強化處理與濾波作業

壹、影像強化處理之基本背景

貳、以點處理進行影像強化作業

參、空間領域之過濾作業

肆、頻率領域之強化作業

伍、空間遮罩之推演

陸、彩色影像處理

強化處理與濾波作業

壹、影像強化處理之基本背景

目的：處理影像使其處理後之結果較原始影像更能適合該影像之特定用途。

一、空間領域之處理方法：

●直接處理運算影像元素(Pixel)。

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

1．T 函數對單一影像元素運作：(e.g. Mapping)

(1).對比伸展(Contrast stretching)

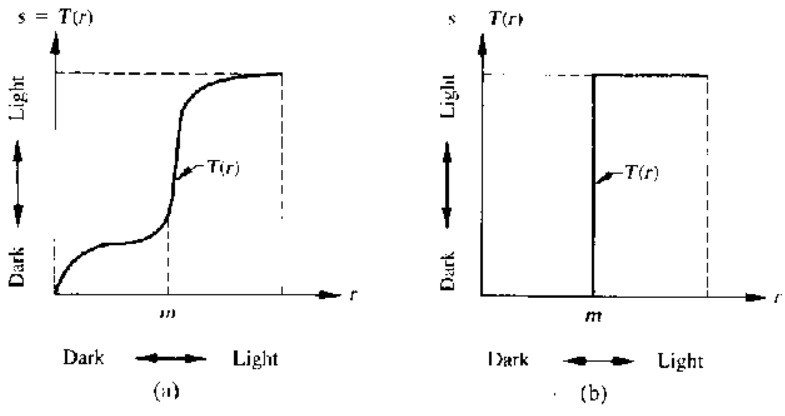


Figure 4.2 Gray-level transformation functions for contrast enhancement.

(2).分割(Thresholding)

(3).二元影像(Binary Image)

２．T 函數對一影像元素集合運作：(e.g. Masking)

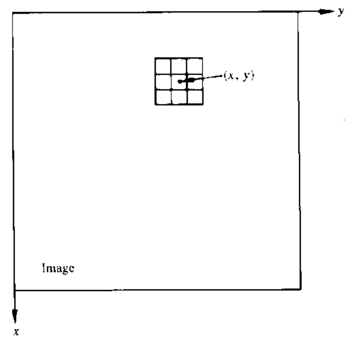


Figure 4.1 A 3 × 3 neighborhood about a point (x, y) in an image.

$$T[f(x,y)] = w_1\, f(x-1,y-1) + w_2\, f(x-1,y) + w_3\, f(x-1,y+1) + w_4\, f(x,y-1) + w_5\, f(x,y) + w_6\, f(x,y+1) + w_7\, f(x+1,y-1) + w_8\, f(x+1,y) + w_9\, f(x+1,y+1)$$

二、頻率領域之處理方法：

１．捲積定理(Convolution Theorem)

$$g(x,y) = h(x,y) * f(x,y)$$

$$G(u,v) = H(u,v)F(u,v)$$

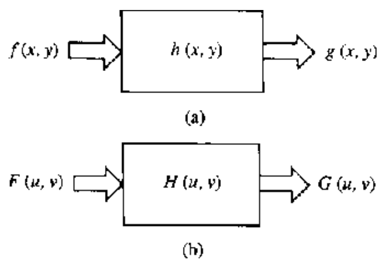


Figure 4.3 Operation of a linear system. In (a), the system output is the convolution of h(x, y) with the input. In (b), the output is the product of H(u, v) with the input.

影像強化處理即是求取 $G(u,v)$之傅利葉反轉換 $g(x,y)$，$h(x,y)$與 $H(u,v)$分別爲空間領域與頻率領域之遮罩。

２．空間領域與頻率領域之對應 － Convolution Mask

貳、以點處理進行影像強化作業

一、基本之影像元素灰度值轉換方法：

１．反白底片轉換(Image Negatives)

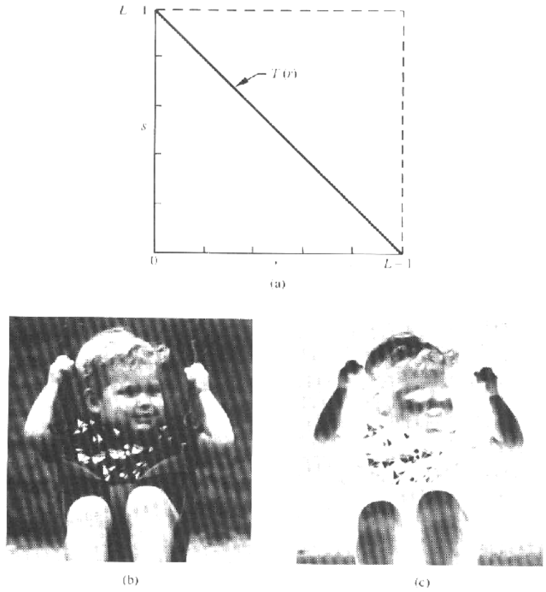


Figure 4.4 Obtaining the negative of an image: (a) gray-level transformation function; (b) an image; and (c) its negative. In (a), r and s denote the input and output gray levels, respectively.

２．對比伸展(Contrast Stretching)

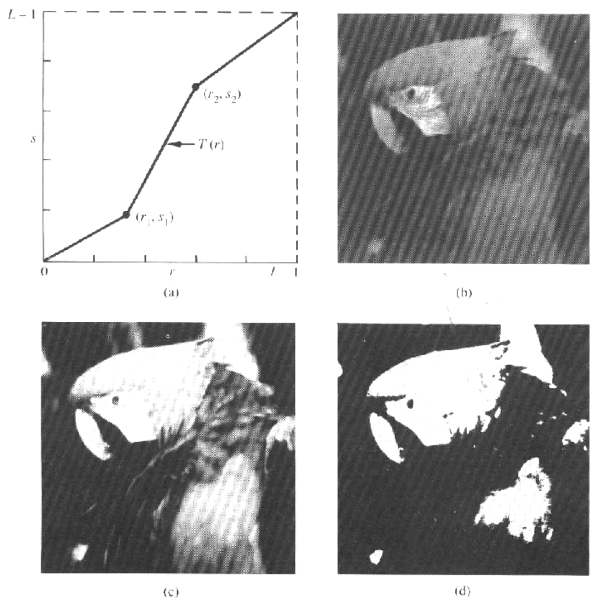


Figure 4.5 Contrast stretching: (a) form of transformation function; (b) a low-contrast image; (c) result of contrast stretching; (d) result of thresholding.

３．動態範圍之壓縮(Dynamic Range Compression)

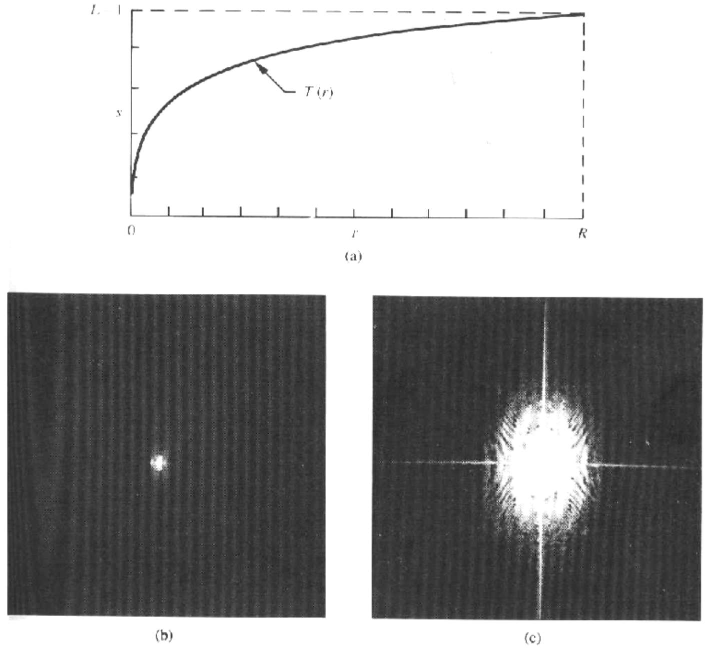


Figure 4.6 *Compression of dynamic range: (a) logarithm transformation function; (b) image with large dynamic range (pixel values ranging from 0 to 2.5 × 10^6); (c) result after transformation.*

４．灰度範圍分切(Gray-level Slicing)

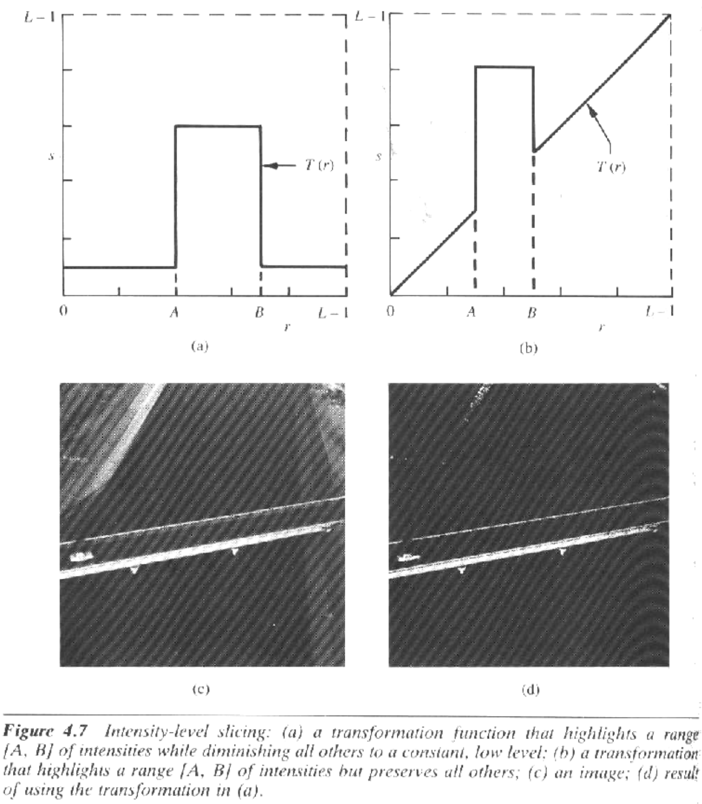


Figure 4.7 *Intensity-level slicing: (a) a transformation function that highlights a range [A, B] of intensities while diminishing all others to a constant, low level; (b) a transformation that highlights a range [A, B] of intensities but preserves all others; (c) an image; (d) result of using the transformation in (a).*

５．位元面分切(Bit-plane Slicing)

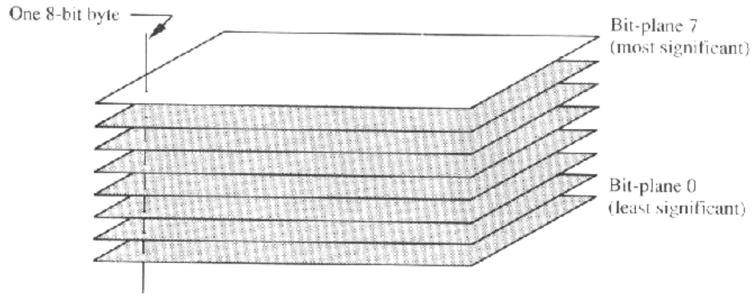


Figure 4.8 *Bit-plane representation of an 8-bit digital image.*

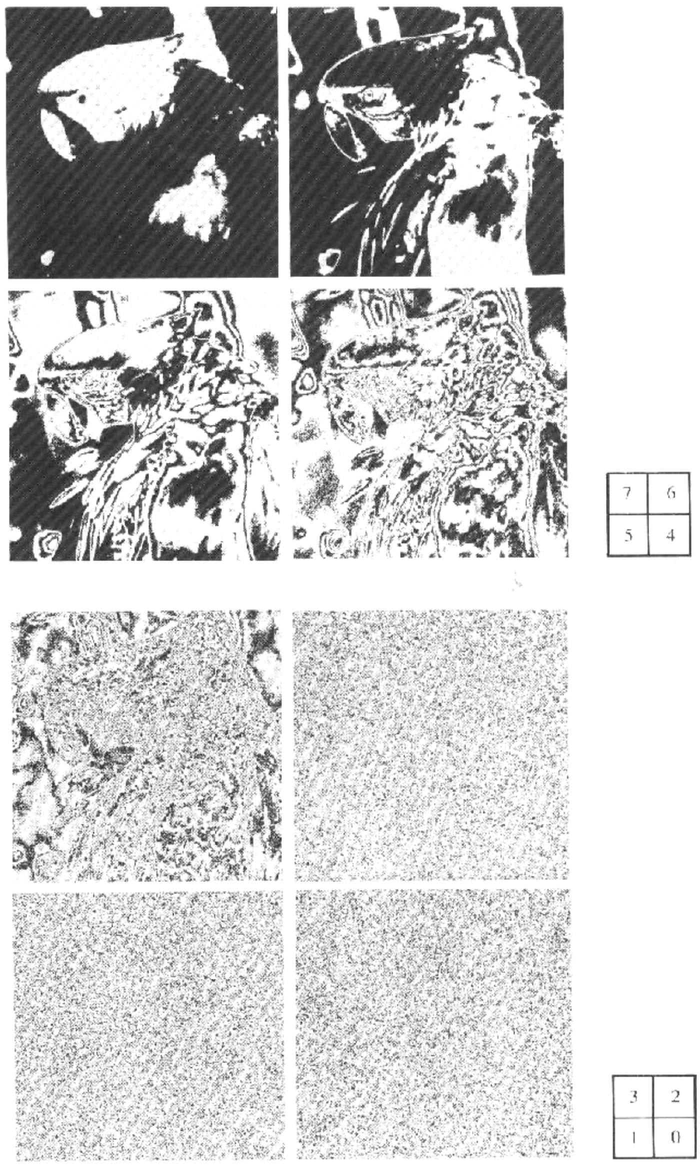


Figure 4.9 *Bit planes for the image in Fig. 4.5(c). The numbers in the small squares identify individual planes. Plane 7 contains the most significant bits, and plane 0 contains the least significant bits of the pixels in the original image.*

二、應用統計特性圖進行強化處理

１．統計特性圖(Histogram)

$$p(r_k) = n_k / n$$

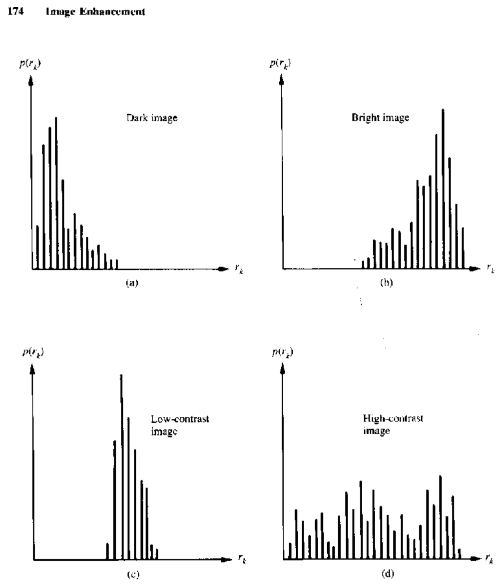


Figure 4.10 *Histograms corresponding to four basic image types.*

２．統計特性圖之等化(Histogram Equalization)

(1).定義：

$$s = T(r), \quad r = T^{-1}(s) \qquad 0 \leqq s \leqq 1$$

符合以下兩條件：

(A).T(r)及 $T^{-1}(s)$在 $0 \leqq r \leqq 1$ 與 $0 \leqq s \leqq 1$ 區間為單一值且為單調遞增。

(B).$0 \leqq T(r) \leqq 1$ 當 $0 \leqq r \leqq 1$; $0 \leqq T^{-1}(s) \leqq 1$ 當 $0 \leqq s \leqq 1$。

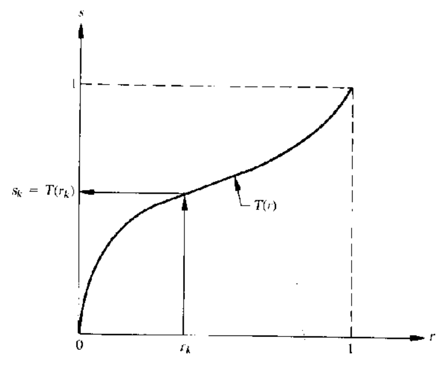


Figure 4.11 *A gray-level transformation function.*

(2).統計特性圖等化之原理：

經 T(r)轉換後影像之機率密度函數爲：

$$p_s(s) = \left[p_r(r) \frac{dr}{ds} \right]_{r=T^{-1}(s)}$$

由此考慮以下之轉換函數 T(r)

$$s = T(r) = \int_0^r p_r(w)dw, \quad 0 \le r \le 1$$

其中 w 爲積分之虛擬變數，而等號右邊之積分項稱爲累積分佈函數(Cumulative Distribution Function, CDF)。

上式中 s 對 r 之微分爲：

$$\frac{ds}{dr} = p_r(r)$$

因此依前面機率密度函數之定義代入 dr/ds，可得：

$$p_s(s) = \left[p_r(r) \frac{1}{p_r(r)} \right]_{r=T^{-1}(s)}$$
$$= 1 \qquad 0 \le s \le 1$$

$p_s(s)$表示定義 s 區間內之機率密度均等，對影像而言其意義爲經轉換後影像元素之灰度值均勻分佈於灰度區間內，因此強化了影像之明暗對比。

(3).範例：

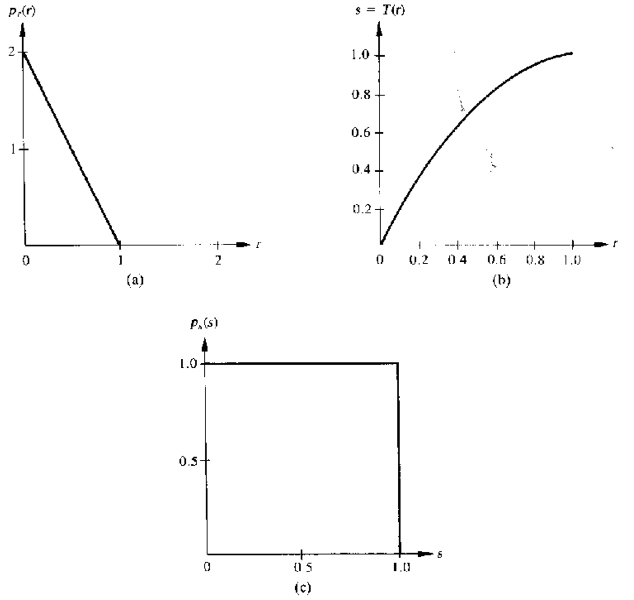


Figure 4.12 Illustration of the uniform density transformation method: (a) original probability density function; (b) transformation function; (c) resulting uniform density.

$$p_r(r) = \begin{cases} -2r + 2 & 0 \le r \le 1 \\ 0 & \text{elsewhere} \end{cases}$$

$$s = T(r) = \int_0^r (-2w + 2)dw$$

$$= -\mathrm{r}^2 + 2r$$

$$r = T^{-1}(s) = 1 - \sqrt{1-s}$$

$$p_s(s) = \left[p_r(r)\frac{dr}{ds} \right]_{r=T^{-1}(s)}$$

$$= \left[(\text{-}2\mathrm{r} + 2)\frac{\mathrm{dr}}{\mathrm{ds}} \right]_{r=1-\sqrt{1-s}}$$

$$= \left[(2\sqrt{1\text{-}\mathrm{s}})\frac{d}{ds}(1 - \sqrt{1-s}) \right]$$

$$= 1 \qquad 0 \le \mathrm{s} \le 1$$

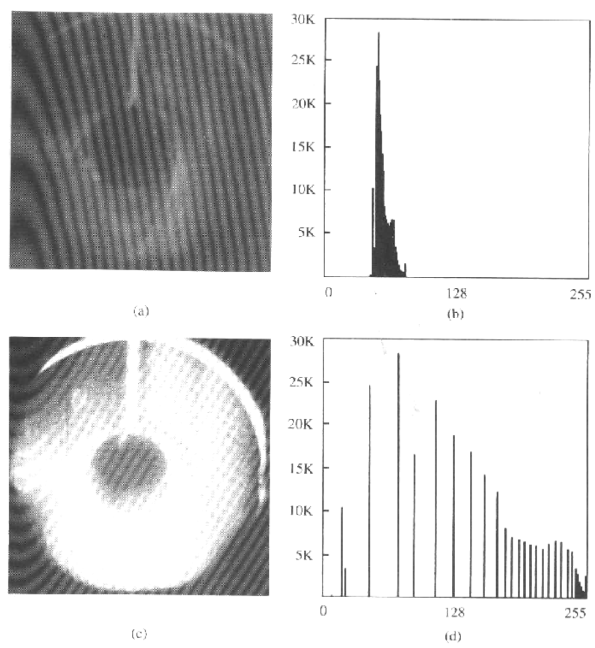


Figure 4.13 (a) Original image and (b) its histogram; (c) image subjected to histogram equalization and (d) its histogram.

(4).數位影像之統計特性圖等化作業：

$$p_r(r_k) = \frac{n_k}{n} \qquad 0 \le r_k \le 1 \quad \mathrm{k} = 0,1,2,\ldots,\mathrm{L}-1$$

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n}$$

$$= \sum_{j=0}^{k} p_r(r_j) \qquad 0 \le r_k \le 1 \quad \mathrm{k} = 0,1,2,\ldots,\mathrm{L}-1$$

$$r_k = T^{-1}(s_k) \quad 0 \le s_k \le 1$$

範例：

$s_0 = 1/7 \rightarrow z_3 = 3/7 \qquad s_3 = 6/7 \rightarrow z_6 = 6/7$

$s_1 = 3/7 \rightarrow z_4 - 4/7 \qquad s_4 = 1 \quad \rightarrow z_7 = 1.$

$s_2 = 5/7 \rightarrow z_5 = 5/7$

Table 4.3

$r_j \rightarrow s_k$	n_k	$p_s(s_k)$
$r_0 \rightarrow s_0 = 1/7$	790	0.19
$r_1 \rightarrow s_1 = 3/7$	1023	0.25
$r_2 \rightarrow s_2 = 5/7$	850	0.21
$r_3, r_4 \rightarrow s_3 = 6/7$	985	0.24
$r_5, r_6, r_7 \rightarrow s_4 = 1$	448	0.11

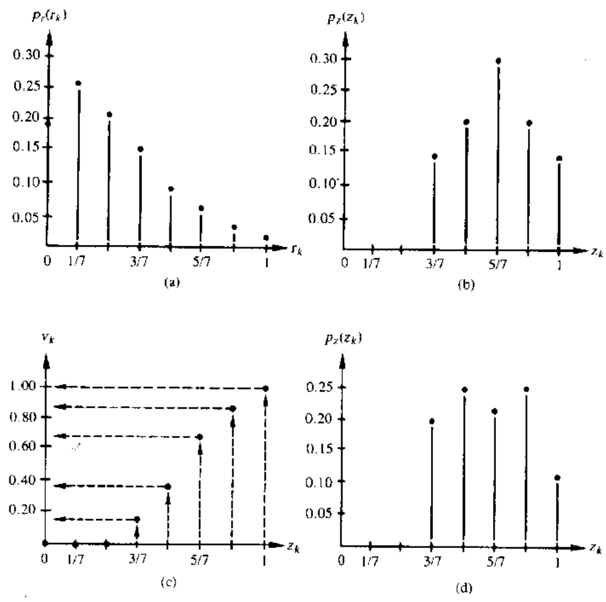


Figure 4.10 Illustration of the histogram-specification method. (a) Original histogram. (b) Specified histogram. (c) Transformation function. (d) Resulting histogram.

３．指定統計特性圖之轉換作業：

(1).基本定義：

$p_r(r)$及 $p_z(z)$分別為原始影像與期望處理後影像之機率密度函數：

$$s = T(r) = \int_0^r p_r(w)dw$$

$$\updownarrow$$

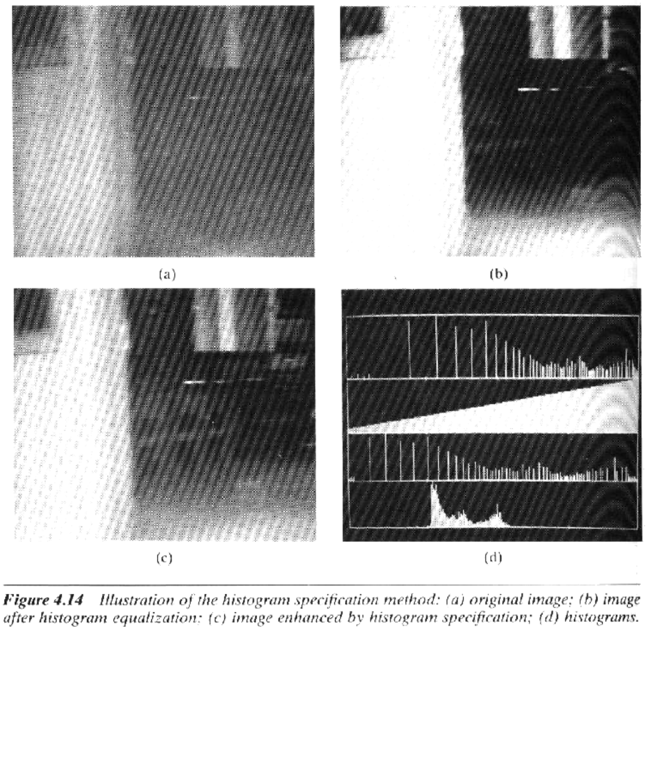
$$v = G(z) = \int_0^z p_z(w)dw$$

(2).作業步驟：

A.對原始影像進行統計特性圖等化作業。

B.指定所期望影像之機率密度函數($p_z(z)$)，並利用上面第二式求得轉換函數 G(z)。

C.對步驟 A 所得之灰度值以 $G^{-1}(s)$進行轉換。



(a) (b) (c) (d)

Figure 4.14 Illustration of the histogram specification method: (a) original image; (b) image after histogram equalization; (c) image enhanced by histogram specification; (d) histograms.

４．區域強化(Local Enhancement)：

(1).統計特性圖法：

步驟：A.決定 n×m 區域及其統計特性圖。

B.依 A 步驟之統計特性圖決定 n×m 區域之中心點轉換函數(應用等化或指定統計特性圖作業)。

C.對影像中所有之影像元素進行上面兩步驟。

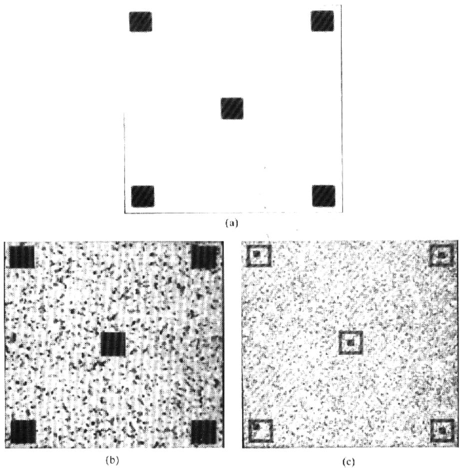


Figure 4.15 (a) Original image; (b) result of global histogram equalization; (c) result of local histogram equalization using a 7 × 7 neighborhood about each pixel. (From Fu, Gonzalez, and Lee [1987].)

(2).統計法：

$$g(x,y) = A(x,y) \cdot [f(x,y) - m(x,y)] + m(x,y),$$
$$A(x,y) = k \cdot M/\sigma(x,y) \qquad 0<k<1.$$

M: Global mean;

m(x,y): Local mean;

σ(x,y): Local standard deviation;

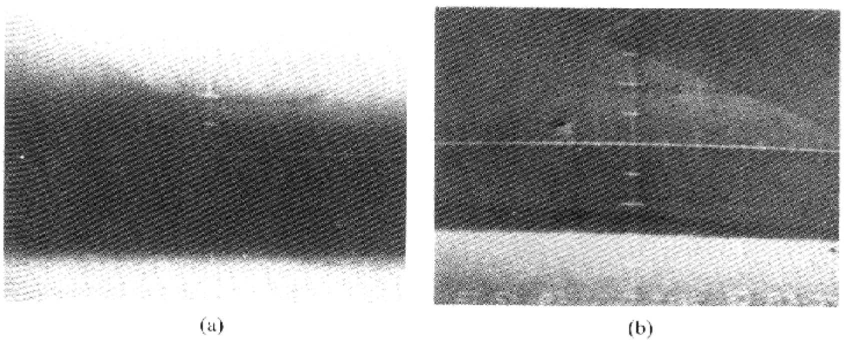


Figure 4.16 *Images before and after local enhancement. (From Narendra and Fitch [1981].)*

三、影像相減(Image Subtraction)

$$g(x,y) = f(x,y) - h(x,y)$$

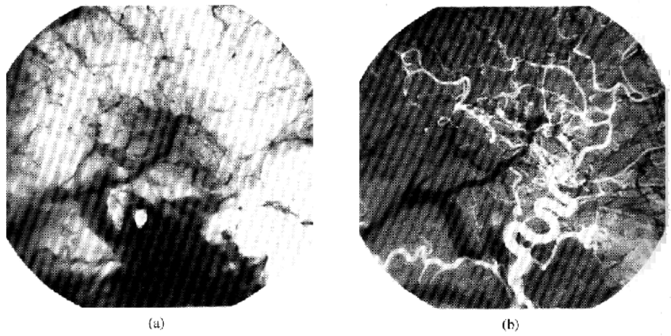


Figure 4.17 Enhancement by image subtraction: (a) mask image; (b) image (after injection of dye into the bloodstream) with mask subtracted out.

四、影像平均(Image Averaging)

$$g(x,y) = f(x,y) + \eta(x,y) \leftarrow \text{雜訊}$$

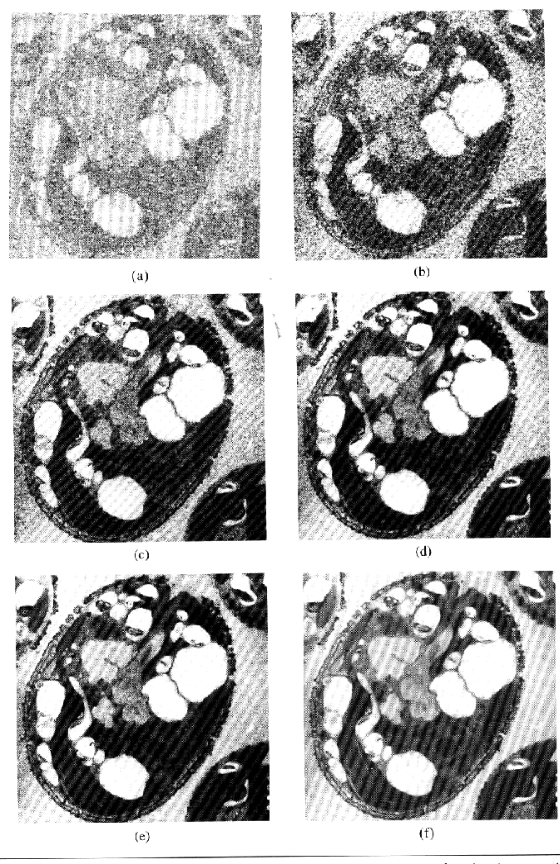


Figure 4.18 Example of noise reduction by averaging: (a) a typical noisy image; (b)–(f) results of averaging 2, 8, 16, 32, and 128 noisy images.

參、空間領域之過濾作業

一、基本背景：

１．高通濾波與低通濾波。

２．線性與非線性空間領域過濾器。

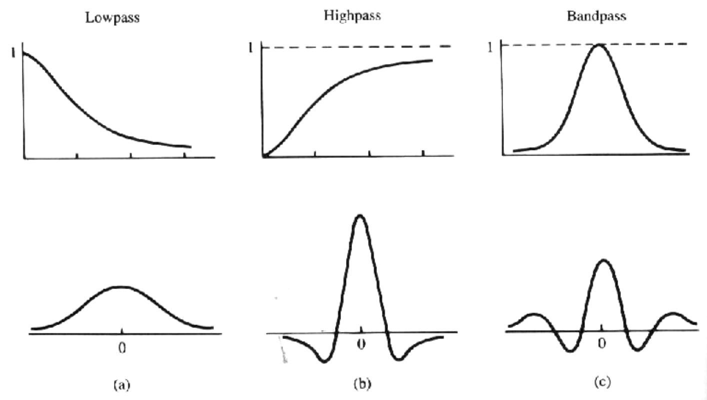


Figure 4.19 Top: cross sections of basic shapes for circularly symmetric frequency domain filters. Bottom: cross sections of corresponding spatial domain filters.

二、平滑過濾器(Smoothing Filters)

１．低通空間領域過濾器：

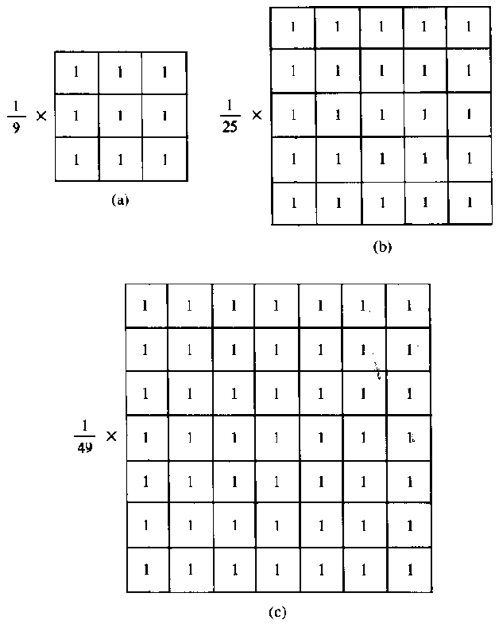


Figure 4.21 Spatial lowpass filters of various sizes.

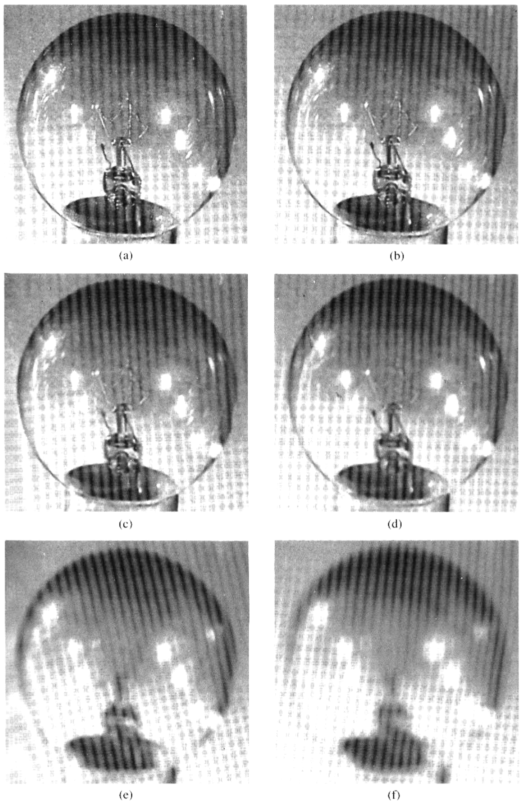


Figure 4.22 (a) Original image; (b)–(f) results of spatial lowpass filtering with a mask of size $n \times n$, $n = 3, 5, 7, 15, 25$.

２．中間值過濾器：

Figure 4.23 (a) Original image; (b) image corrupted by impulse noise; (c) result of 5×5 neighborhood averaging; (d) result of 5×5 median filtering. (Courtesy of Martin Connor, Texas Instruments, Inc., Lewisville, Tex.)

３．低通過濾器與中間值過濾器之異同：

三、銳化過濾器(Sharpening Filters)

１．基本高通空間領域過濾器：

$$\frac{1}{9} \times \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Figure 4.24 A basic highpass spatial filter.

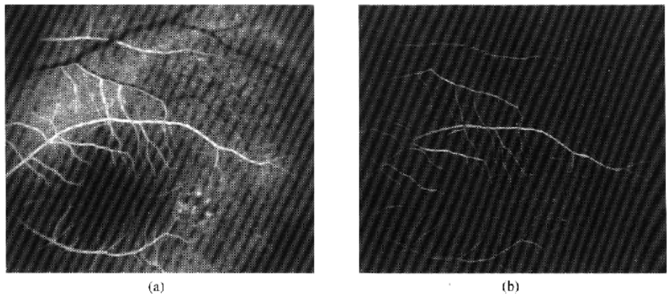


Figure 4.25 (a) Image of a human retina; (b) highpass filtered result using the mask in Fig. 4.24.

２．High-boost 過濾器(Unsharp Masking)：

Highpass = Original - Lowpass

High boost = (A)(Original) - Lowpass

= (A - 1)(Original) + Highpass

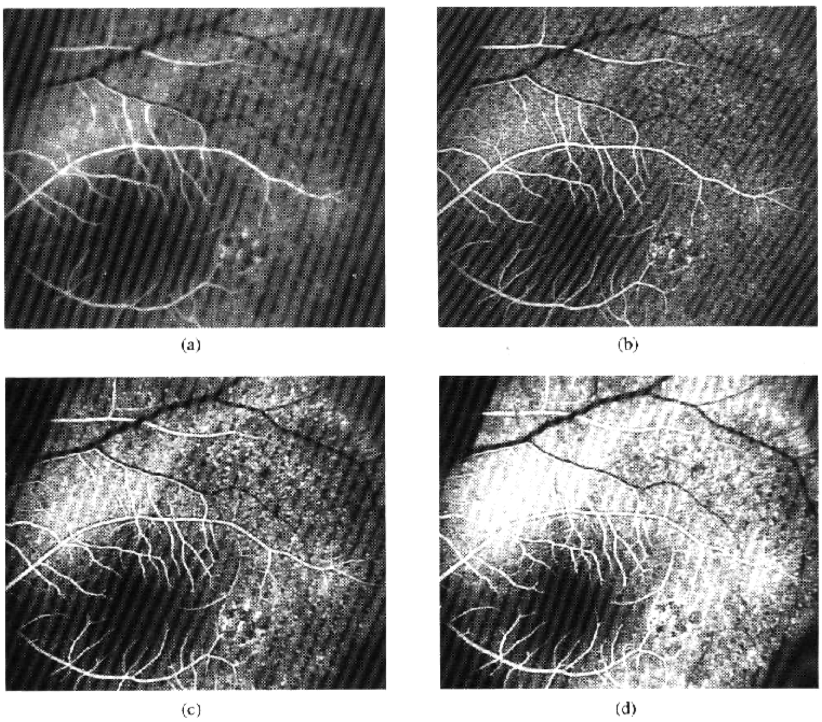


Figure 4.27 (a) Original image; (b)–(d) result of high-boost filtering using the mask in Fig. 4.26, with A = 1.1, 1.15, and 1.2, respectively. Compare these results with those shown in Fig. 4.25.

３．微分過濾器(Derivative Filters)

$$\nabla \mathbf{g} = \begin{bmatrix} \dfrac{\partial f}{\partial x} \\ \dfrac{\partial f}{\partial y} \end{bmatrix} \qquad \nabla f = mag\,(\nabla \mathbf{g}) = \left[\left(\frac{\partial \mathrm{f}}{\partial x} \right)^2 + \left(\frac{\partial \mathrm{f}}{\partial y} \right)^2 \right]^{1/2}$$

近似式為：$\bigtriangledown f \doteqdot [(z_5 - z_8)^2 + (z_5 - z_6)^2]^{1/2}$

$\bigtriangledown f \doteqdot |z_5 - z_8| + |z_5 - z_6|$

或 $\bigtriangledown f \doteqdot [(z_5 \quad z_9)^2 + (z_6 - z_8)^2]^{1/2}$

$\bigtriangledown f \doteqdot |z_5 - z_9| + |z_6 - z_8|$

或 $\bigtriangledown f \doteqdot |(z_7+z_8+z_9) - (z_1+z_2+z_3)|$

$+ \; |(z_3+z_6+z_9) - (z_1+z_4+z_7)|$

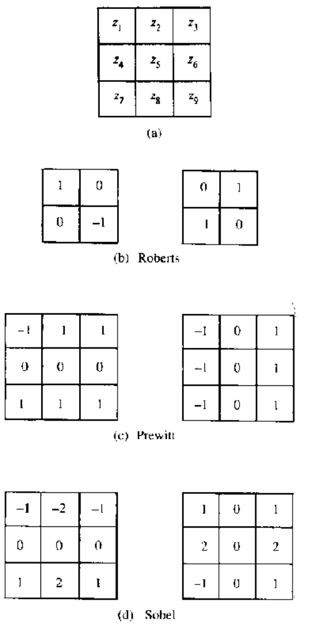


Figure 4.28 *A 3 × 3 region of an image (the z's are gray-level values) and various masks used to compute the derivative at point labeled z_5. Note that all mask coefficients sum to 0, indicating a response of 0 in constant areas, as expected of a derivative operator.*

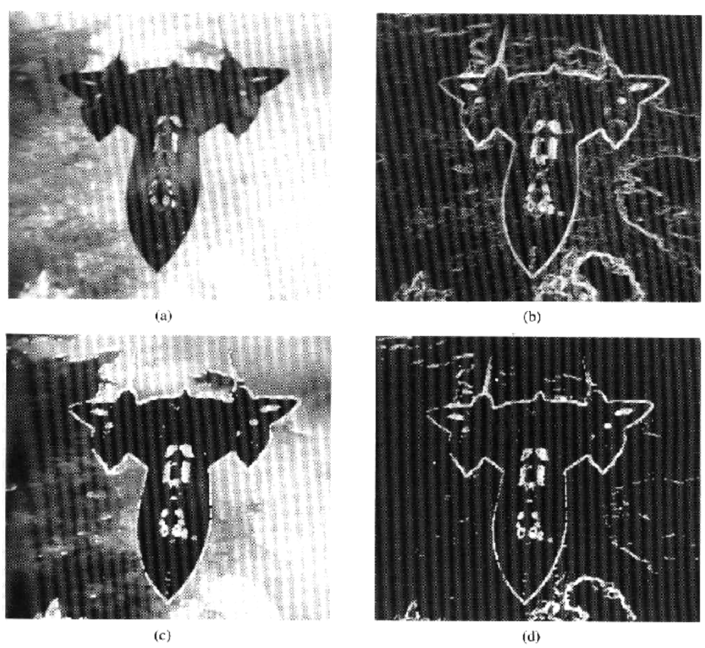


Figure 4.29 *Edge enhancement by gradient techniques (see text).*

肆、頻率領域之強化作業

一、低通濾波

$$G(u,v) = H(u,v)\,F(u,v)$$

H(u,v)為零相位偏離濾波器(Zero-phase-shift Filter)

1．理想低通濾波器(Ideal lowpass filter, ILPF)

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

而　$D(u,v) = (u^2 + v^2)^{1/2}$

D_0 為截斷頻率(Cutoff Frequency)

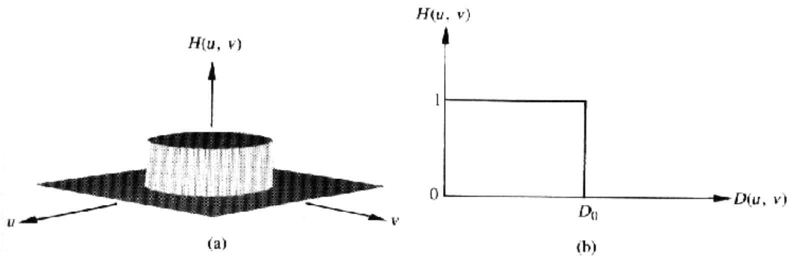


Figure 4.30 *(a) Perspective plot of an ideal lowpass filter transfer function; (b) filter cross section.*

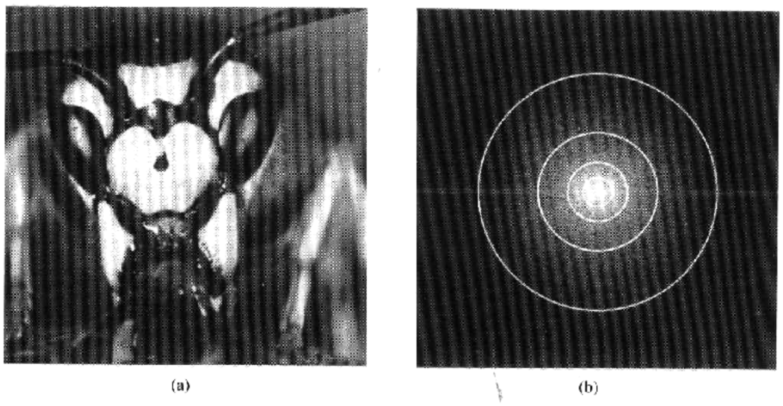


Figure 4.31 *(a) 512 × 512 image and (b) its Fourier spectrum. The superimposed circles, which have radii equal to 8, 18, 43, 78, and 152, enclose 90, 93, 95, 99, and 99.5 percent of the image power, respectively.*

$$P_T = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} P(u,v)$$

$$\beta = 100\left[\sum_{u}\sum_{v} P(u,v) / P_T\right]$$

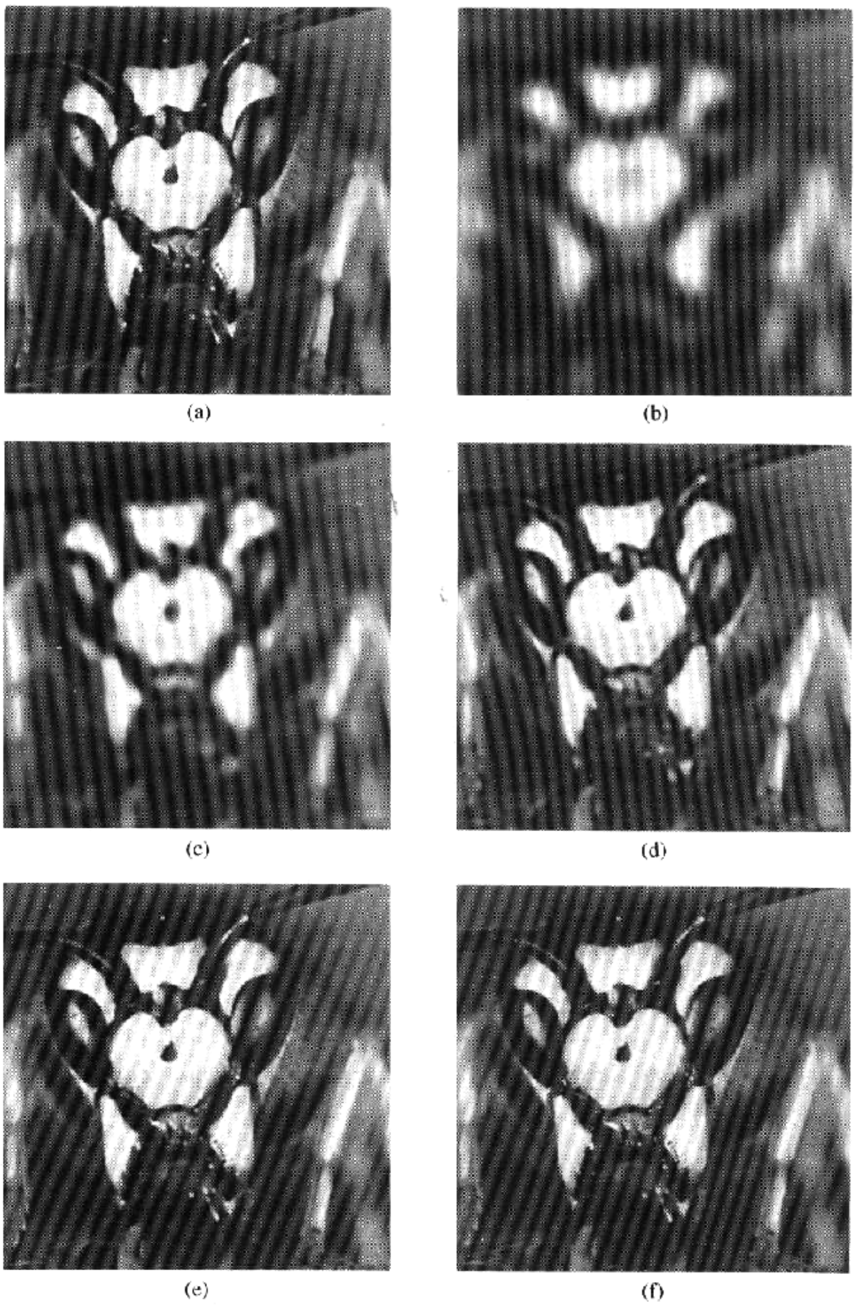


Figure 4.32 *(a) Original image; (b)–(f) results of ideal lowpass filtering with the cutoff frequency set at the radii show in Fig. 4.31(b).*

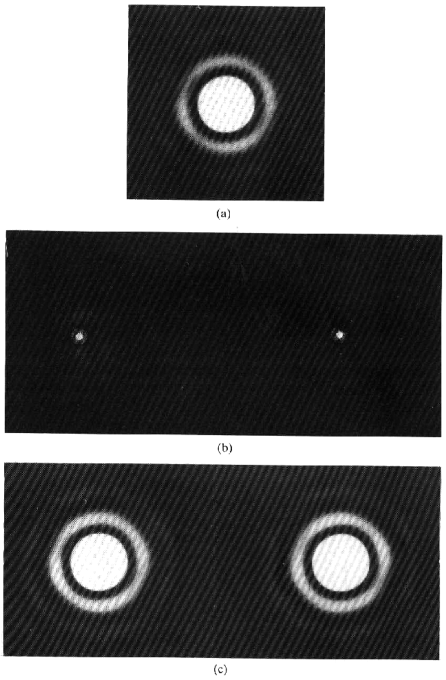


Figure 4.33 Illustration of the blurring process in the spatial domain: (a) blurring function $h(x, y)$ for an ideal lowpass filter; (b) a simple image composed of two bright dots; (c) convolution of $h(x, y)$ and $f(x, y)$.

２．Butterworth 低通濾波器(BLPF)

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

截斷頻率 D_0 則定義爲使 H(u,v) = 0.5 之 D(u,v) = D_0

或以下式定義 BLPF 時 H(u,v) = $1/\sqrt{2}$ 之 D(u,v) = D_0

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

$$=\frac{1}{1+0.414[D(u,v)/D_0]^{2n}}$$

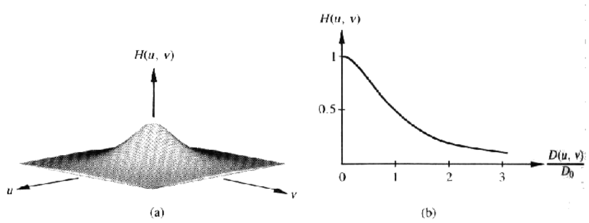


Figure 4.34 (a) A Butterworth lowpass filter; (b) radial cross section for $n = 1$.

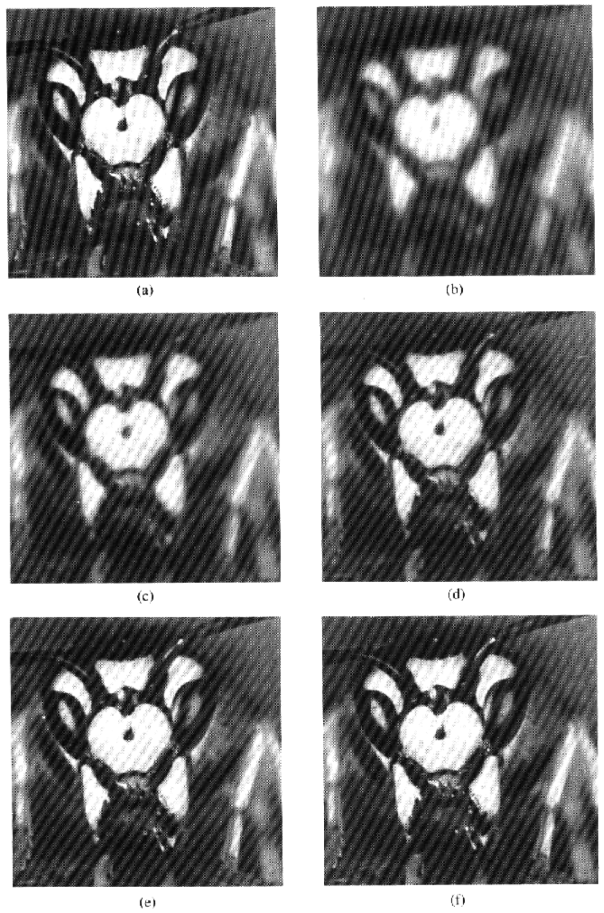


Figure 4.35 (a) Original image; (b)–(f) results of Butterworth lowpass filtering with the cutoff point set at the radii shown in Fig. 4.31(b).

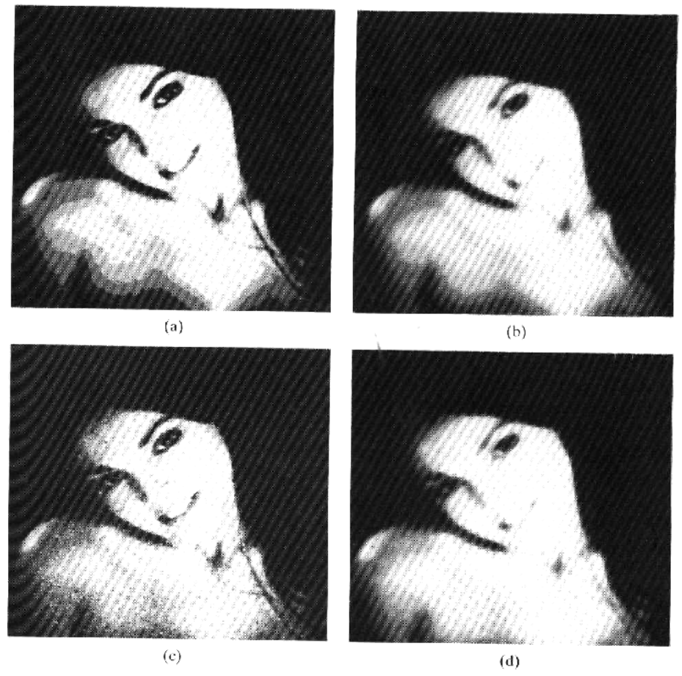


Figure 4.36 Two examples of image smoothing by lowpass filtering (see text).

二、高通濾波

１．理想高通濾波器(Ideal Highpass Filter, IHPF)

$$H(u,v)=\begin{cases}0 & \text{if } \mathrm{D(u,v)}\le \mathrm{D}_0\\ 1 & \text{if } \mathrm{D(u,v)}> \mathrm{D}_0\end{cases}$$

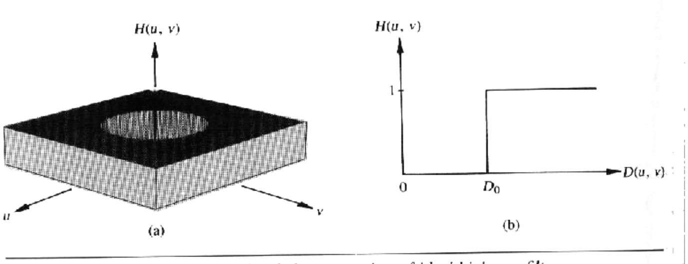


Figure 4.37 Perspective plot and radial cross section of ideal highpass filter.

２．Butterworth 高通濾波器(BHPF)

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

截斷頻率 D_0 則定義爲使 H(u,v) = 0.5 之 D(u,v) = D_0

或以下式定義 BLPF 時 H(u,v) = 1/√2 之 D(u,v) = D_0

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

$$=\frac{1}{1+0.414[D_0/D(u,v)]^{2n}}$$

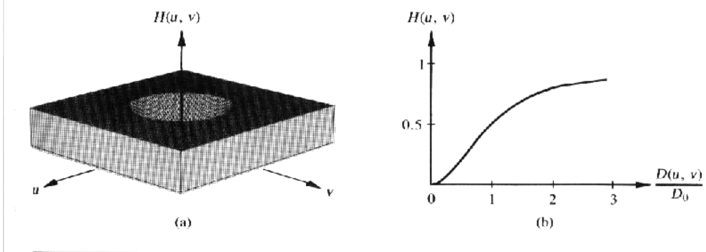
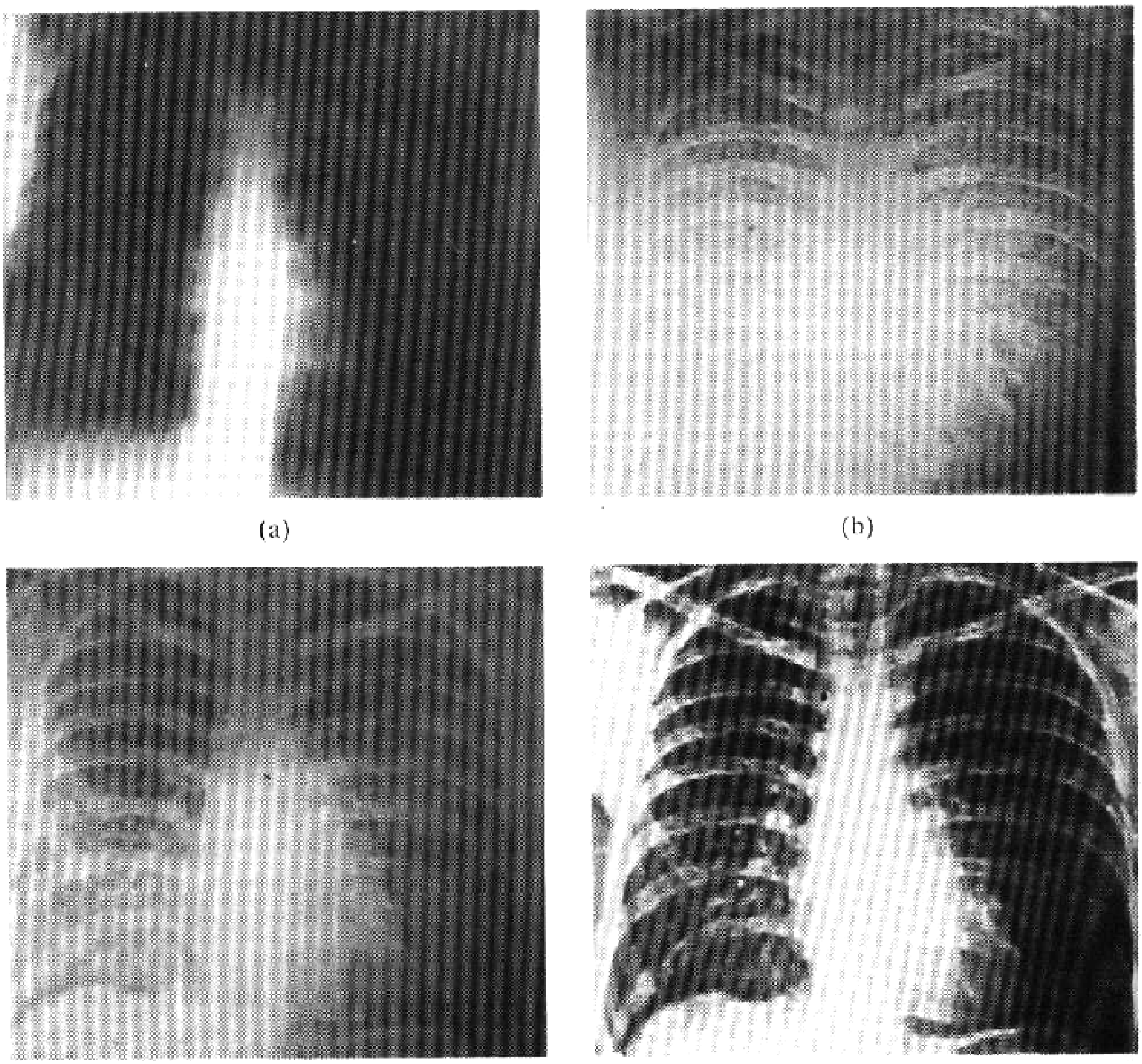


Figure 4.38 Perspective plot and radial cross section of Butterworth highpass filter for *n* = *1*.



(a) (b) (c) (d)

Figure 4.39 *Example of highpass filtering: (a) original image; (b) image processed with a highpass Butterworth filter; (c) result of high-frequency emphasis; (d) high-frequency emphasis and histogram equalization. (From Hall et al. [1971].)*

三、利用照明反射模型進行 Homomorphic 濾波

應用照明反射影像模型在頻率領域同時進行 Brightness range compression 及 Contrast enhancement.

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

i(x,y): slow spatial variation
low frequencies
dynamic range

r(x,y): abrupt spatial variation
high frequency
contrast

數學式之推演：

由於 $F\{f(x,y)\} \neq F\{i(x,y)\, F\{r(x,y)\}$

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

$$F\{z(x,y)\} = F\{\ln f(x,y)\}$$

$$= F\{\ln i(x,y)\} + F\{\ln r(x,y)\}$$

或 $Z(u,v) = I(u,v) + R(u,v)$

以 $H(u,v)$對 $Z(u,v)$進行處理，得

$$S(u,v) = H(u,v)\, Z(u,v)$$

$$= H(u,v)\, I(u,v) + H(u,v)\, R(u,v)$$

故 $s(x,y) = F^{-1}\{S(u,v)\}$

$$= F^{-1}\{H(u,v)\, I(u,v) + F^{-1}\{H(u,v)\, R(u,v)\}$$

註：F 與 F^{-1} 分別表示傅利葉換與反轉換

令 $i'(x,y) = F^{-1}\{H(u,v)\, I(u,v)\}$

$$r'(x,y) = F^{-1}\{H(u,v)\ R(u,v)\}$$

則 $$s(x,y) = i'(x,y) + r'(x,y)$$

如此則所求影像為 $g(x,y)$

$$g(x,y) = \exp\{\ s(x,y)\ \}$$

$$= \exp\{\ i'(x,y)\ \} \cdot \exp\{\ r'(x,y)\ \}$$

$$= i_0(x,y)\ r_0(x,y)$$

其中 $i_0 = \exp\{\ i'(x,y)\ \}$

$$r_0 = \exp\{\ r'(x,y)\ \}$$

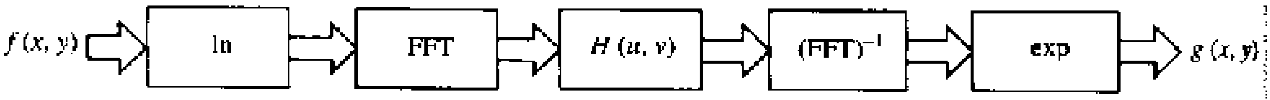
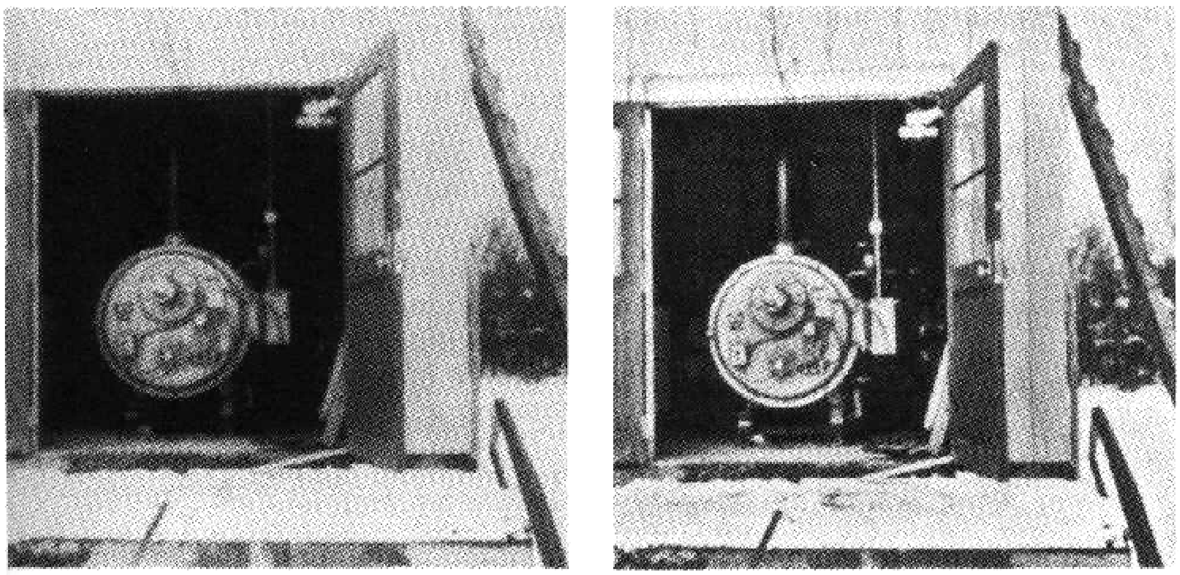


Figure 4.40 *Homomorphic filtering approach for image enhancement.*



(a) (b)

Figure 4.42 *(a) Original image; (b) image processed by homomorphic filtering to achieve simultaneous dynamic range compression and contrast enhancement. (From Stockham [1972].)*

伍、空間遮罩之推演

G(u,v) = H(u,v) F(u,v),

$$g(x,y)=\sum_{i=0}^{N-1}\sum_{k=0}^{N-1}h(x-i,y-k)f(i,k)$$

h(x,y) 爲 spatial convolution mask.

由於

$$H(u,v)=\frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}h(x,y)\exp[-j2\pi(ux+vy)/N]$$

若我們限制以一條件：

h(x,y) = 0 當 x > n 或 y > n, (n < N)

則實際上我們定義了一個 n×n 捲積遮罩

(Convolution Mask)

$$\hat{H}(u,v)=\frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}\hat{h}(x,y)\exp[-j2\pi(ux+vy)/N]$$

而 nxn 捲積遮罩 $\hat{h}(x,y)$ 則爲我們所要推演求得之空間遮罩，推演 $\hat{h}(x,y)$ 則依據計算 H(u,v)與 $\hat{H}(u,v)$ 之間的最小誤差求得：

$$e^2=\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}\left|\hat{H}(u,v)-H(u,v)\right|^2$$

利用矩陣推演：

$$\hat{H} = C\hat{h}$$

式中 $\hat{H}$ 為 N^2 order 之 column vector

$\hat{h}$ 為 n^2order 之 column vector

C 為 $N^2 \times N^2$ 之矩陣

$$\hat{H}(u,v) \Rightarrow \hat{H}(i)$$

$$\hat{h}(x,y) \Rightarrow \hat{h}(k)$$

$$\frac{1}{N}\exp[-j2\pi(ux+vy)/N] \Rightarrow C(i,k)$$

$$\mathrm{i = uN + v, \quad k = xn + y}$$

$$\text{with u, v} = 0,1,2,\dots,\mathrm{N}-1,\ \mathrm{x, y} = 0,1,2,\dots,\mathrm{n}-1$$

因此

$$e^2 = (\hat{H} - H)^*(\hat{H} - H)$$

$$= \left\|\hat{\mathrm{H}} - \mathrm{H}\right\|^2$$

$$= \left\|\mathrm{C}\hat{\mathrm{h}} - \mathrm{H}\right\|^2$$

取其偏微分

$$\frac{\partial e^2}{\partial \hat{h}} = 2C^*(C\hat{h} - \mathrm{H}) = 0$$

故 $\hat{h} = (C^*C)^{-1}C^*H = C^\# H$

而 $C^\#$ 稱為 Moore-Penrose generalized inverse

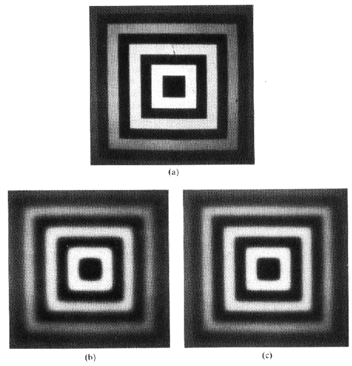


Figure 4.43 (a) Original image; (b) blurred image obtained with a Butterworth lowpass filter of order 1 in the frequency domain; (c) image blurred spatially by a 9 × 9 convolution mask obtained using Eq. (4.5-12). (From Meyer and Gonzalez [1983].)

陸、彩色影像處理

一、色彩基礎

１．色彩頻譜(Color Spectrum)

Chromatic light： 400 - 700 nm

Basic quantities：radiance, luminance, brightness

２．三原色與第二色彩(Primary Color & Secondary Color)

紅(R) 700.0 nm
綠(G) 546.1 nm 三原色
藍(B) 435.8 nm

Magenta
Cyan 第二色彩
Yellow

３．光與顏料之三原色

４．Hue - Saturation - Intensity (Brightness)

Chromaticity

５．Trichromatic Coefficients and Color Table

$$x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z}$$

$$x + y + z = 1$$

二、色彩模式：

建立色彩模式之主要目的爲提供一可接受之指定色彩標準

１．RGB 色彩模式：

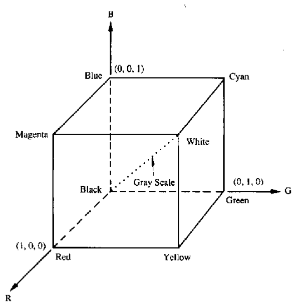


Figure 4.44 RGB color cube. Points along the main diagonal have gray values, from black at the origin to white at point (1, 1, 1).

２．CMY 色彩模式：

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

３．YIQ 色彩模式：

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

其中 Y 爲 Luminance Component，I 與 Q 爲 Color Components，此色彩模式主要應用於電視訊號，以配合黑白電視訊號，應用此模式可將明亮度與彩色成份分離，以利處理。

４．HSI 色彩模式：

HSI 色彩模式較符合人類視覺系統，同樣可以將明亮度與彩色成份分別處理

５．RGB 系統至 HSI 系統之轉換

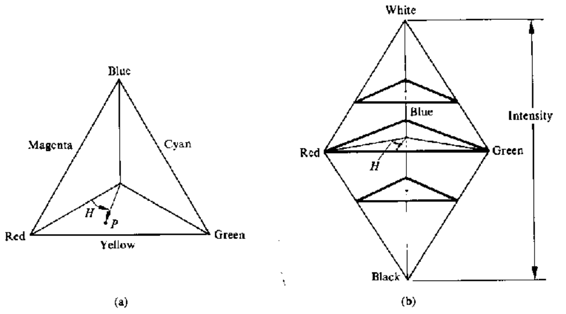


Figure 4.45 (a) HSI color triangle; (b) HSI color solid.

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

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

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

６．HSI 系統至 RGB 系統之轉換

(1). RG sector (0°＜ H ≦ 120°)

$$R = 3I_r,\ G = 3I_g\ \ B = 3I_b$$

$$b = \tfrac{1}{3}(1-S),\ r = \tfrac{1}{3}\left(1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right),\ \ g = 1-(r+b),$$

(2). GB sector (120°＜ H ≦ 240°)

$$H = H - 120^\circ$$

$$r = \tfrac{1}{3}(1-S),\ g = \tfrac{1}{3}\left(1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right),\ \ b = 1-(g+r),$$

(3). BR sector (240°＜ H ≦ 360°)

$$H = H - 240^\circ$$

$$g = \tfrac{1}{3}(1-S),\ b = \tfrac{1}{3}\left(1+\frac{S\cos(H)}{\cos(60^\circ - H)}\right),\ \ r = 1-(g+b),$$

三、假彩色影像處理(Pseudo-color Image Processing)

１．強度分切(Intensity Slicing)

$$f(x,y)=C_k \quad if \quad f(x,y)\in R_k$$

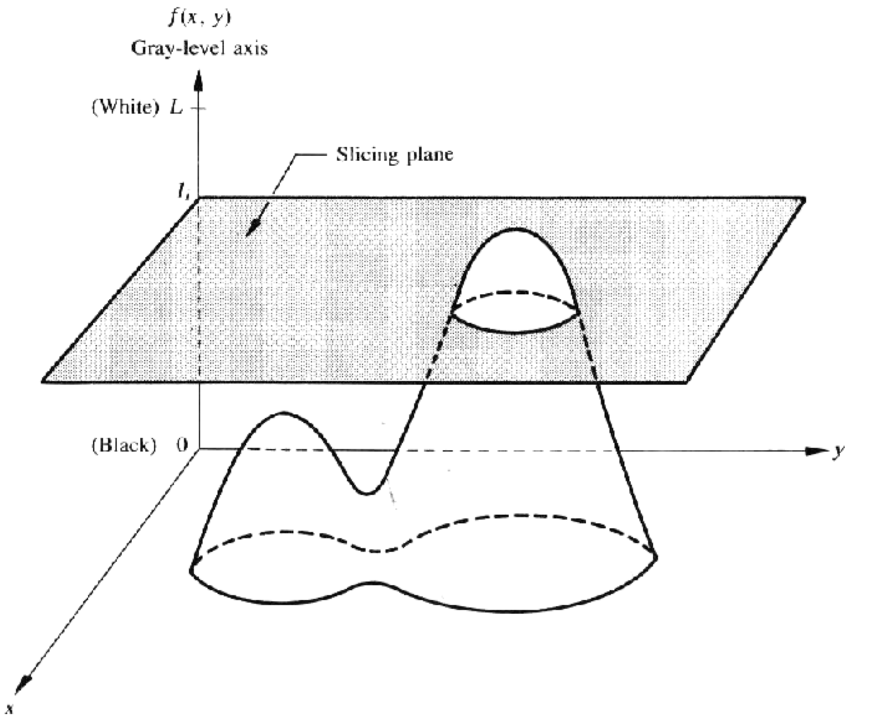


Figure 4.48 Geometric interpretation of the intensity-slicing technique.

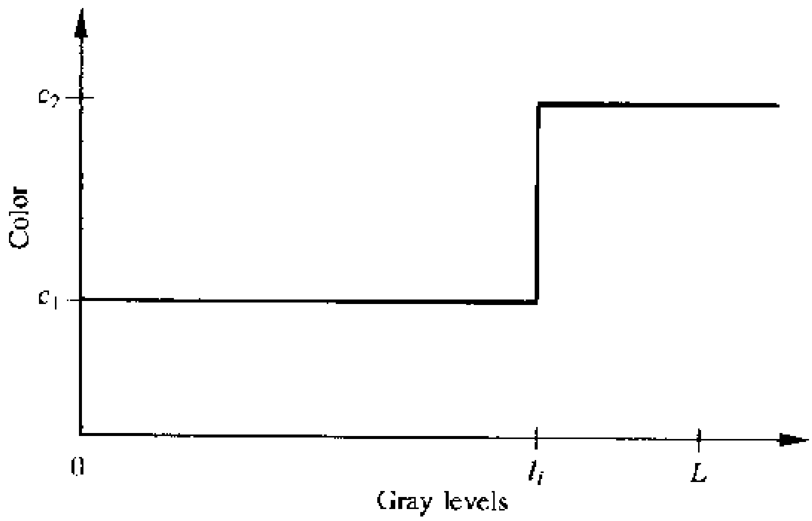


Figure 4.49 An alternative representation of the intensity-slicing method.

2．灰度至色彩之轉換

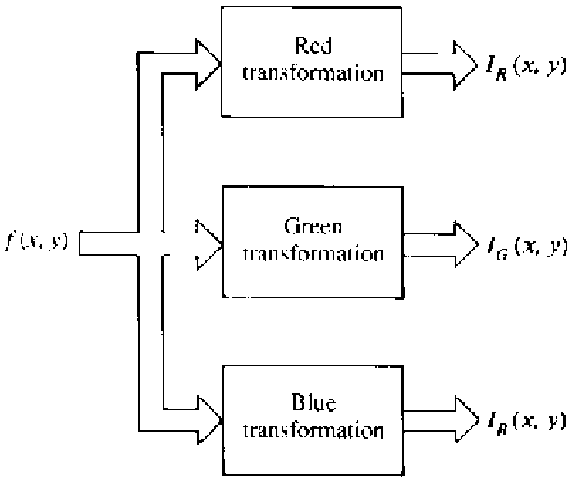


Figure 4.50 *Functional block diagram for pseudo-color image processing. I_R, I_G, and I_B are fed into the red, green, and blue inputs, respectively, of an RGB color monitor.*

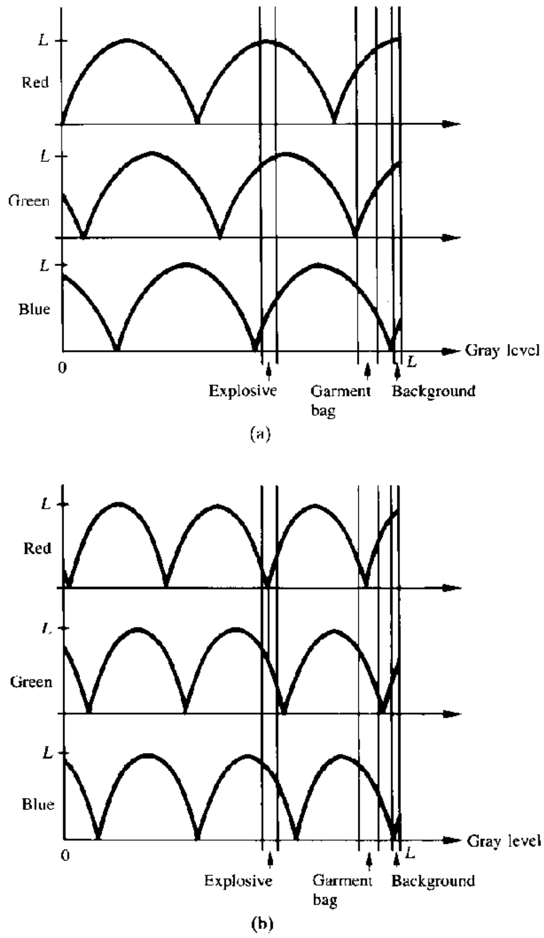


Figure 4.51 *Transformation functions used to obtain the images in Plate VI.*

3．濾波方式

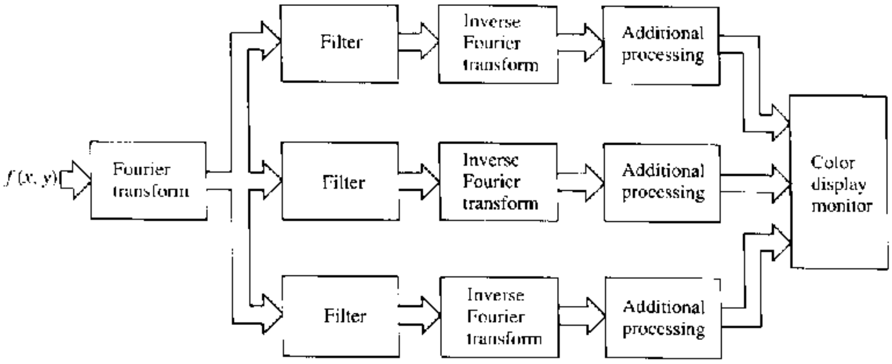


Figure 4.52 *A filtering model for pseudo-color image processing.*

(1).高通濾波

(2).低通濾波

(3).理想 Bandreject 濾波(IBRF)

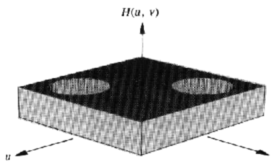


Figure 4.53 *Ideal bandreject filter.*

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

而 $D(u,v) = [(u - u_0)^2 + (v - v_0)^2]^{1/2}$

(4).Butterworth bandreject 濾波(BBRF)

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

(5).Bandpass 濾波

$H(u,v) = -[H_R(u,v) - 1]$

四、全彩色影像處理(Full-color Image Processing)

1．RGB 影像轉換爲 HSI 影像之個別成份

2．以 HSI 模式進行強化處理

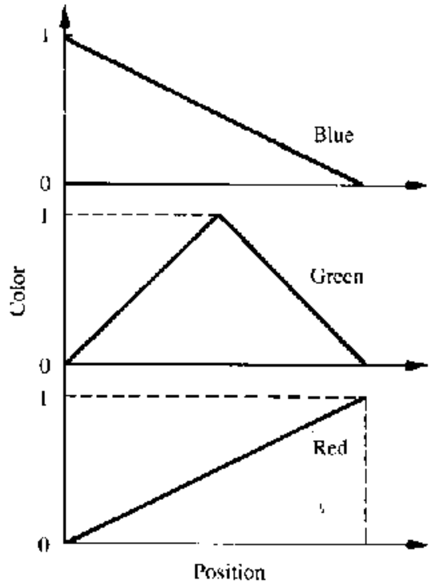


Figure 4.54 *Color functions used to generate the band of varying color in the RGB image of Plate VIII.*

Plate I

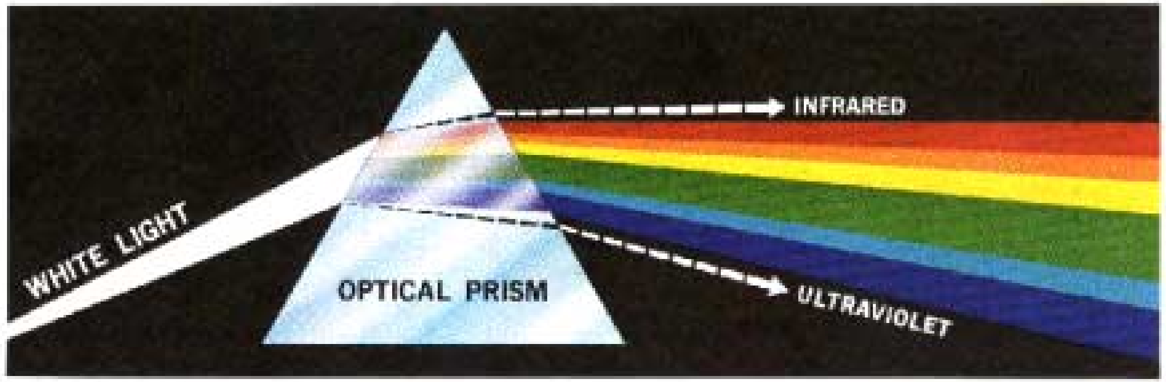


Plate I. Color spectrum seen by passing white light through a prism. (Courtesy of General Electric Co., Lamp Business Division.)

Plate II

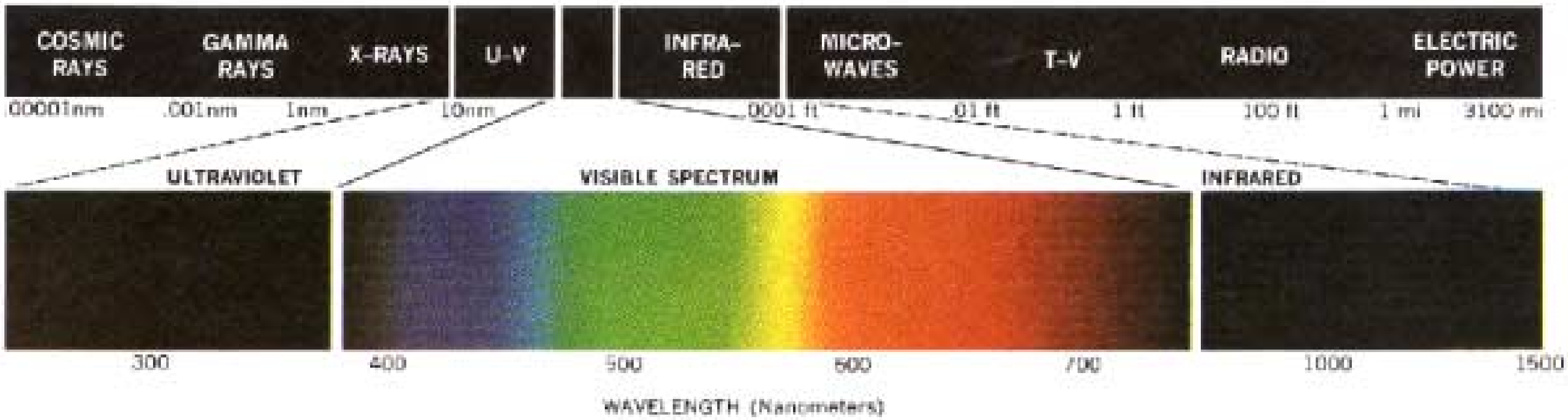


Plate II. A section of the electromagnetic energy spectrum showing the range of wavelengths comprising the visible spectrum. (Courtesy of General Electric Co., Lamp Business Division.)

Plate III

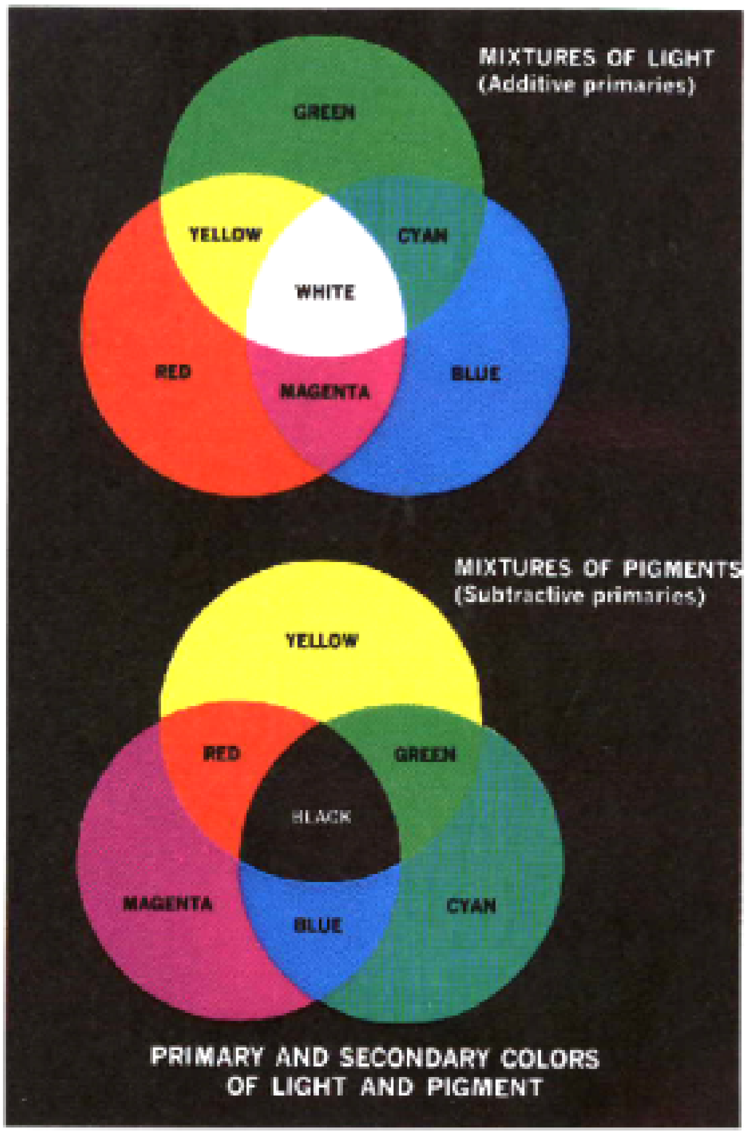


Plate III. Primary and secondary colors of light and pigments. (Courtesy of General Electric Co., Lamp Business Division.)

Plate IV

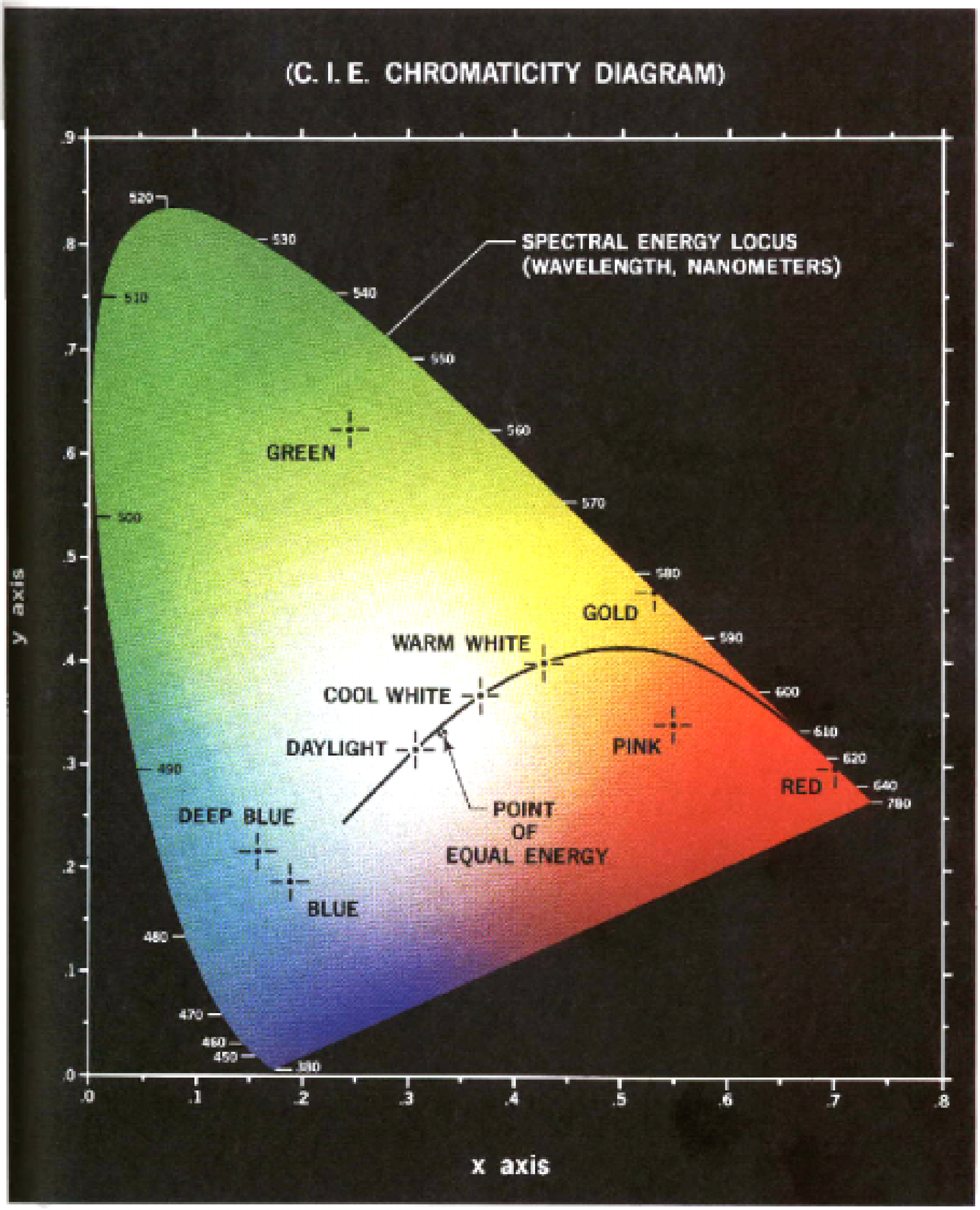
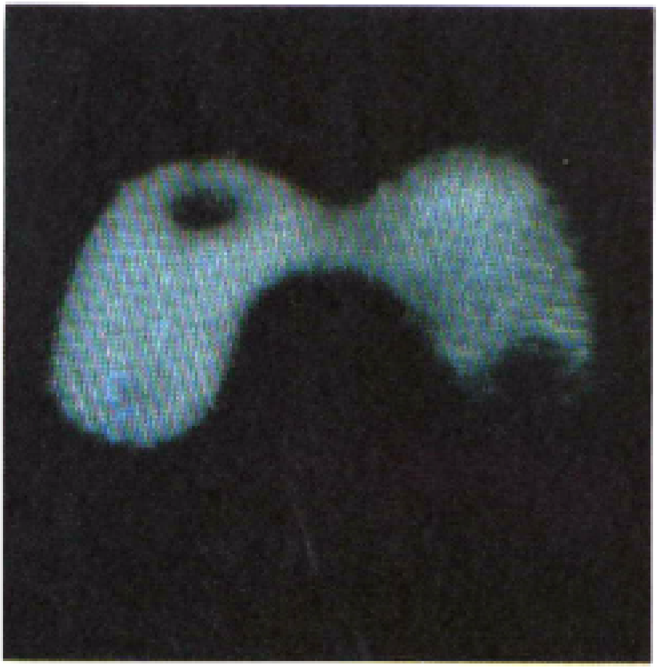
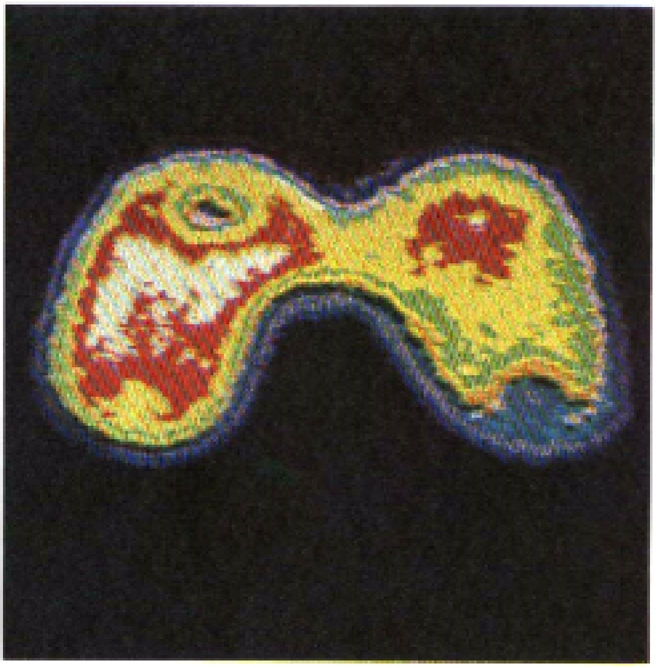


Plate IV. Chromaticity diagram. (Courtesy of General Electric Co., Lamp Business Division.)

Plate V



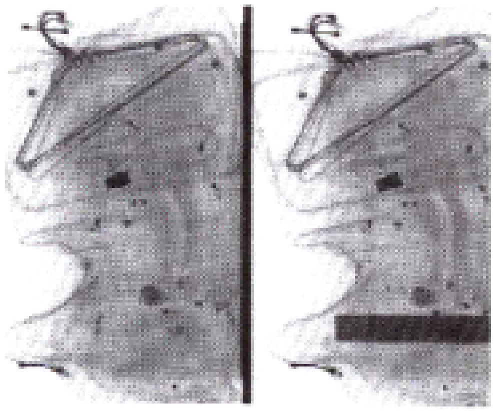
(a)



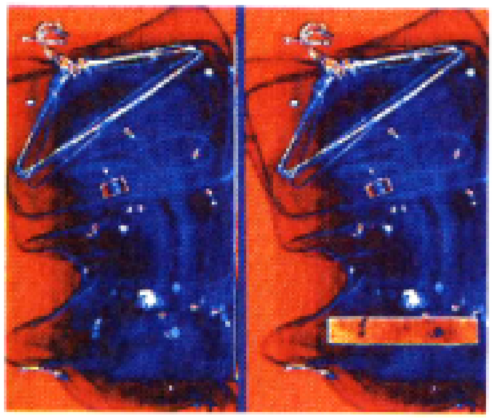
(b)

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

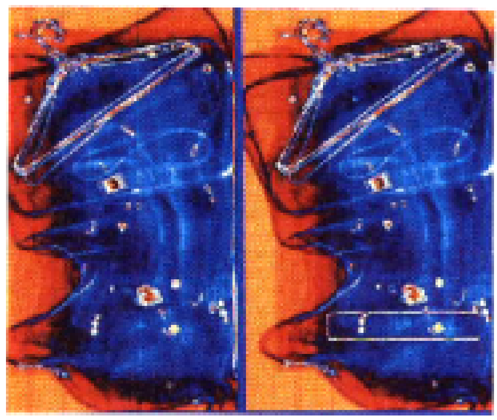
Plate VI



(a)



(b)

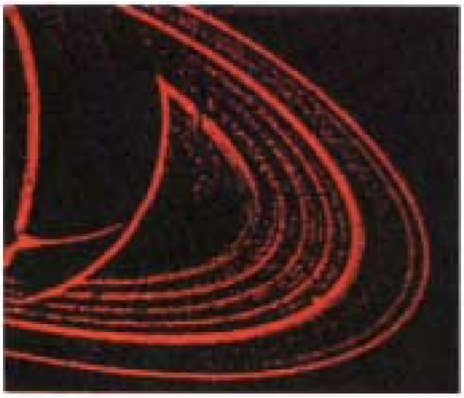


(c)

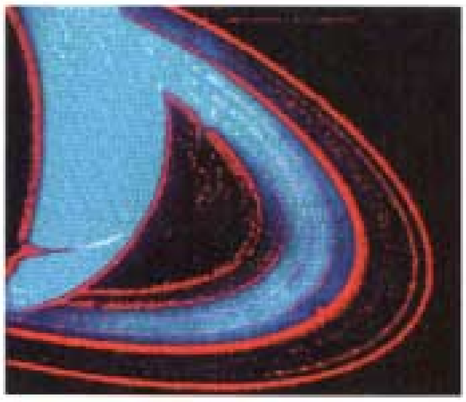
Plate VI. Pseudo-color enhancement by using the gray-level to color transformations in Fig. 4.38. Original image courtesy of Dr. Mike Hurwitz, Research and Development Center, Westinghouse Electric Corporation.

Plate VII

(a)



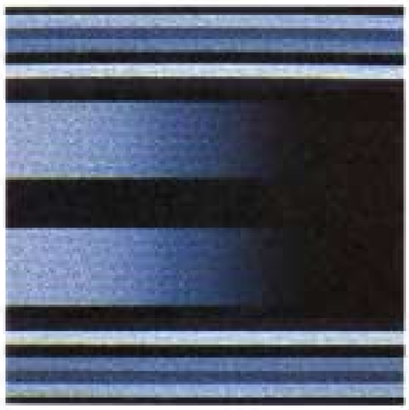
(b)



(c)

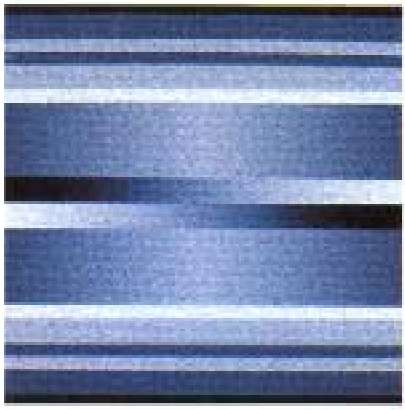
Plate VII. (a) Monochrome image. (b) Result of highpass Butterworth filter displayed on the red gun of a color monitor. (c) Composite image with the lowpass, bandpass, and highpass images displayed on the blue, green, and red guns, respectively.

(a)



(b)

(c)



(d)

Plate VIII. (a) Original RGB image. (b) - (d) Hue, saturation, and intensity images.

(a)

(b)

Plate IX. (a) Original RGB image. (b) Result of histogram equalization (see text).

Plate X

(a)

(b)

Plate X. (a) An original 24-bit color image. (b) Result of compressing and reconstructing the image of (a) using the Joint Photographic Experts Group (JPEG) coding standard. (Courtesy of C-Cube Microsystems, Inc. of San Jose, CA.)