4.4 Image Sharpening

- Introduction
- First-order derivative
- Second-order derivative
- High-pass filter in frequency domain

4.4 Image Sharpening

4.4.1 Introduction

Purposes: easy to detect edges

highlight fine detail

Request: insensitive to noise

4.4 Image Sharpening

4.4.1 Introduction: Sharpening filters

(1) First-order derivative : Robert
Prewitt Sobel
Robinson Kirsch

(2) Second-order derivative : Laplacian
LoG

(3) High-pass filter in frequency domain :
Idea high-pass filter (IHPF)
Butterworth high-pass filter (BHPF)
Gaussian high-pass filter (GHPF)

4.4 Image Sharpening

4.4.2 first-order derivative : foundation

The derivatives of a digital function are defined in terms of differences

For first derivative it must be

(1) zero in flat segment

(2) nonzero at the onset of a gray-level step or ramp

(3) nonzero along ramp

For second derivative it must be

(1) zero in flat segment

(2) nonzero at the onset and end of a gray-level step or ramp

(3) zero along ramp of constant slope

4.4 Image Sharpening

4.4.2 first-order derivative : foundation

A basic definition of the first-order derivative of a 1-D function *f(x)* is the difference

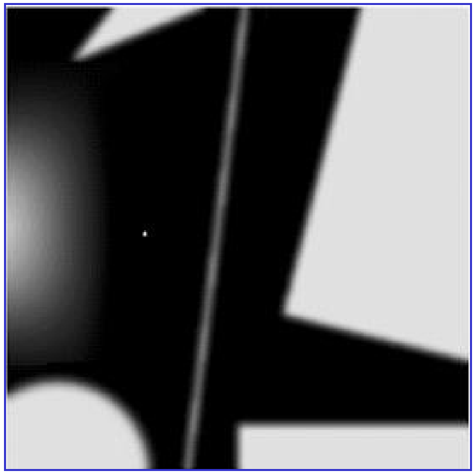
$$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

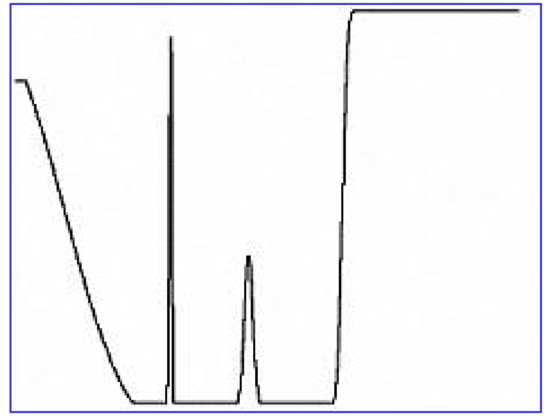
Similarly, we define a second-order derivative as the difference

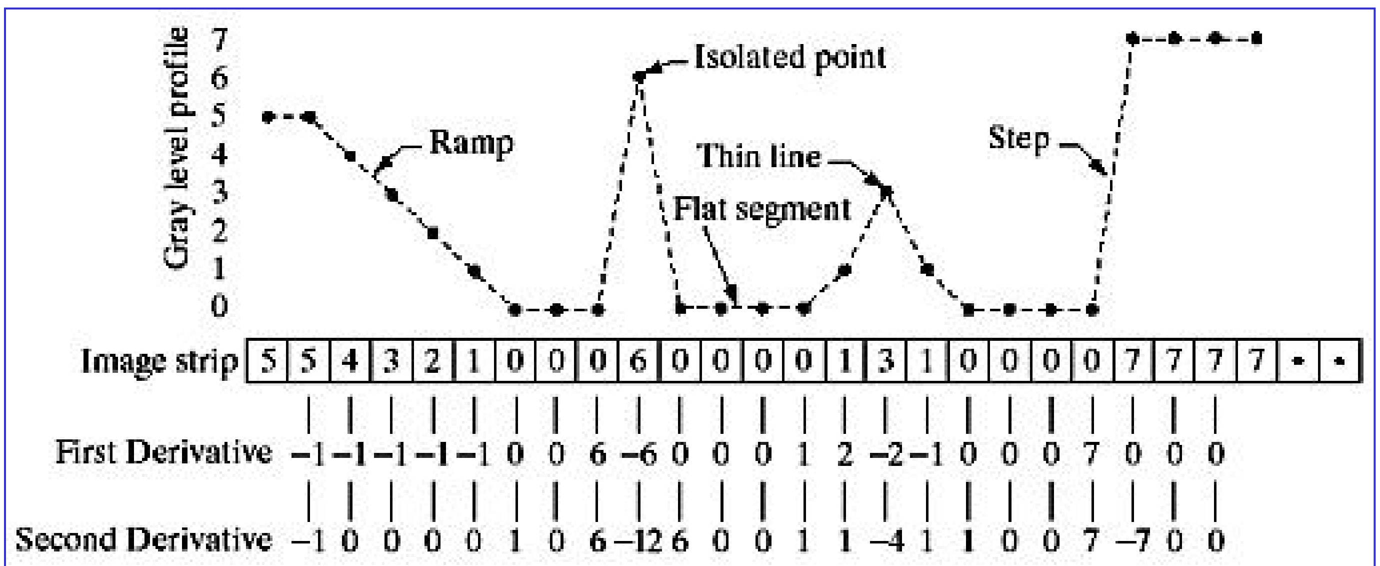
$$\begin{aligned}\frac{\partial^2 f}{\partial x^2} &= [f(x+1) - f(x)] - [f(x) - f(x-1)] \\ &= f(x+1) + f(x-1) - 2f(x)\end{aligned}$$

4.4 Image Sharpening

4.4.2 first-order derivative : foundation







4.4 Image Sharpening

4.4.2 first-order derivative : foundation

First-order derivatives of a digital image are based on various approximations of the 2-D gradient. It is defined as the vector:

$$\nabla f = \left[\frac{\partial f}{\partial x} \quad \frac{\partial f}{\partial y} \right]^T$$

Magnitude:

$$|\nabla f| = \left[\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right]^{1/2} \longrightarrow |\nabla f| \approx \left| \left(\frac{\partial f}{\partial x} \right) \right| + \left| \left(\frac{\partial f}{\partial y} \right) \right|$$

$$\Big\downarrow$$

$$|\nabla f| \approx \max \left\{ \left| \frac{\partial f}{\partial x} \right|, \left| \frac{\partial f}{\partial y} \right| \right\}$$

Direction:

$$\alpha(x, y) = \tan^{-1} \left(\frac{G_y}{G_x} \right)$$

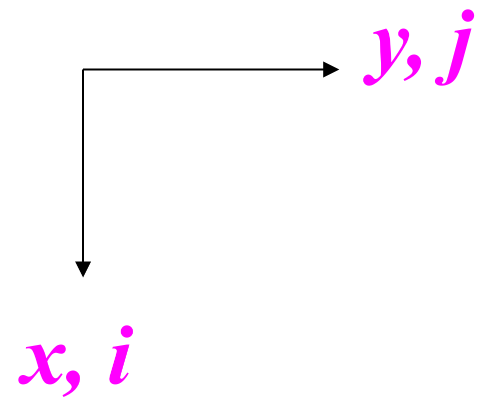
4.4 Image Sharpening

4.4.2 first-order derivative : foundation

where

$$G_x = \frac{\partial f}{\partial x} = f(x+1, y) - f(x, y)$$

$$G_y = \frac{\partial f}{\partial y} = f(x, y+1) - f(x, y)$$



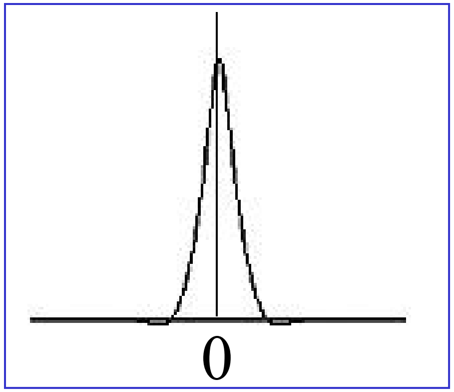
These equations can be implemented using masks

$$G_x = \begin{vmatrix} -1 & 0 \\ 1 & 0 \end{vmatrix} \qquad G_y = \begin{vmatrix} -1 & 1 \\ 0 & 0 \end{vmatrix}$$

4.4 Image Sharpening

4.4.2 first-order derivative : display

$f(x, y) \longrightarrow g(x, y) = \nabla f$



(1) $g(x, y) = |\nabla f|$

(2) $g(x, y) = f(x, y) + |\nabla f|$

(3) Linear scaling $g(x, y)$

(4) $g(x, y) = \begin{cases} L_b & |\nabla f| < \mathrm{T} \\ L_t & \text{othewise} \end{cases}$

4.4 Image Sharpening

4.4.2 first-order derivative : foundation

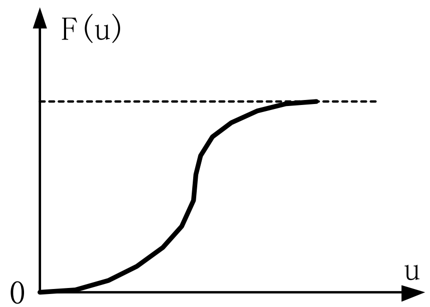
a b
c d

FIGURE 10.10 (a) Original image. (b) $|G_x|$, component of the gradient in the x-direction. (c) $|G_y|$, component in the y-direction. (d) Gradient image, $|G_x| + |G_y|$.

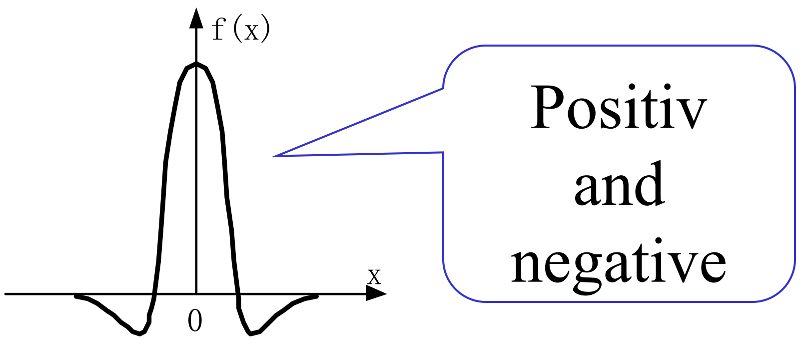
4.4 Image Sharpening

4.4.2 first-order derivative : foundation

Spatial filter: the sign of filter coefficients



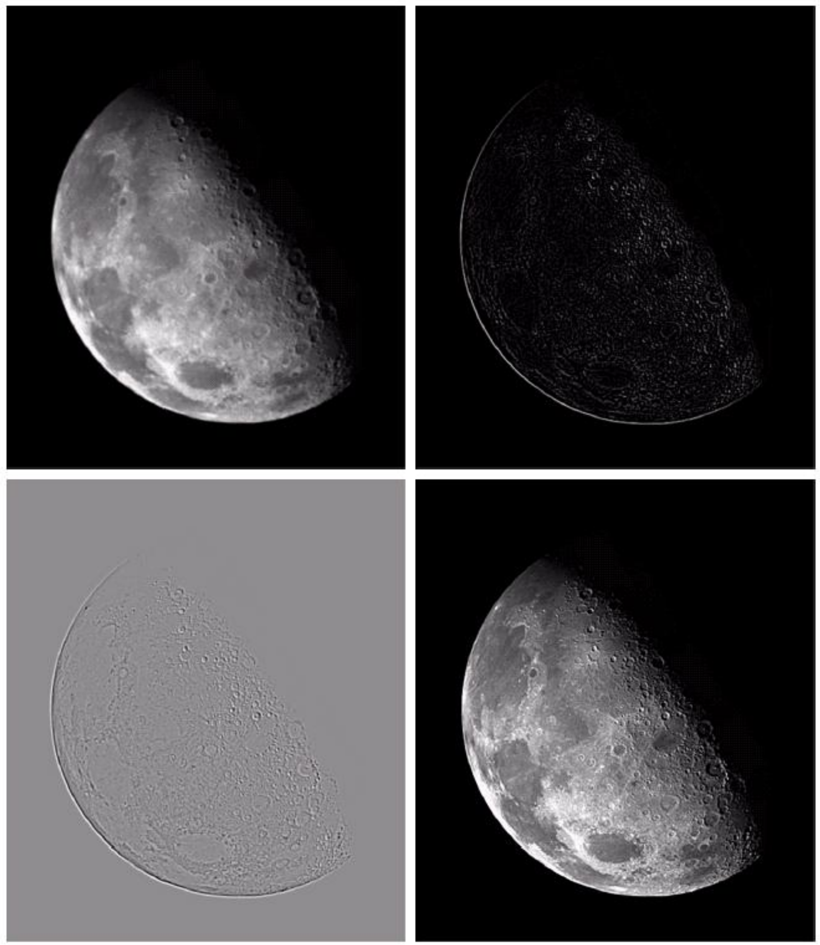
(c)



(d)

4.4 Image Sharpening

4.4.2 first-order derivative : display



a b
c d

FIGURE 3.40 (a) Image of the North Pole of the moon. (b) Laplacian-filtered image. (c) Laplacian image scaled for display purposes. (d) Image enhanced by using Eq. (3.7-5). (Original image courtesy of NASA.)

4.4 Image Sharpening

4.4.2 first-order derivative : gradient operators

Roberts operator

$$G_x = \begin{vmatrix} 1 & 0 \\ 0 & -1 \end{vmatrix} \qquad G_y = \begin{vmatrix} 0 & 1 \\ -1 & 0 \end{vmatrix}$$

Prewitt operator

$$G_x = \begin{vmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{vmatrix} \qquad G_y = \begin{vmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{vmatrix}$$

Sobel operator

$$G_x = \begin{vmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{vmatrix} \qquad G_y = \begin{vmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{vmatrix}$$

4.4 Image Sharpening

4.4.2 first-order derivative : gradient operators

Roberts operator

4.4 Image Sharpening

4.4.2 first-order derivative : gradient operators

Prewitt operator

4.4 Image Sharpening

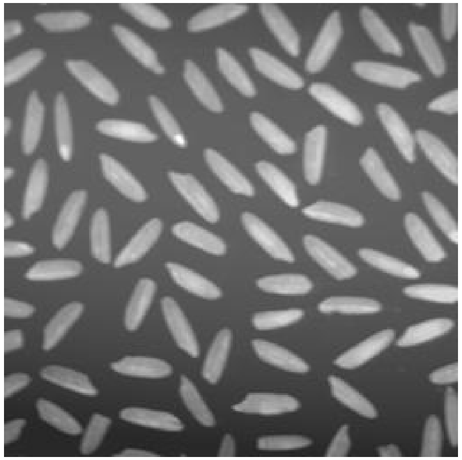
4.4.2 first-order derivative : gradient operators

Sobel operator

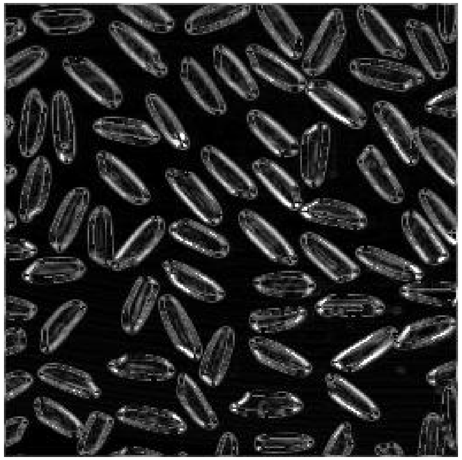
4.4 Image Sharpening

4.4.2 first-order derivative : gradient operators

Sobel operator



original



Sobel

Binary display

4.4 Image Sharpening

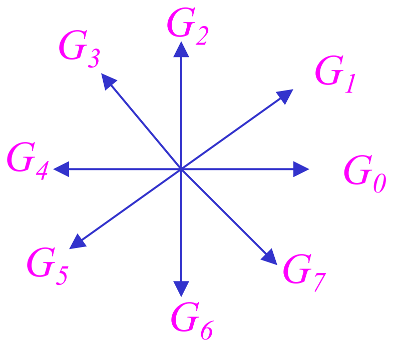
4.4.2 first-order derivative : gradient operators

Robinson

$$G_0 = \begin{vmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{vmatrix} \quad G_1 = \begin{vmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{vmatrix} \quad G_2 = \begin{vmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{vmatrix} \quad G_3 = \begin{vmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{vmatrix}$$

$$G_4 = \begin{vmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{vmatrix} \quad G_5 = \begin{vmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{vmatrix} \quad G_6 = \begin{vmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{vmatrix} \quad G_7 = \begin{vmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{vmatrix}$$

$$|\nabla f| \approx \max_{i=0,1\ldots7} \{G_i\}$$



4.4 Image Sharpening

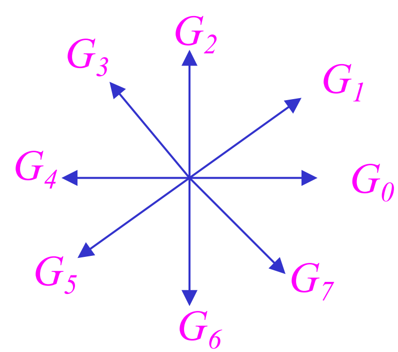
4.4.2 first-order derivative : gradient operators

Kirsch

$$G_0 = \begin{vmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{vmatrix} \quad G_1 = \begin{vmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{vmatrix} \quad G_2 = \begin{vmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{vmatrix} \quad G_3 = \begin{vmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{vmatrix}$$

$$G_4 = \begin{vmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{vmatrix} \quad G_5 = \begin{vmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{vmatrix} \quad G_6 = \begin{vmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{vmatrix} \quad G_7 = \begin{vmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{vmatrix}$$

$$\left|\nabla f\right| \approx \max_{i=0,1\ldots7} \left\{ G_i \right\}$$



4.4 Image Sharpening

4.4.3 second-order derivative : definitions

The second-order derivative is defined as

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

where
$$\frac{\partial^2 f}{\partial x^2} = f(x+1, y) + f(x-1, y) - 2f(x, y)$$

$$\frac{\partial^2 f}{\partial y^2} = f(x, y+1) + f(x, y-1) - 2f(x, y)$$

namely
$$\nabla^2 f = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x, y)]$$

4.4 Image Sharpening

4.4.3 second-order derivative : Laplacian

It is well known as *Laplacian* operator. It can be implemented as a mask

$$G = \begin{vmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{vmatrix}$$

4.4 Image Sharpening

4.4.3 second-order derivative : Laplacian

Experiment result $g(x,y) = f(x,y) + \nabla^2 f(x,y)$

4.4 Image Sharpening

4.4.3 second-order derivative : Laplacian

natural result:

4.4 Image Sharpening

4.4.3 second-order derivative : LoG

Smoothing first

$$h(r) = -e^{-\frac{r^2}{2\sigma^2}}$$

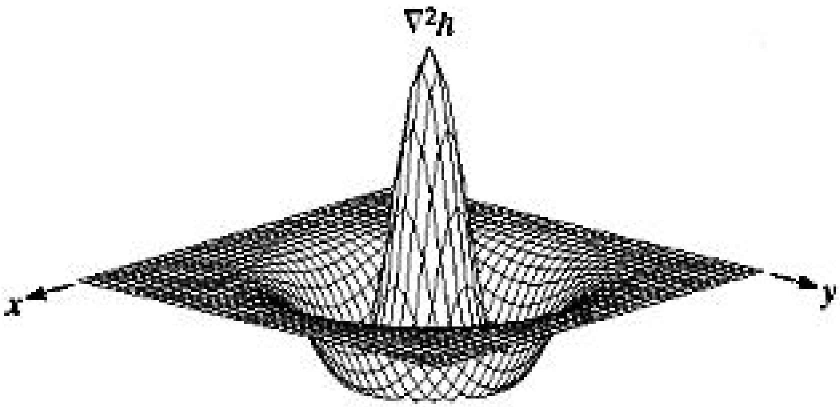
$$r = x^2 + y^2$$

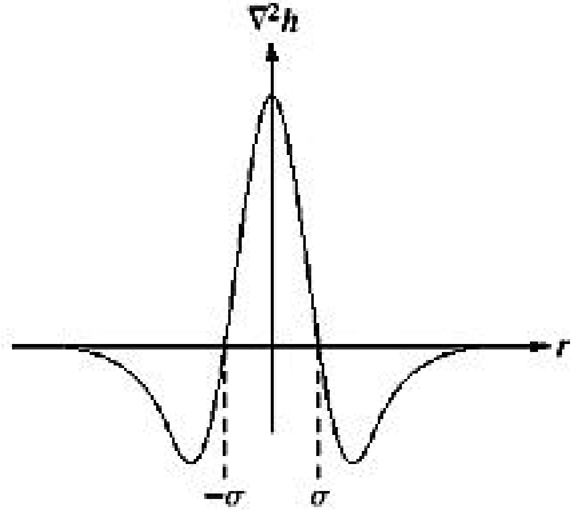
Laplacian sharpening

$$\nabla^2 h(r) = -\left[\frac{r^2 - \sigma^2}{\sigma^4}\right] e^{-\frac{r^2}{2\sigma^2}}$$

4.4 Image Sharpening

4.4.3 second-order derivative : LoG





0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

4.4 Image Sharpening

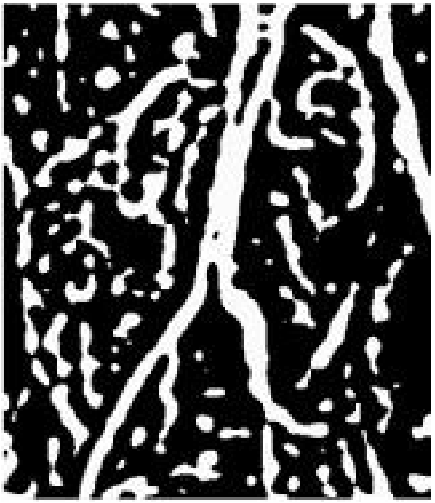
4.4.3 second-order derivative : LoG

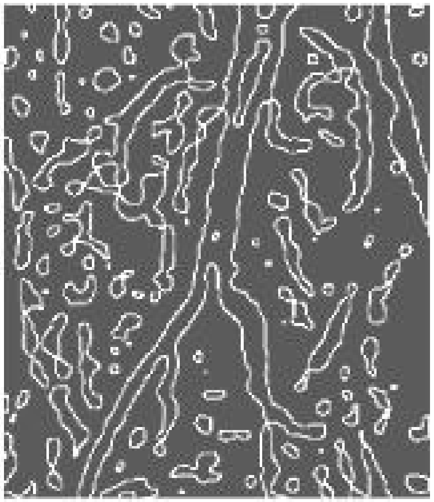
original

Sobel

LoG

Thresholded LoG





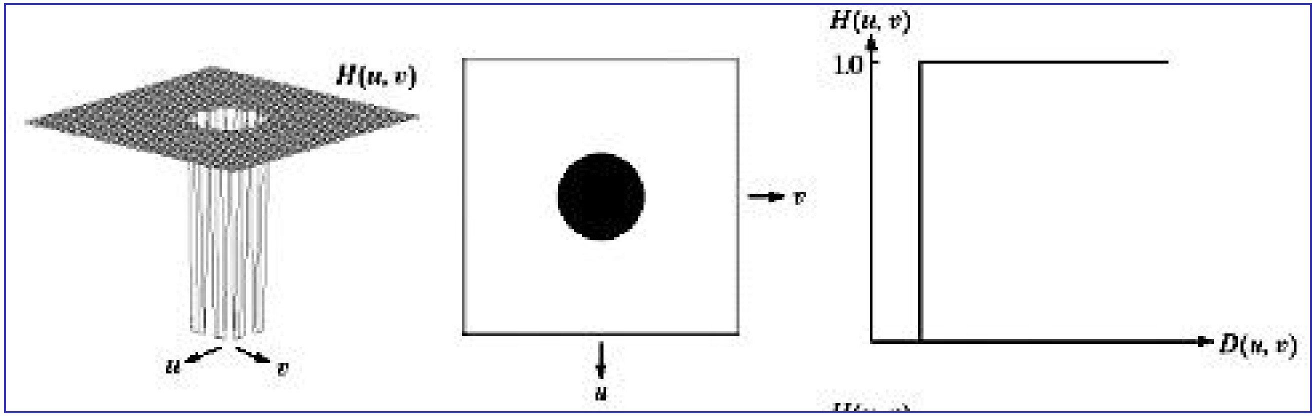
Zero cross

4.4 Image Sharpening

4.4.3 High-pass filter: Ideal highpass filter (IHPF)

formula

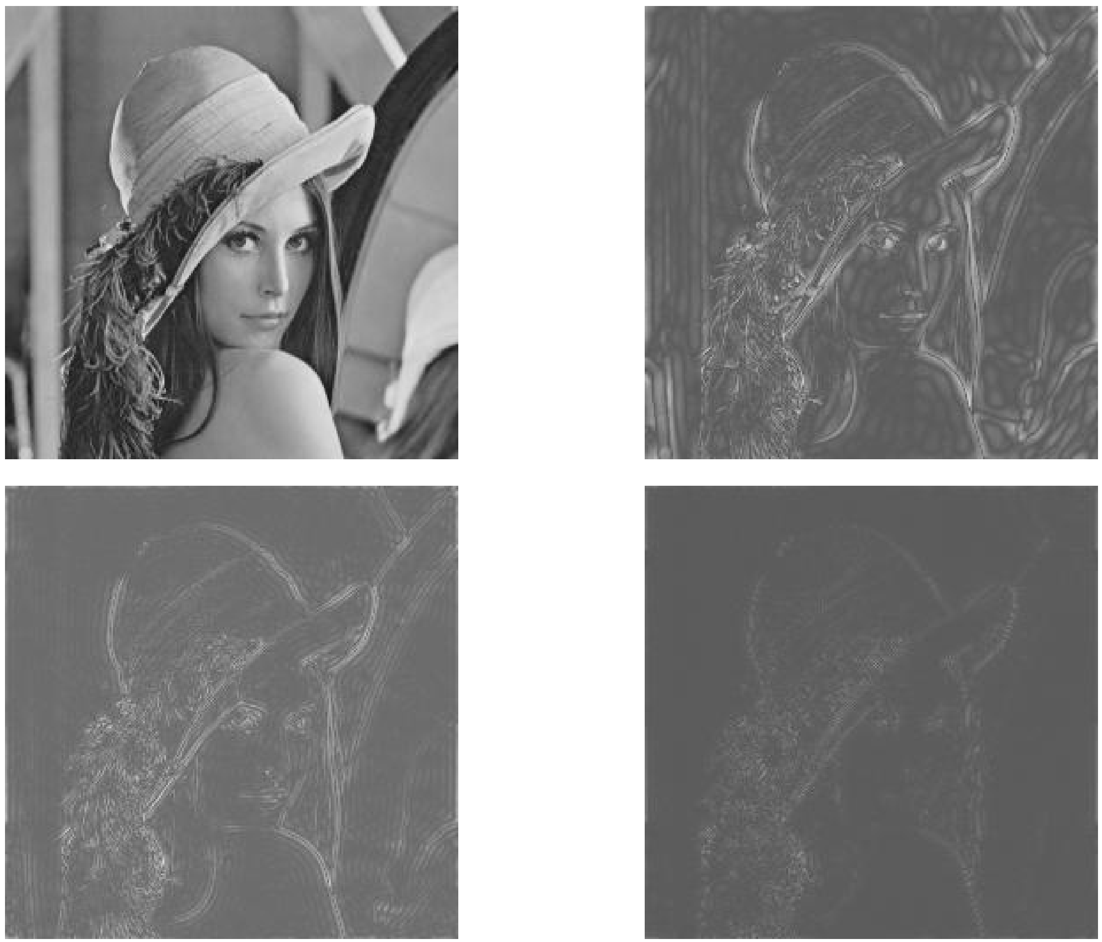
$$H(u,v)=\begin{cases}0 & \text{if} \quad D(u,v)\le D_0\\ 1 & \text{if} \quad D(u,v)>D_0\end{cases}$$



4.4 Image Sharpening

4.4.3 High-pass filter: Ideal highpass filter (IHPF)

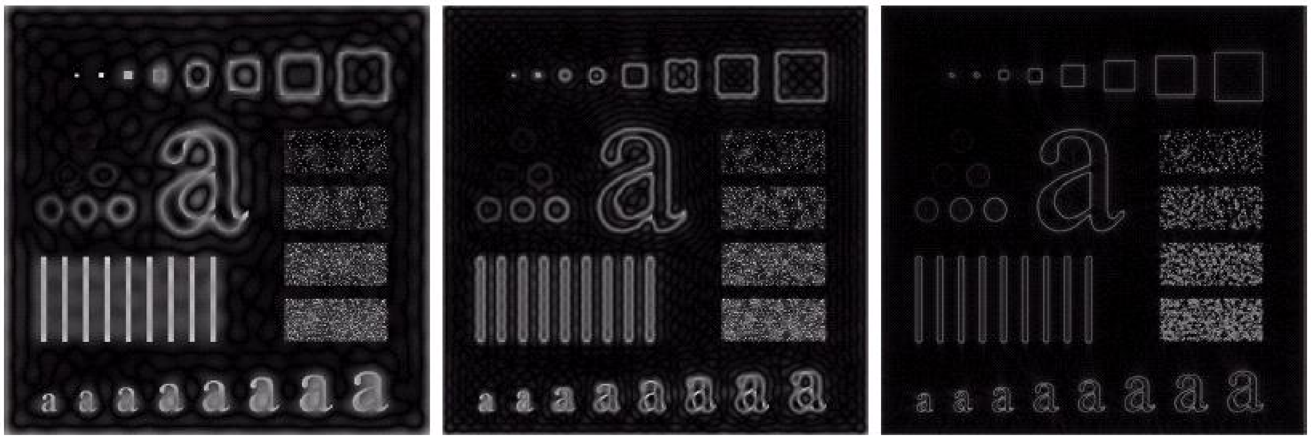
cutoff frequencies set at radii values of 15、30、80



4.4 Image Sharpening

4.4.3 High-pass filter: Ideal highpass filter (IHPF)

cutoff frequencies set at radii values of 15、30、80



a b c

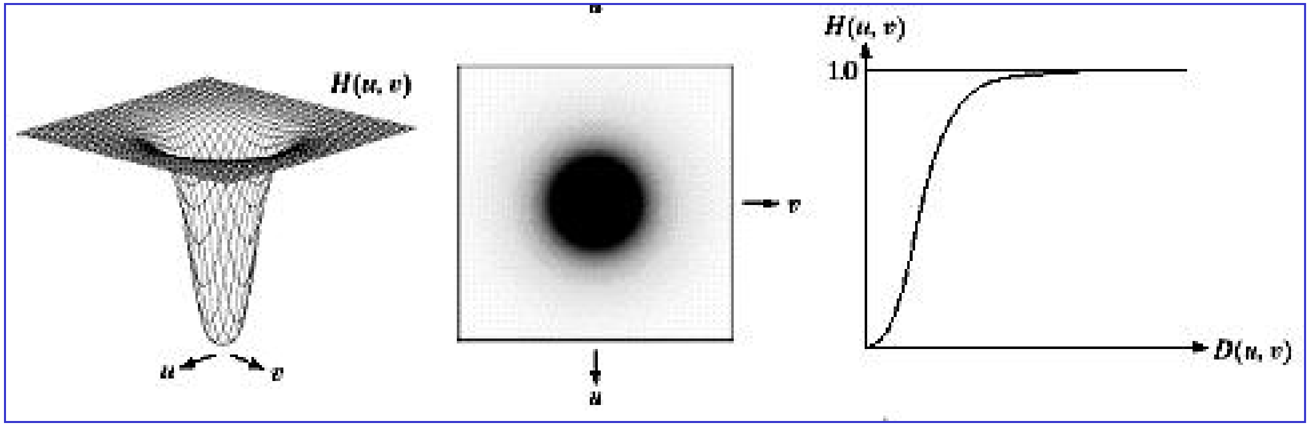
FIGURE 4.24 Results of ideal highpass filtering the image in Fig. 4.11(a) with $D_0 = 15$, 30, and 80, respectively. Problems with ringing are quite evident in (a) and (b).

4.4 Image Sharpening

4.4.3 High-pass filter: Butterworth highpass filter (BHPF)

formula

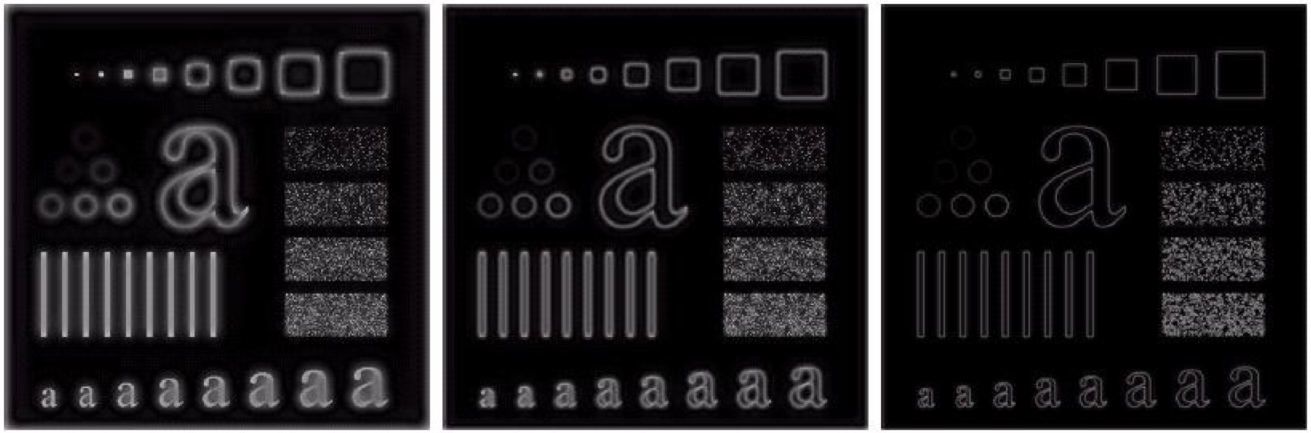
$$H(u,v)=\frac{1}{1+[D_0/D(u,v)]^{2n}}$$



4.4 Image Sharpening

4.4.3 High-pass filter: Butterworth highpass filter (BHPF)

cutoff frequencies set at radii values of 15、30、80



a b c

FIGURE 4.25 Results of highpass filtering the image in Fig. 4.11(a) using a BHPF of order 2 with $D_0 = 15$, 30, and 80, respectively. These results are much smoother than those obtained with an ILPF.

4.4 Image Sharpening

4.4.3 High-pass filter: Butterworth highpass filter (BHPF)

cutoff frequencies set at radii values of 15、30、80.

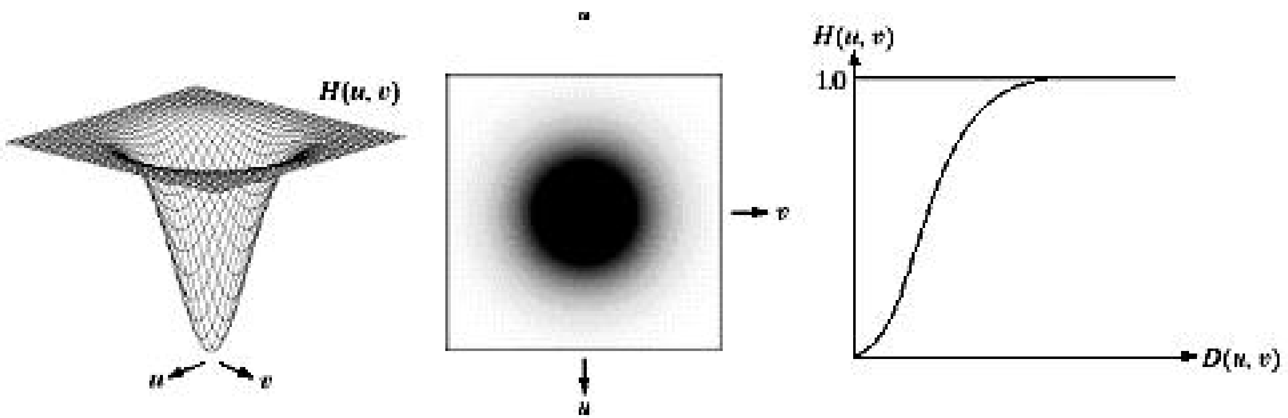



4.4 Image Sharpening

4.4.3 High-pass filter: Gaussian highpass filter (GHPF)

formula

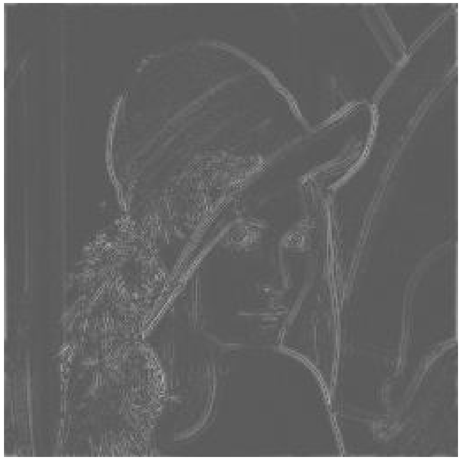
$$H(u,v) = 1 - e^{-D^2(u,v)/2D_0^2}$$



4.4 Image Sharpening

4.4.3 High-pass filter: Gaussian highpass filter (GHPF)

cutoff frequencies set at radii values of 15、30、80.



4.4 Image Sharpening

4.4.3 High-pass filter: Homomorphic filter

An image f(x,y) can be expressed as the product of illumination and reflectance components

$$f(x, y) = i(x, y)r(x, y)$$

let

$$z(x, y) = \ln f(x, y) = \ln i(x, y) + \ln r(x, y)$$

4.4 Image Sharpening

4.4.3 High-pass filter: Homomorphic filter

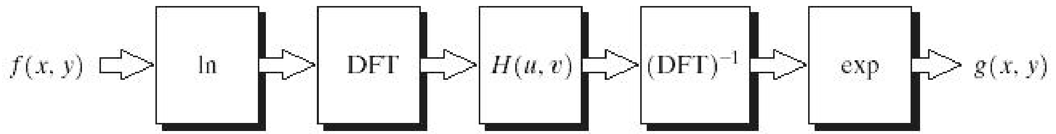


FIGURE 4.31 Homomorphic filtering approach for image enhancement.

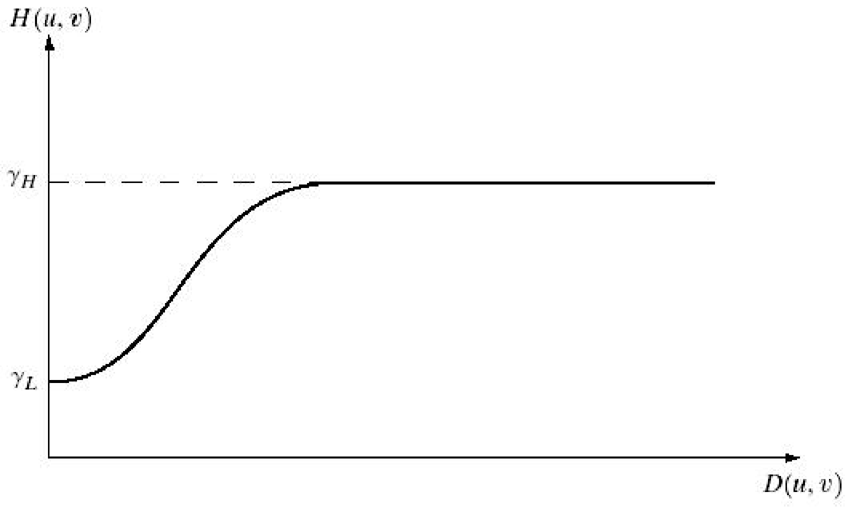
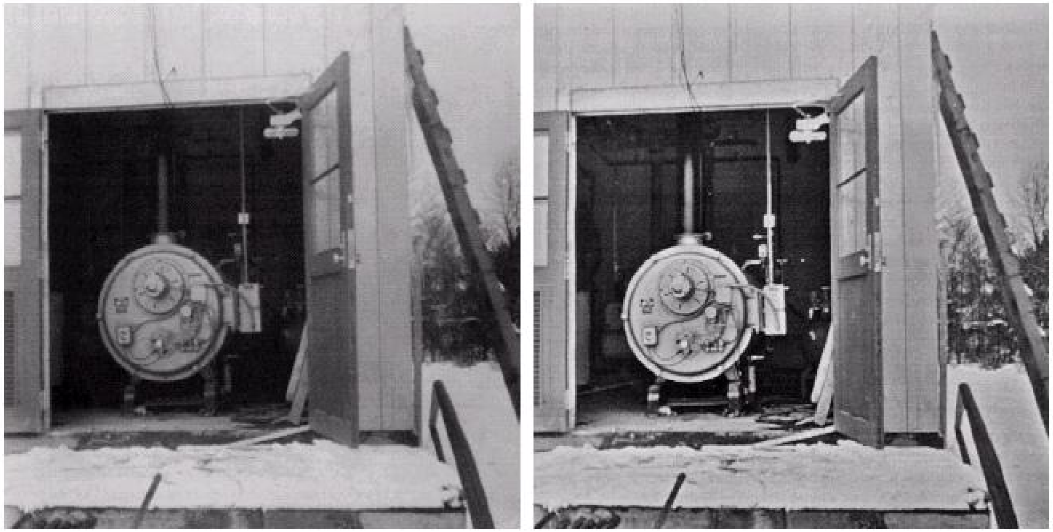


FIGURE 4.32 Cross section of a circularly symmetric filter function. $D(u, v)$ is the distance from the origin of the centered transform.

4.4 Image Sharpening

4.4.3 High-pass filter: Homomorphic filter

Experimental result



a b

FIGURE 4.33 (a) Original image. (b) Image processed by homomorphic filtering (note details inside shelter). (Stockham.)

4.5 Color Image Enhancement

- Introduction
- Pseudo color image processing
- Full color enhancement
- Noise in color image

4.5 Color Image Enhancement

4.5.1 Introduction: review

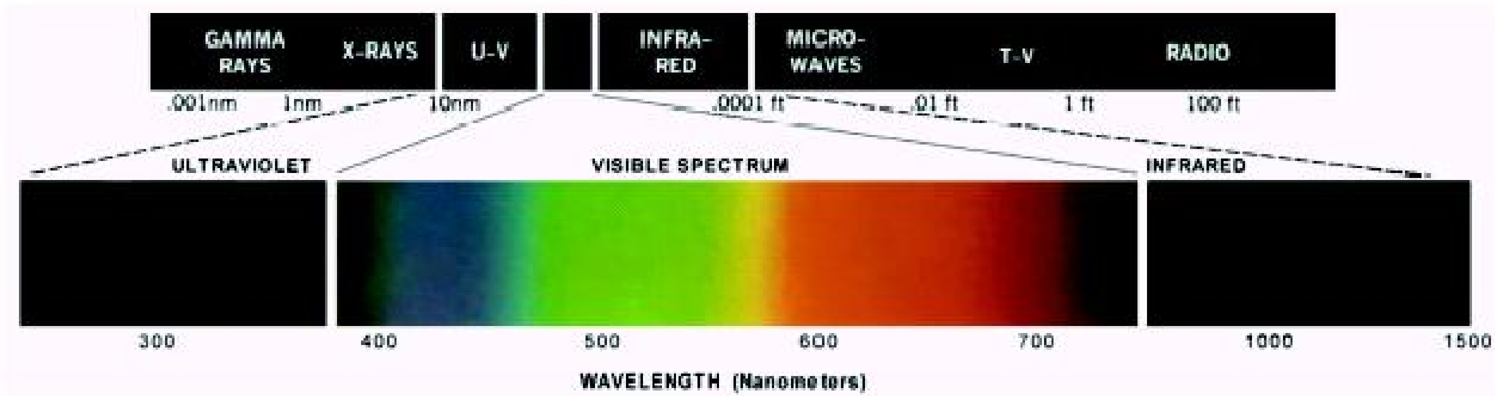
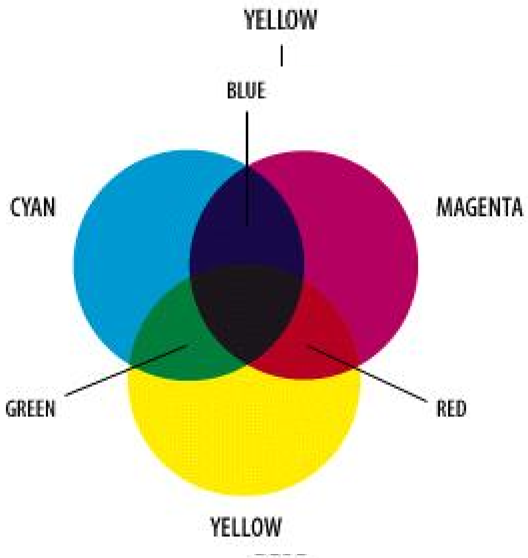


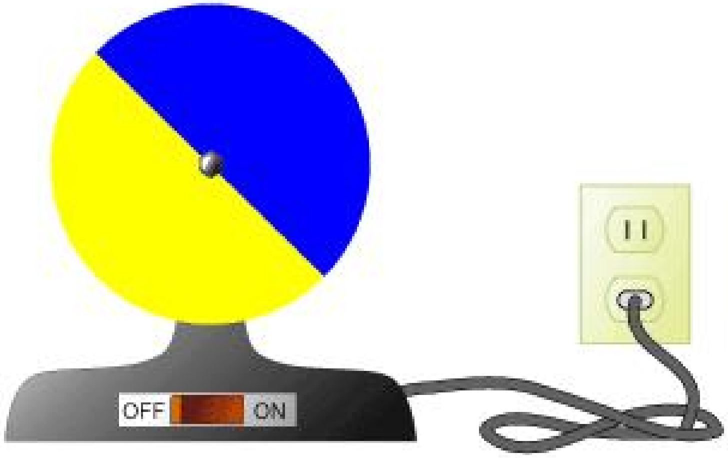
FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

4.5 Color Image Enhancement

4.5.1 Introduction: review



Primary colors of light



Color wheel

Rotate slowly

4.5 Color Image Enhancement

4.5.1 Introduction: review

$$C = X\left[R\right] + Y\left[G\right] + Z\left[B\right]$$

Eg:

Red=1[R]+0[G]+0[B]

Yellow=1[R]+1[G]+0[B]

Cyan=0[R]+1[G]+1[B]

Magenta=1[R]+0[G]+1[B]

Black=0[R]+0[G]+0[B]

White=1[R]+1[G]+1[B]

Hue 色调

Saturation饱和度

Intensity辉度

Chroma 色度

4.5 Color Image Enhancement

4.5.1 Introduction: review

If the tristimulus values are denoted, X,Y and Z, then the trichromatic coefficients are defined as:

$$x = \frac{X}{X+Y+Z} \qquad (2.3.1)$$

$$y = \frac{Y}{X+Y+Z} \qquad (2.3.2)$$

$$z = \frac{Z}{X+Y+Z} \qquad (2.3.3)$$

$$x + y + z = 1 \qquad (2.3.4)$$

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Fundament: CIE chromaticity diagram

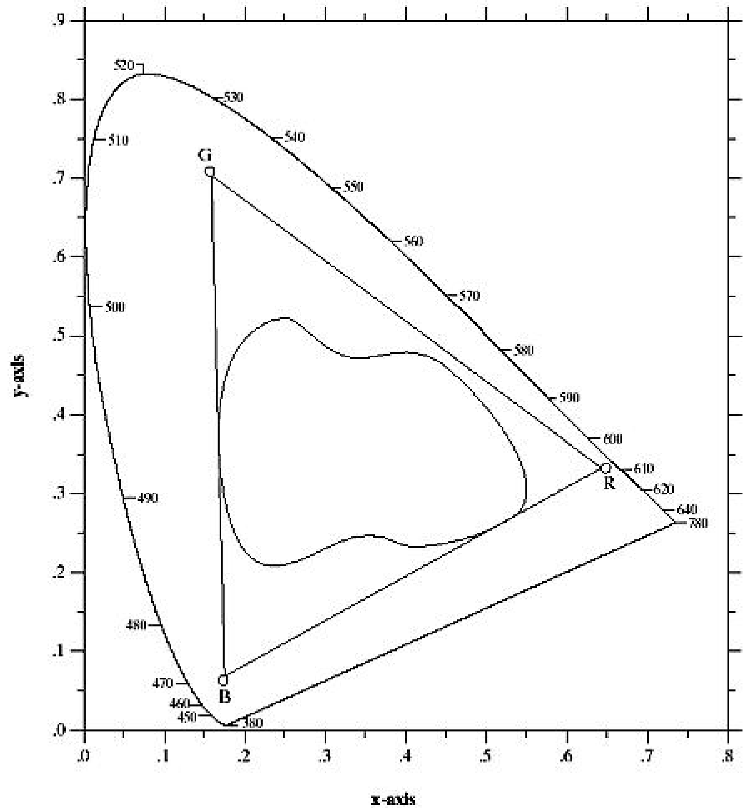
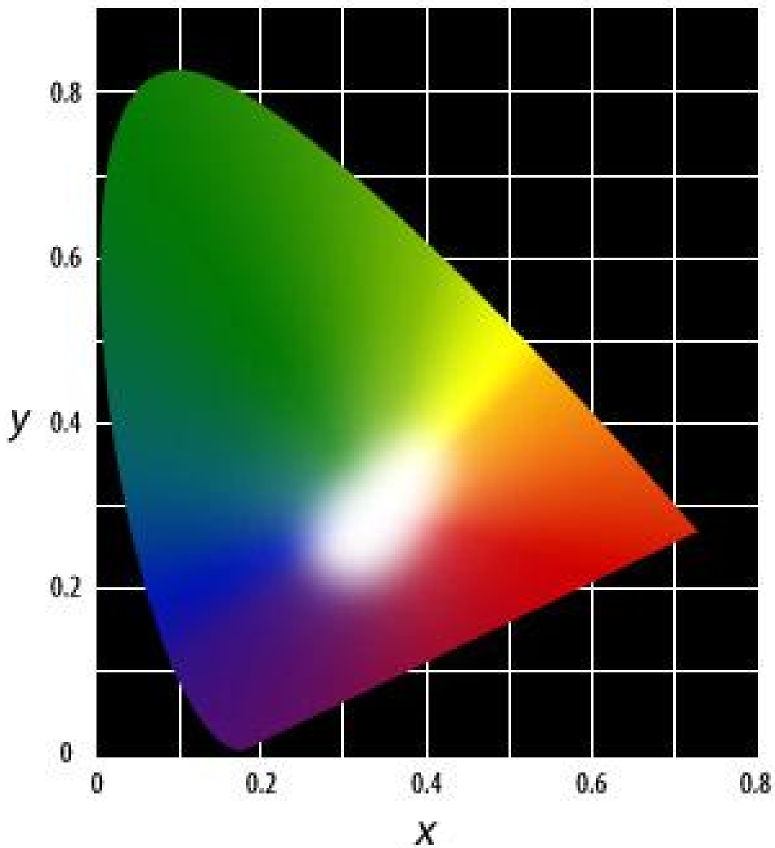


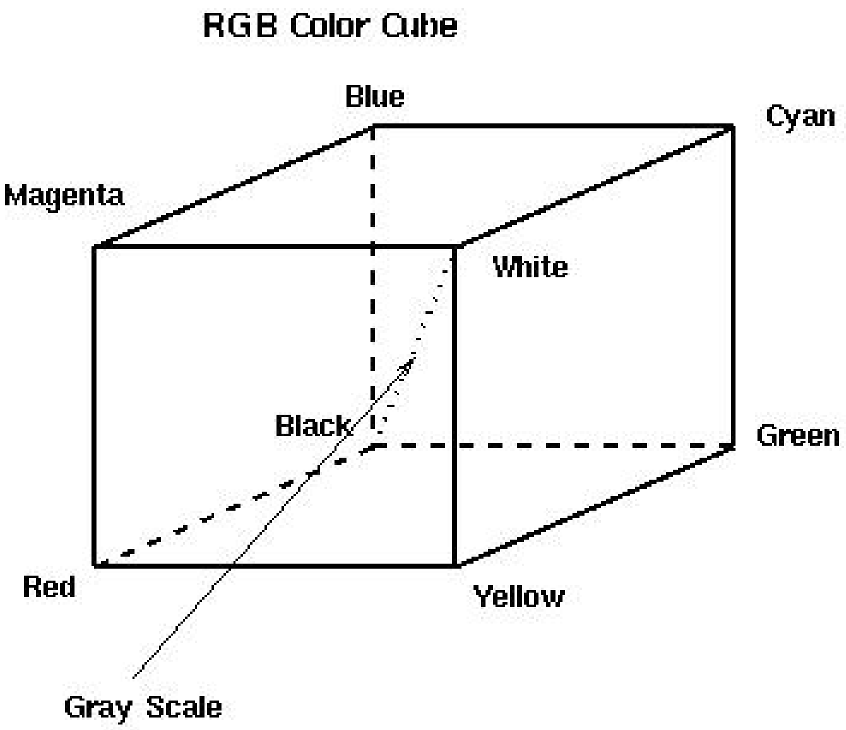
FIGURE 6.6 Typical color gamut of color monitors (triangle) and color printing devices (irregular region).

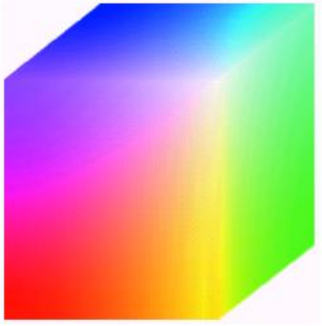


4.5 Color Image Enhancement

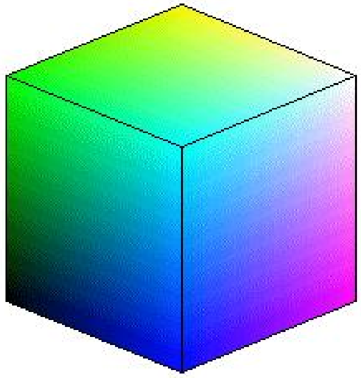
4.5.1 Introduction: review

Color Model: RGB model





6.8 RGB 24-bit color cube.



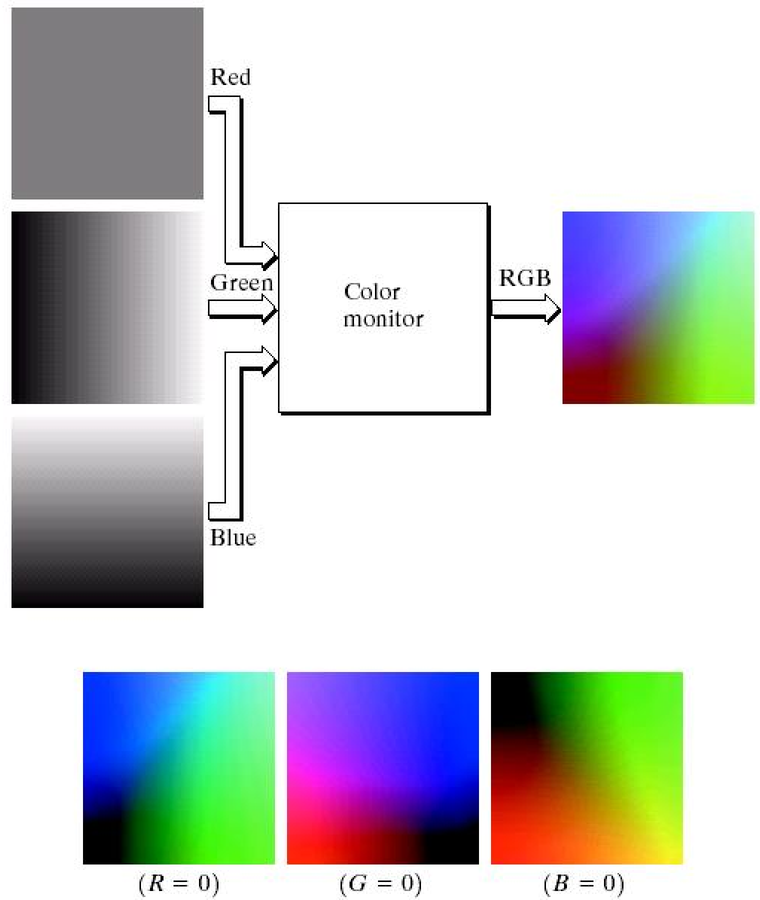
4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: RGB model

a
b

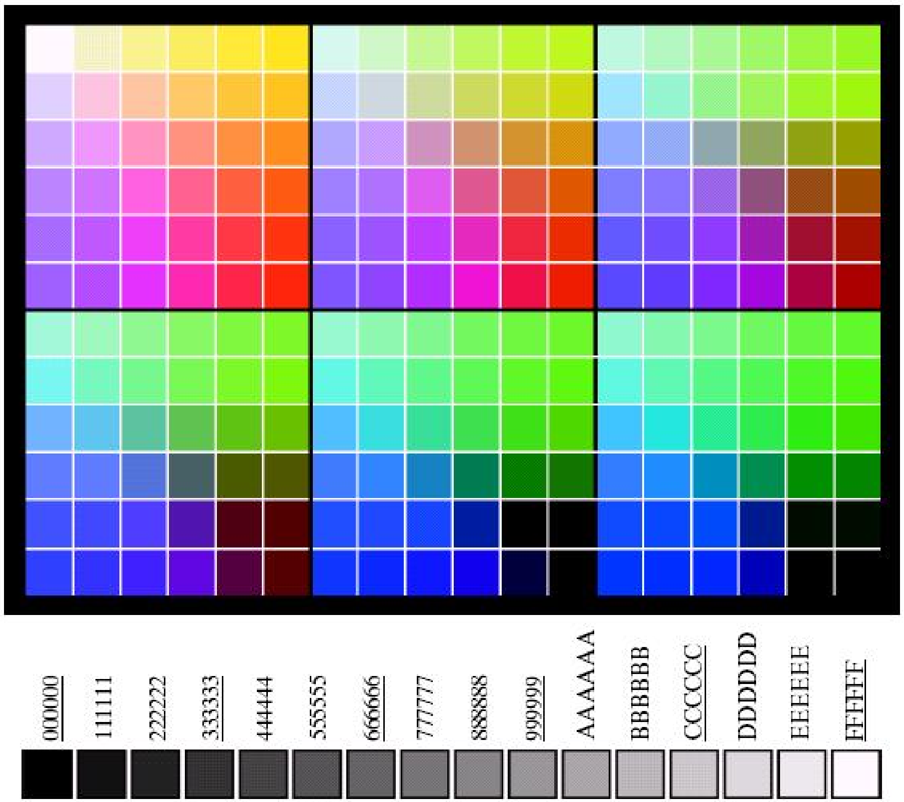
FIGURE 6.9 (a) Generating the RGB image of the cross-sectional color plane (127, *G*, *B*). (b) The three hidden surface planes in the color cube of Fig. 6.8.



4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: RGB model



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).

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: safe colors of RGB model

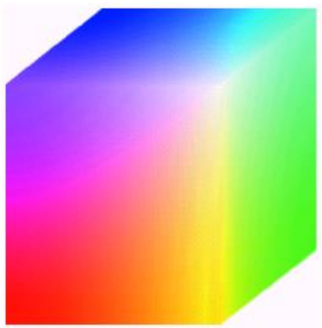


FIGURE 6.8 RGB 24-bit color cube.

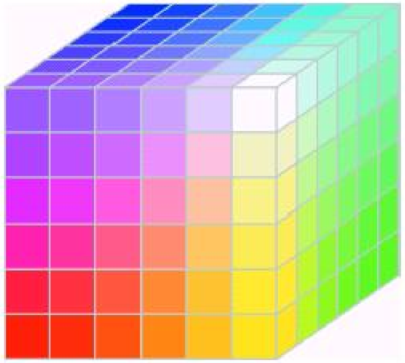


FIGURE 6.11 The RGB safe-color cube.

4.5 Color Image Enhancement

4.5.1 Introduction: review

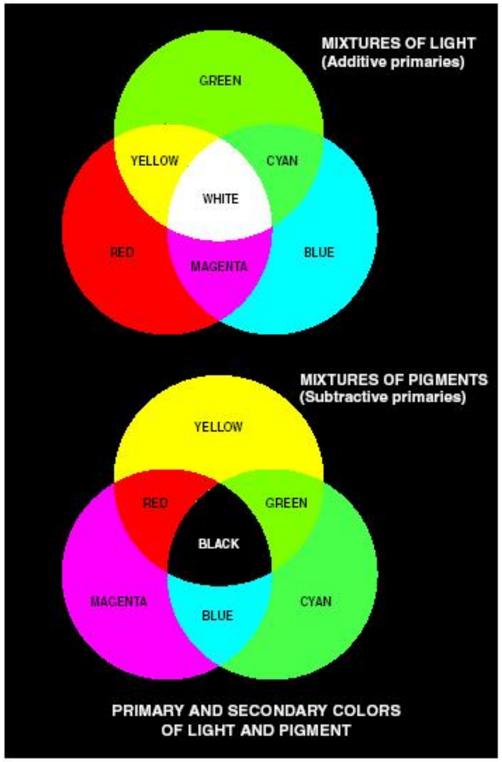
Color Model: CMY model

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

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: CMY model



a
b

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

4.5 Color Image Enhancement

4.5.1 Introduction: review

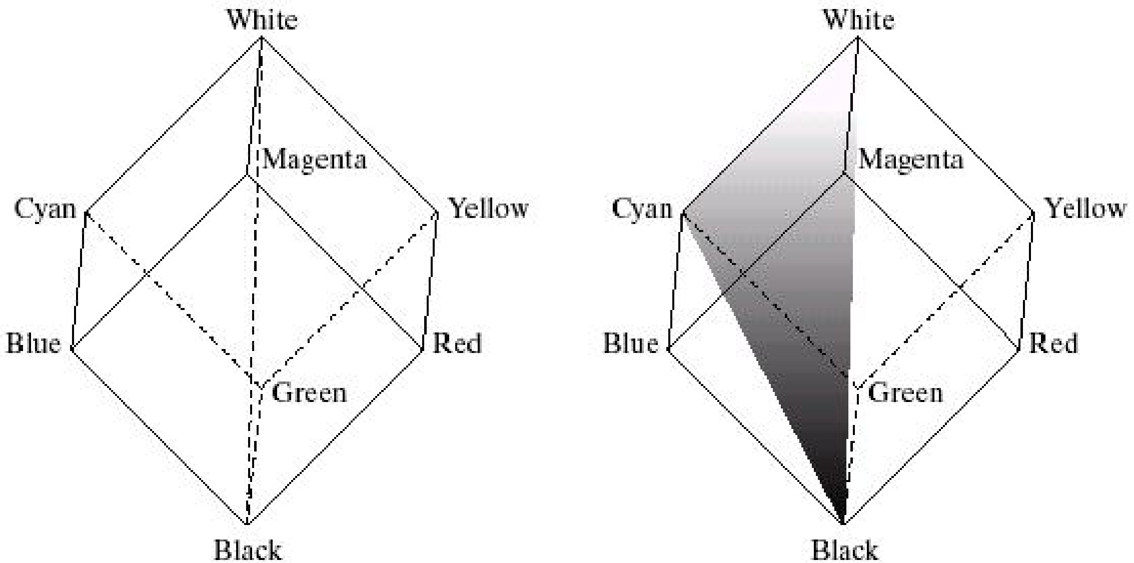
Color Model: HSI model

- **Hue:** associated with the dominant wavelength in a mixture of light waves
- **Saturation:** refer to the relative purity or the amount of white light mixed with hue.
- **Intensity:** brightness

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: HSI model



a b

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

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: HSI model

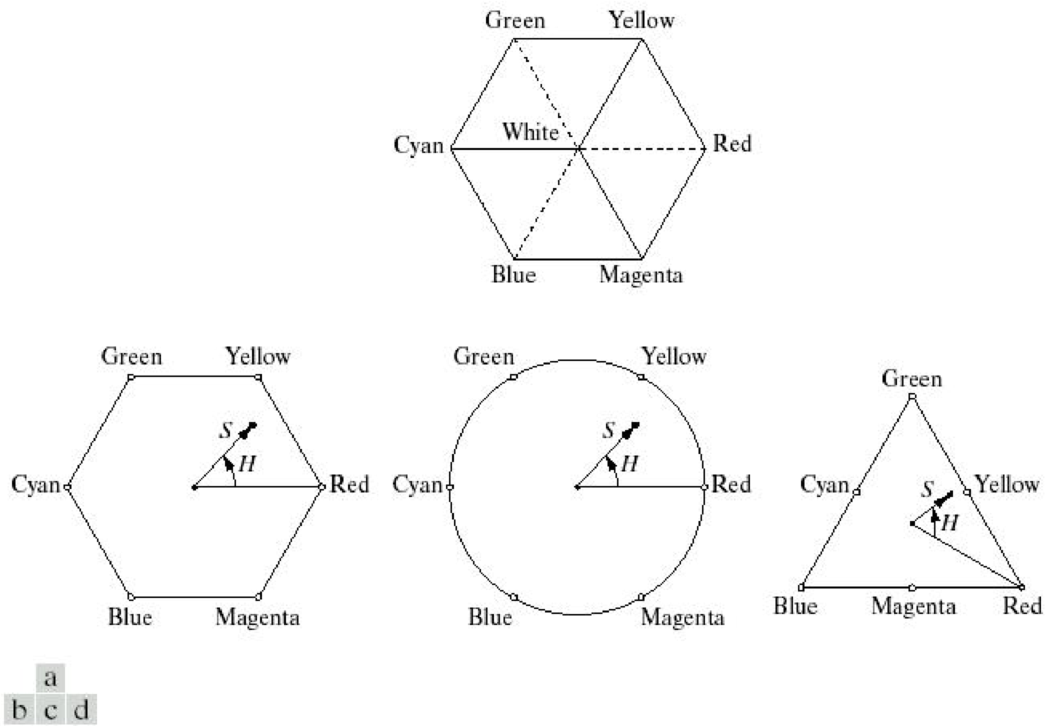
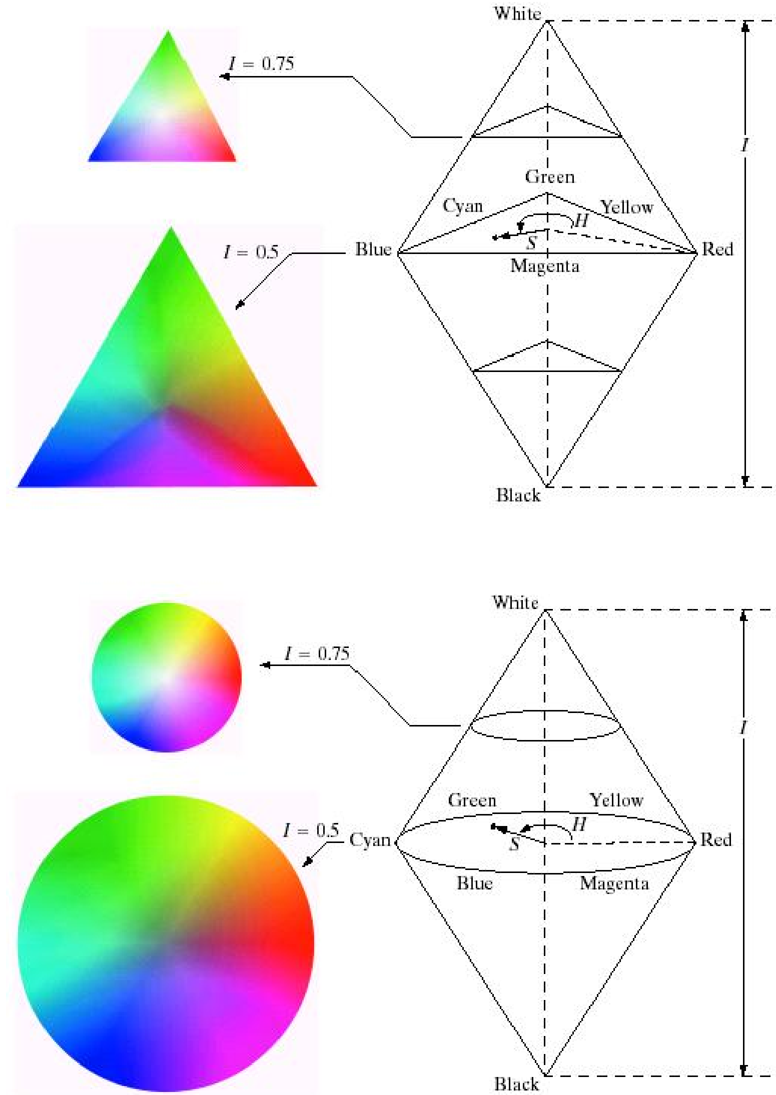


FIGURE 6.13 Hue and saturation in the HSI color model. The dot is an arbitrary color point. The angle from the red axis gives the hue, and the length of the vector is the saturation. The intensity of all colors in any of these planes is given by the position of the plane on the vertical intensity axis.

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: HSI model



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.

Color	H	S	I
Red	0	1	0.5
Green	120	1	0.5
Blue	240	1	0.5
White	0	0	1
Black	0	0	0

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from RGB to HSI

$$I = \frac{1}{3}(R+G+B)$$

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

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

$$H = \begin{cases} \theta & B \le G \\ 360-\theta & \text{others} \end{cases}$$

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from HSI to RGB

RG Sector: $0^o \le H < 120^o$

$$B = I(1 - S)$$

$$R = I\left[1 + \frac{S\cos H}{\cos(60^\circ - H)}\right]$$

$$G = 3I - (B + R)$$

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from HSI to RGB

GB Sector: $120^o \le H < 240^o$

$$R = I(1 - S)$$

$$G = I\left[1 + \frac{S\cos\left(H - 120^\circ\right)}{\cos(180^\circ - H)}\right]$$

$$B = 3I - (R + G)$$

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from HSI to RGB

BR Sector: $240^o \le H < 360^o$

$$G = I(1 - S)$$

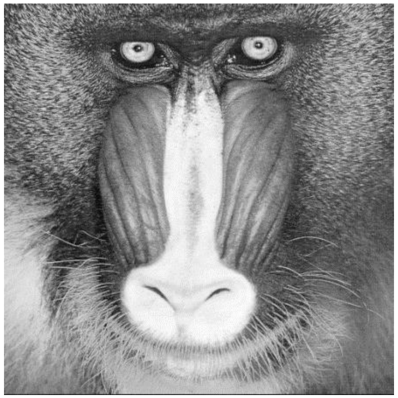
$$B = I\left[1 + \frac{S\cos(H - 240^\circ)}{\cos(300^\circ - H)}\right]$$

$$R = 3I - (G + B)$$

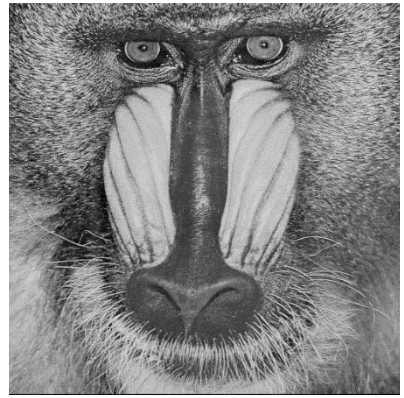
FIGURE 6.30 A full-color image and its various color-space components. (Original image courtesy of Med-Data Interactive.)

4.5 Color Image Enhancement

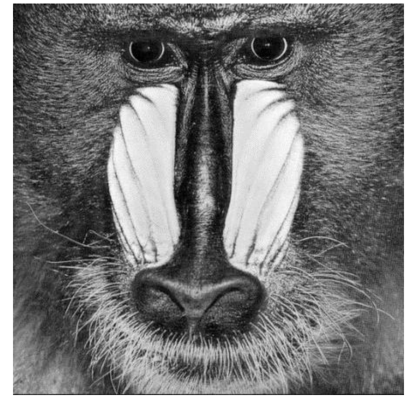
4.5.1 Introduction: review



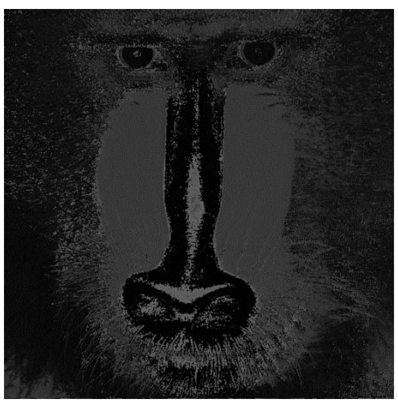
R



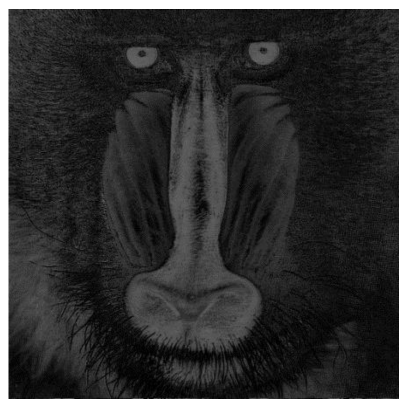
G



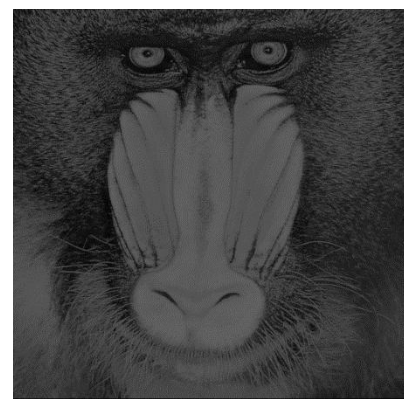
B



H



S

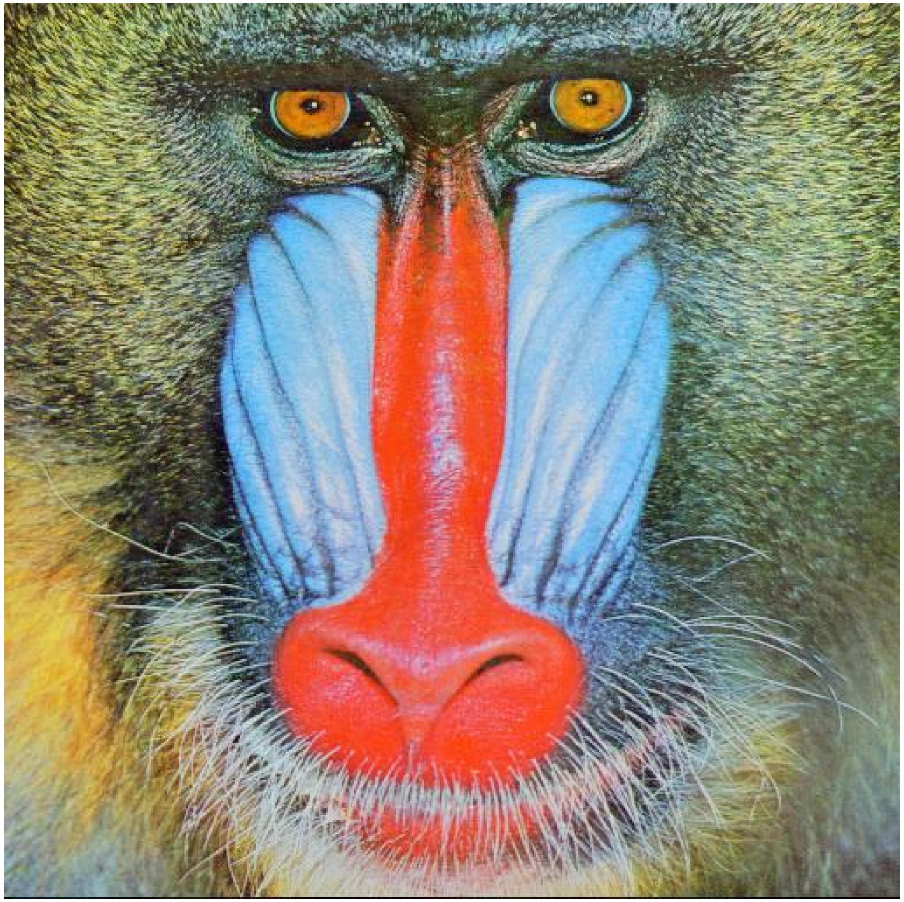


I

4.5 Color Image Enhancement

4.5.1 Introduction: review

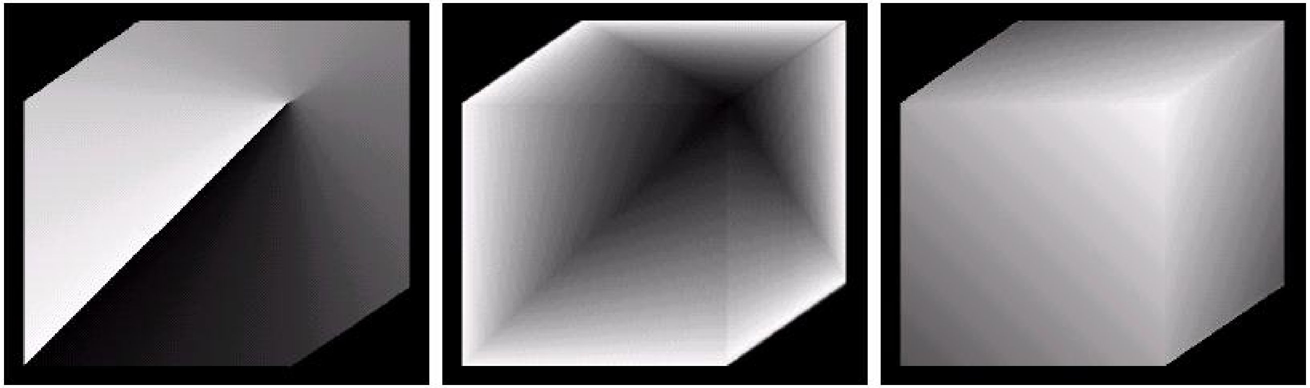
The answer is:



4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from HSI to RGB



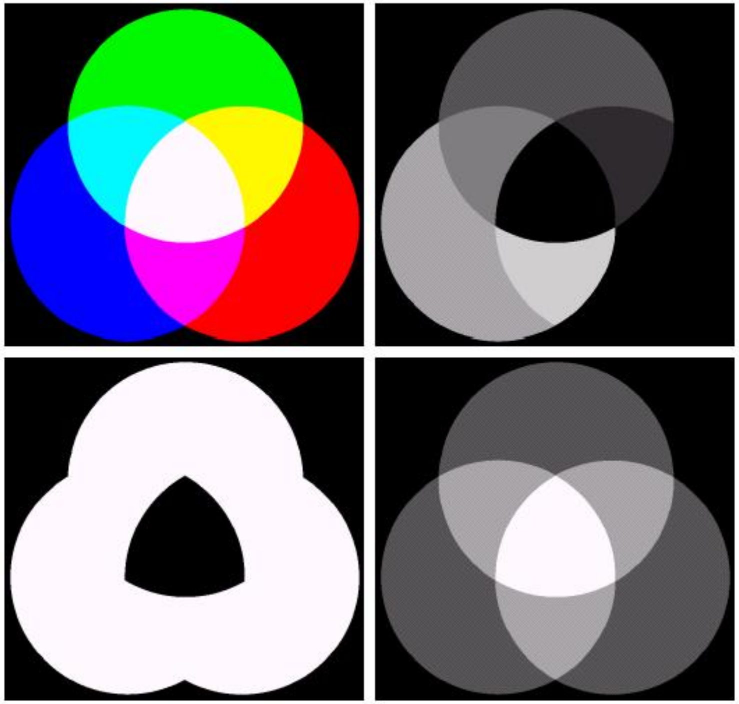
a b c

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

4.5 Color Image Enhancement

4.5.1 Introduction: review

Color Model: converting colors from HSI to RGB



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.

附加题： 从色彩定义的角度写出你对2015年安徽高考作文题的理解：

作文题如下：

阅读下面的材料，根据要求写一篇不少于800字的文章。

为了丰富中小学生的课余生活，让同学们领略科技的魅力，过一把尖端科技的瘾，中科院某研究所推出了公众开放日系列科普活动。活动期间，科研人员特地设计了一个有趣的实验，让同学们亲手操作扫描式电子显微镜，观察蝴蝶的翅膀。

通过这台可以看清纳米尺度物体三维结构的显微镜，同学们惊奇地发现：原本色彩斑斓的蝴蝶翅膀竟然失去了色彩，显现出奇妙的凹凸不平的结构。

原来，蝴蝶的翅膀本是无色的，只是因为具有特殊的微观结构，才会在光线的照射下呈现出缤纷的色彩......

要求自选角度，确定立意，明确文体(诗歌除外)，自拟标题；

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Intensity Slicing

formula

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

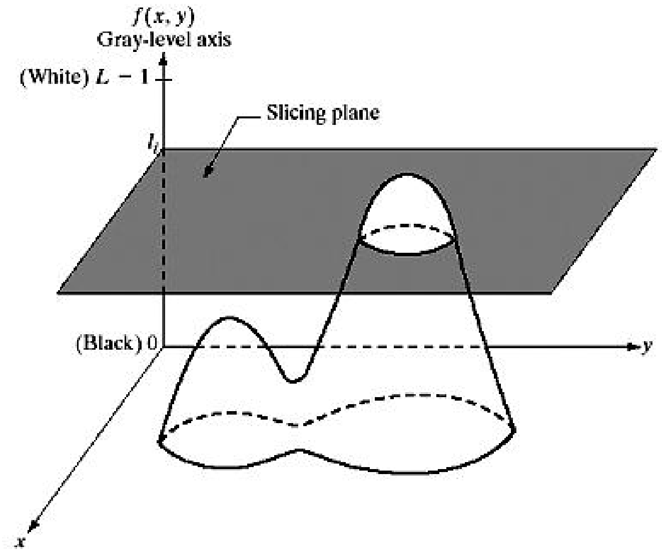


FIGURE 6.18 Geometric interpretation of the intensity-slicing technique.

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Intensity Slicing

example

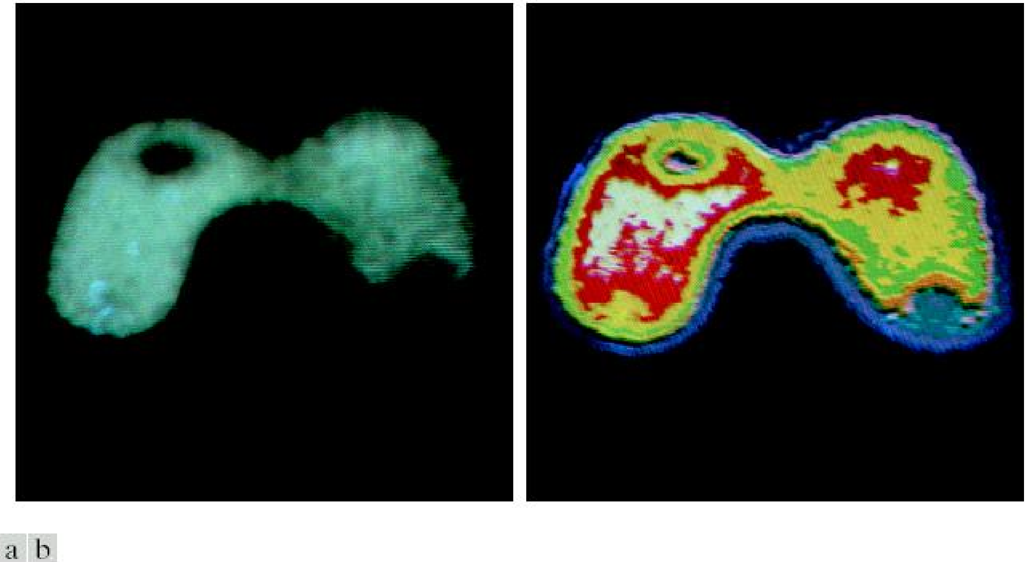


FIGURE 6.20 (a) Monochrome image of the Picker Thyroid Phantom. (b) Result of density slicing into eight colors. (Courtesy of Dr. J. L. Blankenship, Instrumentation and Controls Division, Oak Ridge National Laboratory.)

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Intensity Slicing

example

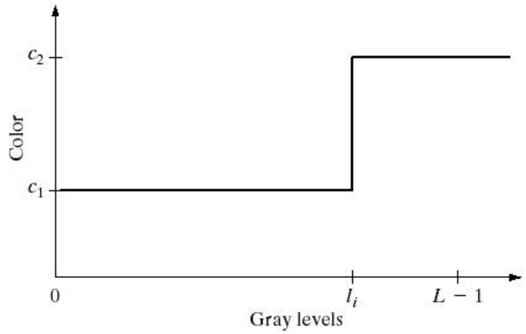
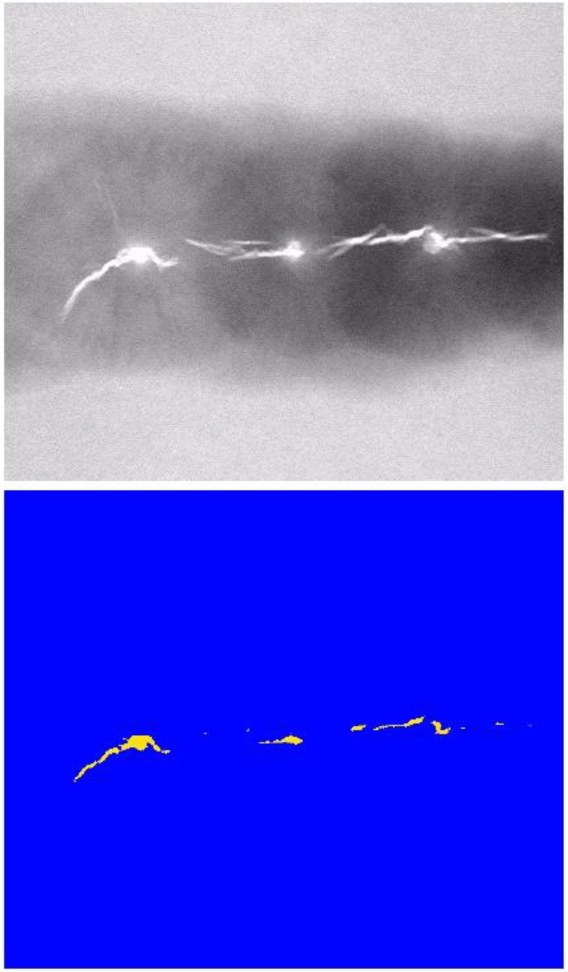


FIGURE 6.19 An alternative representation of the intensity-slicing technique.

a
b

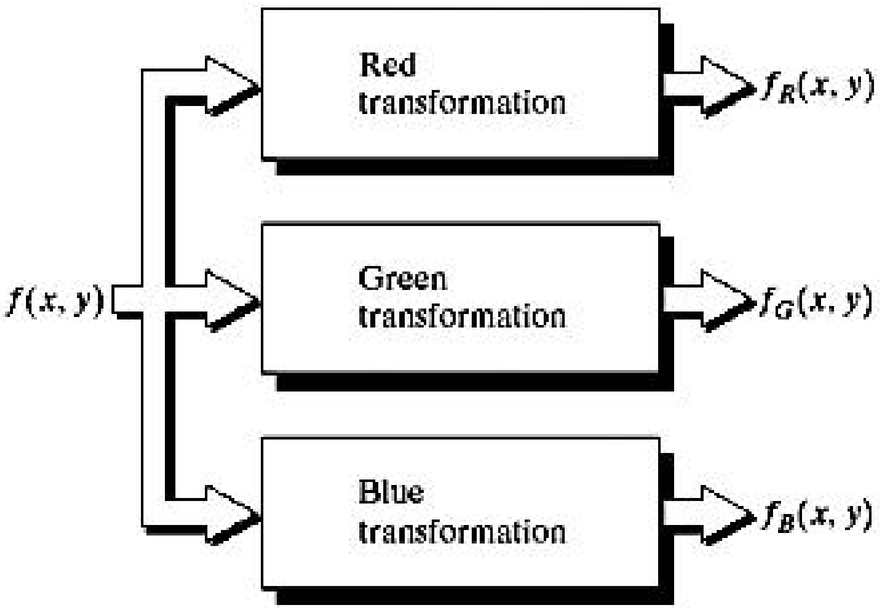
FIGURE 6.21 (a) Monochrome X-ray image of a weld. (b) Result of color coding. (Original image courtesy of X-TEK Systems, Ltd.)

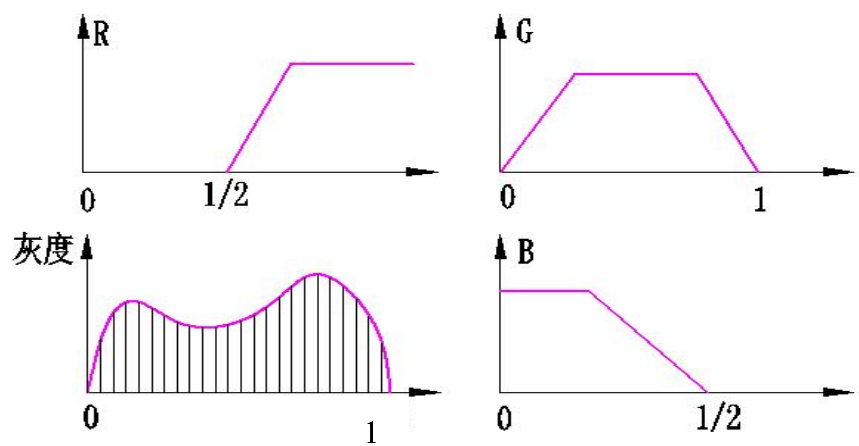


4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Gray level to color

In general, we perform three independent transformations on the gray level of any input pixel

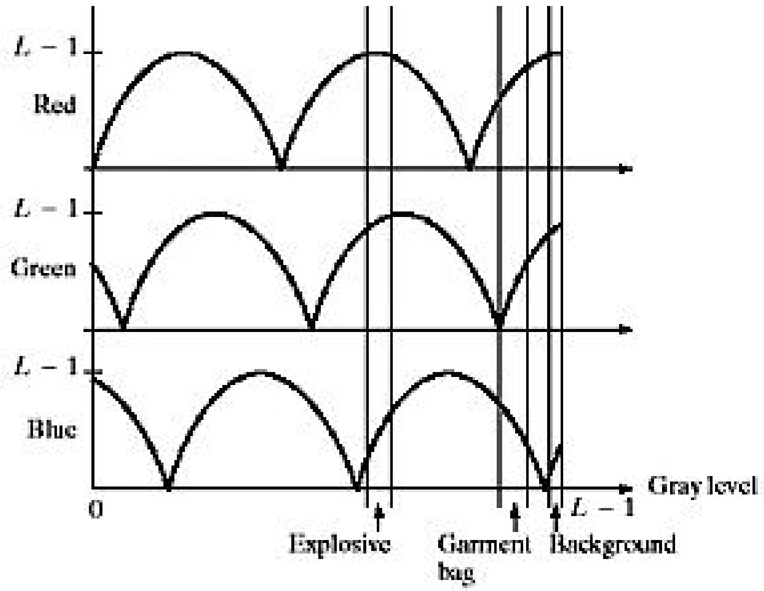


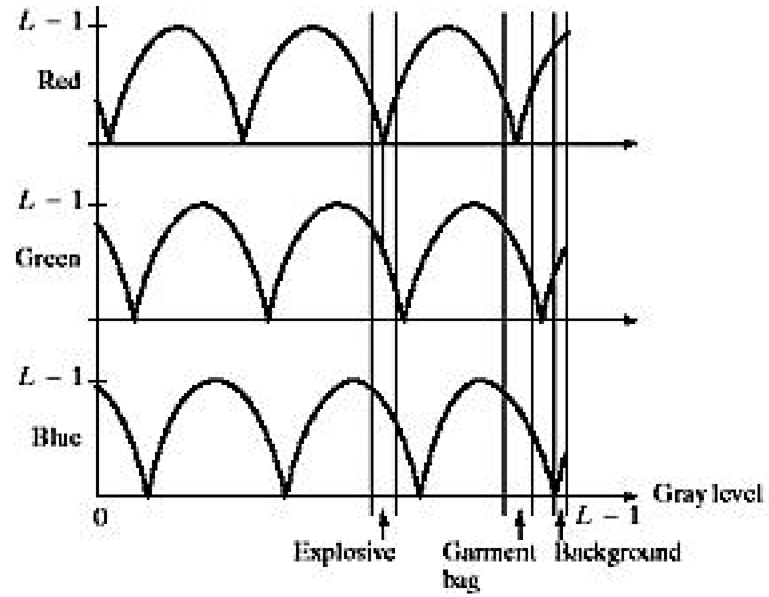


4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Gray level to color

For example

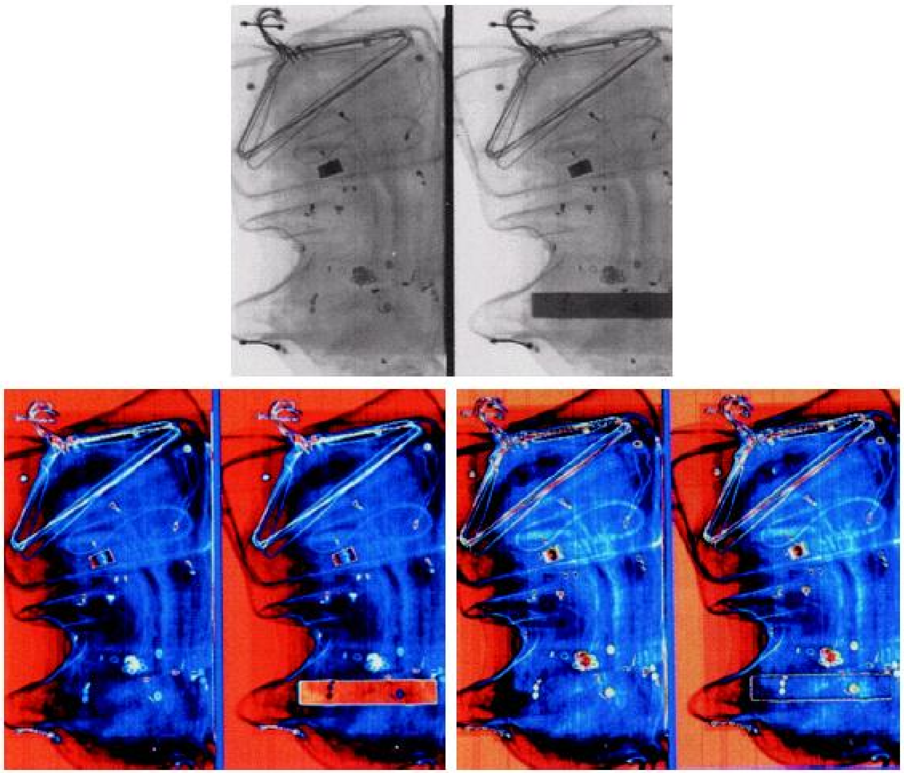




transforms

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Gray level to color



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.)

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Gray level to color

Combine several monochrome images into a single color composite

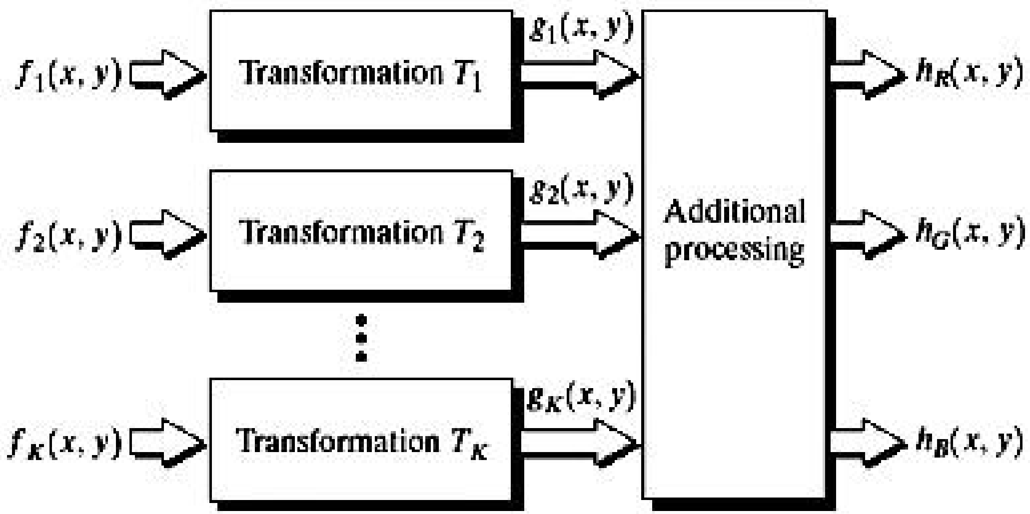
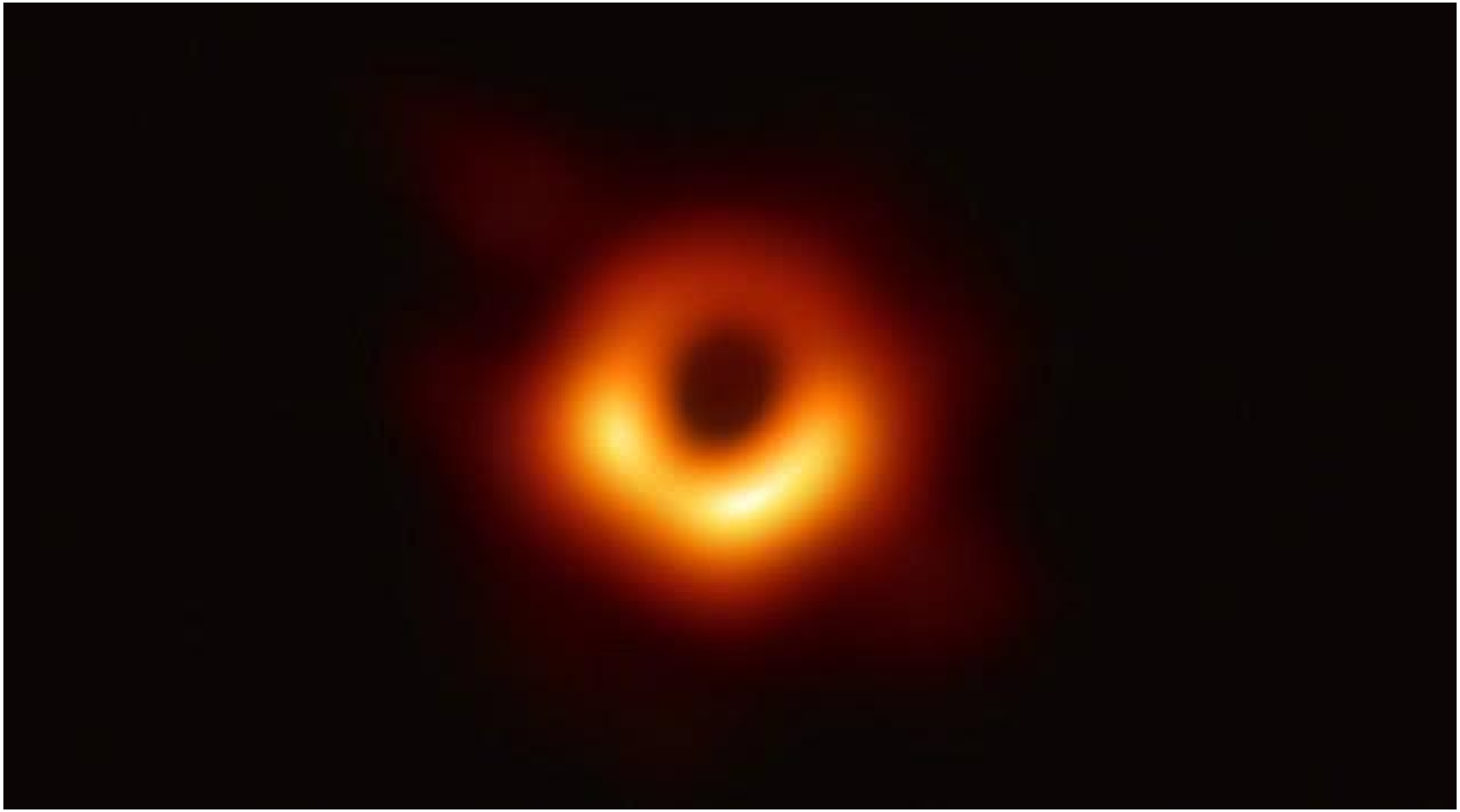


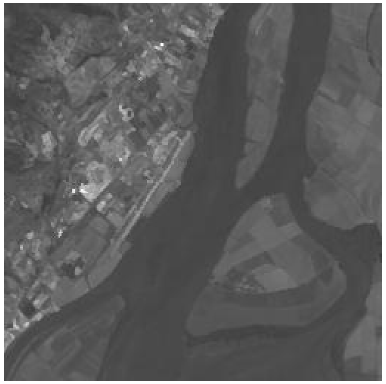
FIGURE 6.26 A pseudocolor coding approach used when several monochrome images are available.



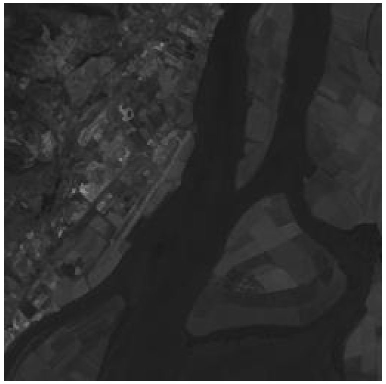
拍黑洞的望远镜收集到的不是我们日常的可见光，而是一种波长更长的亚毫米波，

4.5 Color Image Enhancement

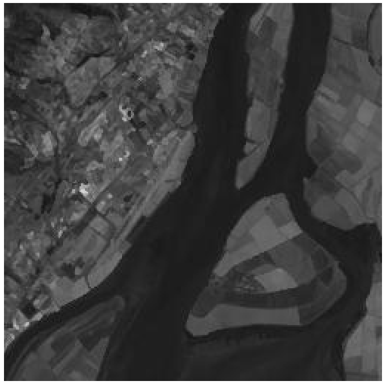
4.5.2 Pseudo color image processing : Gray level to color



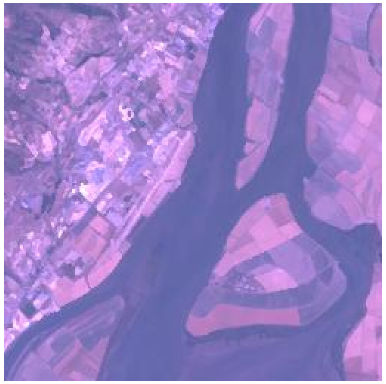
band1



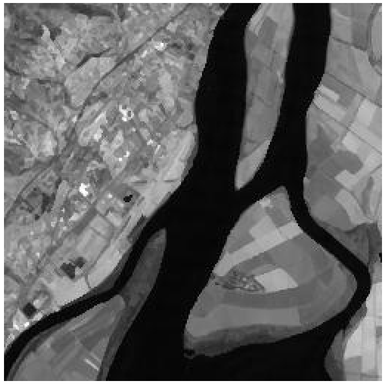
band2



band3

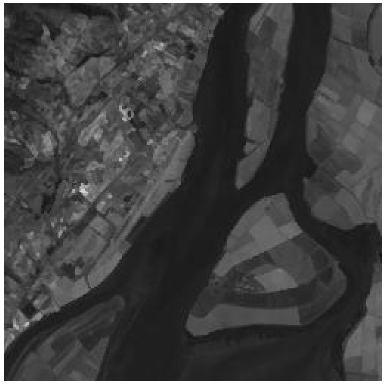


band1,2,3 false color



band5

band4

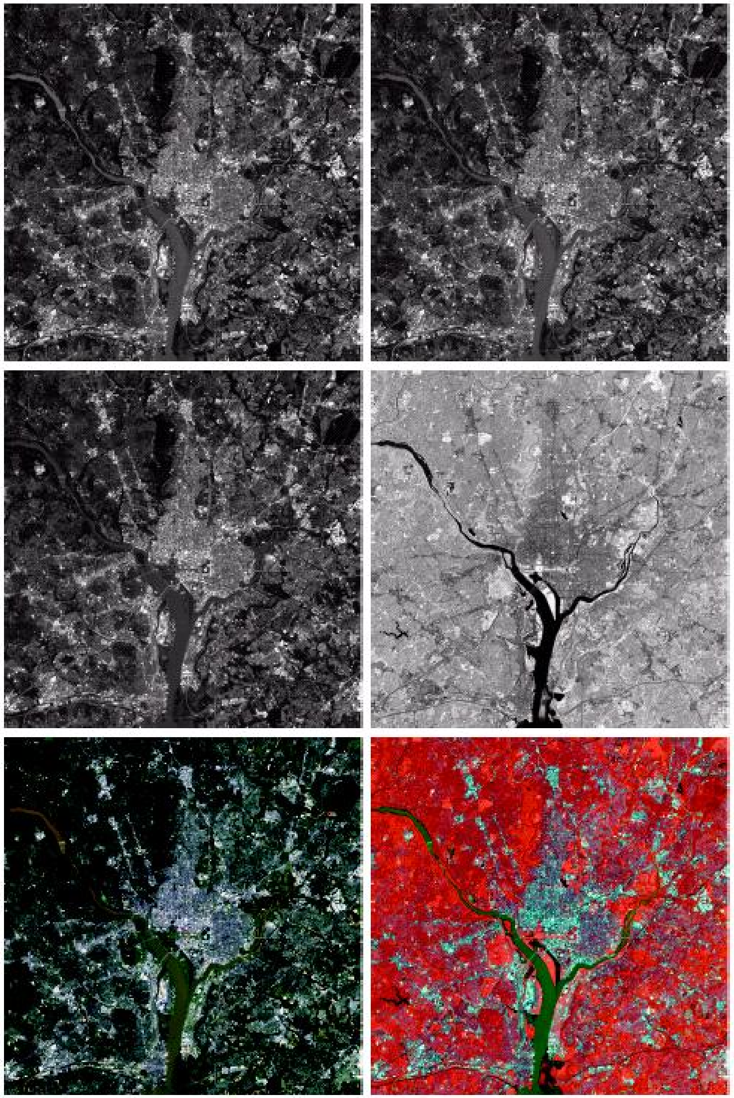


band3

band5,4,3 false color

4.5 Color Image Enhancement

4.5.2 Pseudo color image processing : Gray level to color



4.5 Color Image Enhancement

4.5.3 Full color enhancement : Fundamentals

A full color image can be expressed as

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

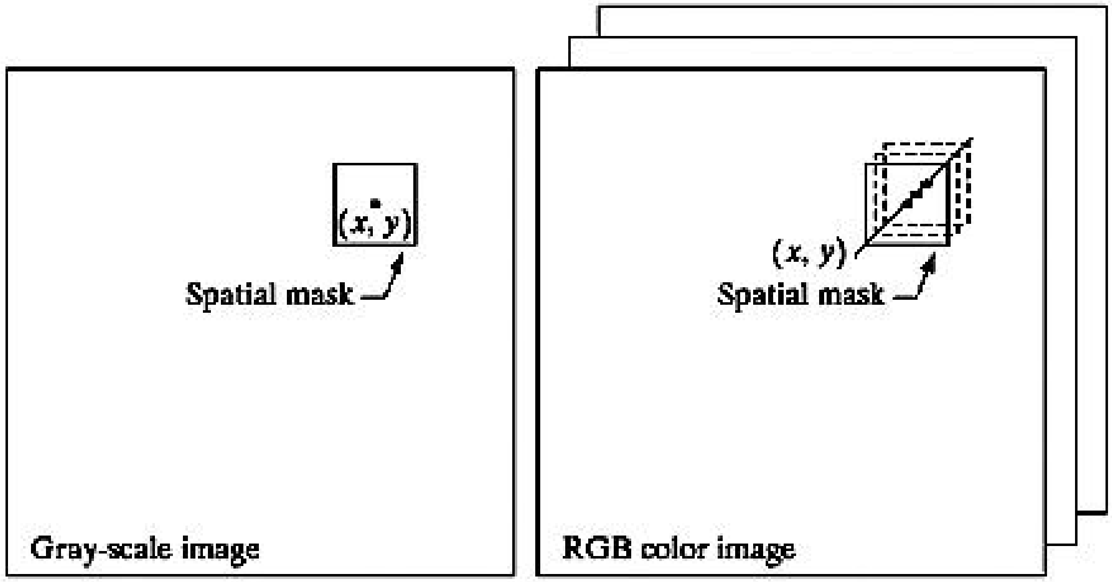
A pixel in color image interpreted as vector

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

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Fundamentals

Mask operation in color image



4.5 Color Image Enhancement

4.5.3 Full color enhancement : Color transformations

Adjusting the intensity of an image:

in RGB color space three components must be transformed:

$$s_i = kr_i \quad i = 1, 2, 3 \quad 0 < k < 1$$

in HSI color space only intensity components is modified:

$$s_3 = kr_3$$

$$s_1 = r_1$$

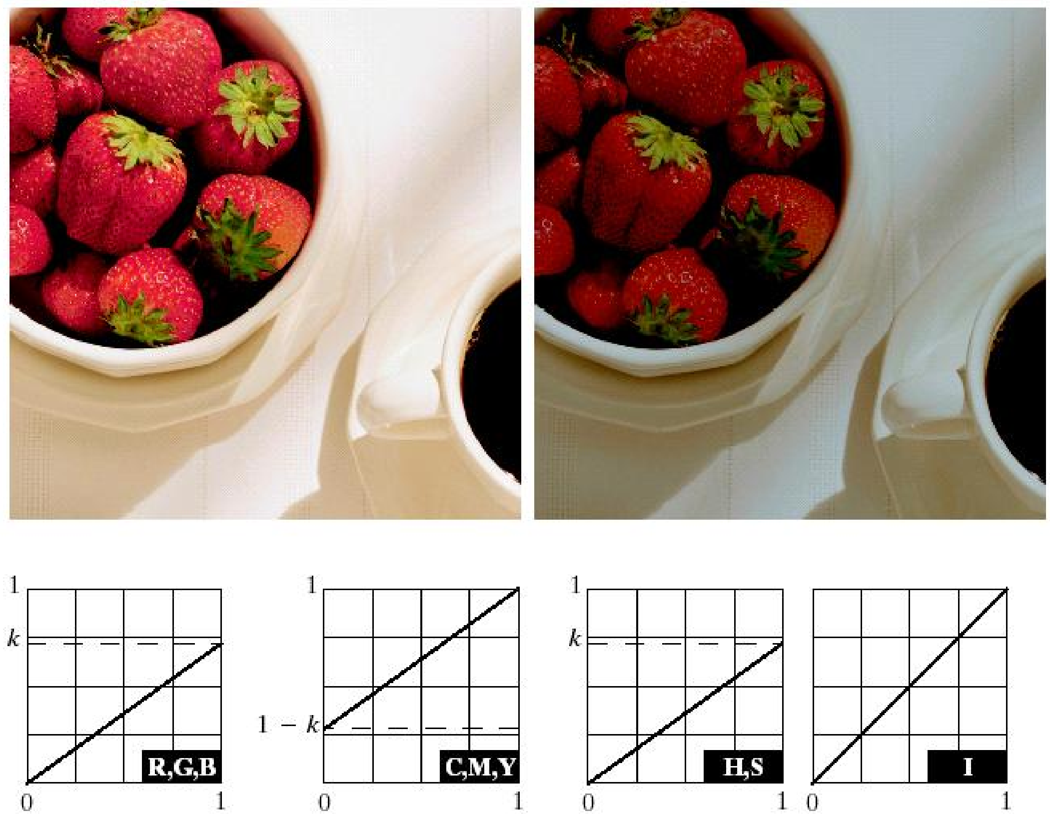
$$s_2 = r_2$$

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Color transformations

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.)



I HS

S HI

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Color Complement

in RGB color space three components must be transformed:

$$s_i = 1 - r_i \quad i = 1,2,3 \quad 0 < k < 1$$

in HSI color space only intensity components is modified:

$$s_1 = (r_1 + 0.5)$$

$$s_2 = r_2$$

$$s_3 = 1 - r_3$$

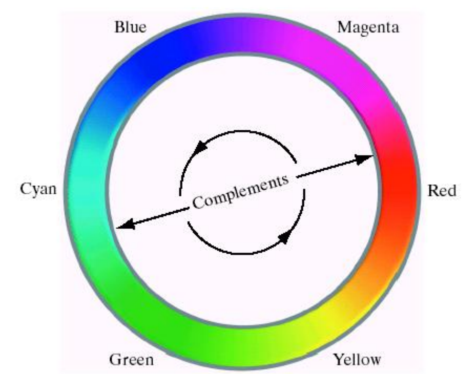
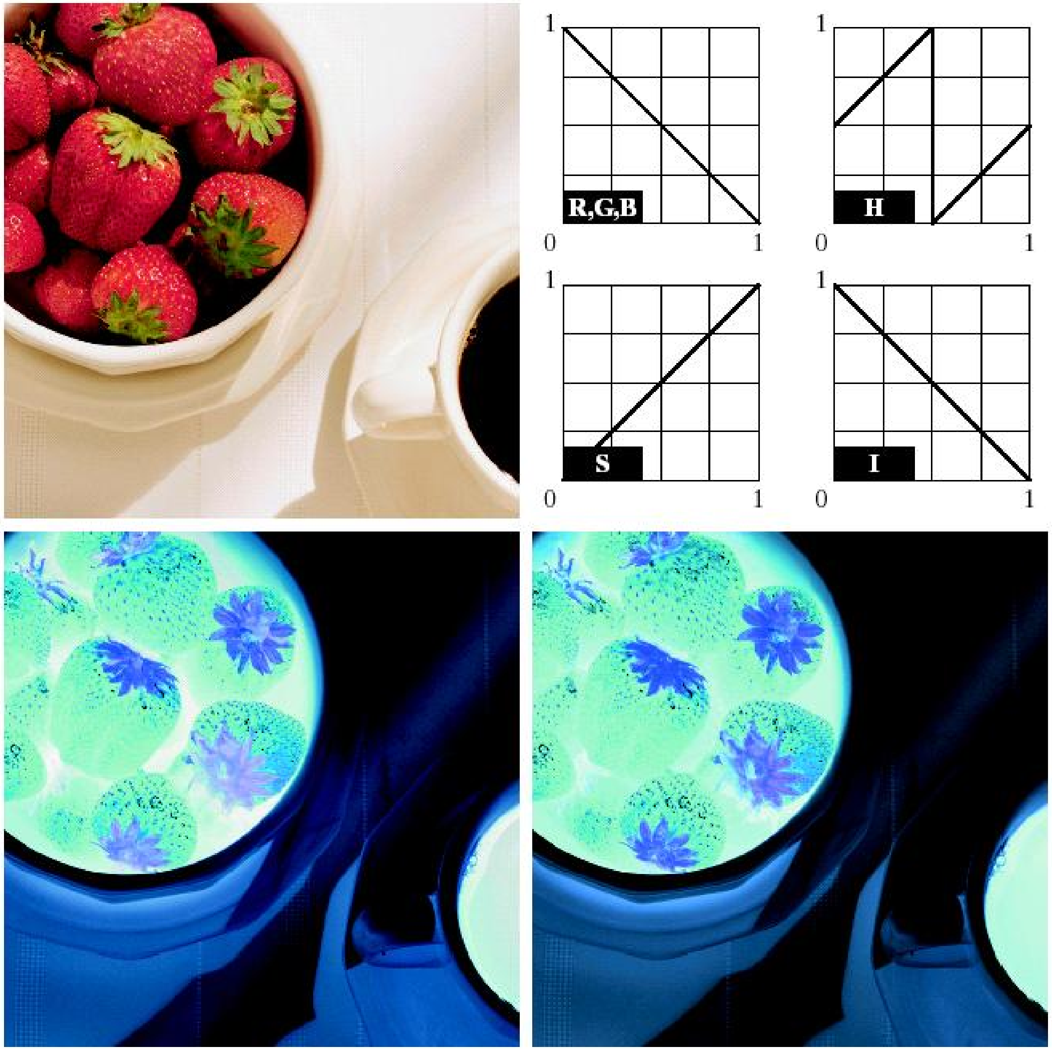


FIGURE 6.32 Complements on the color circle.

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Color Complement



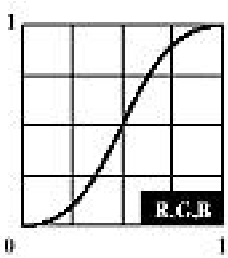
a b
c d

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.

4.5 Color Image Enhancement

4.5.3 Full color enhancement : color corrections

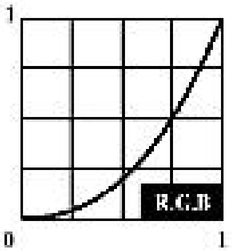
In RGB and CMY(K) space, map all tree (or four) color components with the same transform function



4.5 Color Image Enhancement

4.5.3 Full color enhancement : color corrections

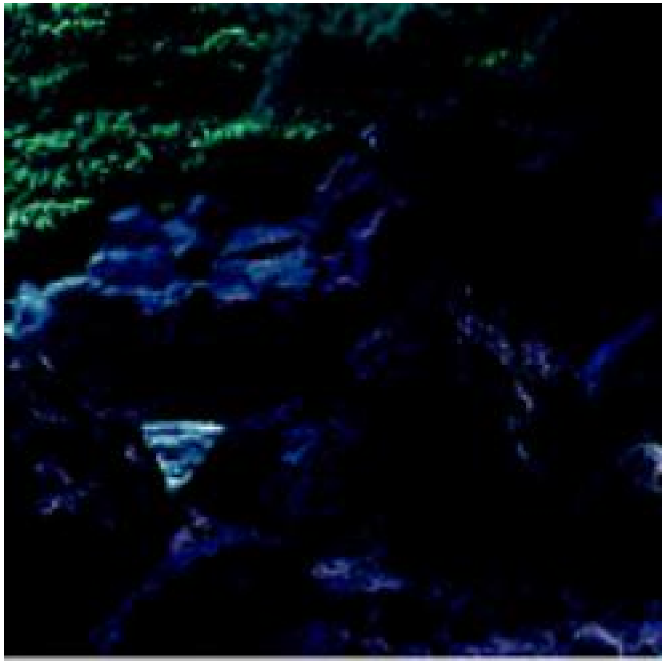
example

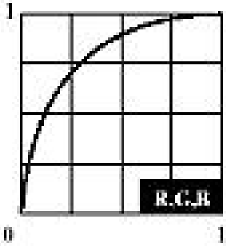


4.5 Color Image Enhancement

4.5.3 Full color enhancement : color corrections

example





4.5 Color Image Enhancement

4.5.3 Full color enhancement : color corrections

example

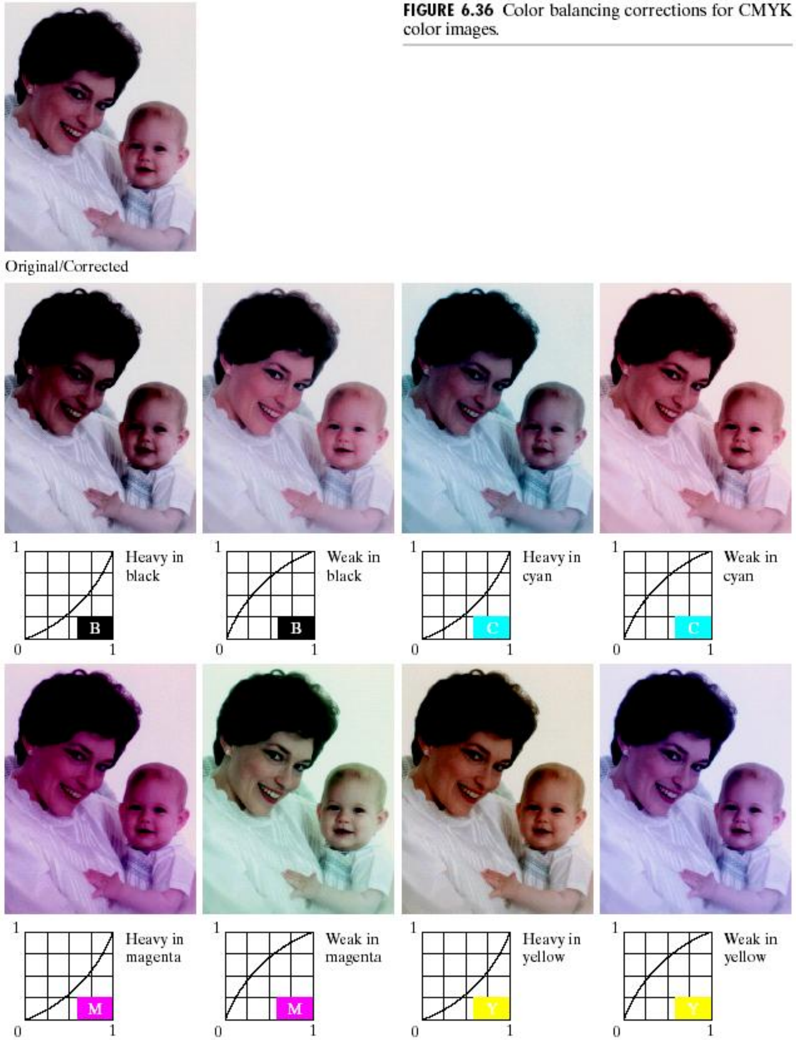
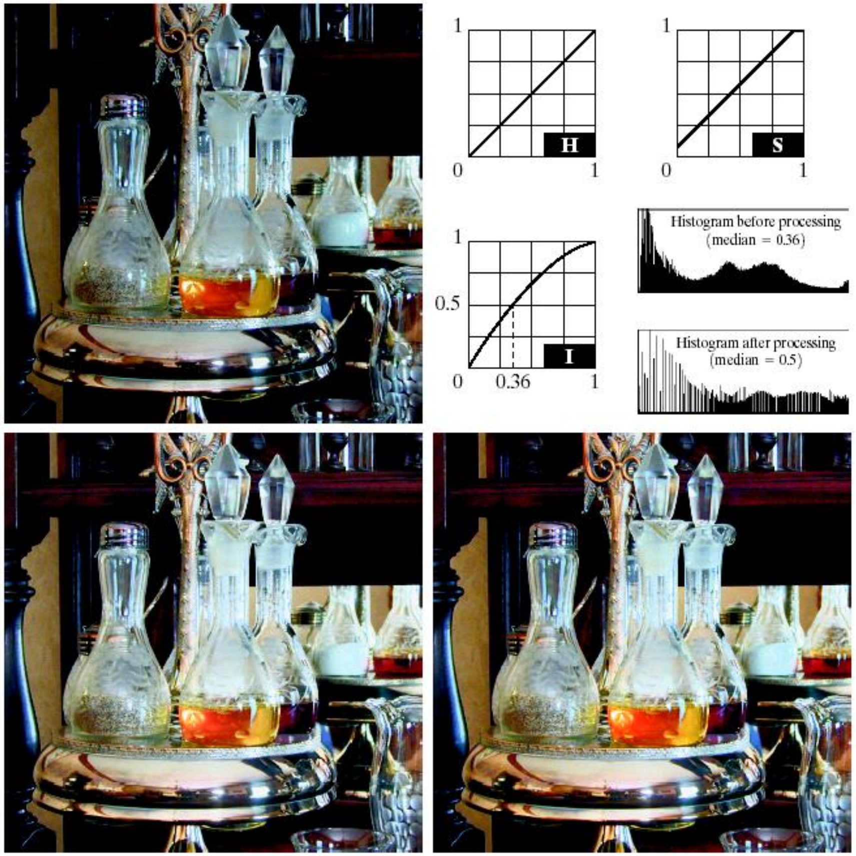


FIGURE 6.36 Color balancing corrections for CMYK color images.

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Histogram processing

In the HSI color space, only the intensity component is modified

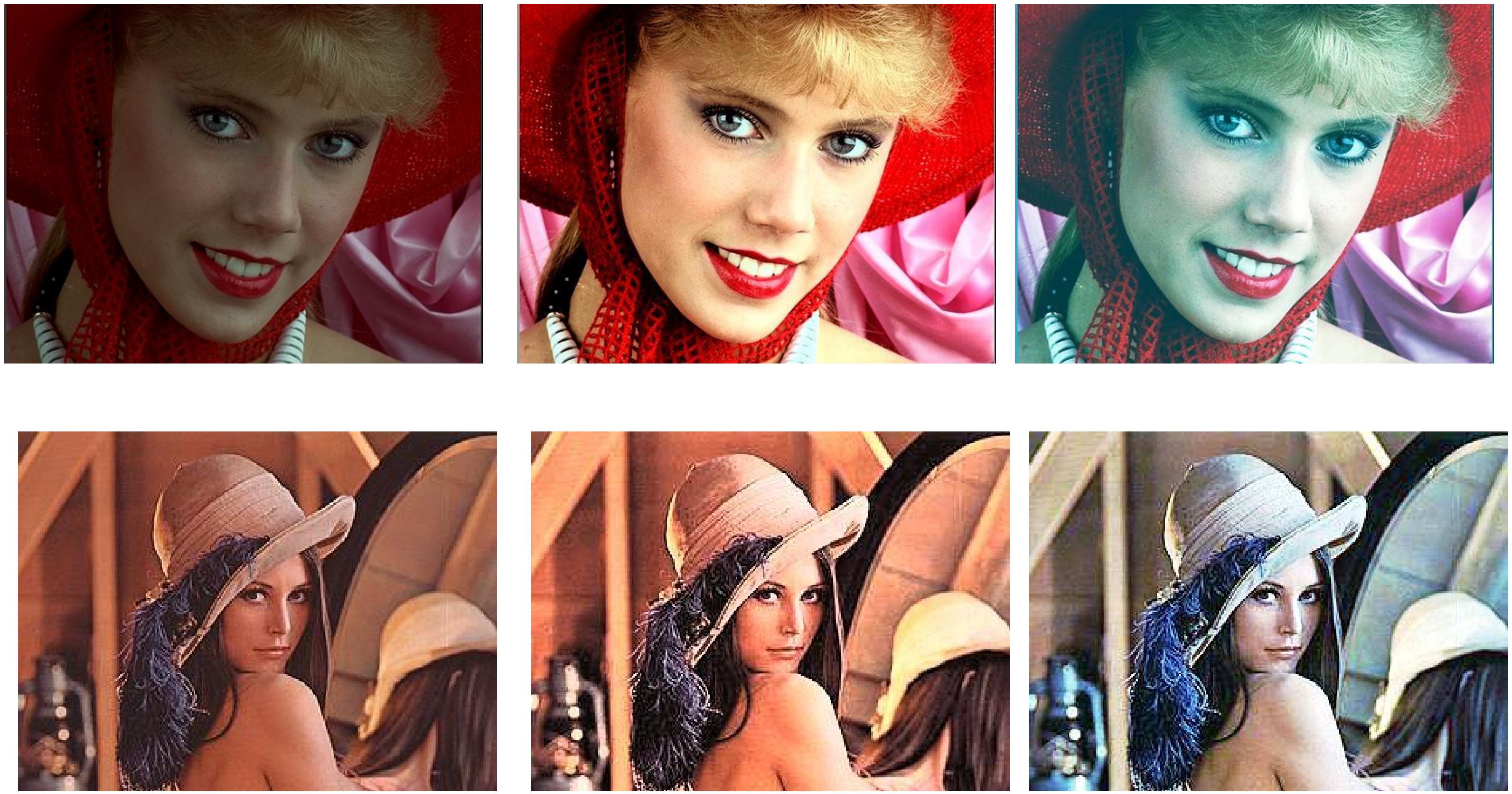


a b
c d

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

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Histogram processing



原图　　I分量均衡化　　RGB分量均衡化

4.5 Color Image Enhancement

4.5.3 Full color enhancement : Smoothing and Sharping

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.

a b c

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

4.5 Color Image Enhancement

4.5. 6 Noise in color image :

Noise in RGB channels

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).]

4.5 Color Image Enhancement

4.5. 6 Noise in color image :

Noise in HSI channels

a b c

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

Questions?

1、 在一条自动装配线上，有三类形状相同的工件，为了检测方便，将工件用不同颜色标注，现只有1个单色摄象机，请提出一种用这个摄象机检测3种颜色的方法。

2、设有一个能输出RGB模拟信号的彩色摄象机，一个能将这 些模拟信号转化为以（1/30）s的视频速度输出RGB或HIS图象的数字化器，3块能以视频速度接受图象的帧缓存卡，以及一个能以视频速度计算直方图的硬件。所有这些都可以与1台微机组合在一起，现要解决以下问题：生产线上有一系列形状相同但颜色不同的工件，他们按红、黄、绿、蓝的次序排列。请借助以上硬件设计一个图象处理软件系统将工件的的颜色检测出来。这里假设工件移动速度相当慢，所以可忽略由此产生的图象模糊问题，请画出系统的流程图并对每个模块及所选处理技术进行讨论。

Homework：

1、 为什么一般情况下对离散图象的直方图均衡并不能产生完全平坦的直方图？

2、 设已用直方图均衡化技术对一幅图象进行了增强，试证明再用这个方法对所得结果增强并不会改变其结果

3、讨论用于空间滤波的平滑滤波器和锐化滤波器的相同点、不同点以及联系。

4、有一种常用的图象增强技术是将高频增强和直方图均衡化结合起来以达到使边缘锐化的反差增强效果，以上两个操作的先后次序对增强结果有影响吗？为什么？

5、编程实现对lena.bmp分别加入高斯噪声和椒盐噪声，再进行局域平均和中值滤波。

The End