CPE409 Image Processing

Part 8
Color Image Processing

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For a long time, I limited myself to one color—as a form of discipline.
~Pablo Picasso

Outline

6. Color Image Processing

- Color Fundamentals
- Color Models
- Pseudocolor Image Processing
- Basics of Full-Color Image Processing
- Color Transformations
- Smoothing and Sharpening
- Image Segmentation Based on Color
- Noise in Color Images
- Color Image Compression

Color Transformations

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

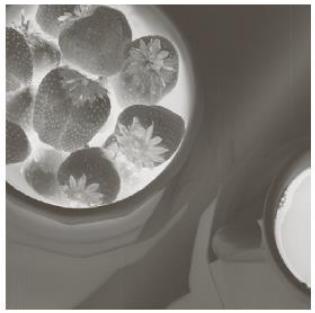
f(x,y) is a color input image, g(x,y) is a transformed or processed color output image, and T is an operator operating in the spatial neighborhood of (x,y) on f.

$$s_i = T_i(r_1, r_2, ..., r_n), \qquad i = 1, 2, ..., n.$$

r_i and s_i are variables that represent the color components of f(x,y) and g(x,y) at any point (x,y). N is the set of transformation or color matching functions that operate on r_i to produce the number of color components and $\{T_1, T_2, ..., T_n\}$, s.

Full color

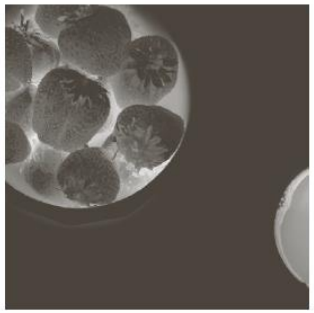
FIGURE 6.30 A full-color image and its various color-space components. Interactive.)



Cyan

Magenta

Yellow

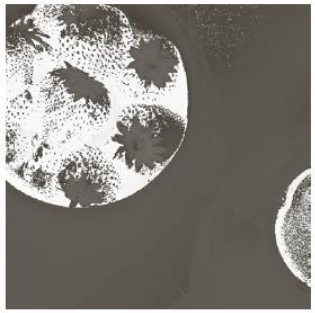


Black

Red

Green

Blue



Hue

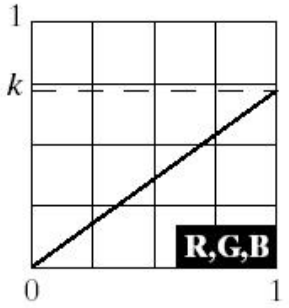
Saturation

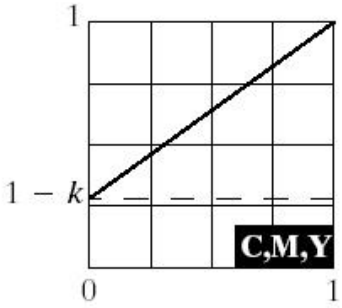
Intensity

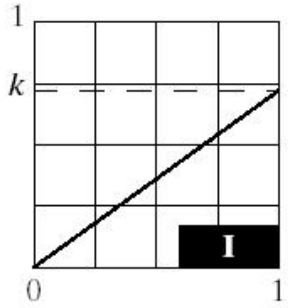
$$g(x,y) = kf(x,y)$$

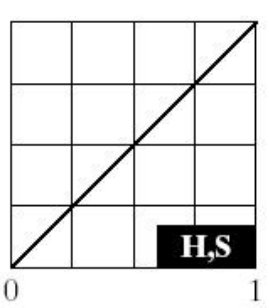
a b
c d e

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.)









$$s_i = kr_i, \quad i = 1,2,3.$$

$$s_i = kr_i + (1-k), \quad i = 1,2,3.$$

$$s_3 = kr_3$$

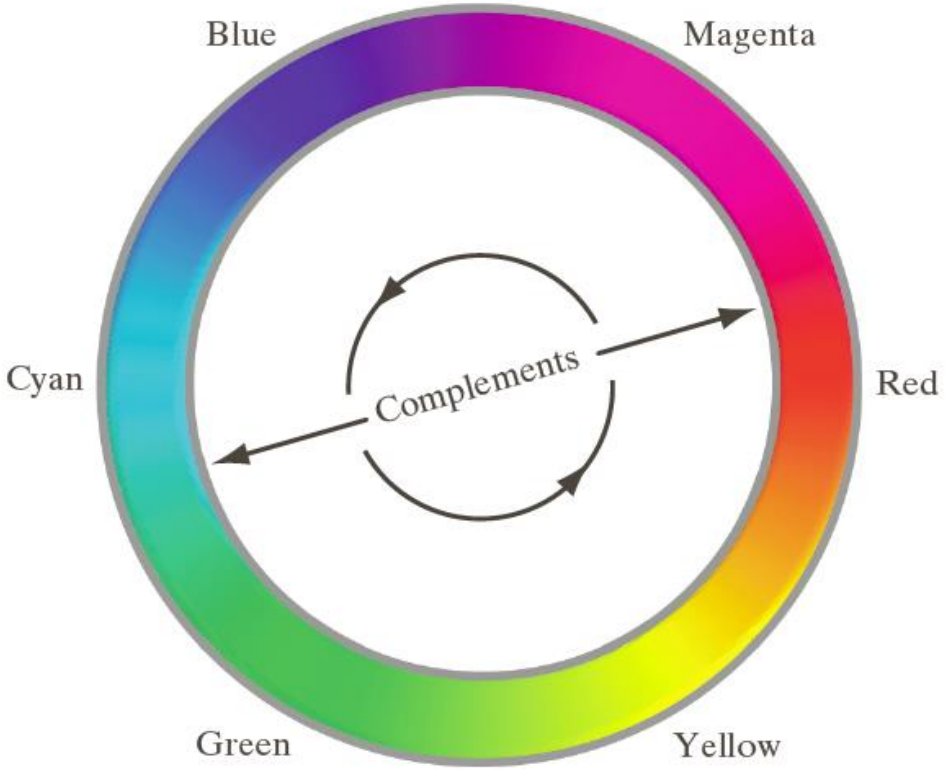
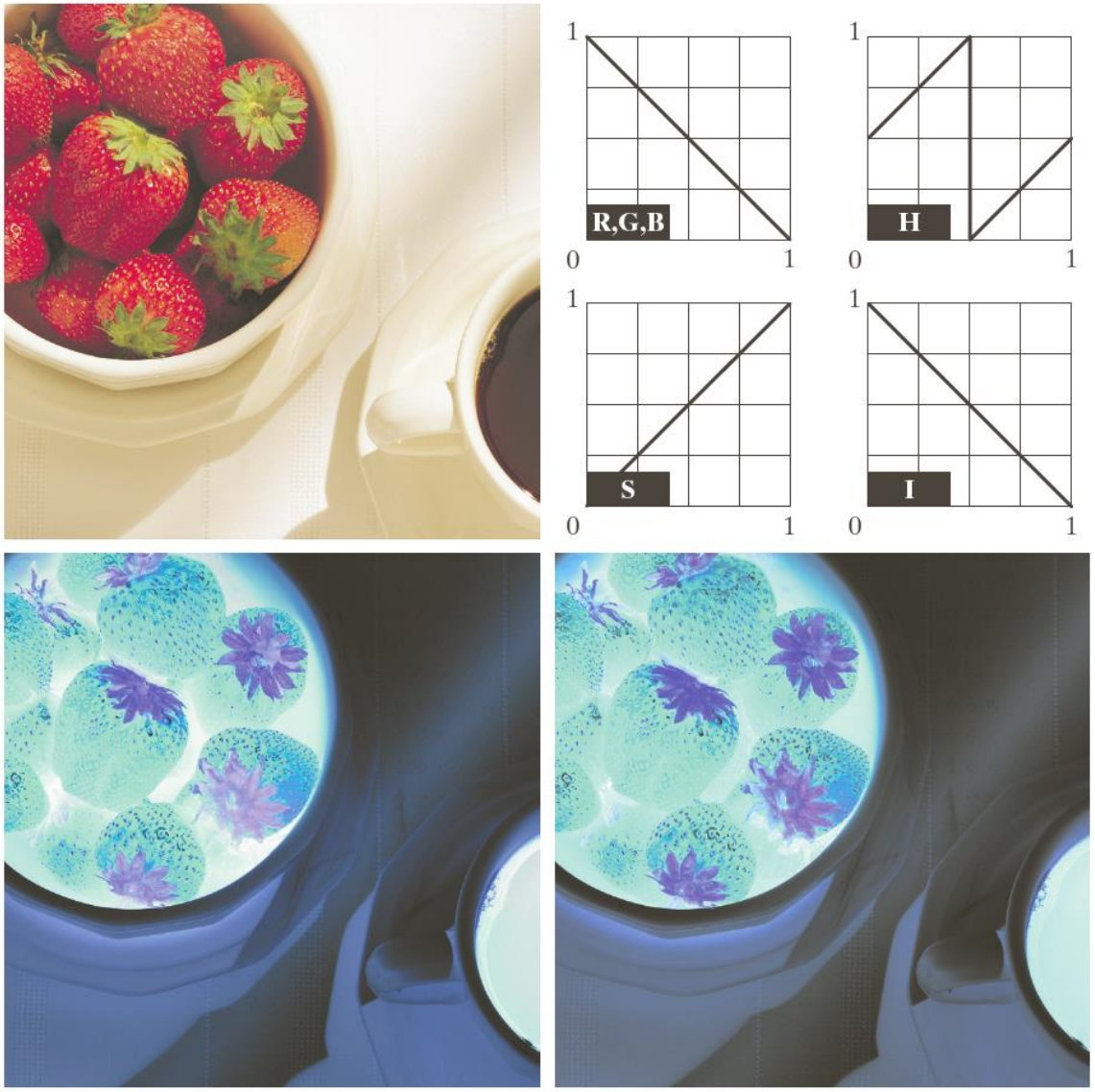


FIGURE 6.32
Complements on the color circle.



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.

Color Slicing

- Highlighting a specific range of colors in an image

If the colors of interest are enclosed by a cube of width W and centered at a protypical color with components $(a_1, a_2, ..., a_n)$, the necessary set of transformations is

$$s_i = \begin{cases} 0.5 & \text{if } \left[| r_j - a_j | > W / 2 \right]_{\text{any } 1 \le j \le n} \\ r_i & \text{otherwise} \end{cases}$$

Color Slicing

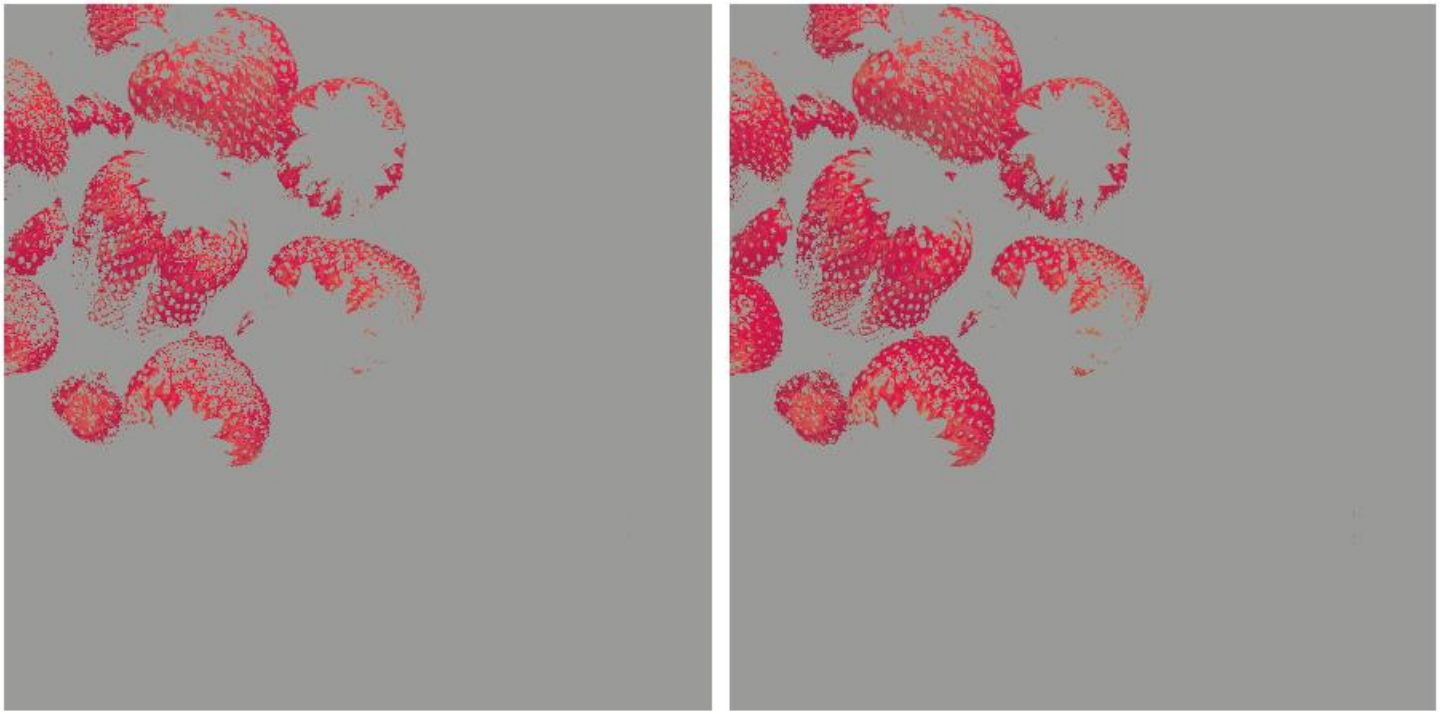
If a sphere is used to specify the colors of interest,

R_0 is the radius of the enclosing of its center.

The transformations is

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

Color Slicing



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).

Tone and Color Corrections

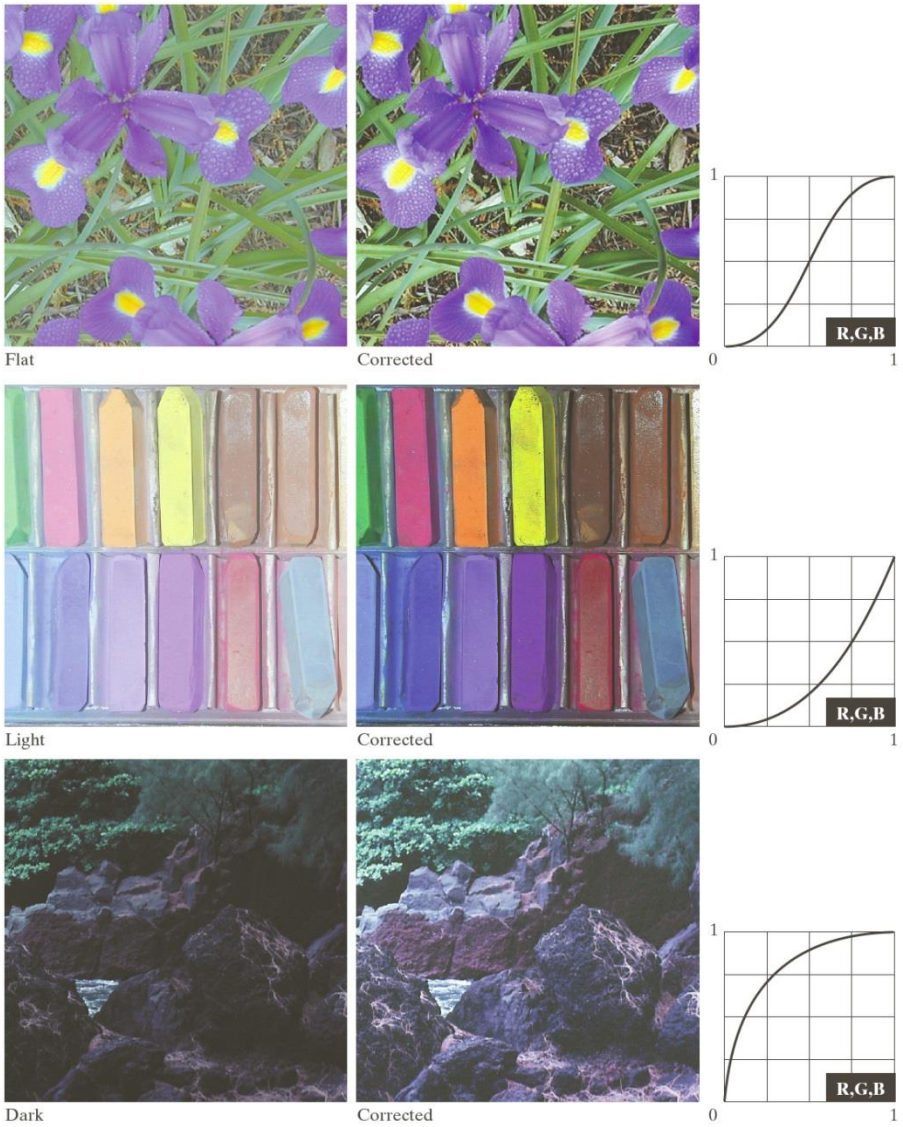
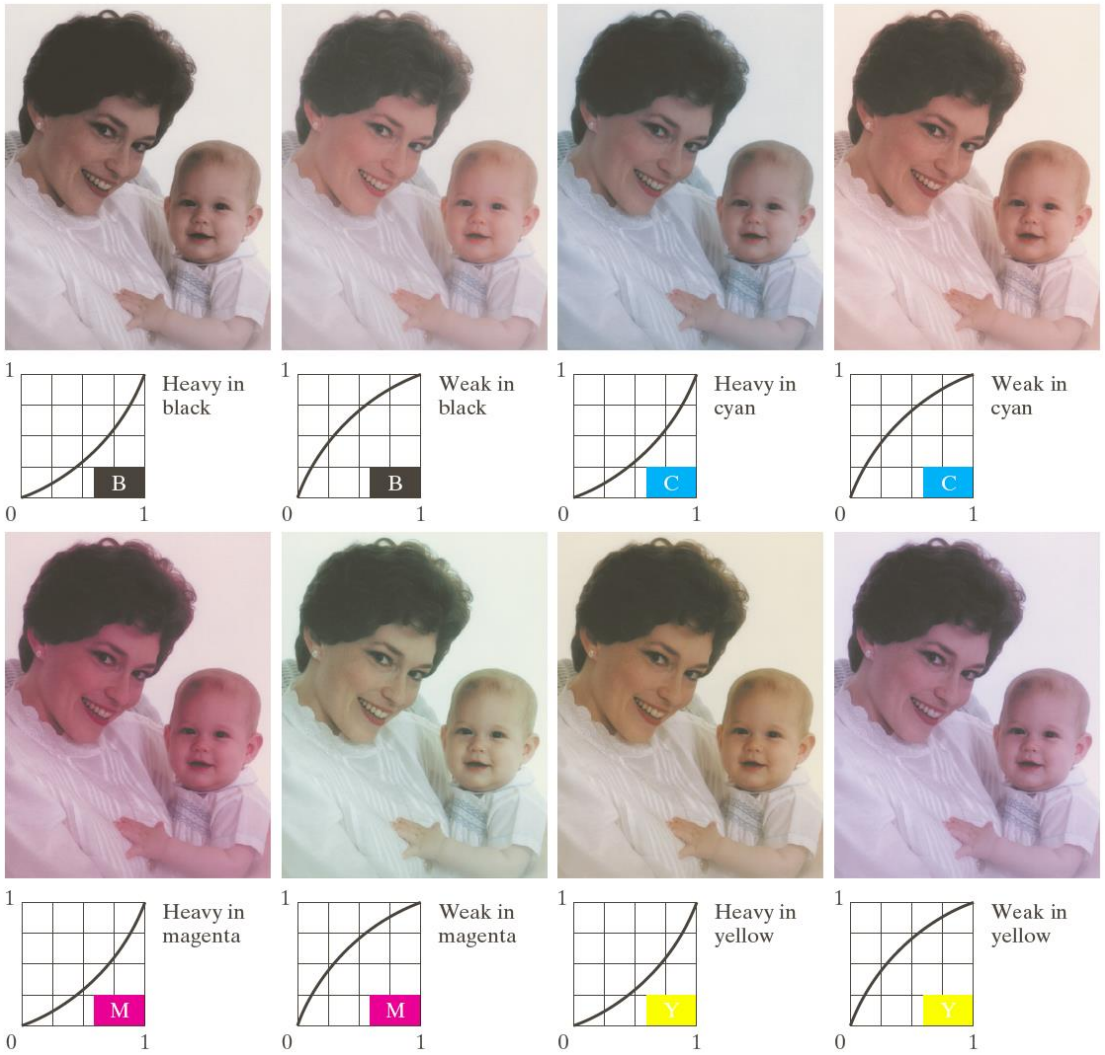
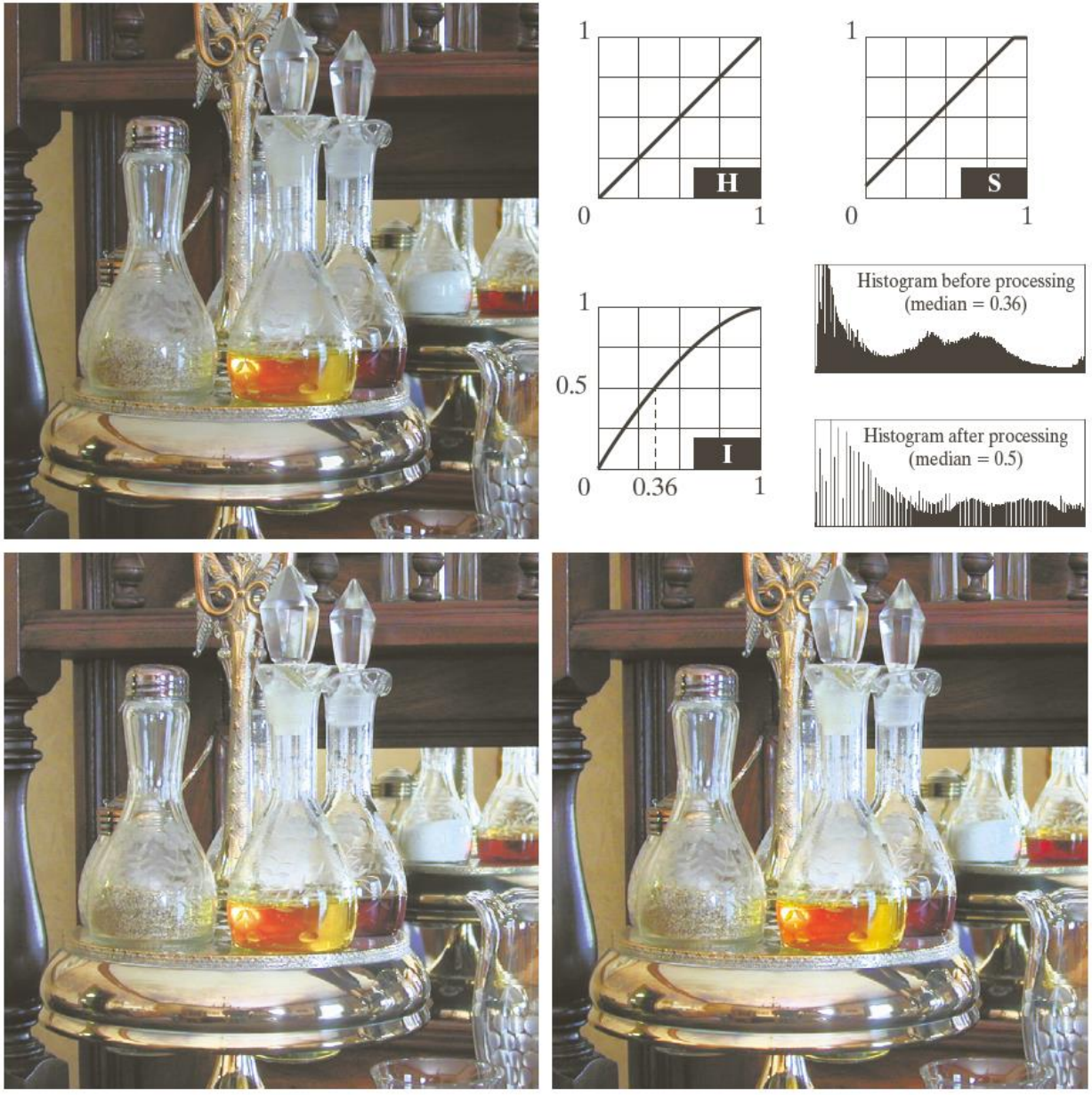


FIGURE 6.35 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

Original/Corrected

FIGURE 6.36 Color balancing corrections for CMYK color images.





a b
c d

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

Color Image Smoothing

Let S_{xy} denote the set of coordinates defining a neighborhood centered at (x, y) in an RGB color image. The average of the RGB component vectors in this neighborhood is

$$\bar{c}(x,y) = \frac{1}{K}\sum_{(s,t)\in S_{xy}} c(s,t) = \begin{bmatrix} \frac{1}{K}\sum_{(s,t)\in S_{xy}} R(s,t) \\ \frac{1}{K}\sum_{(s,t)\in S_{xy}} G(s,t) \\ \frac{1}{K}\sum_{(s,t)\in S_{xy}} B(s,t) \end{bmatrix}$$

a b
c d

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

a b c

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

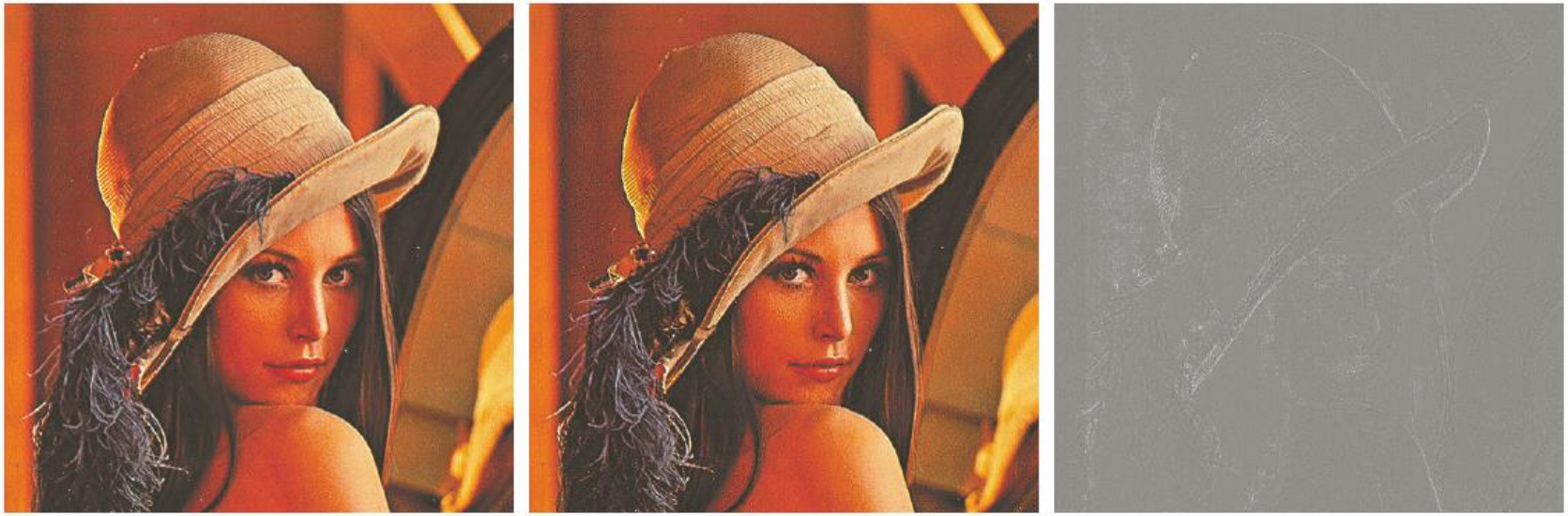
a b c

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.

Color Image Sharpening

The Laplacian of vector c is

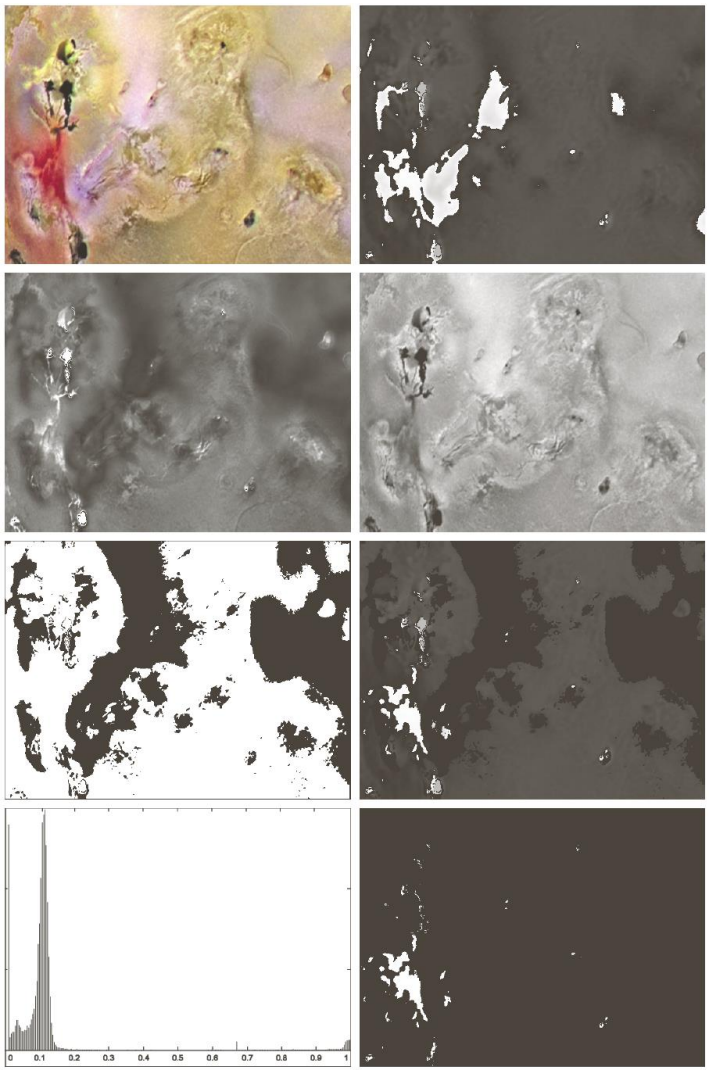
$$\nabla^2\left[c(x,y)\right] = \begin{bmatrix} \nabla^2 R(x,y) \\ \nabla^2 G(x,y) \\ \nabla^2 B(x,y) \end{bmatrix}$$



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.

Image Segmentation Based on Color Information



a b
c d
e f
g h

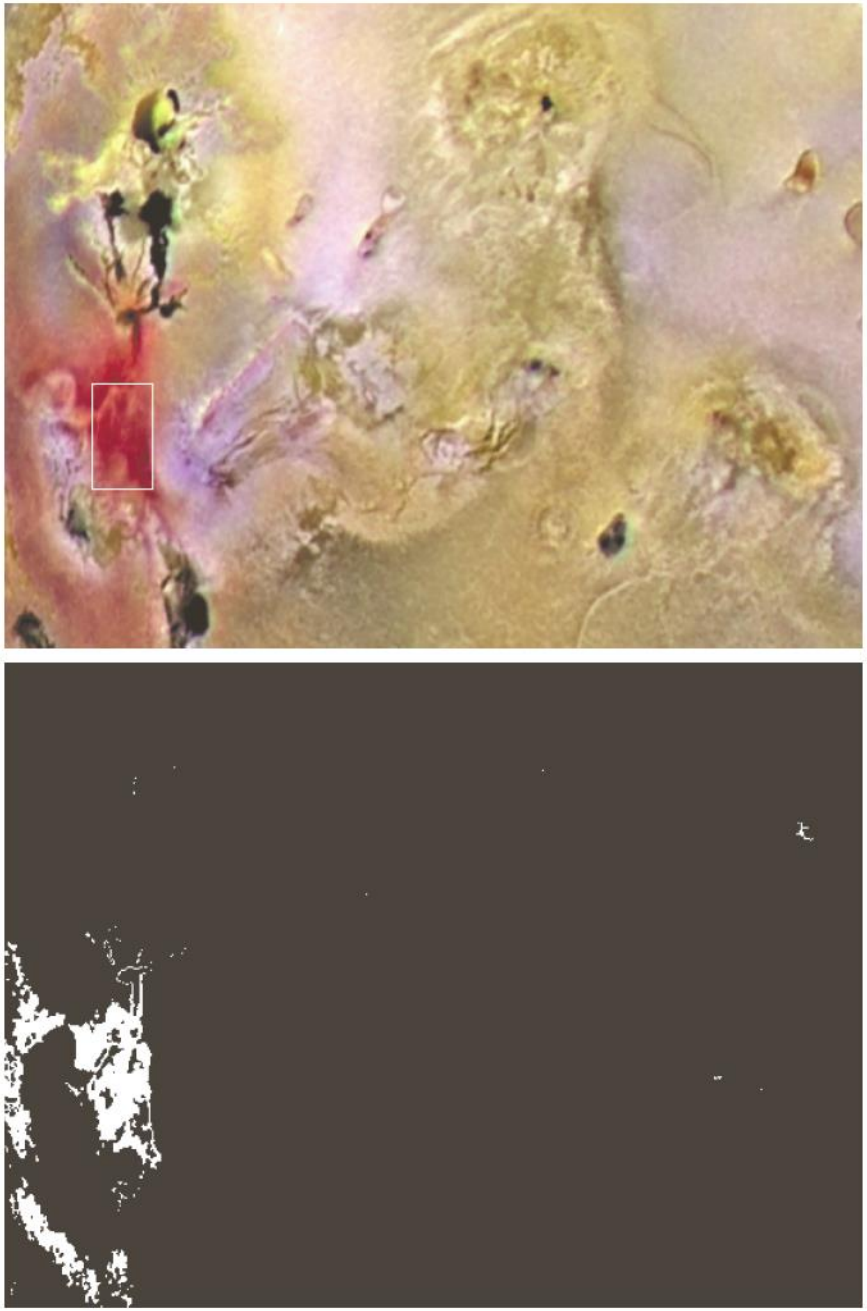
FIGURE 6.42 Image segmentation in HSI space. (a) Original. (b) Hue. (c) Saturation. (d) Intensity. (e) Binary saturation mask (black = 0). (f) Product of (b) and (e). (g) Histogram of (f). (h) Segmentation of red components in (a).

Segmentation in RGB Vector Space

Let the average color of interest is denoted by the RGB vector *a*. Let z denote an arbitrary point in RGB space.

$$D(z,a) = \|z-a\| = \left[(z-a)^T(z-a)\right]^{1/2}$$

$$= \left[(z_R-a_R)^2 + (z_G-a_G)^2 + (z_B-a_B)^2\right]^{1/2}$$



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).

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).]

a b c

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

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.

a
b

FIGURE 6.51
Color image compression. (a) Original RGB image. (b) Result of compressing and decompressing the image in (a).

References

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