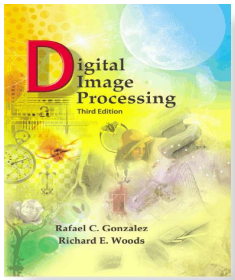
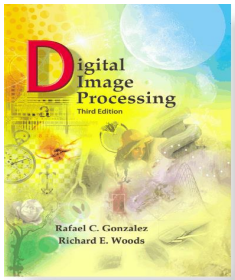


Chapter 6

Color Image Processing

- *Color Fundamentals and models*
- *Pseudo-Color Image Processing*
- *Full-color Image processing*

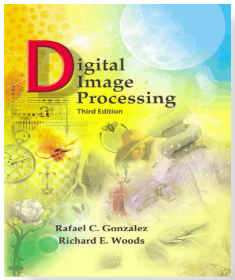


Chapter 6
Color Image Processing

Pseudocolor Image Processing

- *Pseudocolor (also called false color) image processing consists of assigning colors to gray values based on a specified criterion.*

- *The principal use of pseudocolor is for human visualization and interpretation of gray-scale events in an image or sequence of images.*



Chapter 6
Color Image Processing

Pseudocolor Image Processing

- *Intensity slicing*

Let [0,L-1] represent the gray scale, let level l_0 *represent black* $[f(x,y) = 0]$, *and level* l_{L-1} *represent white* $[f(x,y) = L-1]$.

$$f(x,y) = c_k \text{ if } f(x,y) \in V_k$$

Where c_k *is the color associated with the k-th intensity, interval* V_k *defined by the partitioning planes at* $l = k-1$ *and* $l = k$

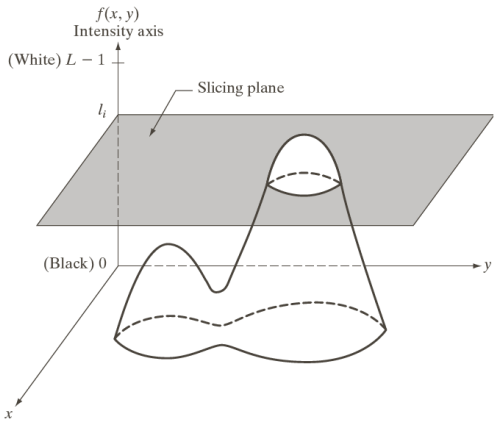


FIGURE 6.18 Geometric interpretation of the intensity-slicing technique.

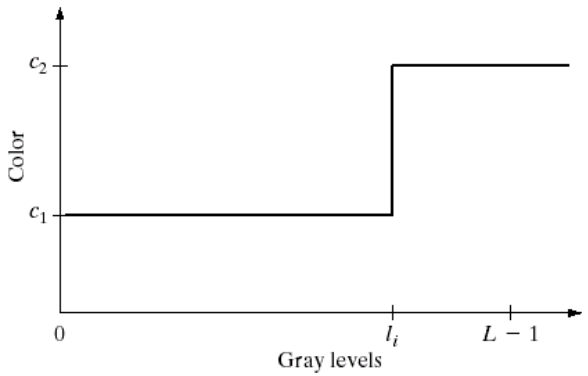
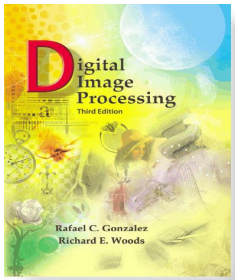
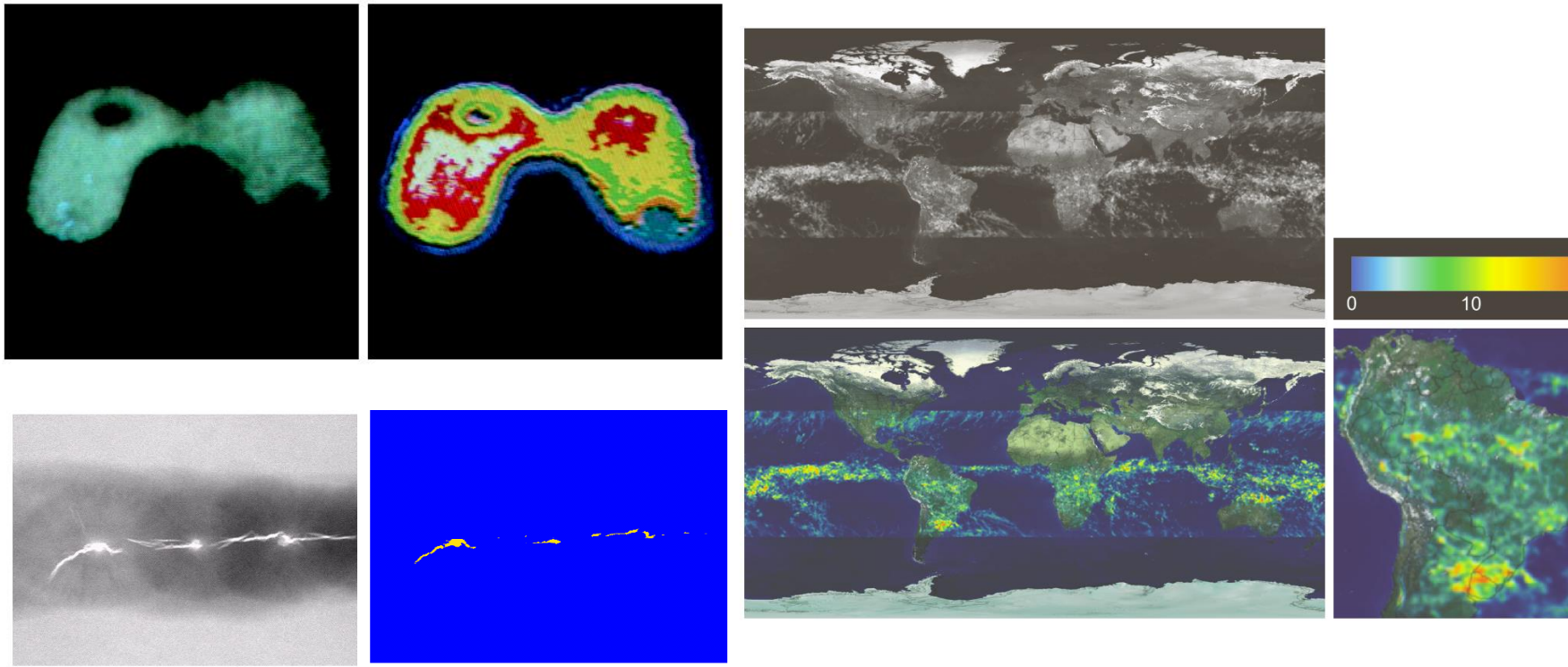


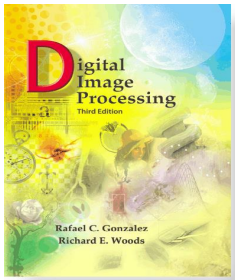
FIGURE 6.19 An alternative representation of the intensity-slicing technique.



Chapter 6
Color Image Processing

- *Example of intensity slicing*





Chapter 6
Color Image Processing

- *Intensity to color transformations*
  - *The idea is to perform three independent transformations on the intensity of any input pixel.*

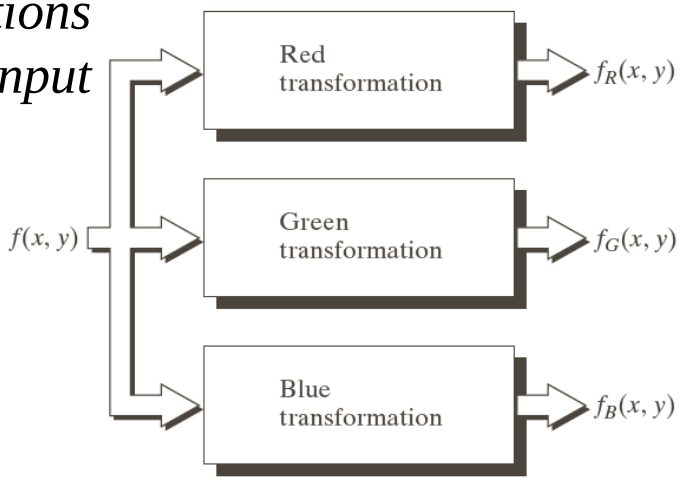
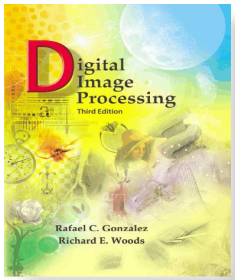
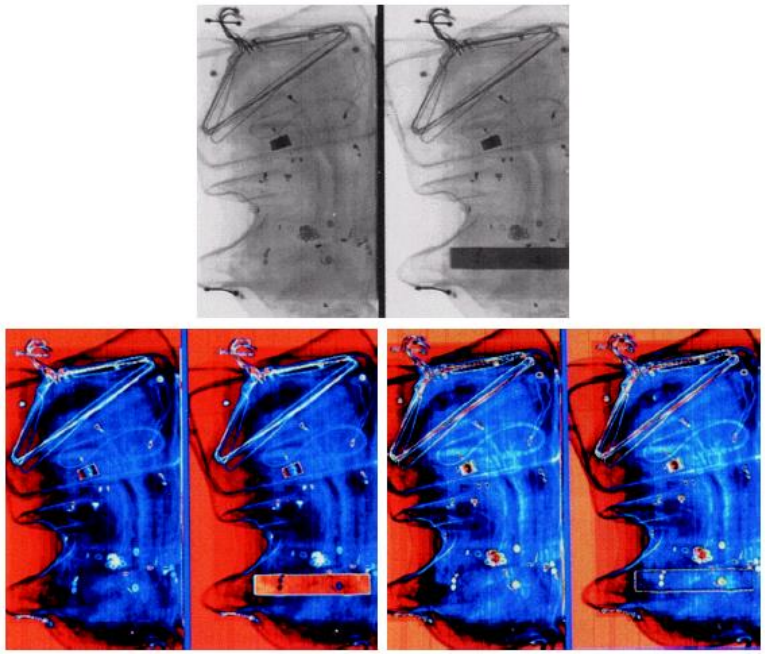


FIGURE 6.23 Functional block diagram for pseudocolor image processing. f_R, f_G, and f_B are fed into the corresponding red, green, and blue inputs of an RGB color monitor.



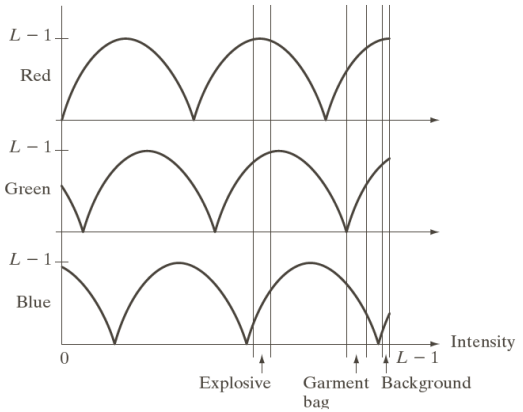
Chapter 6
Color Image Processing

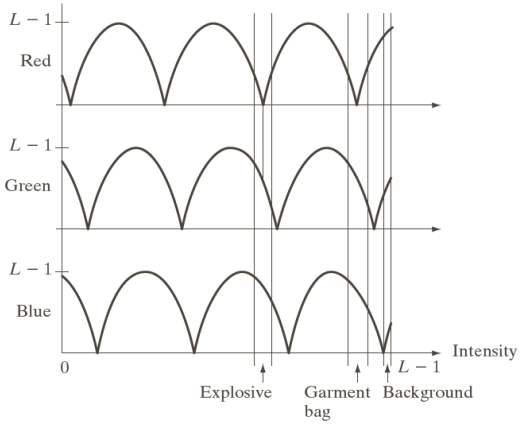
- *Example: Use of pseudocolor for highlighting explosives contained in luggage.*

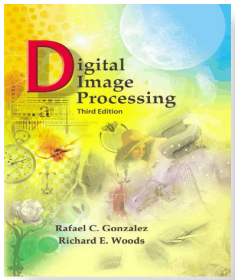


a
b c

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.)







Chapter 6
Color Image Processing

- *Combine several monochrome images into a single color composite.*

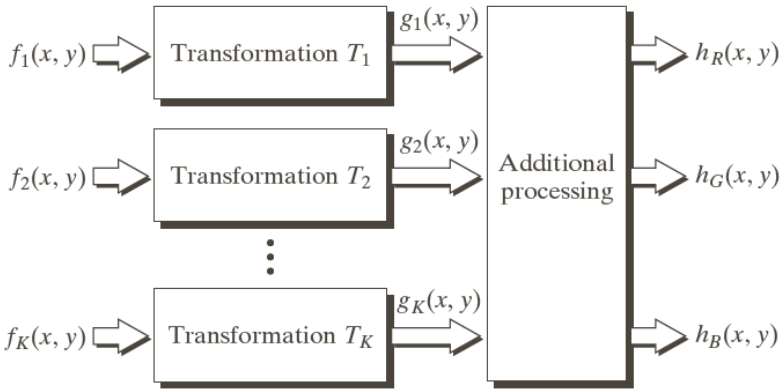
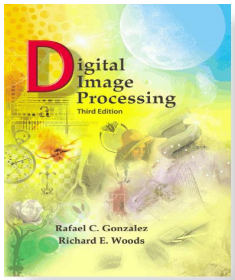


FIGURE 6.26 A pseudocolor coding approach used when several monochrome images are available.



Chapter 6
Color Image Processing

- *Example: Color coding of multispectral images.*

TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

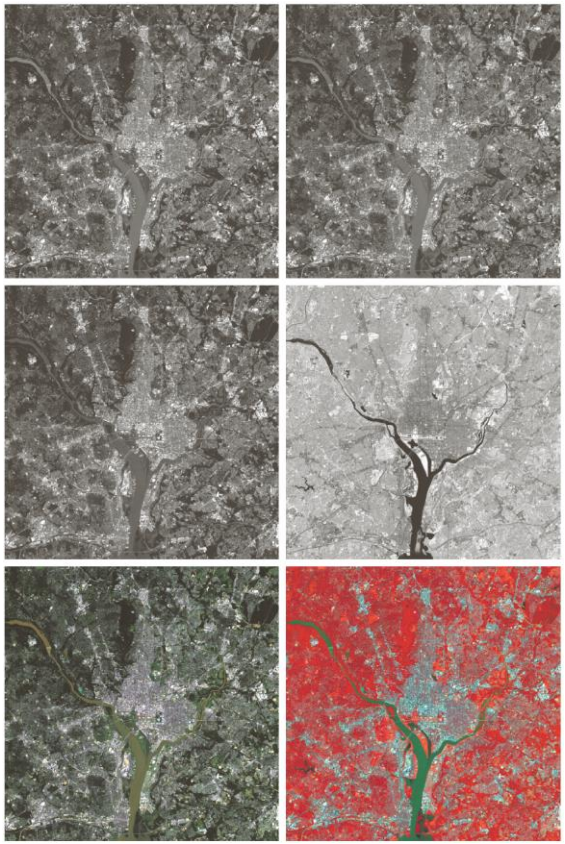
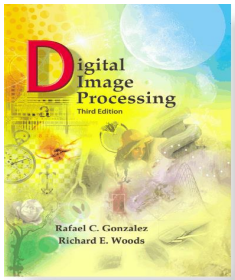


FIGURE 6.27 (a)–(d) Images in bands 1–4 in Fig. 1.10 (see Table 1.1). (e) Color composite image obtained by treating (a), (b), and (c) as the red, green, blue components of an RGB image. (f) Image obtained in the same manner, but using in the red channel the near-infrared image in (d). (Original multispectral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

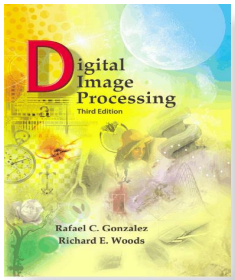
a b
c d
e f



Chapter 6

Color Image Processing

- *Color Fundamentals and models*
- *Pseudo-Color Image Processing*
- *Full-color Image processing*



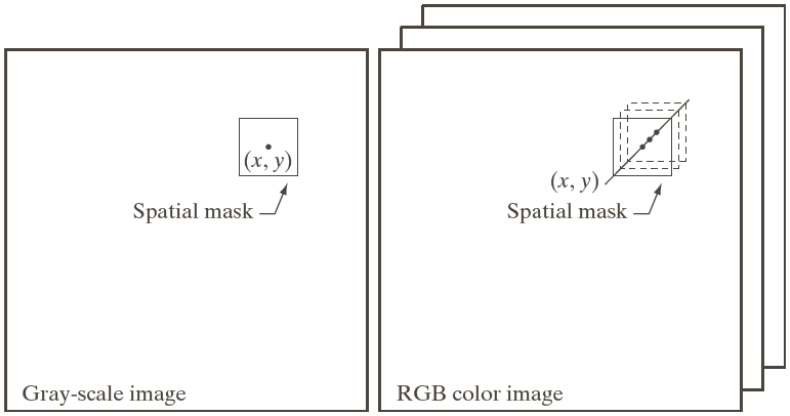
Chapter 6
Color Image Processing

Basic of Full-Color Image Processing

- *Let c represent an arbitrary vector in RGB color space:*

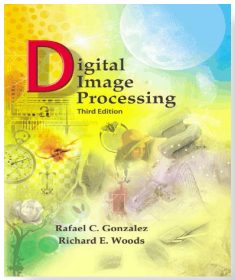
$$c = \begin{bmatrix} c_R \\ c_G \\ c_B \end{bmatrix} = \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$c(x,y) = \begin{bmatrix} c_R(x,y) \\ c_G(x,y) \\ c_B(x,y) \end{bmatrix} = \begin{bmatrix} R(x,y) \\ G(x,y) \\ B(x,y) \end{bmatrix}$$



a b

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



Chapter 6
Color Image Processing

Color Transformations

- *Formualtion*

$$g(x,y) = T[f(x,y)]$$

$$g(x,y) = kf(x,y)$$

Where $0 < k < 1$

- *In theory, any transformation can be performed in any color model.*

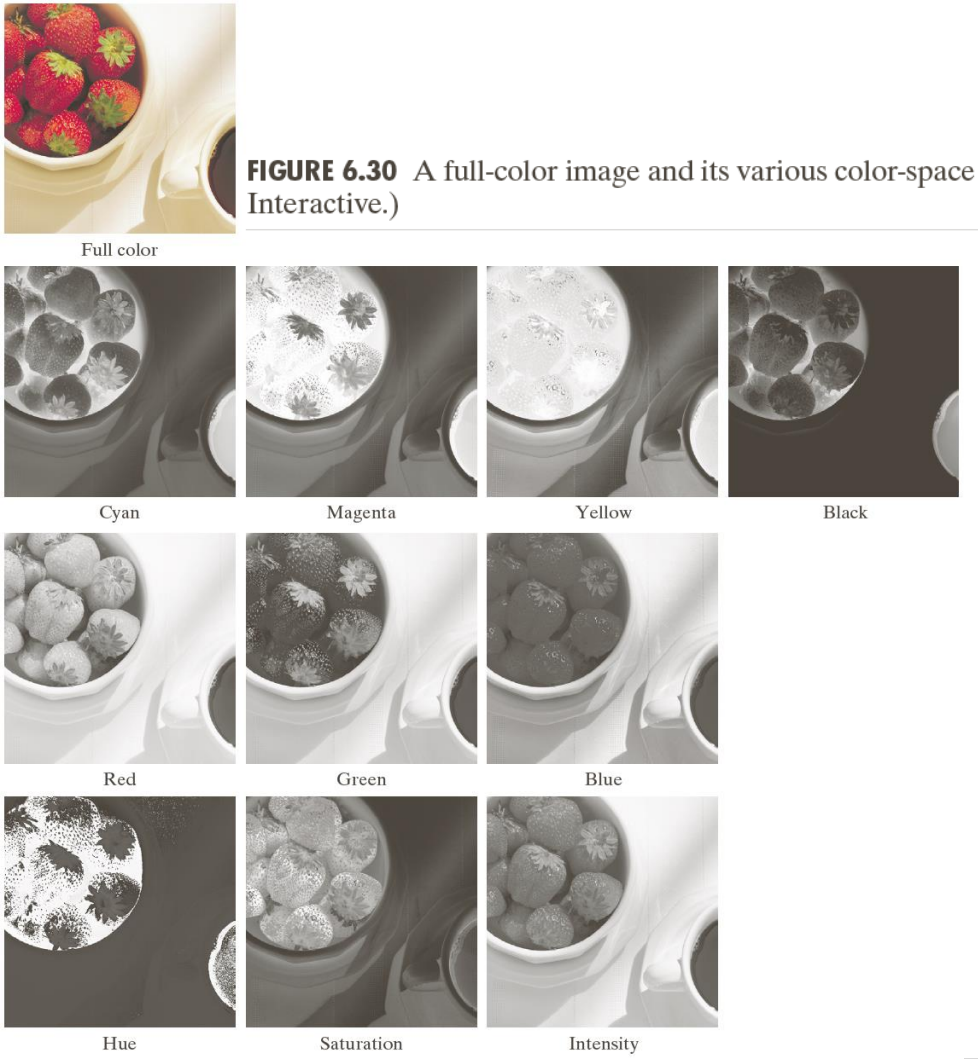
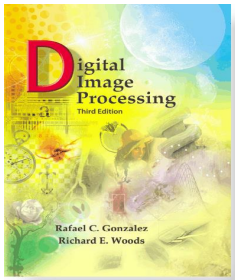


FIGURE 6.30 A full-color image and its various color-space components. Interactive.)



Chapter 6
Color Image Processing

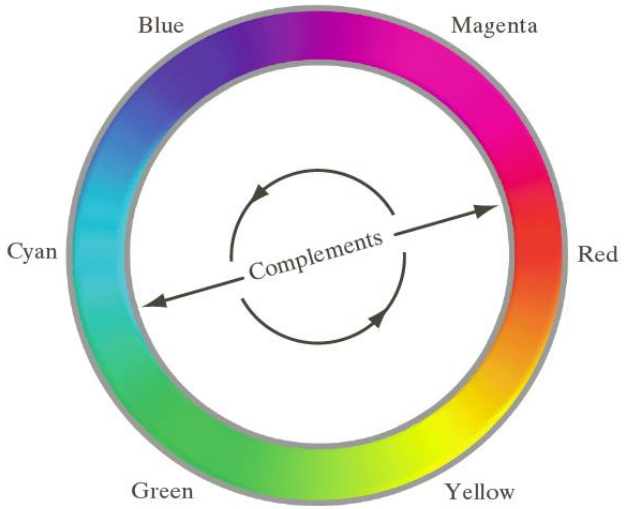
- *In the HIS color space:* $s_3 = kr_3$
- *In the RGB color space:* $s_i = kr_i$ i =1,2,3
- *In the CMY space:*
  $s_i = kr_i + (1 - k)$ i =1,2,3

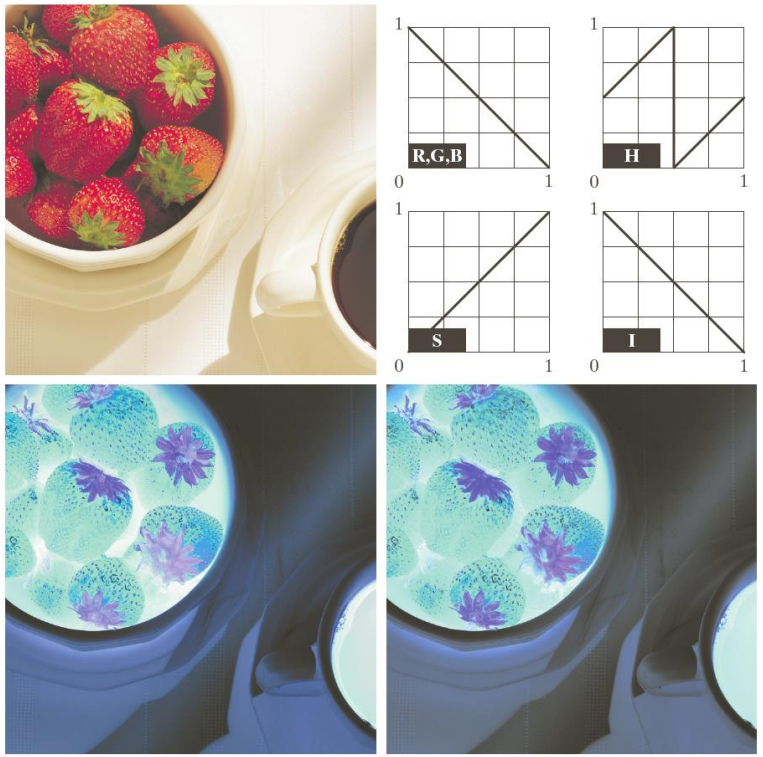
a b
c d e

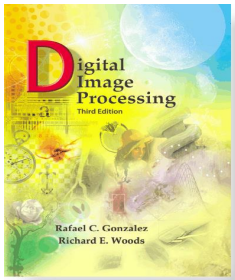
FIGURE 6.31 Adjusting the intensity of an image using color transformations. (a) Original image. (b) Result of decreasing its intensity by 30% (i.e., letting $k = 0.7$). (c)–(e) The required RGB, CMY, and HSI transformation functions. (Original image courtesy of MedData Interactive.)

Color Complements

- *The hues directly opposite one another on the color circle of Figure.6.32 are called complements.*







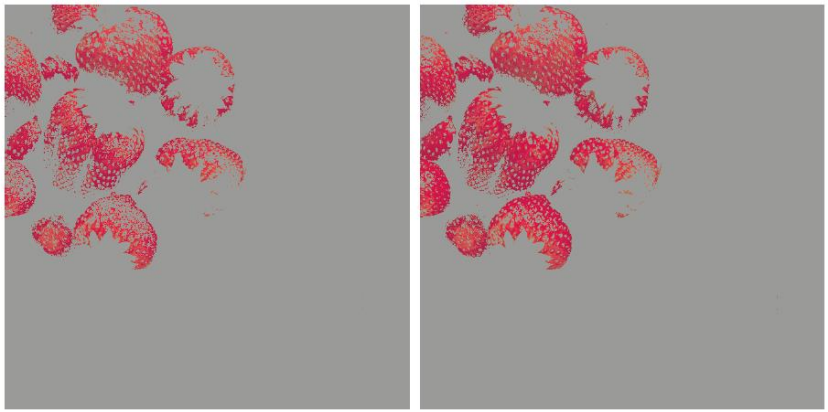
Chapter 6
Color Image Processing

Color Slicing

- *Display the colors of interest so that they stand out from the background*
- *Use the region defined by rhe colors as a mask for further processing*

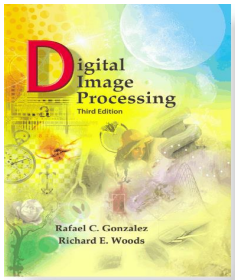
- *Example:*
  if a sphere is used to specify the colors of interest,

$$s_i = \begin{cases} 0.5 & if \sum_{j-1}^{n} (r_j - a_j)^2 > R_0^2 \\ r_i & otherwise \end{cases}$$



a b

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).



Chapter 6
Color Image Processing

Tone and Color Corrections

- *Phone enhancement and color reproduction*
- *CIELAB model*
- *Example: Tonal transformations*

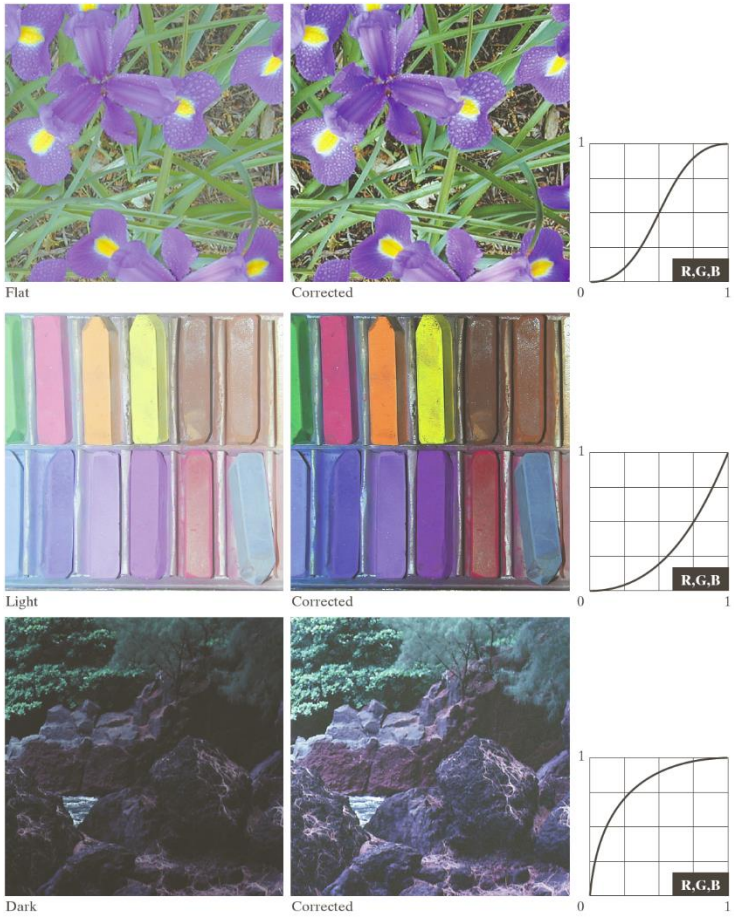
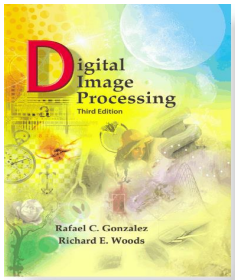


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.



Chapter 6
Color Image Processing

- *Example: Color balancing*

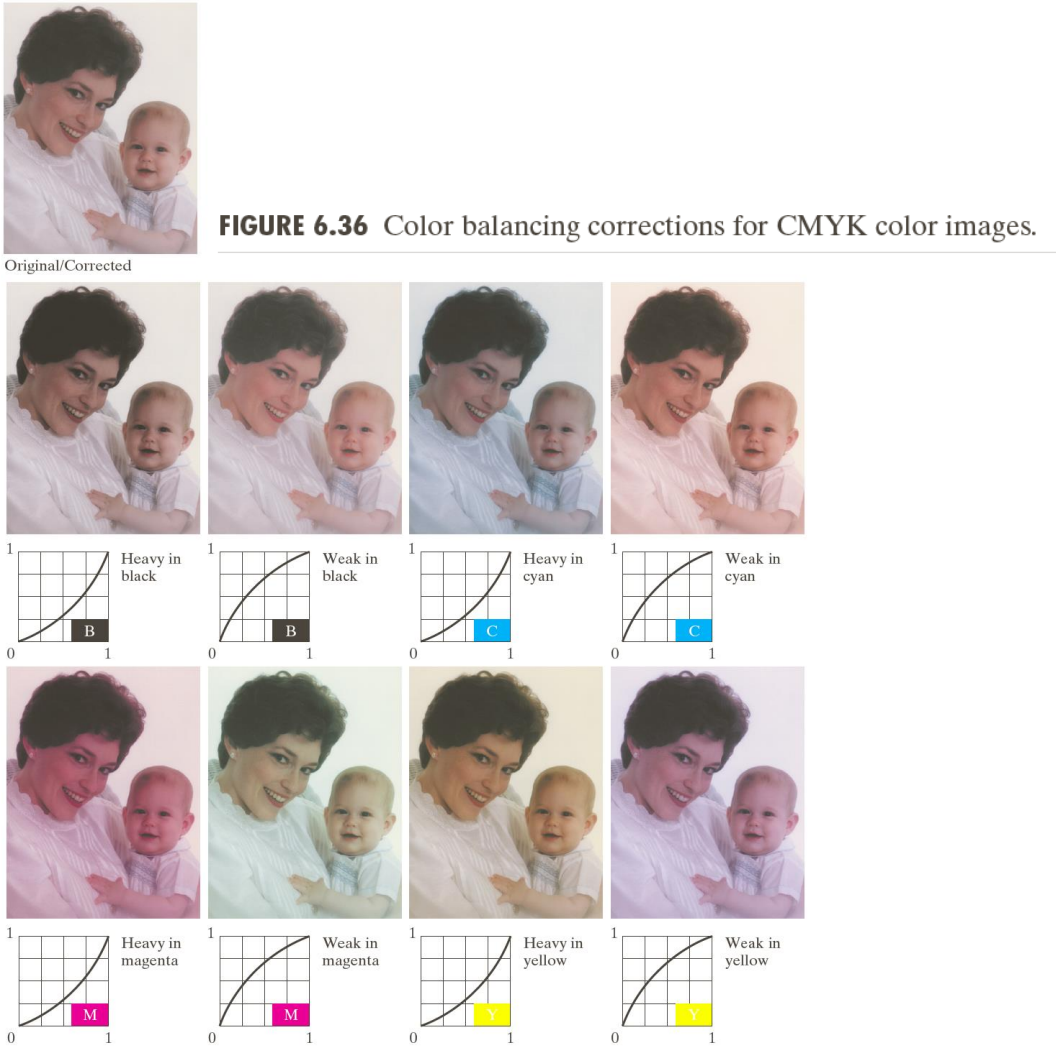
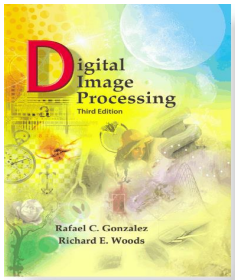


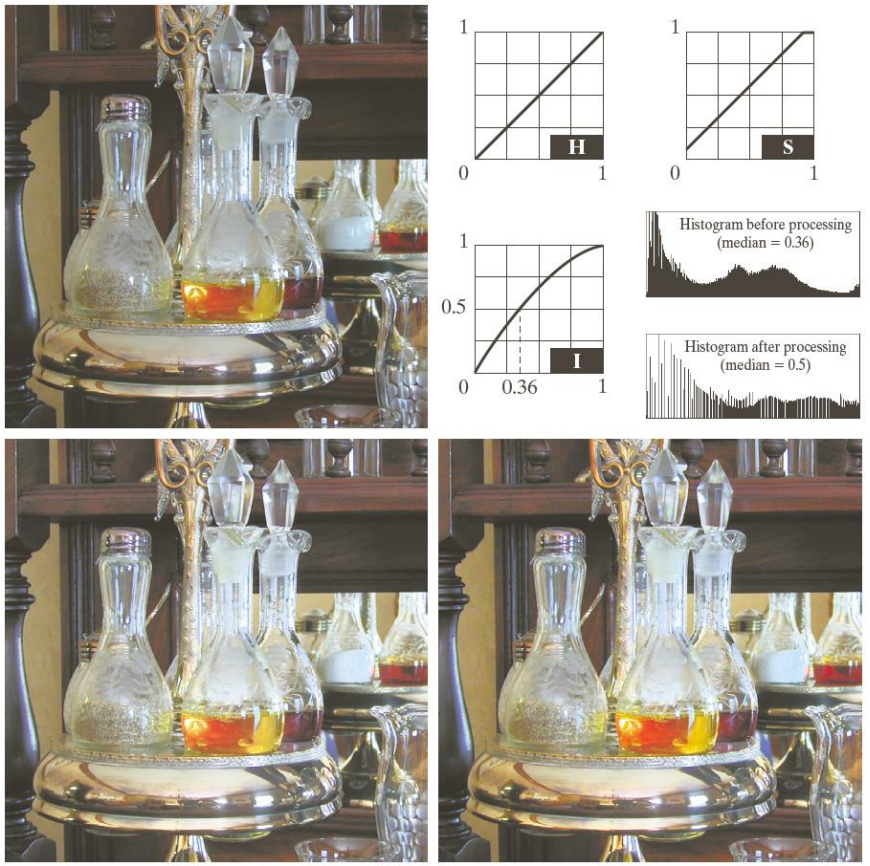
FIGURE 6.36 Color balancing corrections for CMYK color images.



Chapter 6
Color Image Processing

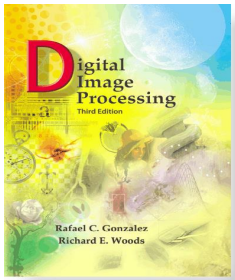
Histogram Processing

- *The gray-level histogram processing transformations can be applied to color images in an automated way.*



a b
c d

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



Chapter 6
Color Image Processing

Smoothing and Sharpening

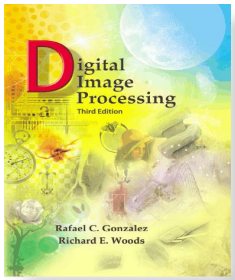
- *Color image smoothing*

$$\bar{c}(x,y) = \frac{1}{K} \sum_{(s,t)\epsilon S_{xy}} c(s,t)$$

let S_{xy} denote the set of coordinates defining a neighborhood centered at (x,y) in an RGB color image.

a b
c d

FIGURE 6.38
(a) RGB image. (b) Red component image (c) Green component. (d) Blue component.



Chapter 6
Color Image Processing

- *Color image smoothing*

We conclude that smoothing by neighborhood averaging can be carried out on a per-color plane basis.

a b c

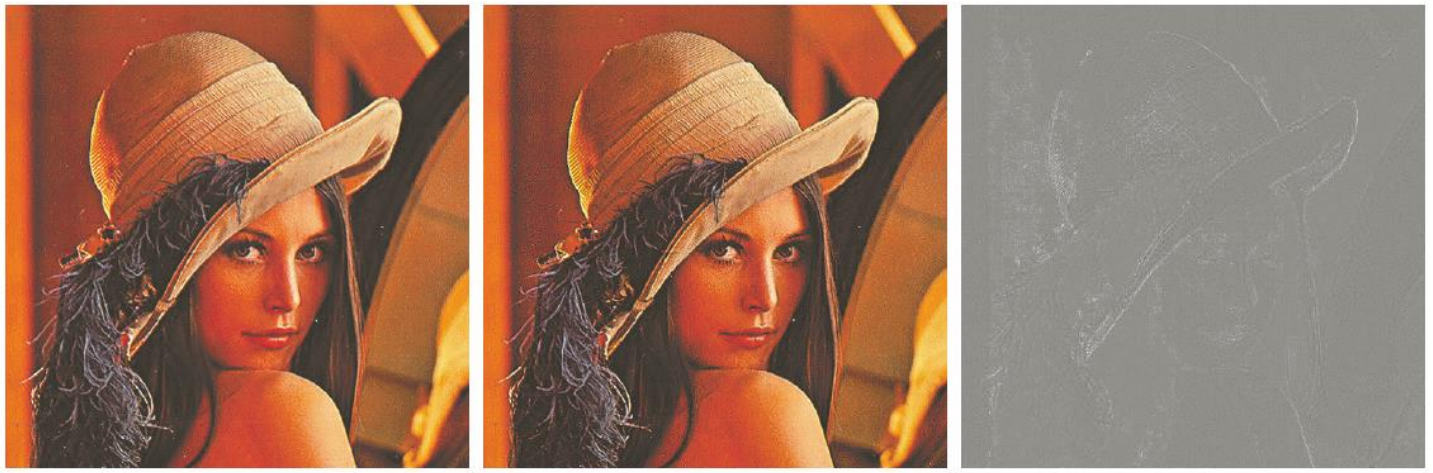
FIGURE 6.40 Image smoothing with a 5×5 averaging mask. (a) Result of processing each RGB component image. (b) Result of processing the intensity component of the HSI image and converting to RGB. (c) Difference between the two results.

Chapter 6
Color Image Processing

- *Color image sharpening*

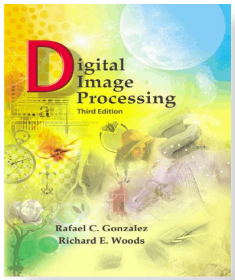
  In the RGB color system, the Laplacian of vector c is:

$$\nabla^2[c(x,y)] = \begin{bmatrix} \nabla^2 R(x,y) \\ \nabla^2 G(x,y) \\ \nabla^2 B(x,y) \end{bmatrix}$$



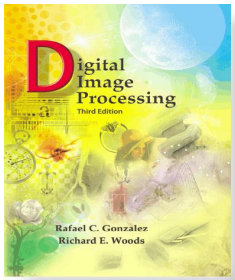
a b c

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.



Chapter 6
Color Image Processing

- *Image Segmentation Based on Color*
- *Color edge detection*
- *Noise in Color Images*
- *Color Image Compression*



Chapter 6

Color Image Processing

summary

Pseudocolor Image Processing

- *Intensity Slicing*
- *Intensity to Color Transformation*

Full-Color Image Processing

- *Color Transformation*
- *Color Complements*
- *Color Slicing*
- *Tone and Color Corrections*
- *Histogram Processing*
- *Other Color Image Processing*