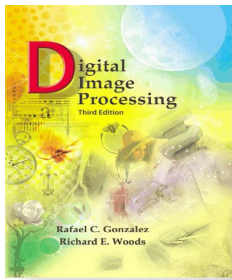
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a
b

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



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

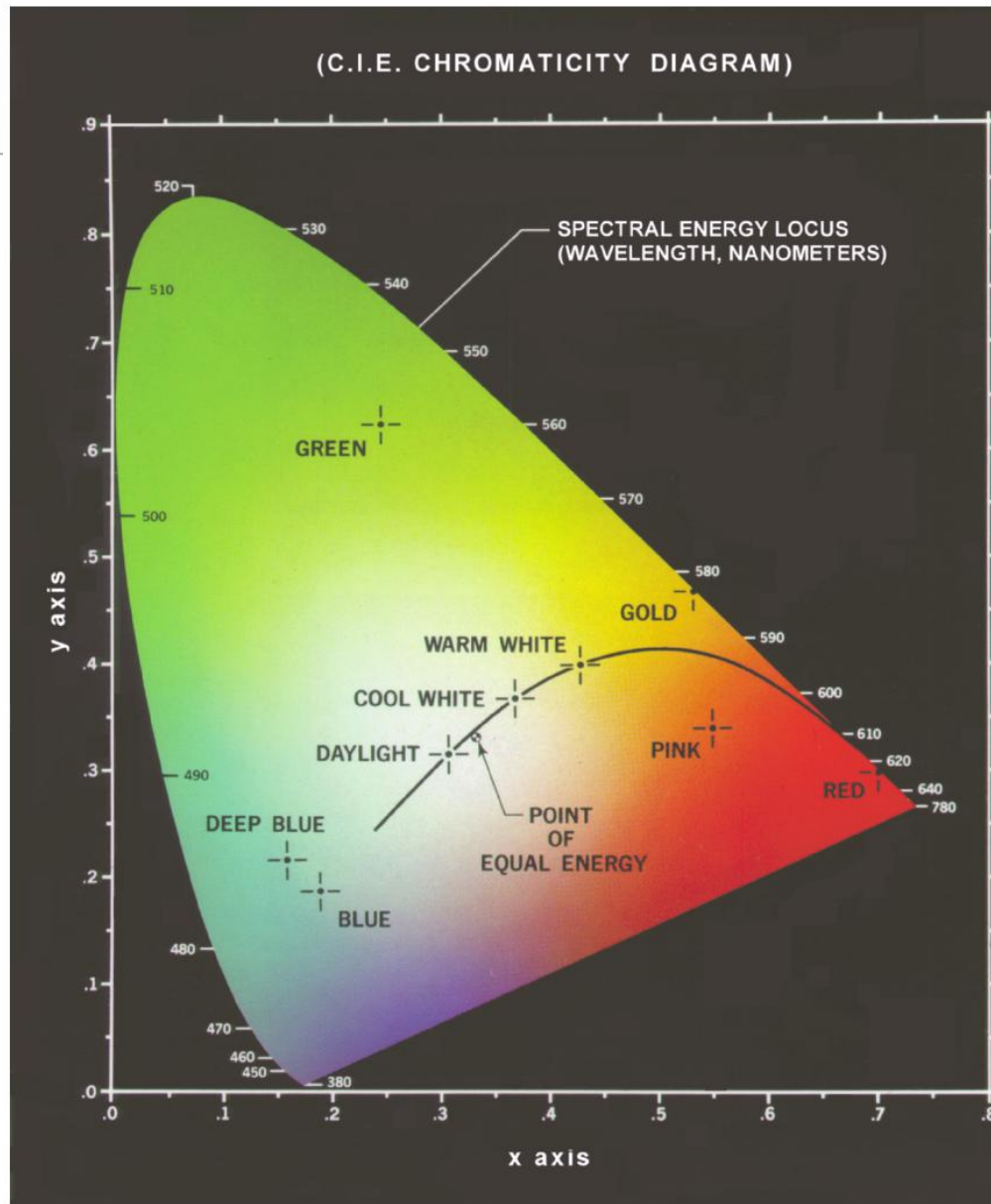
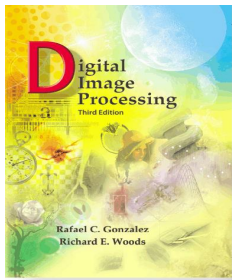


FIGURE 6.5
Chromaticity diagram.
(Courtesy of the General Electric Co., Lamp Business Division.)



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

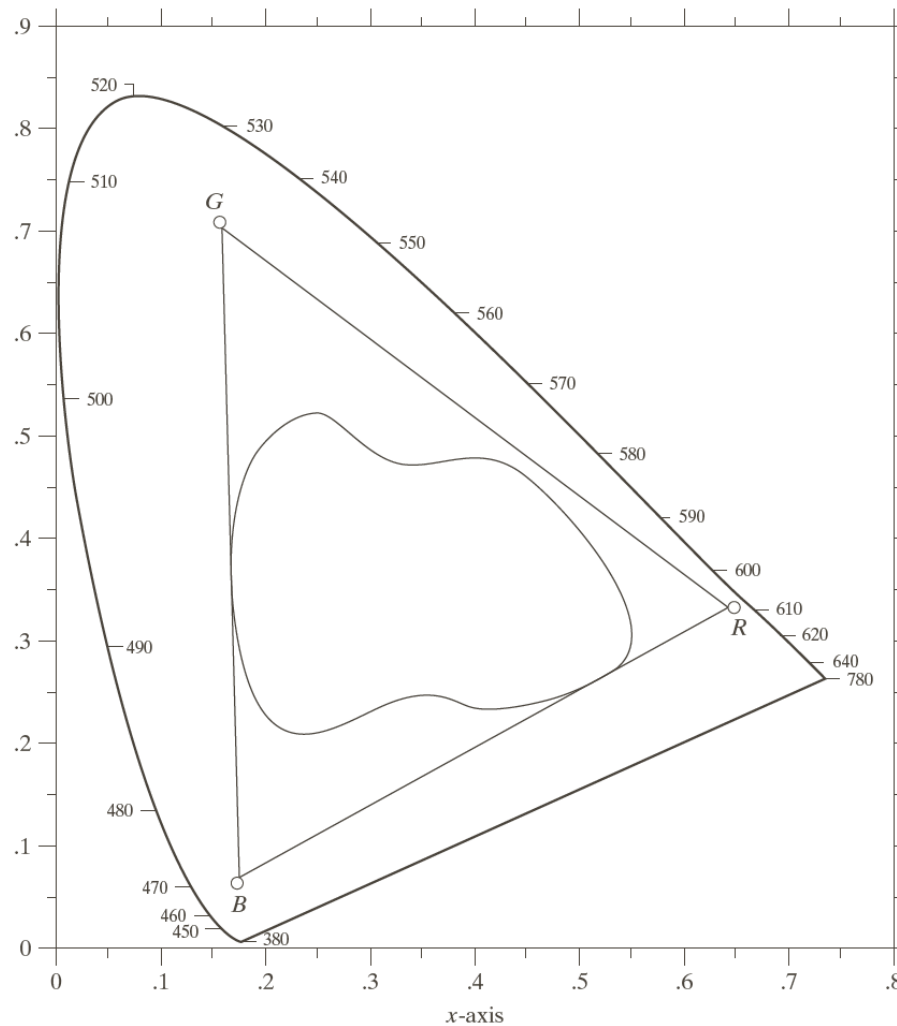
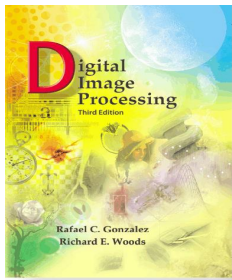


FIGURE 6.6
Typical color gamut of color monitors (triangle) and color printing devices (irregular region).



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

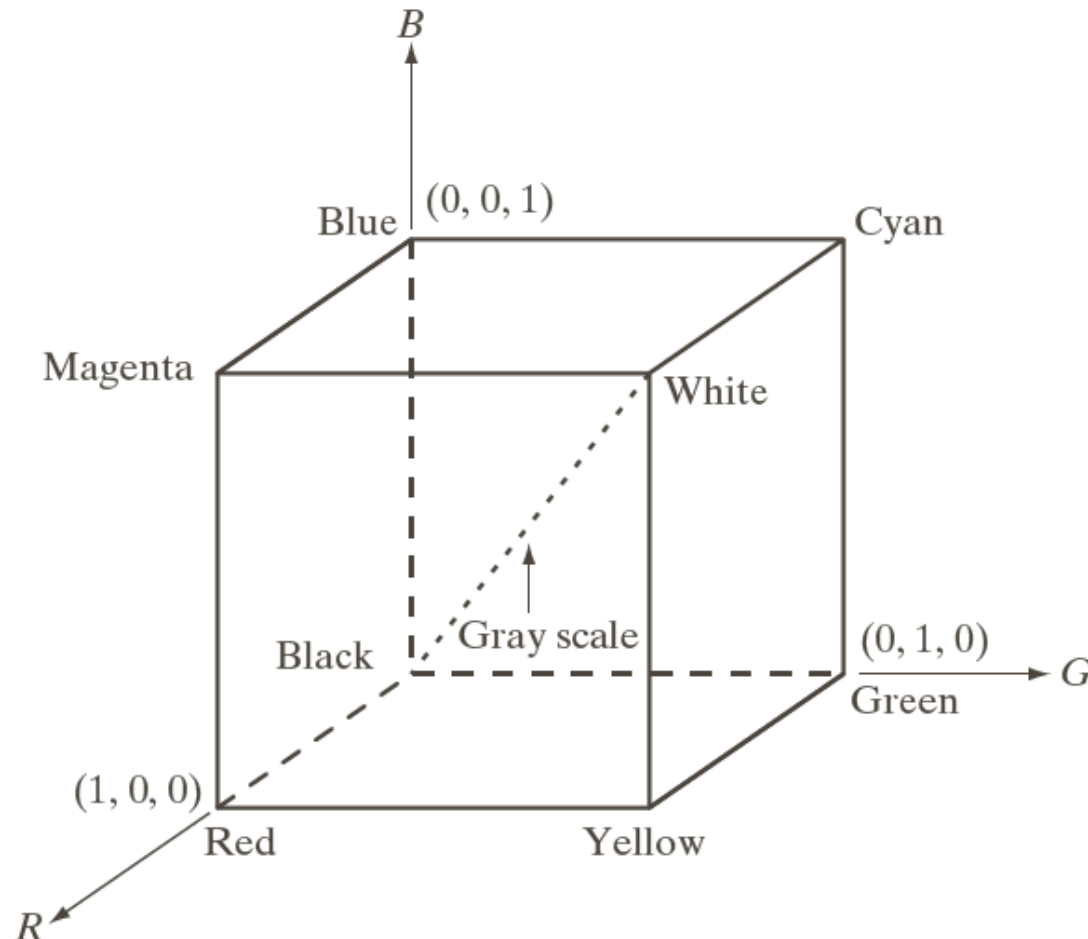


FIGURE 6.7

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



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



FIGURE 6.8 RGB
24-bit color cube.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

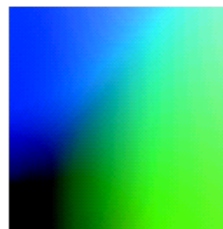
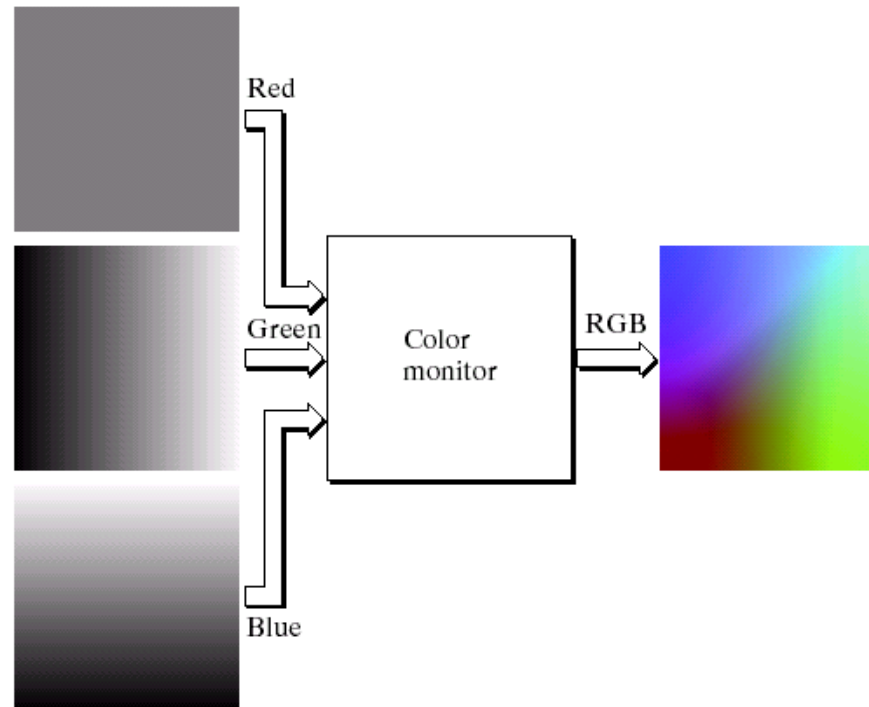
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

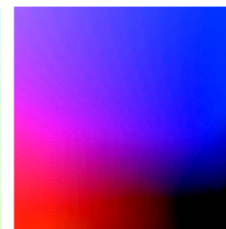
a
b

FIGURE 6.9

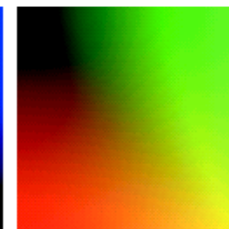
(a) Generating the RGB image of the cross-sectional color plane $(127, G, B)$.
(b) The three hidden surface planes in the color cube of Fig. 6.8.



$(R = 0)$



$(G = 0)$



$(B = 0)$

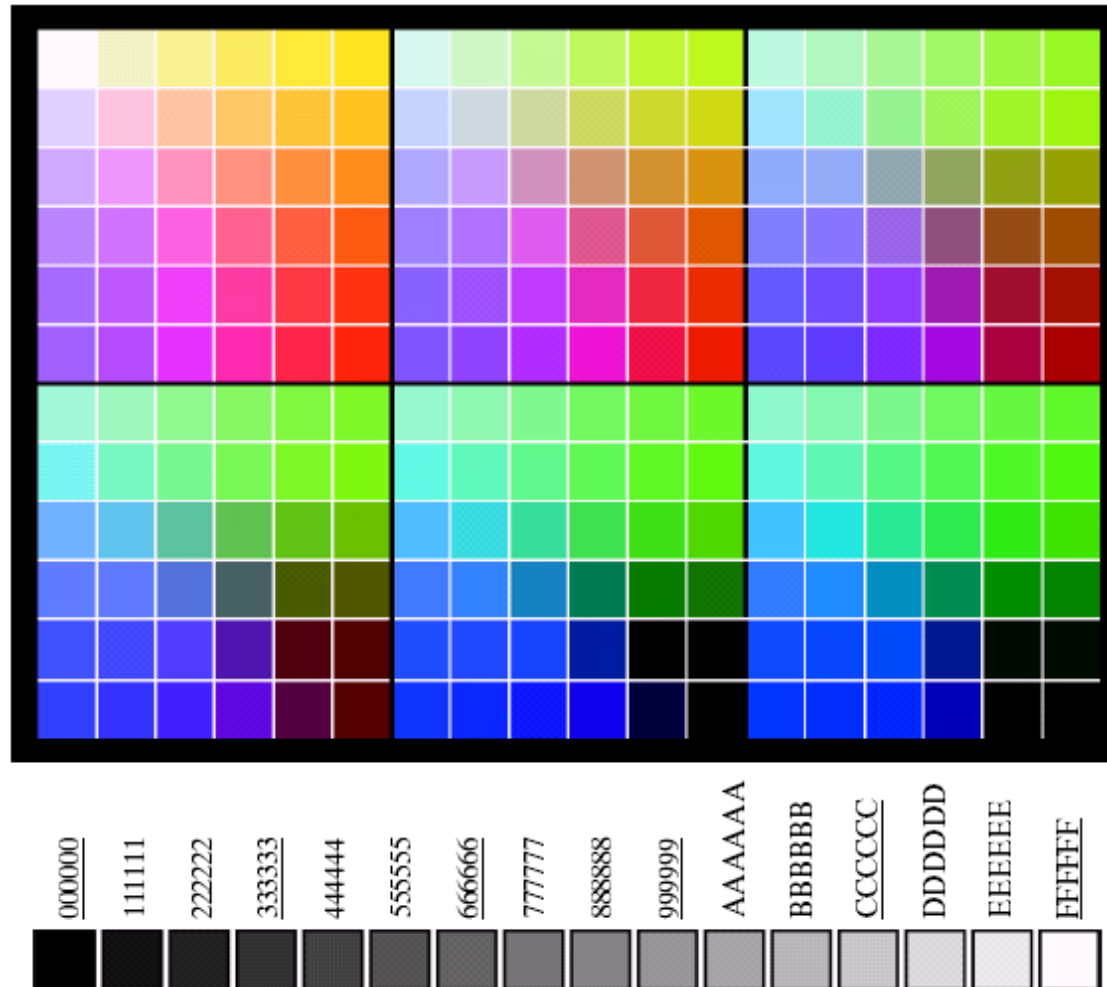


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



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).



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

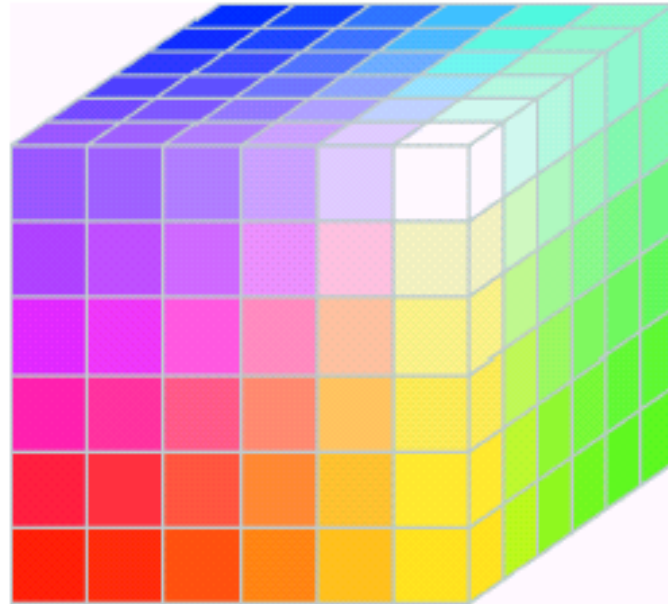


FIGURE 6.11 The RGB safe-color cube.

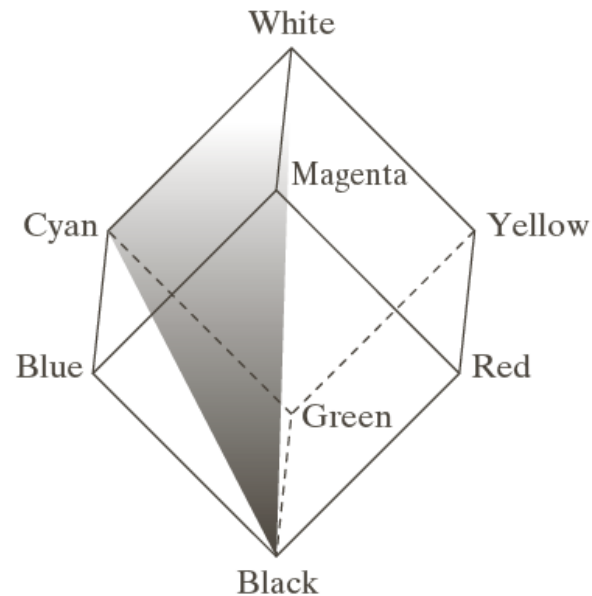
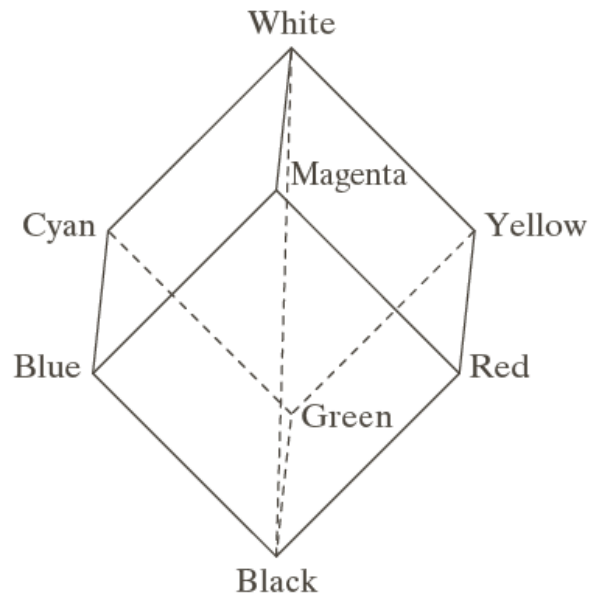


Digital Image Processing, 3rd ed.

Gonzalez & Woods

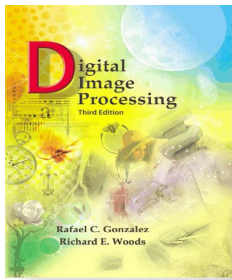
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b

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



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

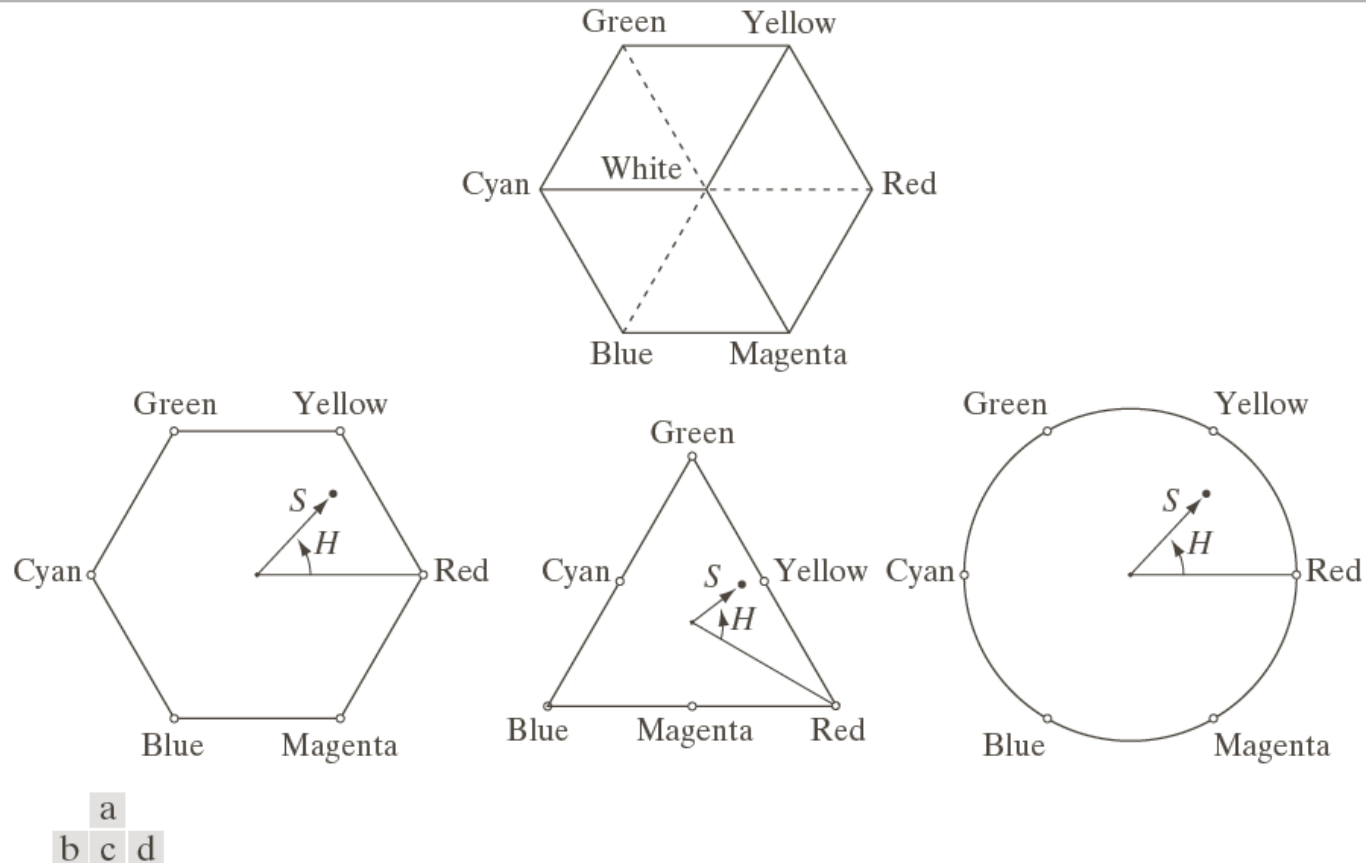
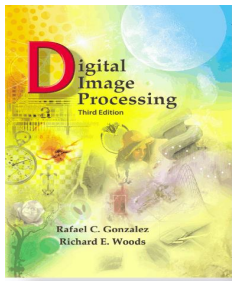


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

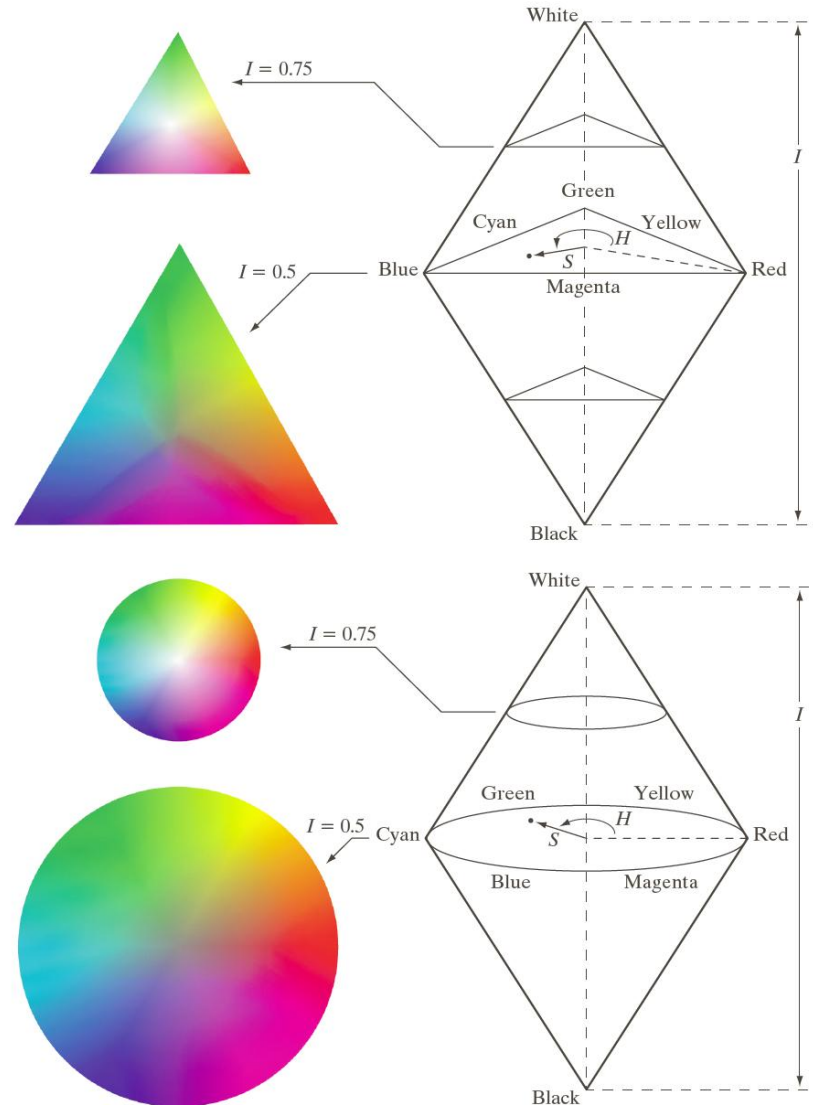


Digital Image Processing, 3rd ed.

Gonzalez & Woods

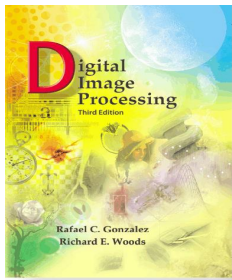
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



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.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

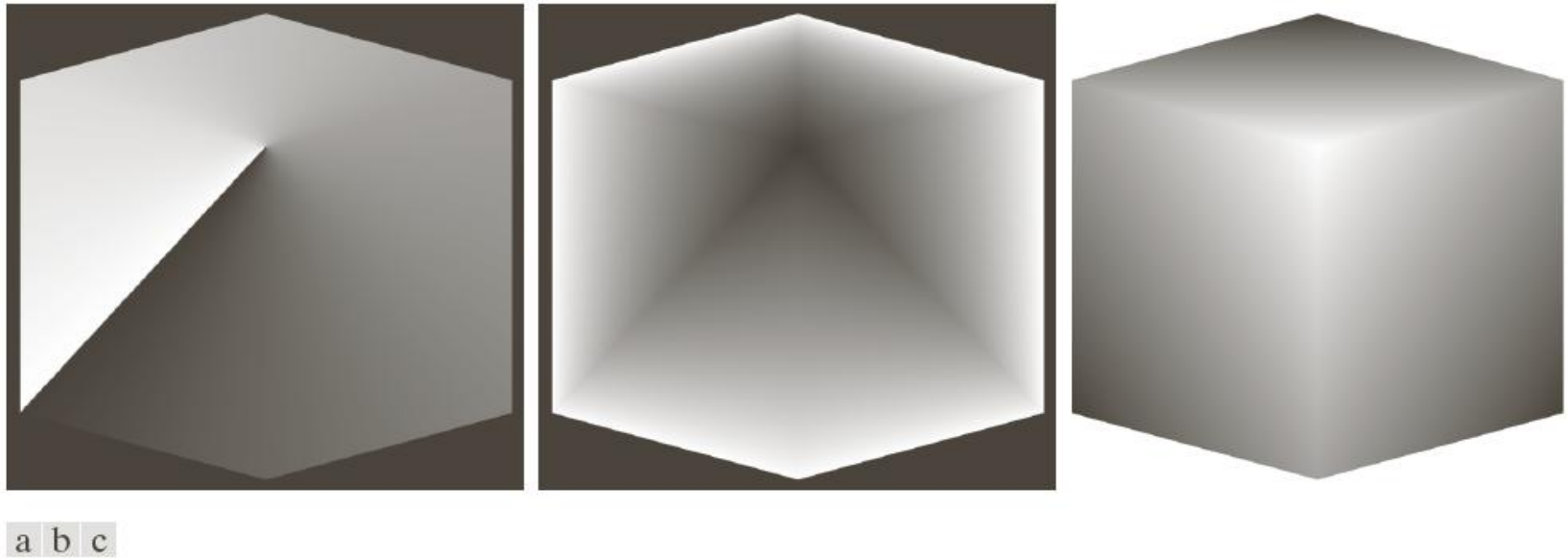


FIGURE 6.15 HSI components of the image in Fig. 6.8. (a) Hue, (b) saturation, and (c) intensity images.

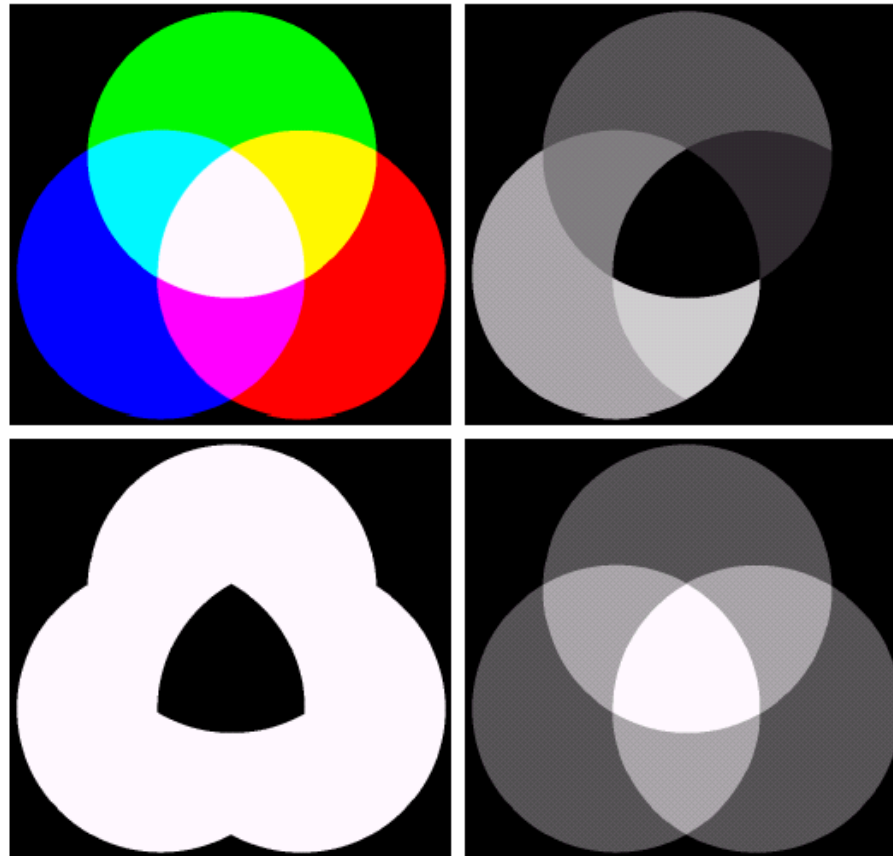


Digital Image Processing, 3rd ed.

Gonzalez & Woods

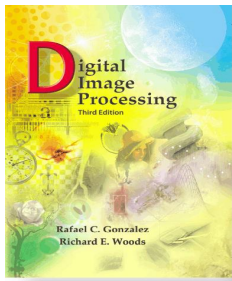
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



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.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

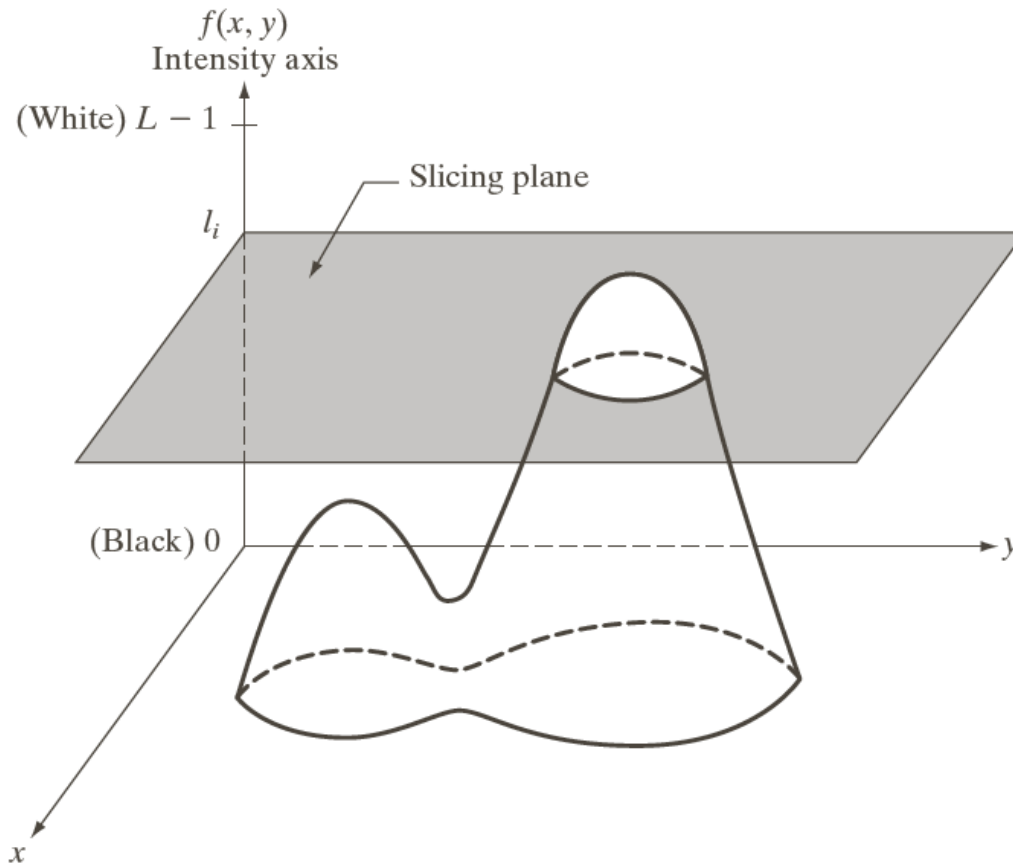


FIGURE 6.18
Geometric interpretation of the intensity-slicing technique.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

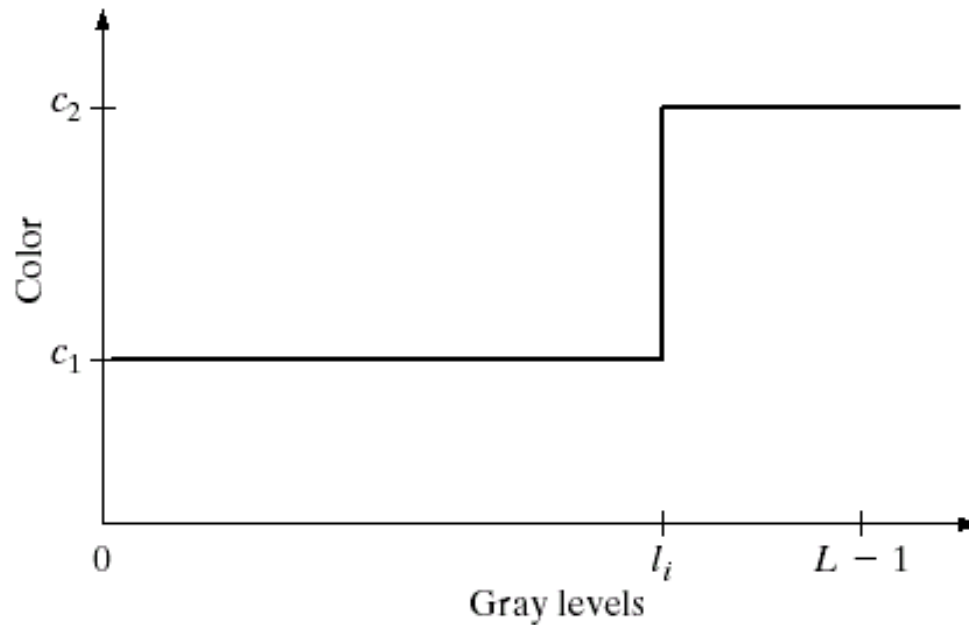


FIGURE 6.19 An alternative representation of the intensity-slicing technique.

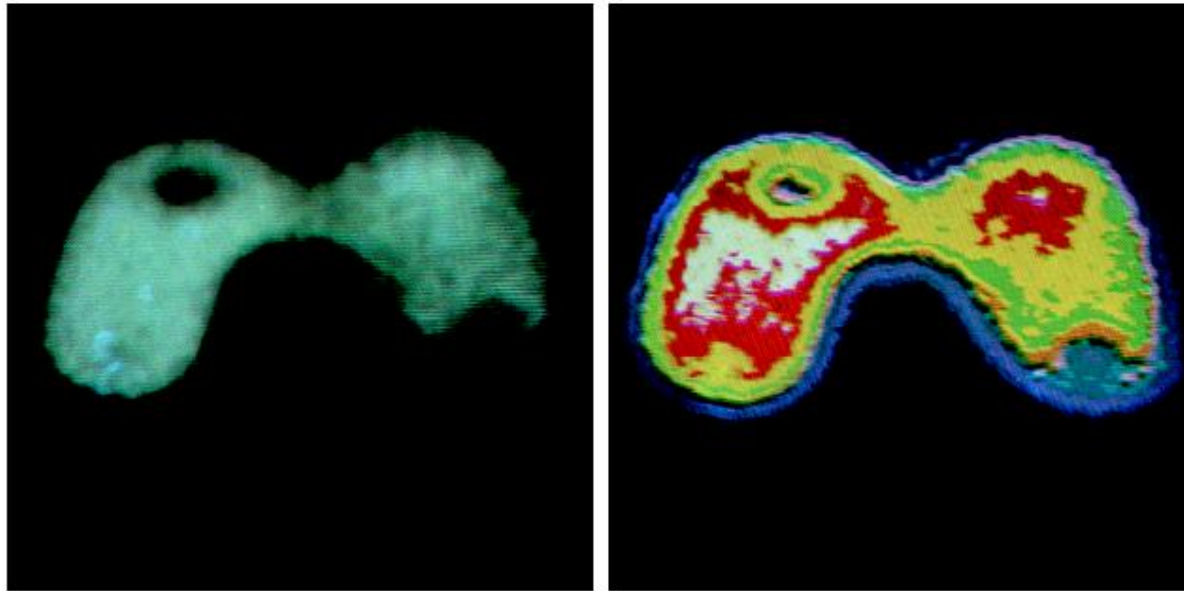


Digital Image Processing, 3rd ed.

Gonzalez & Woods

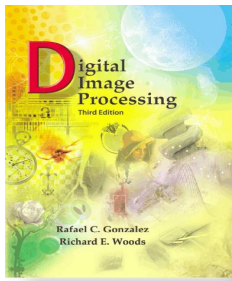
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b

FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)



Digital Image Processing, 3rd ed.

Gonzalez & Woods

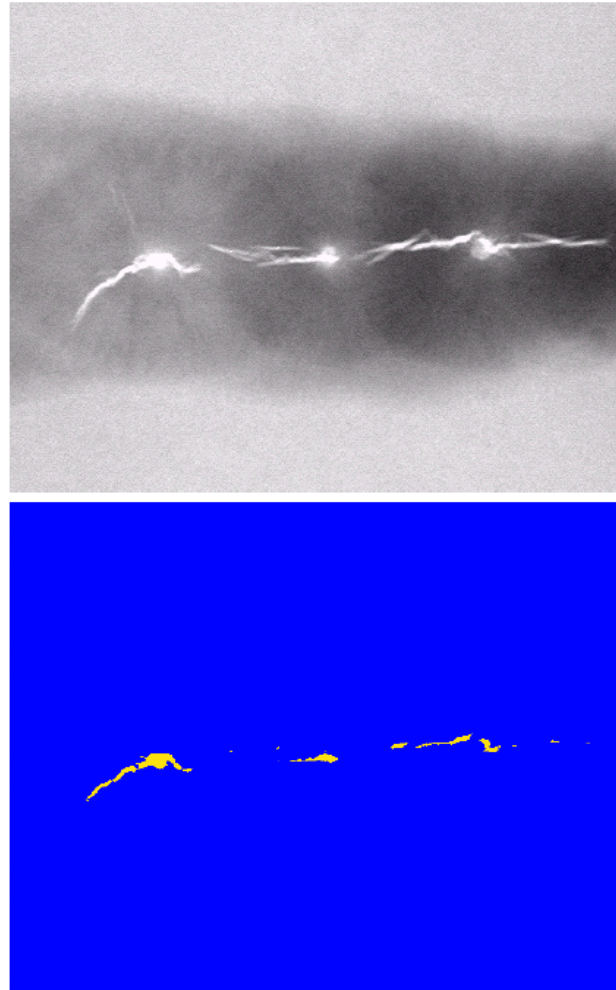
www.ImageProcessingPlace.com

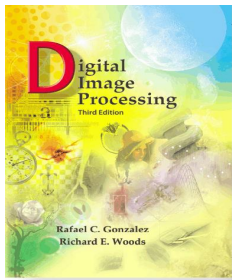
Chapter 6 Color Image Processing

a
b

FIGURE 6.21

(a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

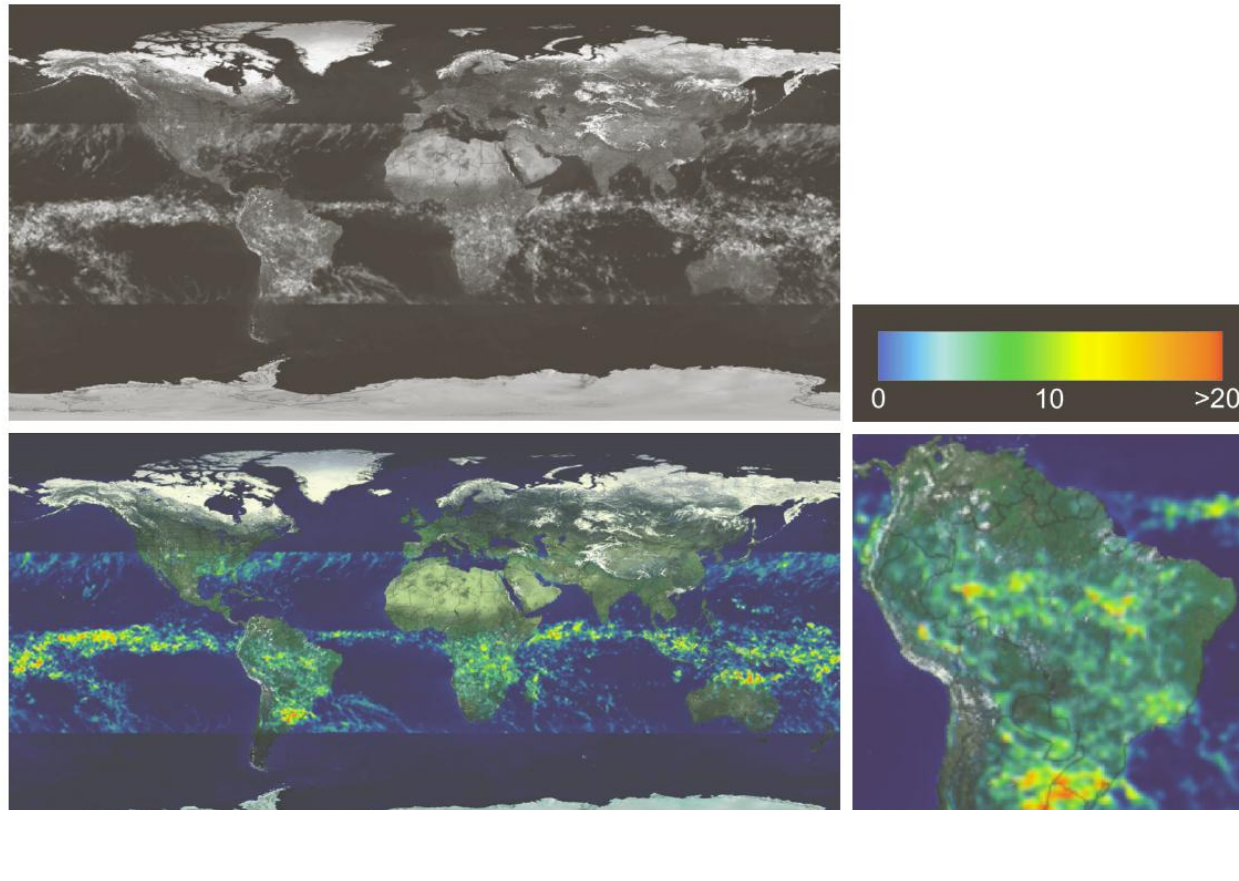


FIGURE 6.22 (a) Gray-scale image in which intensity (in the lighter horizontal band shown) corresponds to average monthly rainfall. (b) Colors assigned to intensity values. (c) Color-coded image. (d) Zoom of the South American region. (Courtesy of NASA.)



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

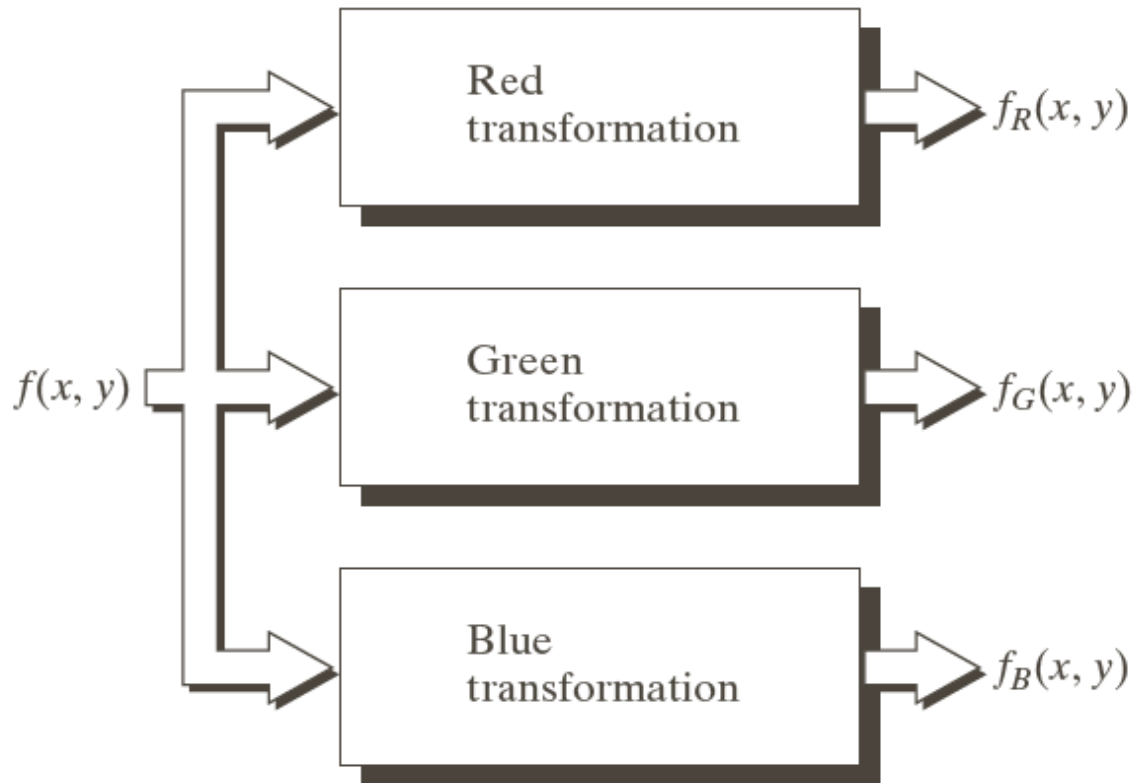


FIGURE 6.23
Functional block diagram for pseudocolor image processing. f_R , f_G , and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.

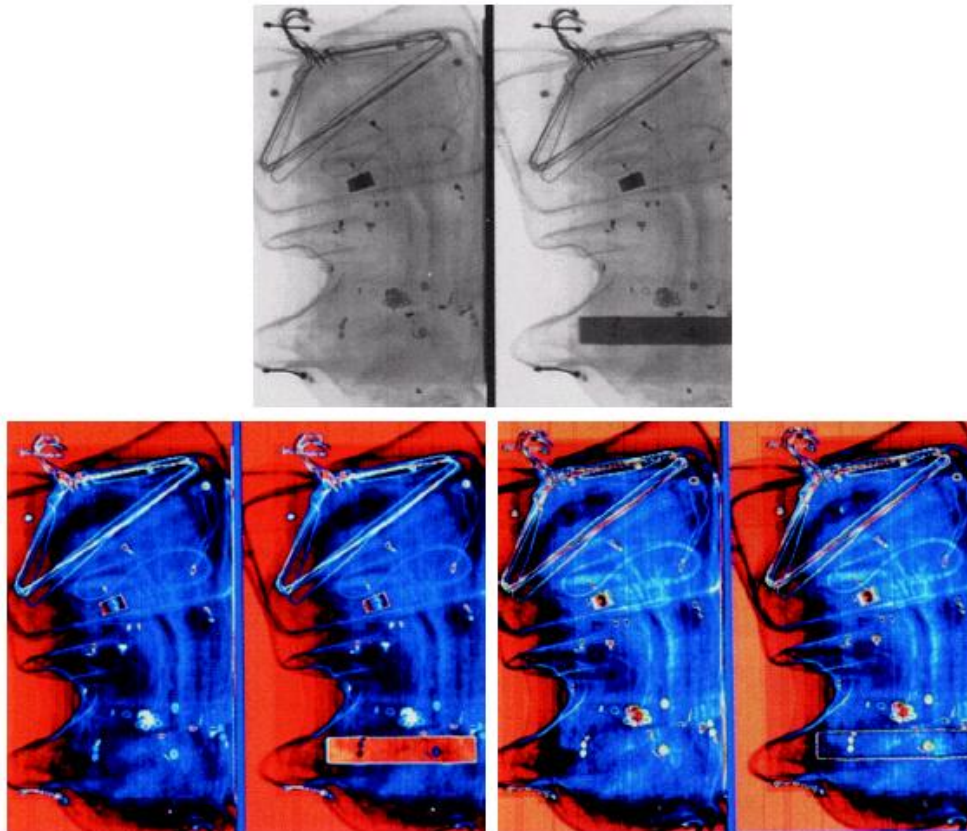


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



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.)

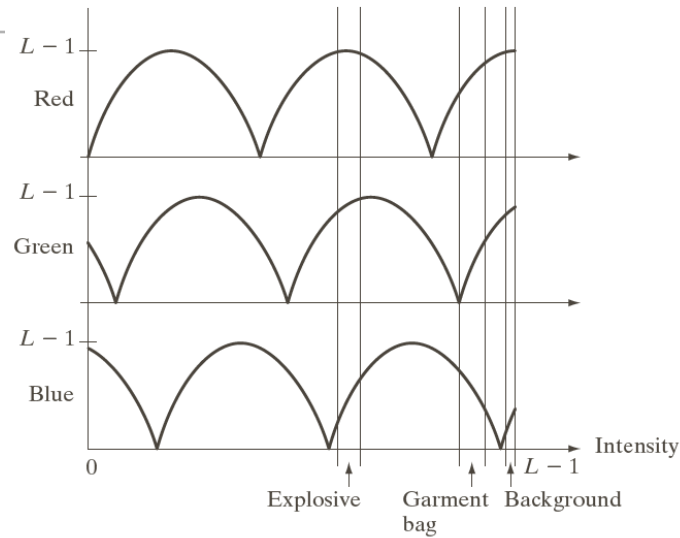


Digital Image Processing, 3rd ed.

Gonzalez & Woods

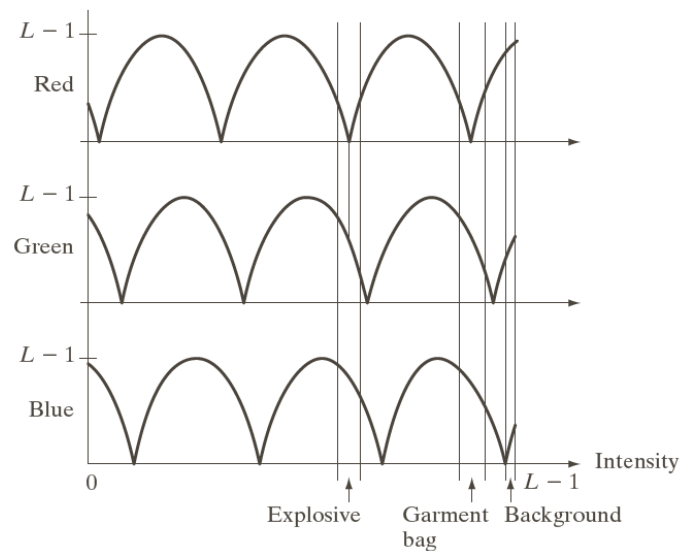
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a
b

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





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

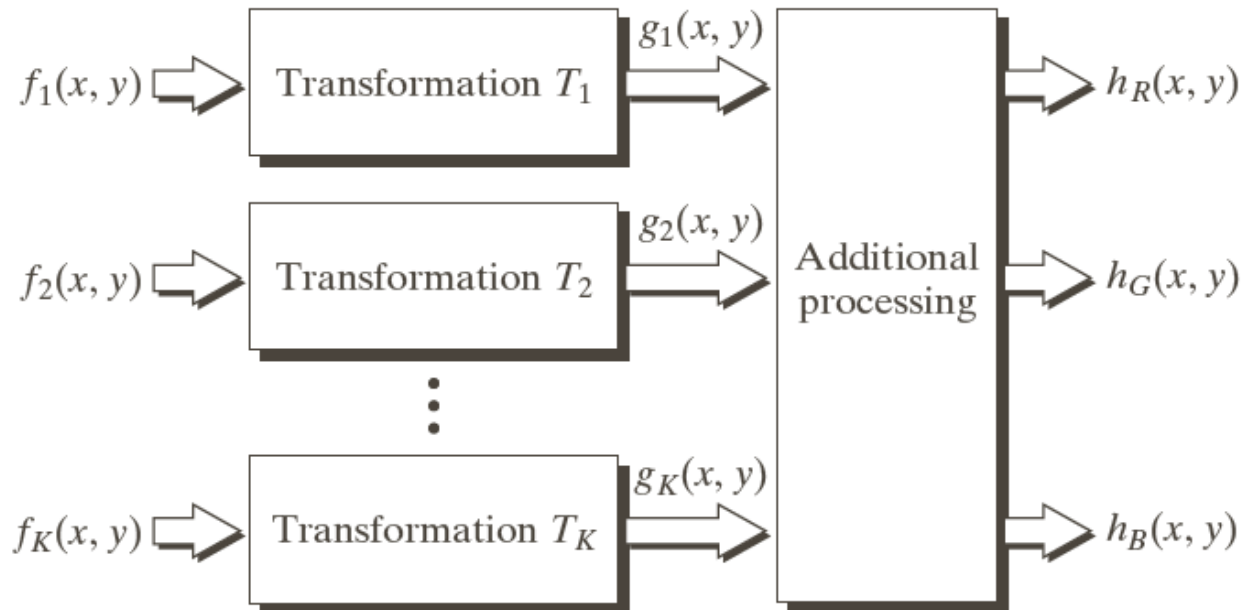
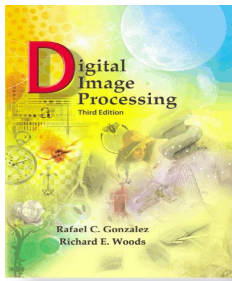


FIGURE 6.26 A pseudocolor coding approach used when several monochrome images are available.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

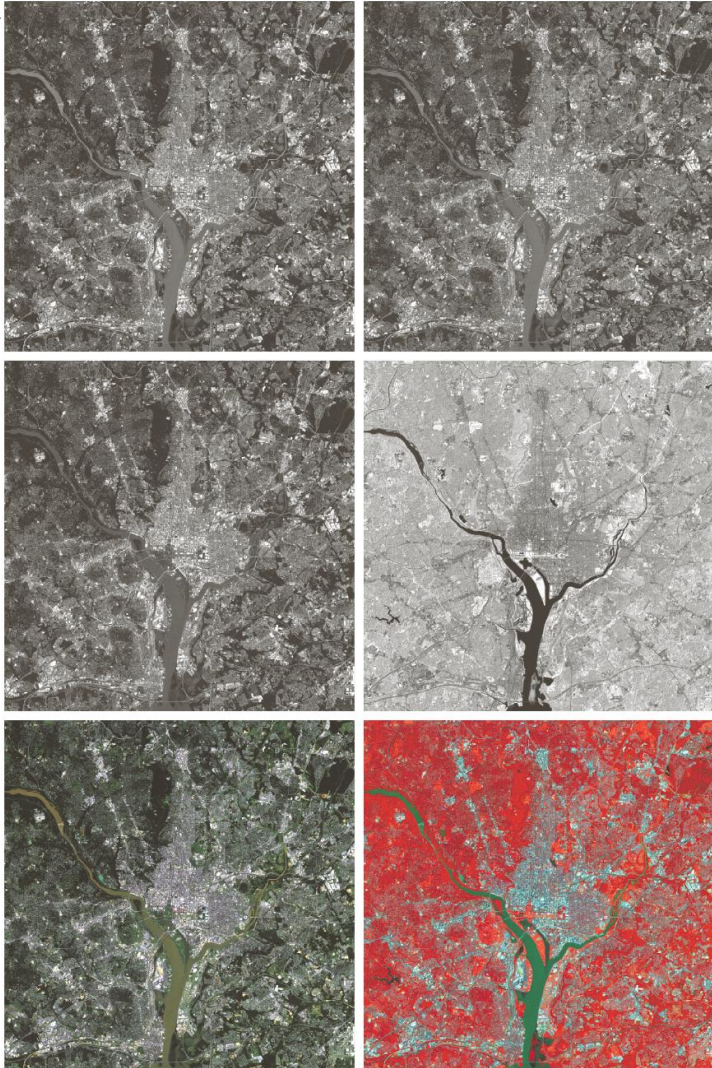


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral images courtesy of NASA.)

a	b
c	d
e	f

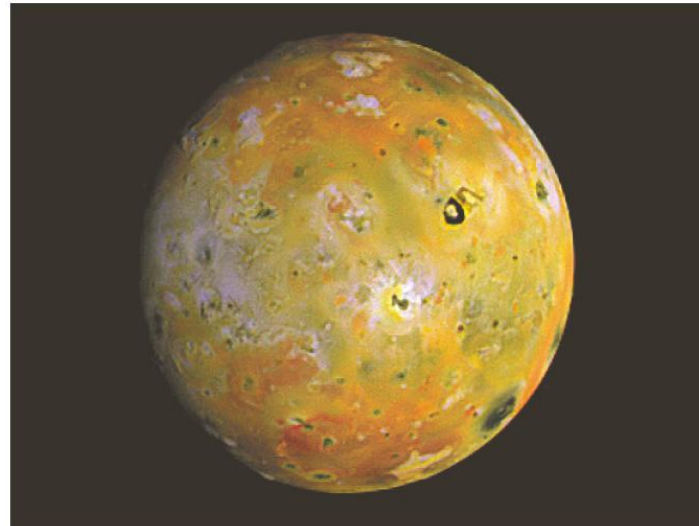


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

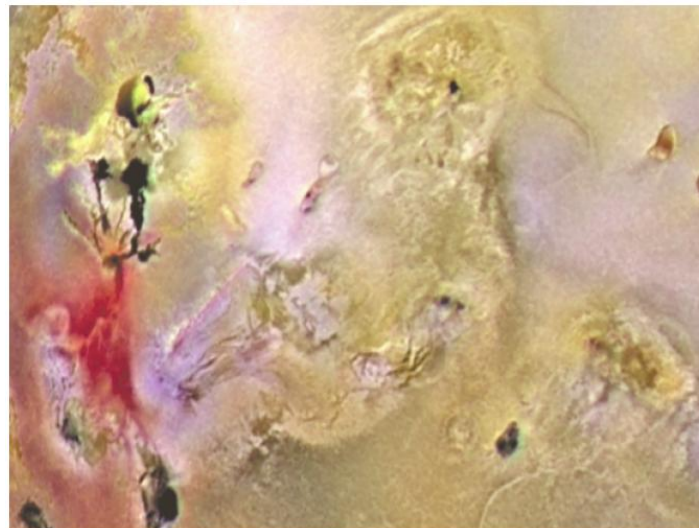


a

b

FIGURE 6.28

(a) Pseudocolor
rendition of
Jupiter Moon Io.
(b) A close-up.
(Courtesy of
NASA.)



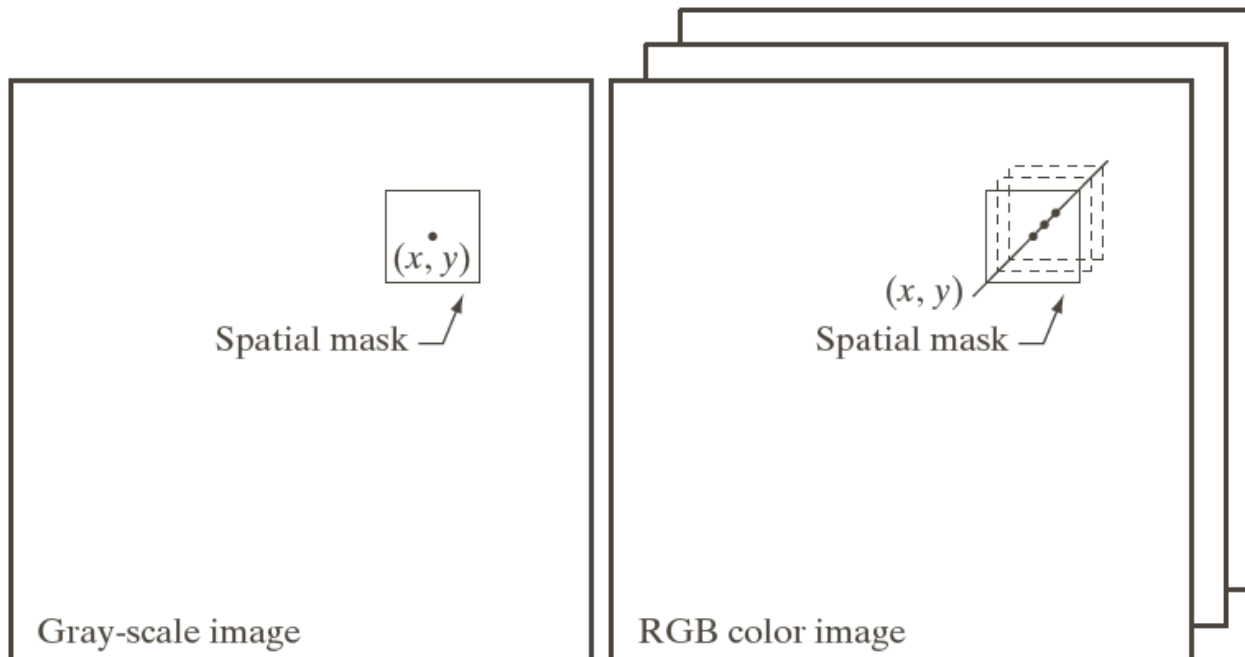


Digital Image Processing, 3rd ed.

Gonzalez & Woods

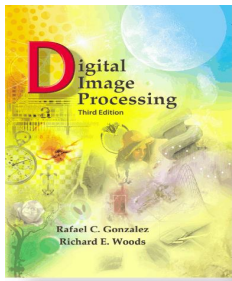
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b

FIGURE 6.29
Spatial masks for
gray-scale and
RGB color
images.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

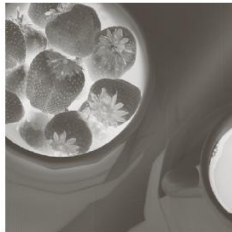
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



Full color

FIGURE 6.30 A full-color image and its various color-space components. (Interactive.)



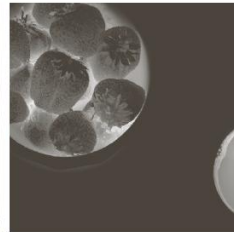
Cyan



Magenta



Yellow



Black



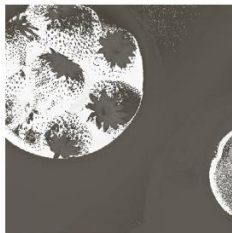
Red



Green



Blue



Hue



Saturation



Intensity



Digital Image Processing, 3rd ed.

Gonzalez & Woods

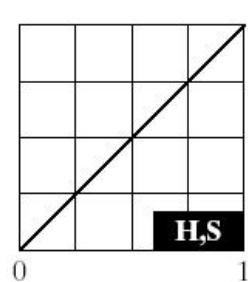
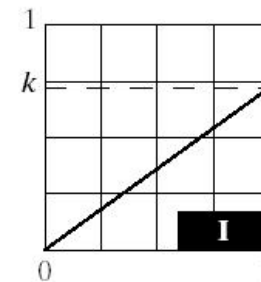
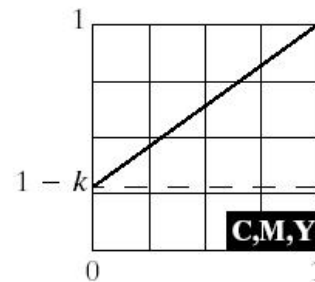
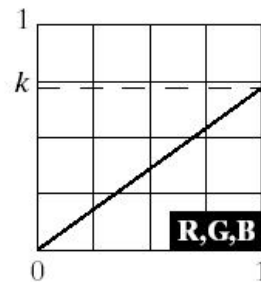
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

a b
c d e

FIGURE 6.31

Adjusting the intensity of an image using color transformations. (a) Original image. (b) Result of decreasing its intensity by 30% (i.e., letting $k = 0.7$). (c)–(e) The required RGB, CMY, and HSI transformation functions. (Original image courtesy of MedData Interactive.)





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

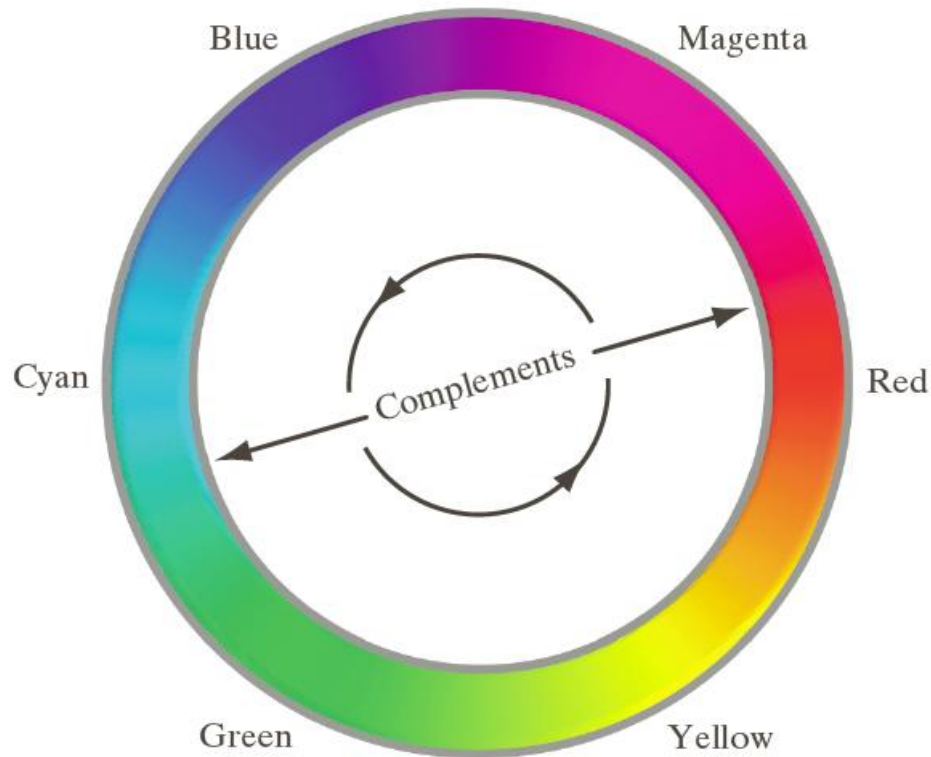
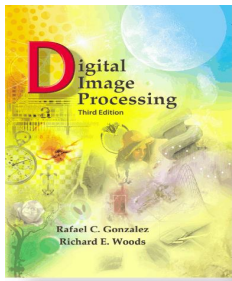


FIGURE 6.32
Complements on
the color circle.

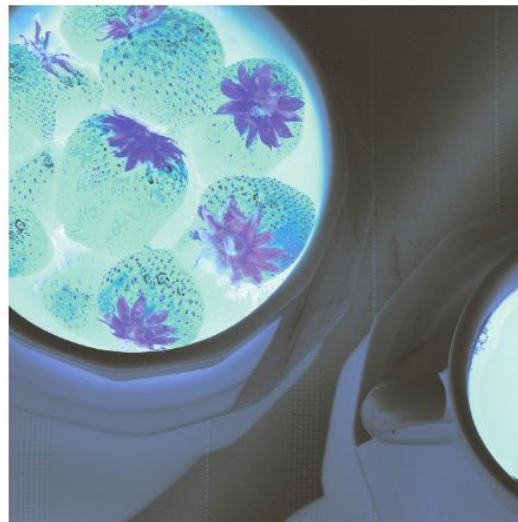
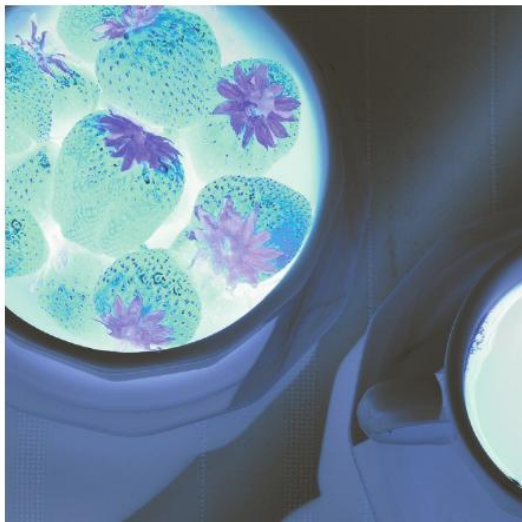
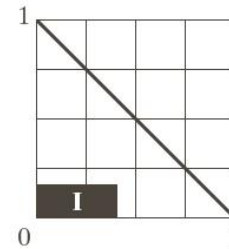
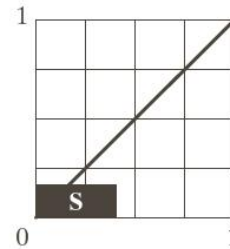
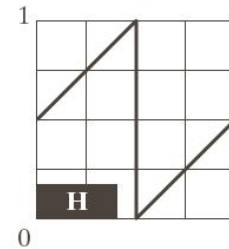
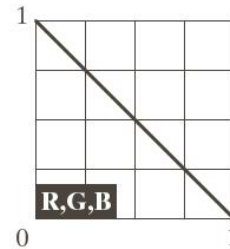


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a	b
c	d

FIGURE 6.33

Color complement transformations. (a) Original image. (b) Complement transformation functions. (c) Complement of (a) based on the RGB mapping functions. (d) An approximation of the RGB complement using HSI transformations.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

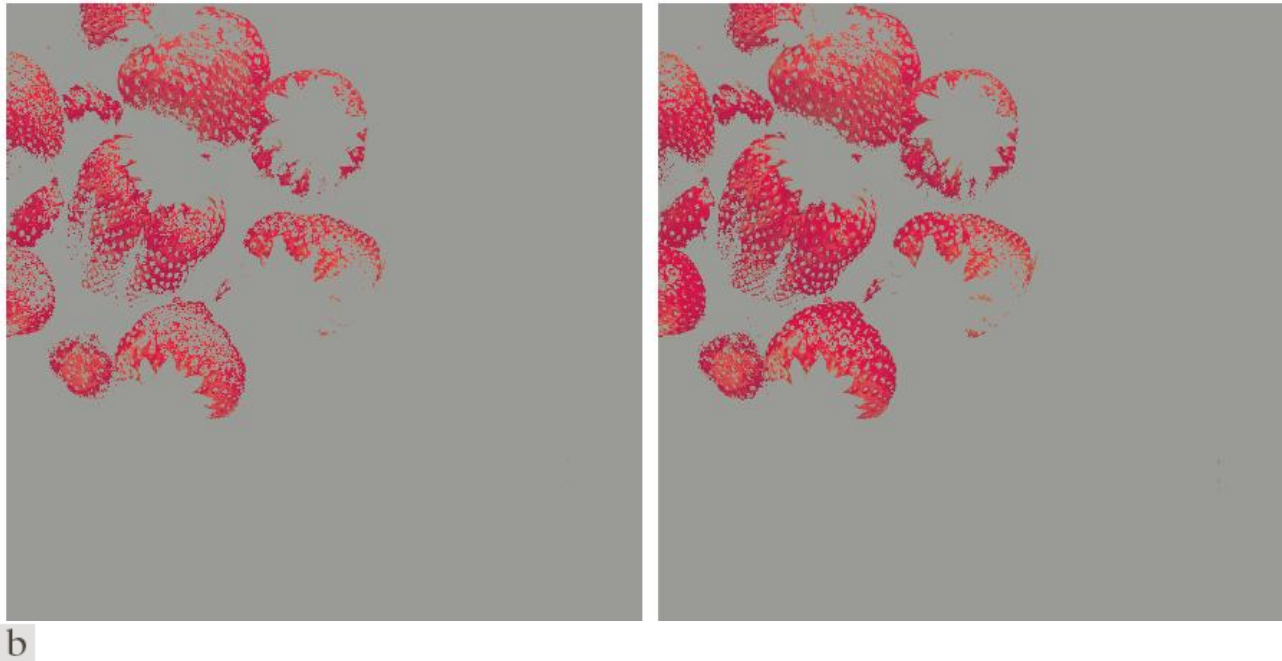
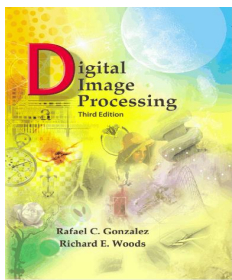


FIGURE 6.34 Color-slicing transformations that detect (a) reds within an RGB cube of width $W = 0.2549$ centered at $(0.6863, 0.1608, 0.1922)$, and (b) reds within an RGB sphere of radius 0.1765 centered at the same point. Pixels outside the cube and sphere were replaced by color $(0.5, 0.5, 0.5)$.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

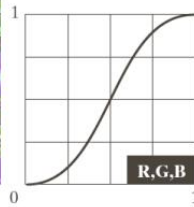
Chapter 6 Color Image Processing



Flat

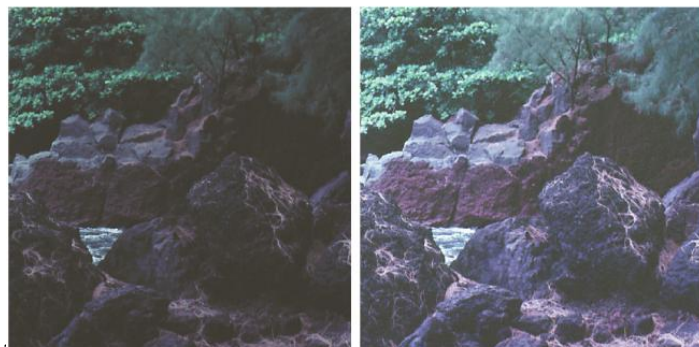
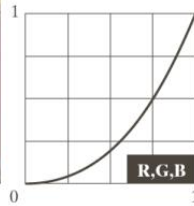
Corrected

FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.



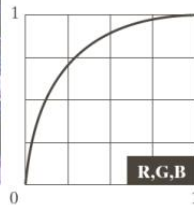
Light

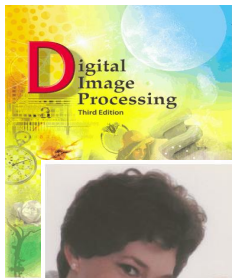
Corrected



Dark

Corrected





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

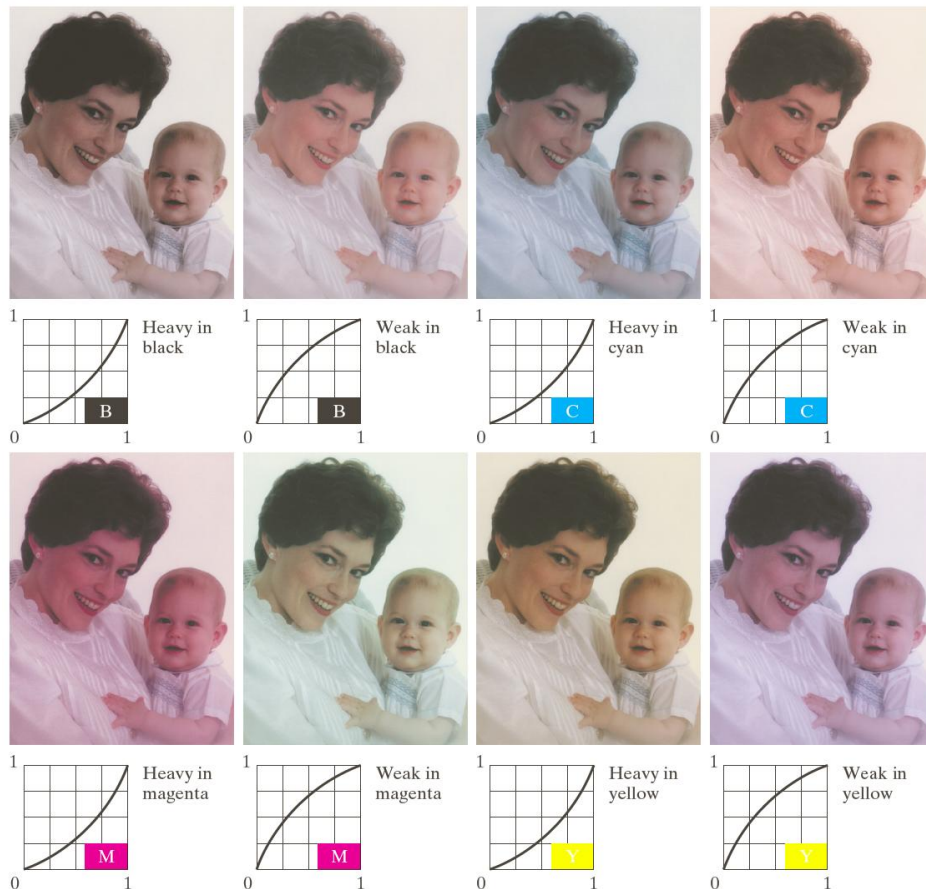
6

rocessing



Original/Corrected

FIGURE 6.36 Color balancing corrections for CMYK color images.



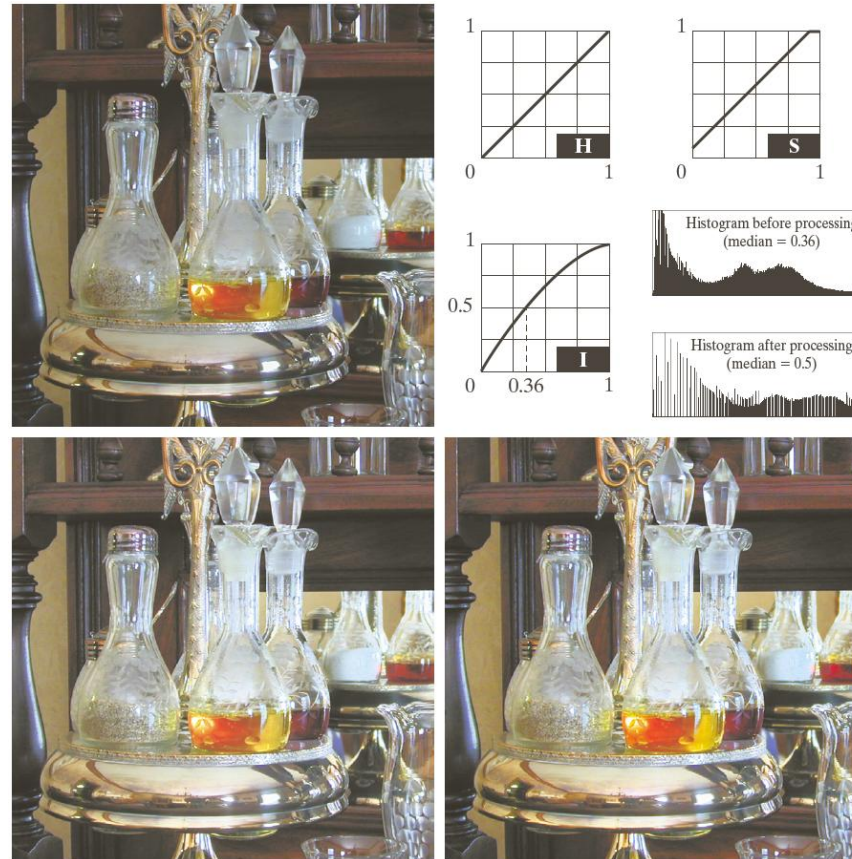


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b
c d

FIGURE 6.37
Histogram
equalization
(followed by
saturation
adjustment) in the
HSI color space.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a	b
c	d

FIGURE 6.38

(a) RGB image.
(b) Red component image.
(c) Green component.
(d) Blue component.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b c

FIGURE 6.39 HSI components of the RGB color image in Fig. 6.38(a). (a) Hue. (b) Saturation. (c) Intensity.



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b c

FIGURE 6.40 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.

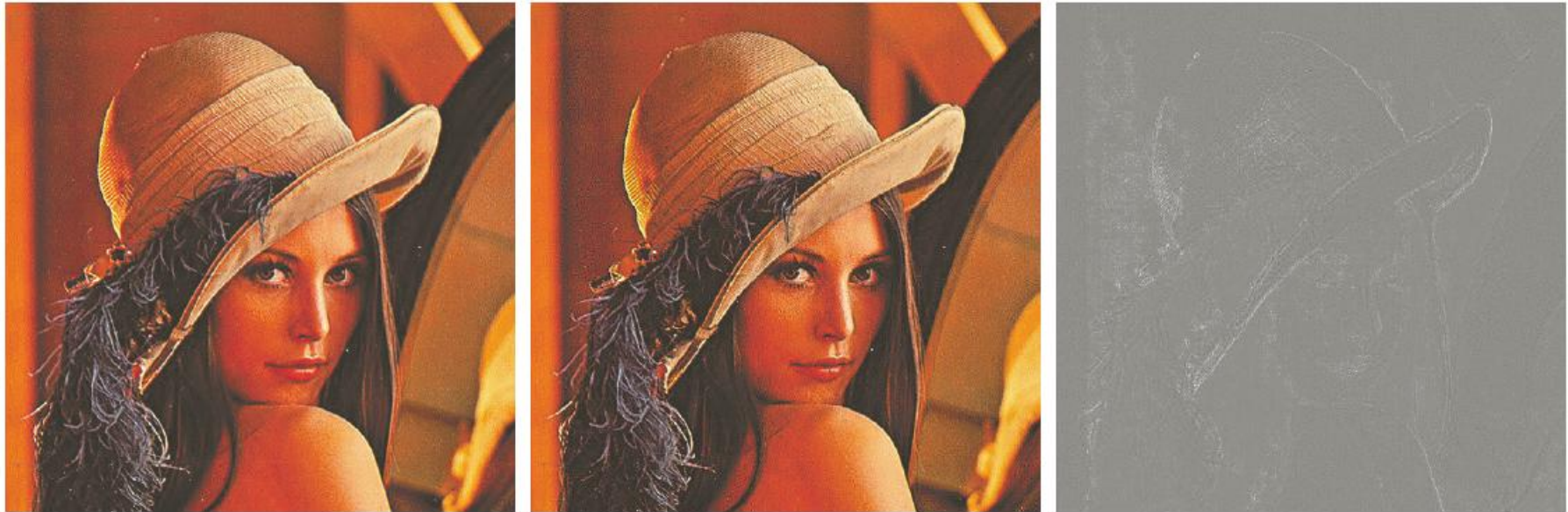


Digital Image Processing, 3rd ed.

Gonzalez & Woods

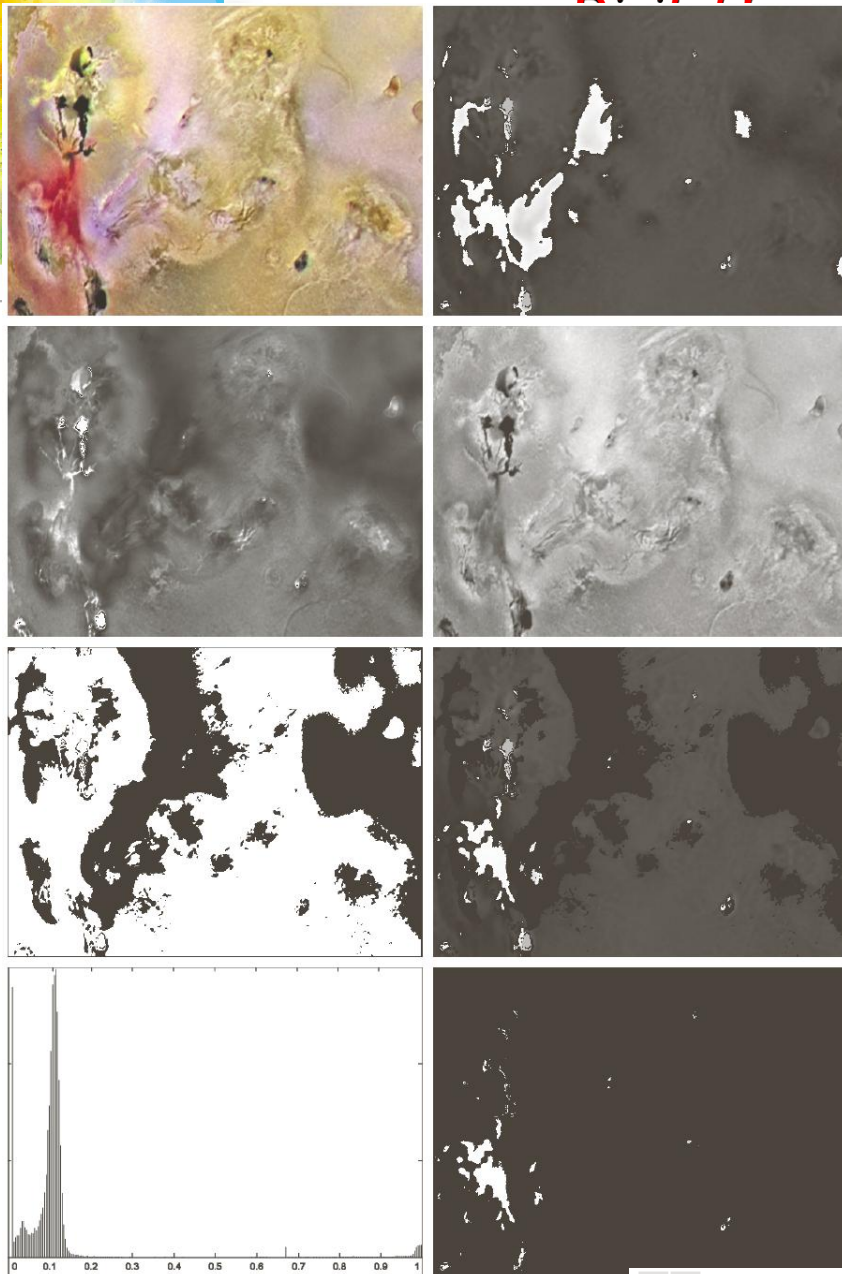
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



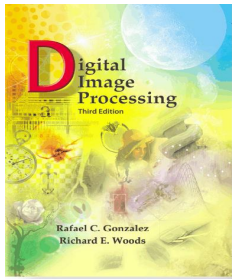
a b c

FIGURE 6.41 Image sharpening with the Laplacian. (a) Result of processing each RGB channel. (b) Result of processing the HSI intensity component and converting to RGB. (c) Difference between the two results.



a b
c d
e f
g h

FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (e). (g) Histogram of (f). (h) Segmentation of red components in (a).

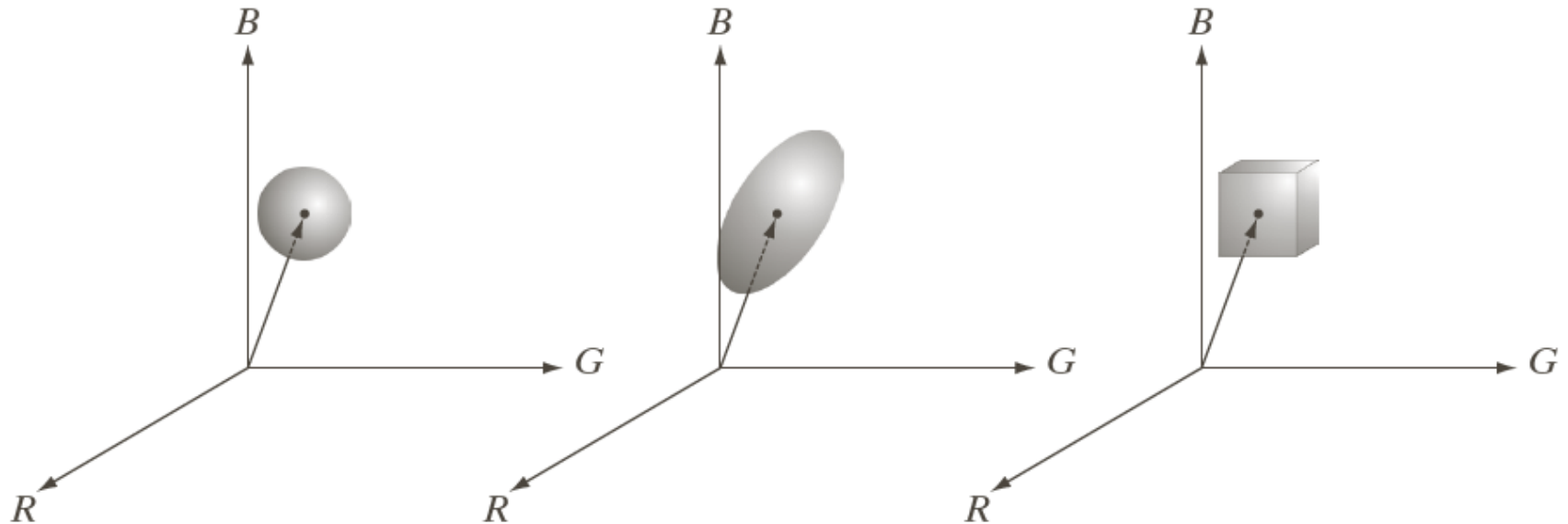


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b c

FIGURE 6.43

Three approaches for enclosing data regions for RGB vector segmentation.

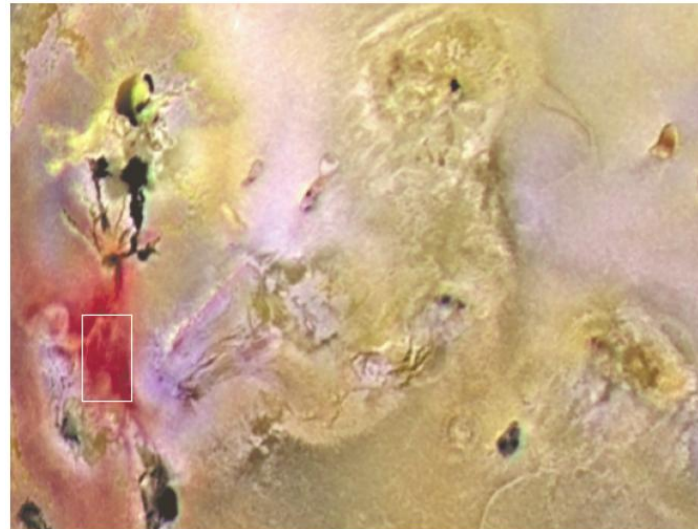


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing

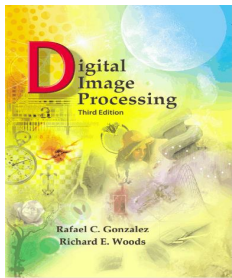


a
b

FIGURE 6.44

Segmentation in RGB space.
(a) Original image with colors of interest shown enclosed by a rectangle.
(b) Result of segmentation in RGB vector space. Compare with Fig. 6.42(h).





Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



FIGURE 6.45 (a)–(c) R , G , and B component images and (d) resulting RGB color image. (e)–(g) R , G , and B component images and (h) resulting RGB color image.

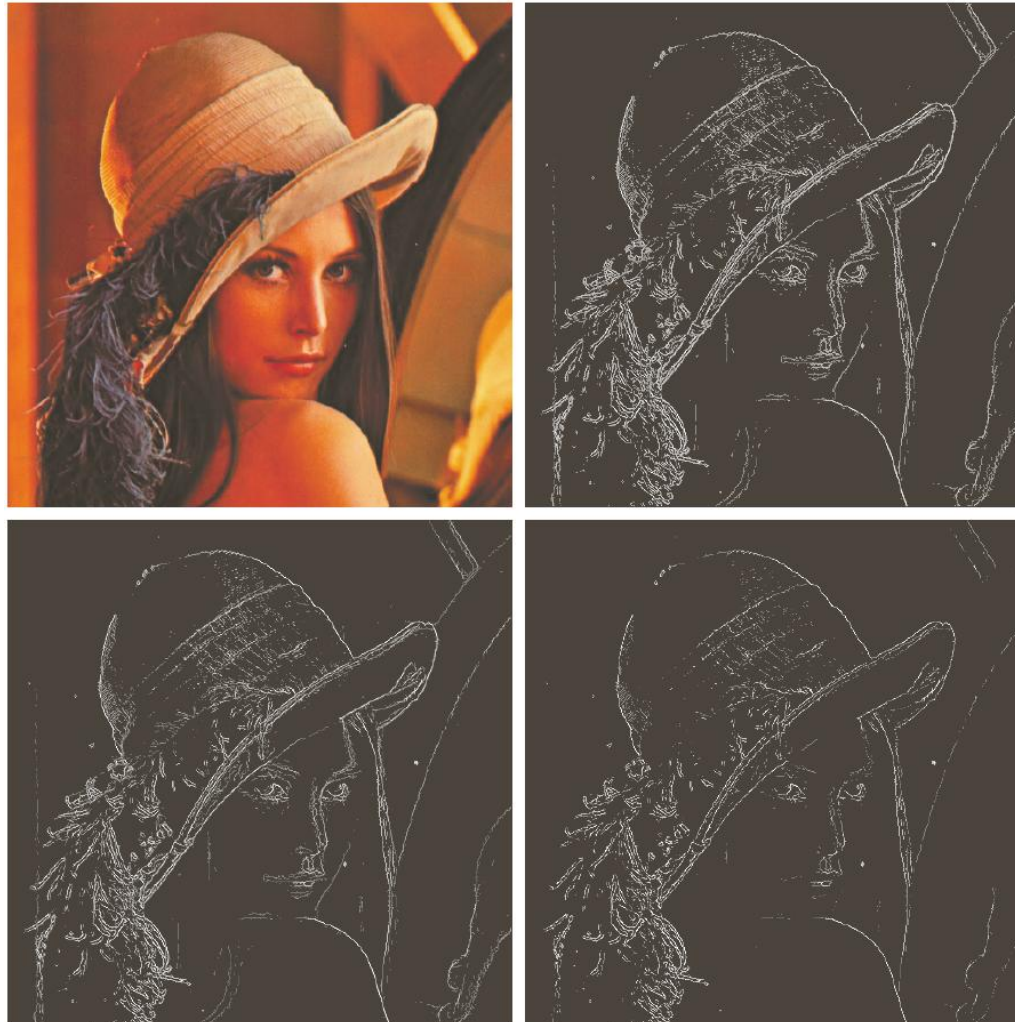


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a	b
c	d

FIGURE 6.46

(a) RGB image.

(b) Gradient computed in RGB color vector space.

(c) Gradients computed on a per-image basis and then added.

(d) Difference between (b) and (c).



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b c

FIGURE 6.47 Component gradient images of the color image in Fig. 6.46. (a) Red component, (b) green component, and (c) blue component. These three images were added and scaled to produce the image in Fig. 6.46(c).



Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

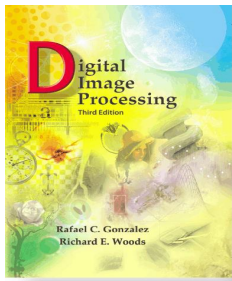
Chapter 6 Color Image Processing



a	b
c	d

FIGURE 6.48

(a)–(c) Red, green, and blue component images corrupted by additive Gaussian noise of mean 0 and variance 800. (d) Resulting RGB image. [Compare (d) with Fig. 6.46(a).]



Digital Image Processing, 3rd ed.

Gonzalez & Woods

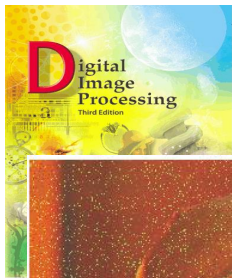
www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a b c

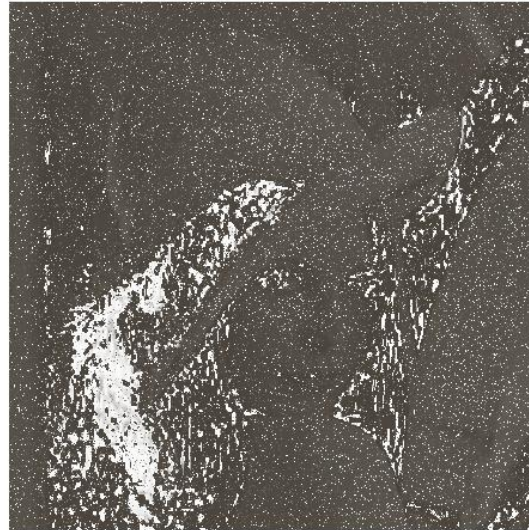
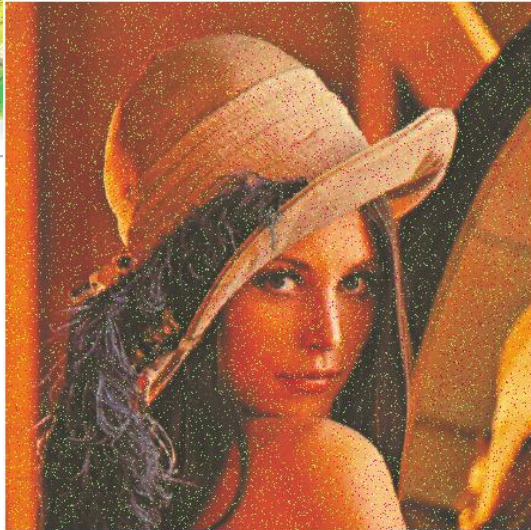
FIGURE 6.49 HSI components of the noisy color image in Fig. 6.48(d). (a) Hue. (b) Saturation. (c) Intensity.



Digital Image Processing, 3rd ed.

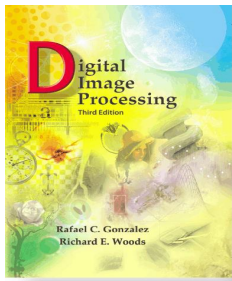
Gonzalez & Woods

www.ImageProcessingPlace.com



a	b
c	d

FIGURE 6.50 (a) RGB image with green plane corrupted by salt-and-pepper noise. (b) Hue component of HSI image. (c) Saturation component. (d) Intensity component.

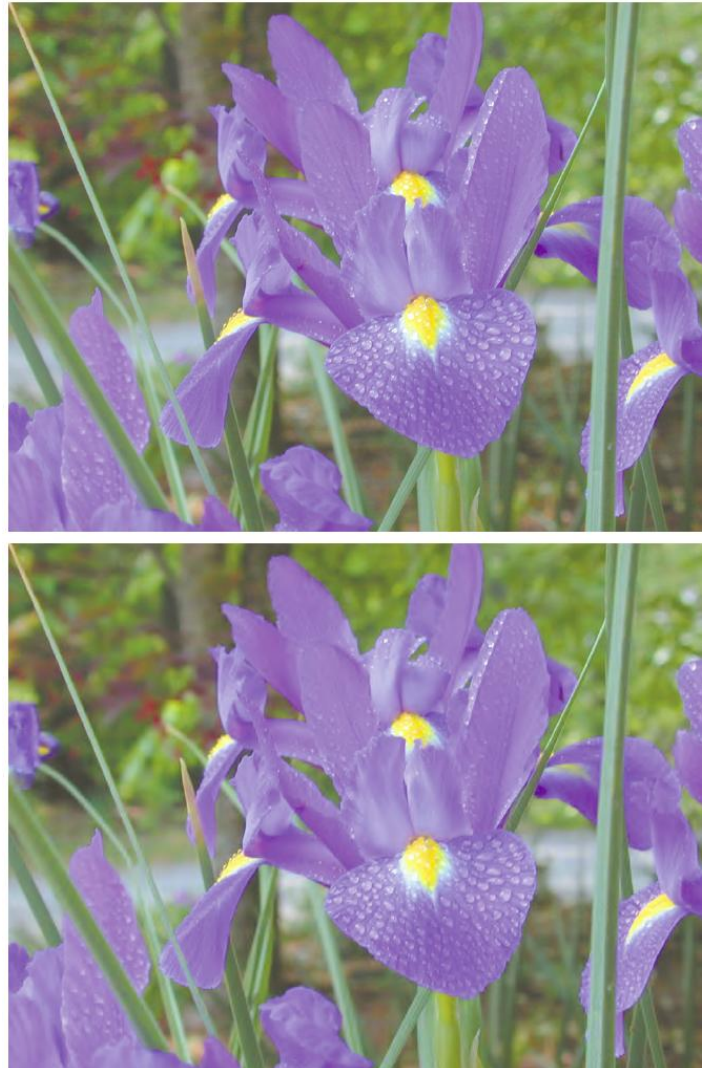


Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 6 Color Image Processing



a
b

FIGURE 6.51

Color image compression.
(a) Original RGB image. (b) Result of compressing and decompressing the image in (a).