影像之分割與辨識

壹、影像中不連續性之偵測

貳、邊緣連結與邊界偵測

參、分割

肆、區域導向之分割方法

伍、運動在分割上之應用

壹、影像中不連續性之偵測

W_1	W_2	W_3
W_2	W_5	W_6
W_7	W_8	W_9

$$w = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_9 \end{bmatrix} \qquad x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_9 \end{bmatrix}$$

$$R = w_1 z_1 + w_2 z_2 + \ldots + w_9 z_9$$
$$= \Sigma\, w_i z_i$$

一、點的偵測(Point Detection)

-1	-1	-1
-1	8	-1
-1	-1	-1

$$|R| > T$$

二、線的偵測(Line Detection)

$$|R_i| > |R_j| \quad \text{for all } j \neq I$$

Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+ 45°

−1	−1	2
−1	2	−1
2	−1	−1

Vertical

−1	2	−1
−1	2	−1
−1	2	−1

−45°

2	−1	−1
−1	2	−1
−1	−1	2

Figure 7.3 *Line masks.*

三、邊緣偵測(Edge Detection)

１．基本原理：

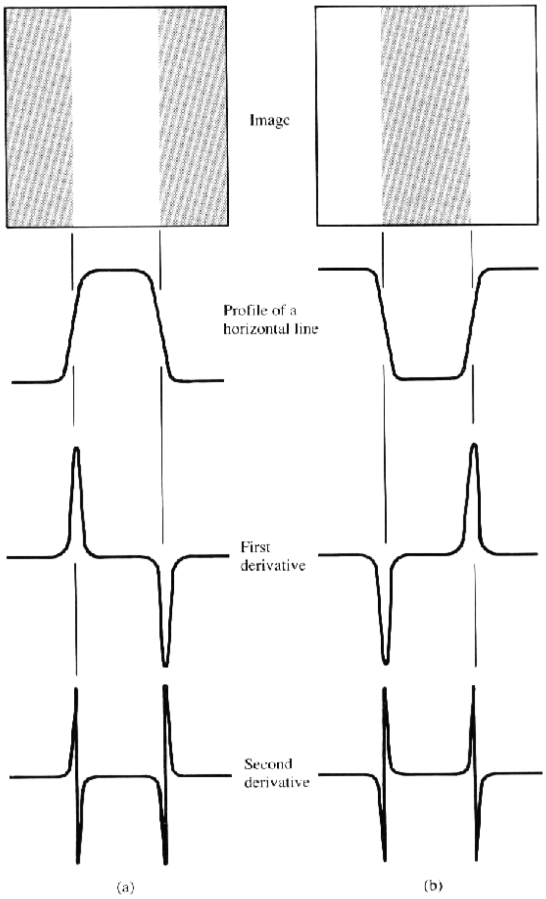


Figure 7.4 Edge detection by derivative operators: (a) light stripe on a dark background; (b) dark stripe on a light background. Note that the second derivative has a zero crossing at the location of each edge.

２．梯度運算子(Gradient Operator)：

$$\mathbf{G}[f(x,y)] = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \dfrac{\partial f}{\partial x} \\ \dfrac{\partial f}{\partial y} \end{bmatrix}$$

$$G[f(x,y)] = [G_x^2 + G_y^2]^{1/2}$$

$$G[f(x,y)] \approx |G_x| + |G_y|$$

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

Sobel Operators:

$$G_x=(x_7+2x_8+x_9)-(x_1+2x_2+x_3)$$

$$G_y=(x_3+2x_6+x_9)-(x_1+2x_4+x_7)$$

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

(a)

−1	−2	−1
0	0	0
1	2	1

(b)

−1	0	1
−2	0	2
−1	0	1

(c)

Figure 7.5 *(a) 3 × 3 image region; (b) mask used to compute G_x at center point of the 3 × 3 region; (c) mask used to compute G_y at that point. These masks are often referred to as the Sobel operators.*

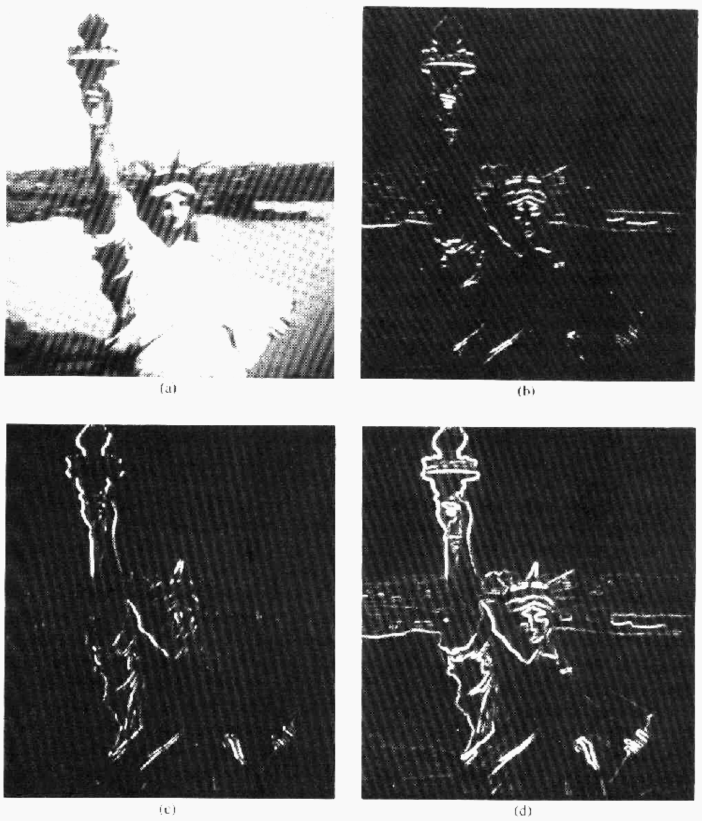


Figure 7.6 *(a) Original image; (b) result of applying the mask in Fig. 7.5(b) to obtain G_x; (c) result of using the mask in Fig. 7.5(c) to obtain G_y; (d) complete gradient image obtained by using Eq. (7.1-5).*

３．Laplacian 運算子：

0	-1	0
-1	4	-1
0	-1	0

$$h(x,y)=\exp(-\frac{x^2+y^2}{2\sigma^2})$$

$$\nabla^2 h=(\frac{r^2-\sigma^2}{\sigma^4})\exp(-\frac{r^2}{2\sigma^2})$$

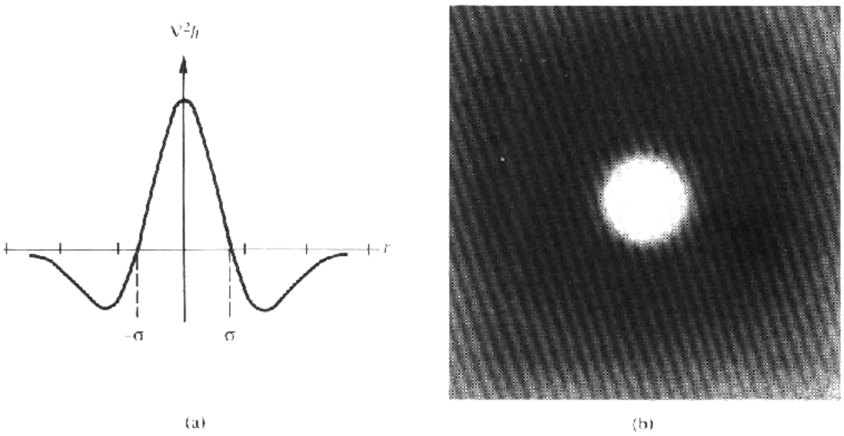


Figure 7.8 (a) Cross section of $\nabla^2 h$; (b) $\nabla^2 h$ shown as an intensity function (image). (From Marr [1982].)

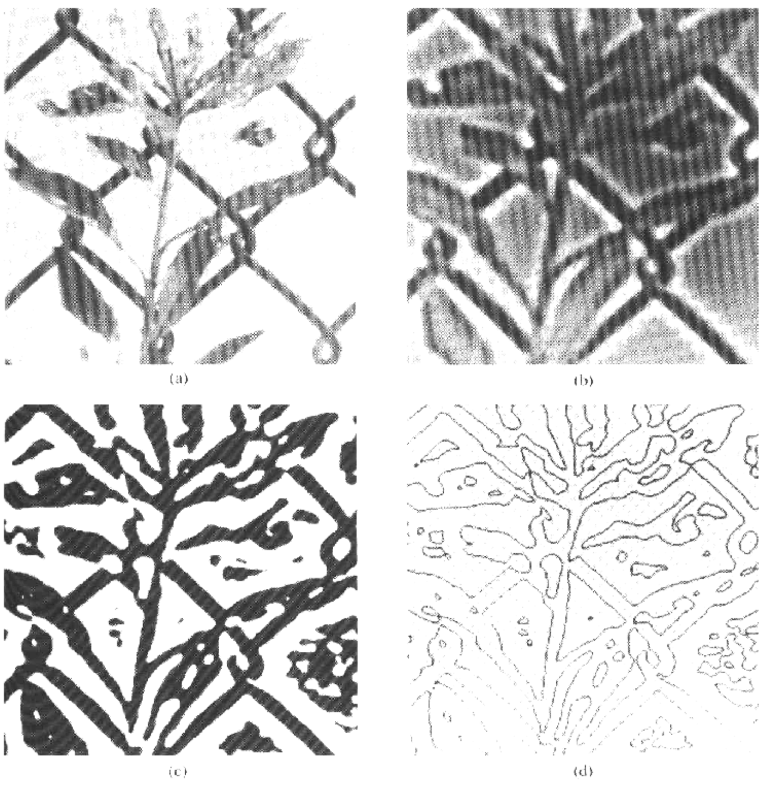


Figure 7.9 (a) Original image; (b) result of convolving (a) with $\nabla^2 g$; (c) result of making (b) binary to simplify detection of zero crossings; (d) zero crossings. (From Marr [1982].)

４．組合偵測(Combined Detection)

$$w_1^T z = \|w_1\| \|z\| \cos\theta$$

$$\|z\| \cos\theta = w_1^T z$$

$$\|z\| = [(w_1^T z)^2 + (w_2^T z)^2 + (w_3^T z)^2]^{1/2}$$

$$\theta = \cos^{-1}\{\frac{1}{\|z\|}[\sum_{i=1}^{2}(w_i^T z)^2]^{1/2}\}$$

$$\phi = \cos^{-1}\{\frac{1}{\|z\|}|w_3^T z|\}$$

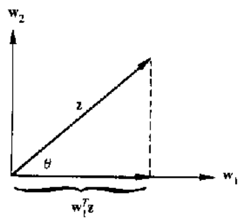


Figure 7.10 Projection of $\mathbf{z}$ onto unit vector $\mathbf{w}_1$.

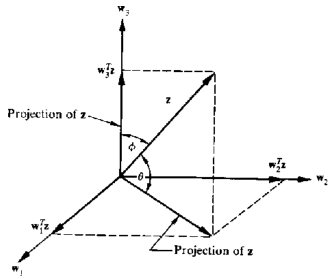


Figure 7.11 Projections of $\mathbf{z}$ onto subspace (plane) determined by $\mathbf{w}_1$ and $\mathbf{w}_2$, and onto subspace $\mathbf{w}_3$.

Frei and Chen's 基底：

(1). Projection Magnitudes:

$$p_e = [\sum_{i=1}^{4}(w_i^T z)^2]^{1/2} \qquad p_l = [\sum_{i=5}^{8}(w_i^T z)^2]^{1/2} \qquad p_a = |w_9^T z|$$

(2). Projection Angles:

$$\theta_e = \cos^{-1}\{\frac{1}{\|z\|}[\sum_{i=1}^{4}(w_i^T z)^2]^{1/2}\}$$

$$\theta_l = \cos^{-1}\{\frac{1}{\|z\|}[\sum_{i=5}^{8}(w_i^T z)^2]^{1/2}\}$$

$$\theta_a = \cos^{-1}\{\frac{1}{\|z\|}|w_9^T z|\}$$

1	$\sqrt{2}$	1
0	0	0
-1	$-\sqrt{2}$	-1

$\mathbf{w}_1$

1	0	-1
$\sqrt{2}$	0	$-\sqrt{2}$
1	0	-1

$\mathbf{w}_2$

0	-1	$\sqrt{2}$
1	0	-1
$-\sqrt{2}$	1	0

$\mathbf{w}_3$

$\sqrt{2}$	-1	0
-1	0	1
0	1	$-\sqrt{2}$

$\mathbf{w}_4$

Basis of edge subspace

0	1	0
-1	0	-1
0	1	0

$\mathbf{w}_5$

1	0	1
0	0	0
1	0	-1

$\mathbf{w}_6$

1	-2	1
-2	4	2
1	-2	1

$\mathbf{w}_7$

-2	1	2
1	4	1
-2	1	-2

$\mathbf{w}_8$

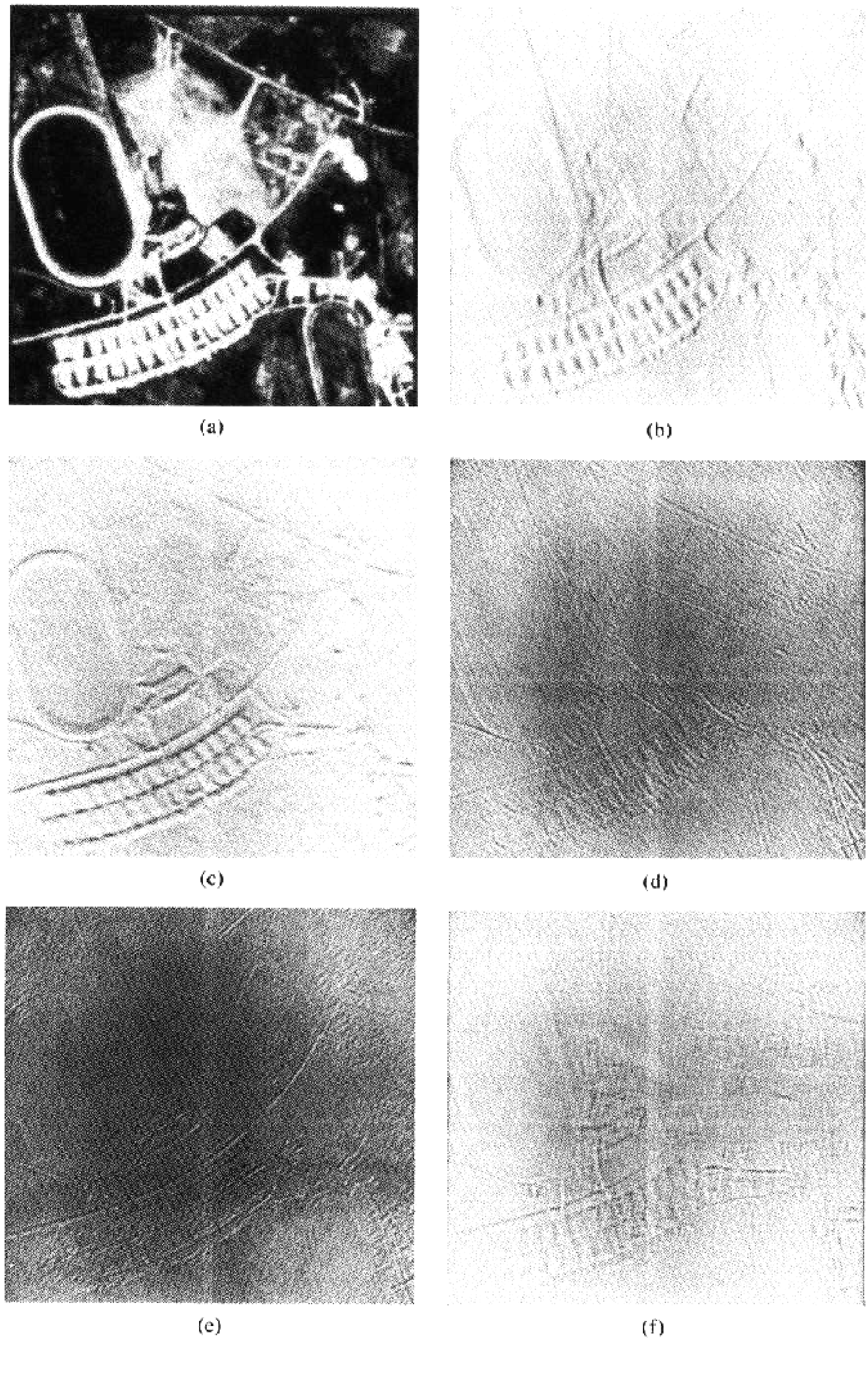
Basis of line subspace

1	1	1
1	1	1
1	1	1

$\mathbf{w}_9$

"Average" subspace

Figure 7.12 *Orthogonal masks. (From Frei and Chen [1977].)*



(a) (b) (c) (d) (e) (f)

Figure 7.13 (a) Original image; (b)–(f) projections onto $\mathbf{w}_1$, $\mathbf{w}_2$, $\mathbf{w}_3$, $\mathbf{w}_4$, and $\mathbf{w}_5$ subspaces, respectively. (From Hall and Frei [1976].)

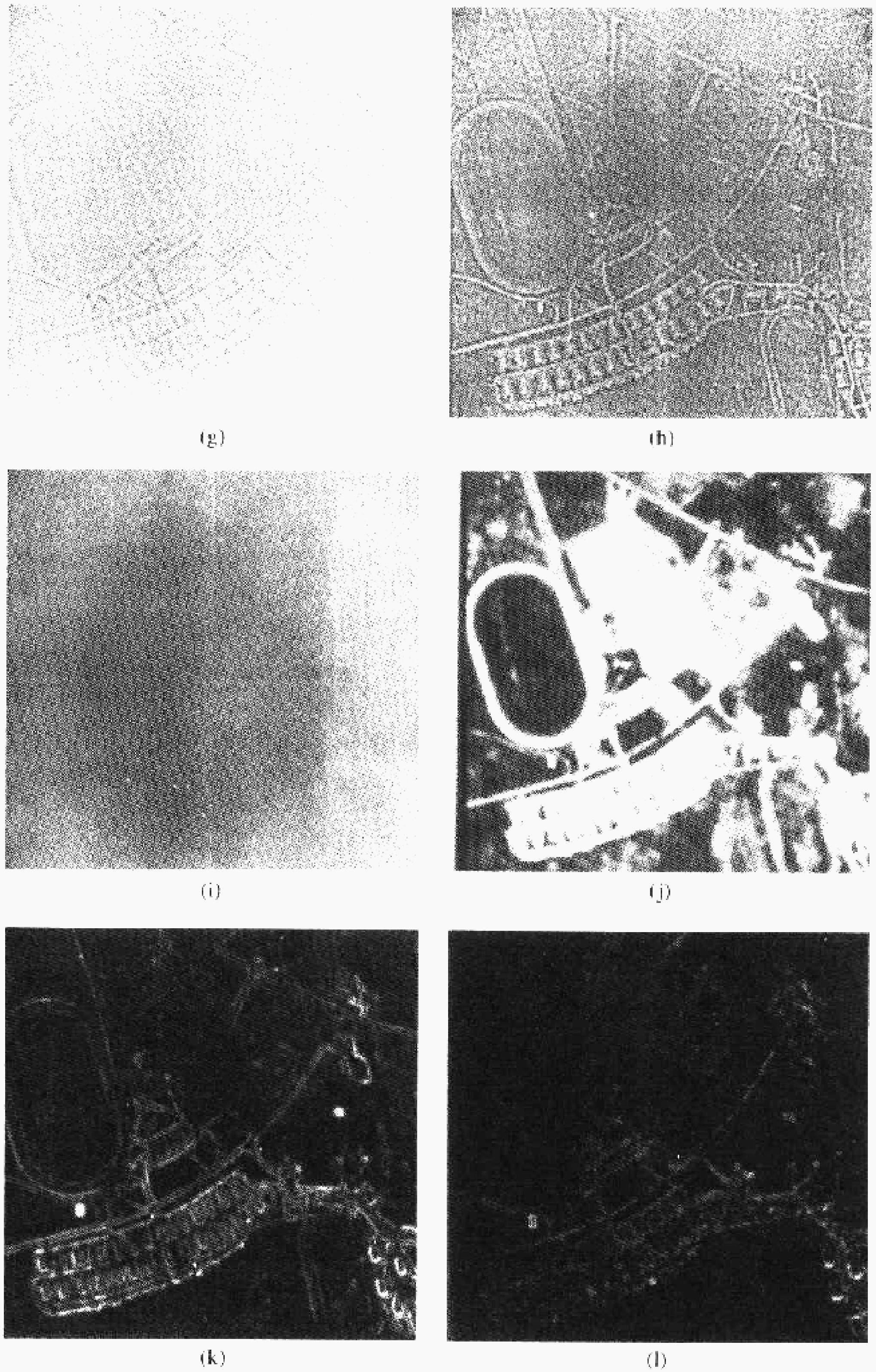


Figure 7.13 *(Continued) (g)–(j) projections onto* $\mathbf{w}_6$, $\mathbf{w}_7$, $\mathbf{w}_8$, *and* $\mathbf{w}_9$ *subspaces; (k) magnitude of projection onto edge subspace; (l) magnitude of projection onto line subspace. (From Hall and Frei [1976].)*

平滑運算子

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

(a)

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & 3 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

(b)

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

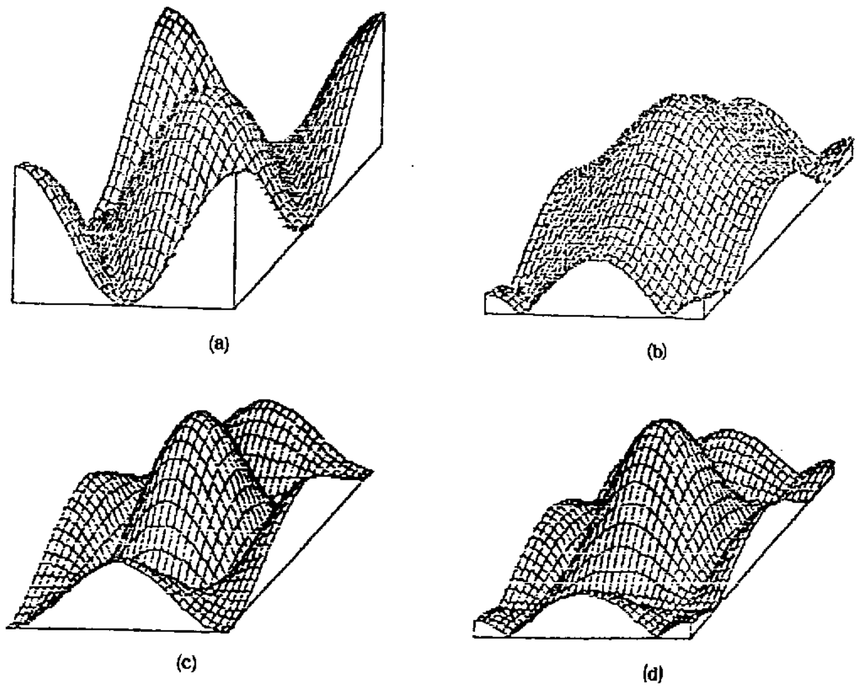
(c)

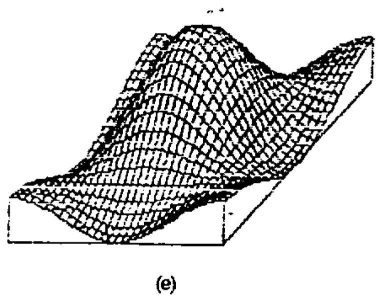
$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(d)

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

(e)





3×3 平滑化運算子
之頻域特性

邊緣偵測運算子

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

(a)拉普拉辛Ⅰ

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

(b)拉普拉辛Ⅱ

$$\begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

(c)拉普拉辛Ⅲ

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$$

(d)布雷維特 (Prewitt)

$$\begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

(e)克希 (Kirsch-Ⅰ)

$$\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix}$$

(f)克希Ⅱ

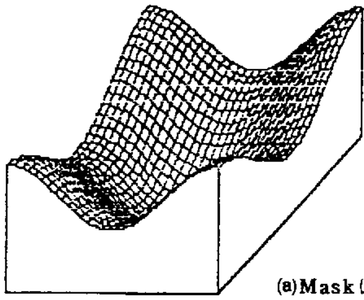
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

(g)梭柏 (Sobel) Sx

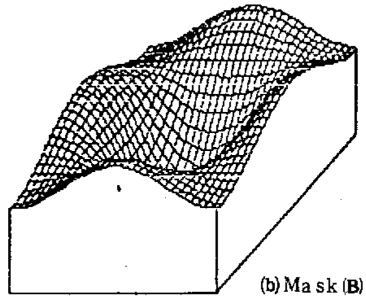
$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

(h)梭柏 Sy

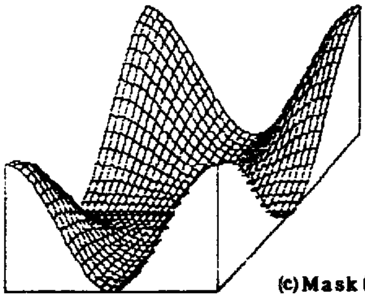
邊緣探測運算子



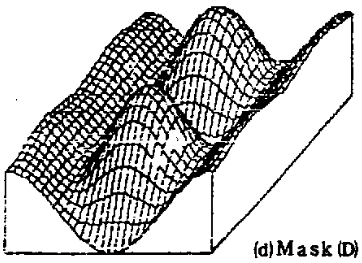
(a)Mask (A)



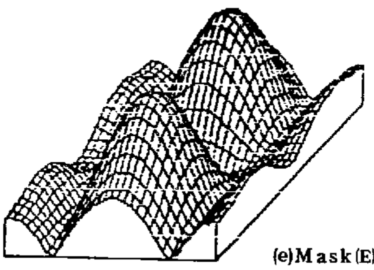
(b)Mask (B)



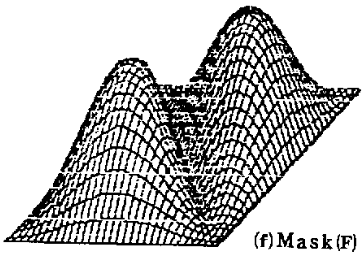
(c)Mask (C)



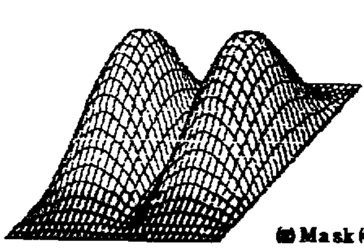
(d)Mask (D)



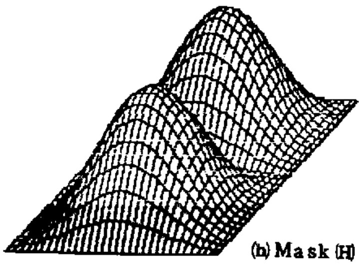
(e)Mask (E)



(f)Mask (F)



(g)Mask (G)



(h)Mask (H)

由最小平方差法所導出的3×3邊緣探測運算子

$$\begin{bmatrix}-3 & 0 & 3\\ -2 & 0 & 2\\ -3 & 0 & 3\end{bmatrix}\quad\begin{bmatrix}3 & 2 & 3\\ 0 & 0 & 0\\ -3 & -2 & -3\end{bmatrix}\quad\begin{bmatrix}1 & -2 & 1\\ 1 & -2 & 1\\ 1 & -2 & 1\end{bmatrix}\quad\begin{bmatrix}1 & 1 & 1\\ -2 & -2 & -2\\ 1 & 1 & 1\end{bmatrix}$$

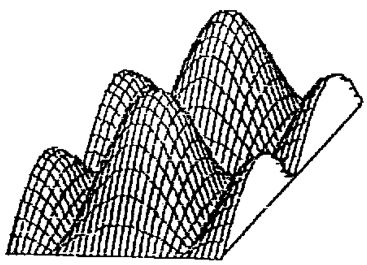
(a) (b) (c) (d)

$$\begin{bmatrix}-1 & 0 & 1\\ 0 & 0 & 0\\ 1 & 0 & -1\end{bmatrix}\quad\begin{bmatrix}2 & -1 & 2\\ -1 & -4 & -1\\ 2 & -1 & 2\end{bmatrix}\quad\begin{bmatrix}-3 & -1 & 0\\ -1 & 0 & 1\\ 0 & 1 & 3\end{bmatrix}\quad\begin{bmatrix}0 & 1 & 3\\ -1 & 0 & 1\\ -3 & -1 & 0\end{bmatrix}$$

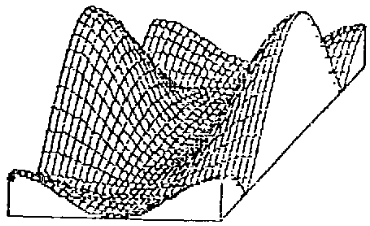
(e) (f) (g) (h)

$$\begin{bmatrix}7 & -2 & 1\\ -2 & -8 & -2\\ 1 & -2 & 7\end{bmatrix}\quad\begin{bmatrix}1 & -2 & 7\\ -2 & -8 & -2\\ 7 & -2 & 1\end{bmatrix}\quad\begin{bmatrix}0 & -1 & 0\\ 1 & 0 & 1\\ 0 & -1 & 0\end{bmatrix}$$

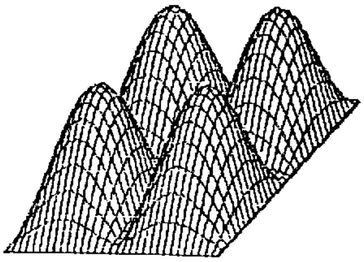
(i) (j) (k)



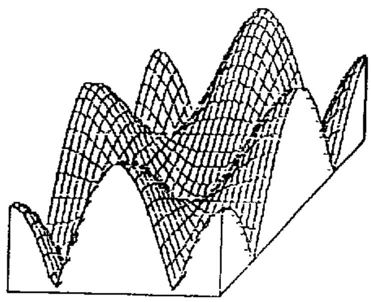
(a) Mask (B)



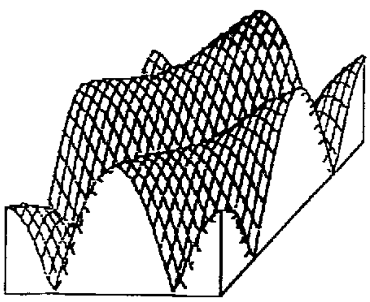
(b) Mask (C)



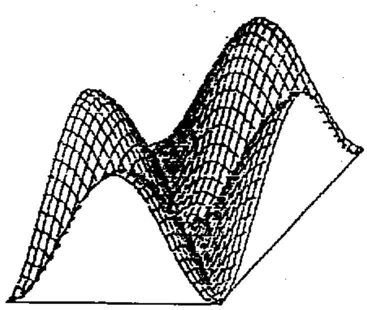
(c) Mask (E)



(d) Mask (F)



(e) Mask (I)



(f) Mask (K)

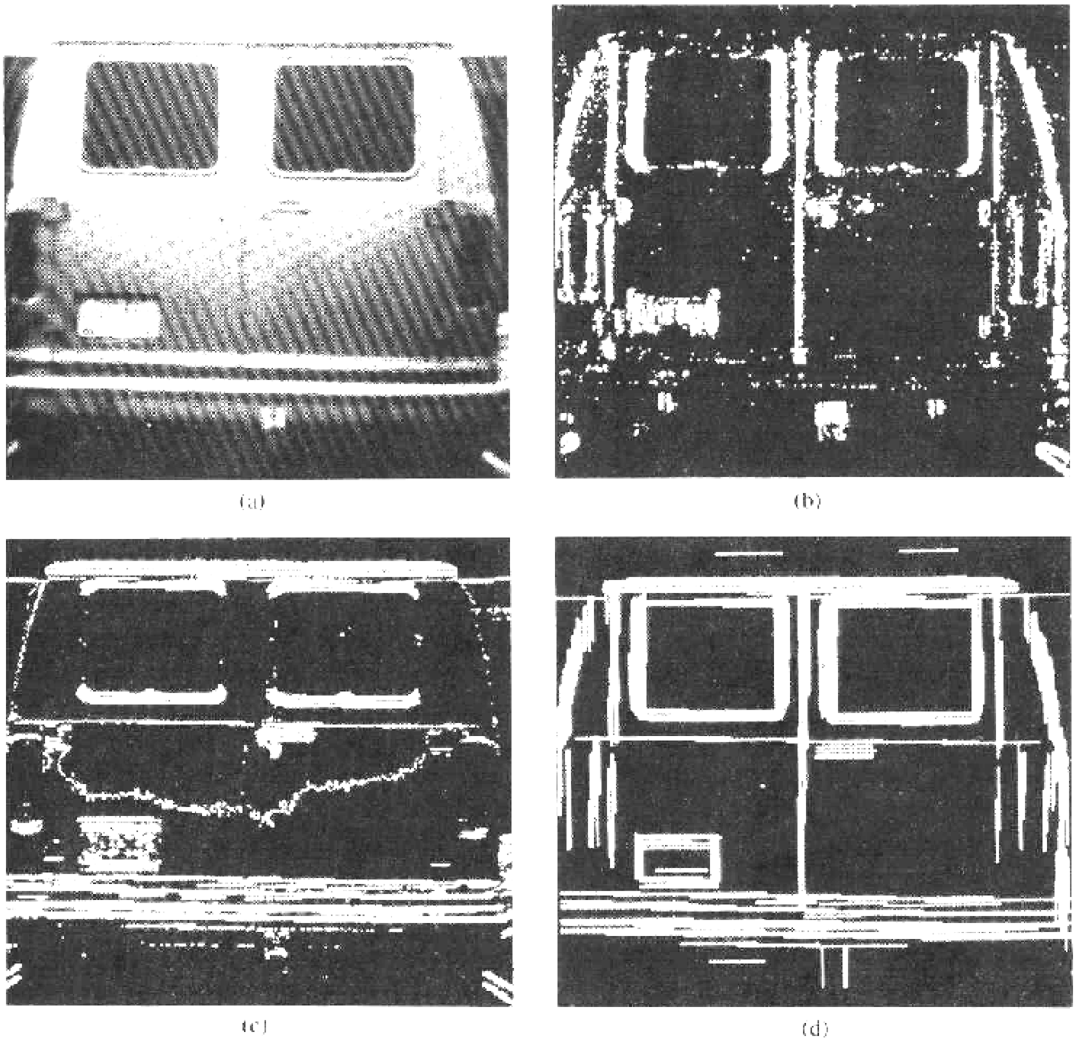
貳、邊緣連結與邊界偵測

一、局部性處理(Local Processing)

●利用 3×3 或 5×5 之局部區域，對中心點 f(x,y)進行下列二式之運算，以決定是否連接 f(x',y')。

$$|\nabla f(x,y) - \nabla f(x',y')| \leqq T$$

$$|\alpha(x,y) - \alpha(x',y')| < A$$



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

Figure 7.14 *(a) Input image; (b) G_y component of the gradient; (c) G_x component of the gradient; (d) result of edge linking. (Courtesy of Perceptics Corporation.)*

二、利用霍氏轉換進行總體性分析

1．霍氏轉換原理：

(1). xy 平面與參數空間(Parameter Space)

$y_i = a\ x_i + b \quad \leftarrow\rightarrow \quad b = -x_i\ a + y_i$

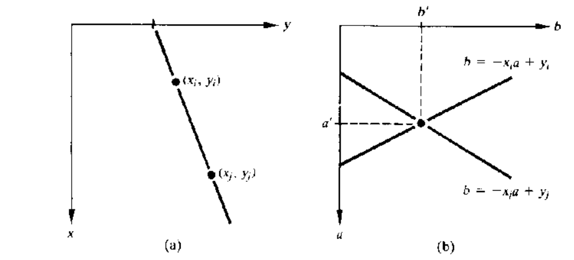


Figure 7.15 (a) xy plane; (b) parameter space.

(2).累積方格(Accumulator Cells)

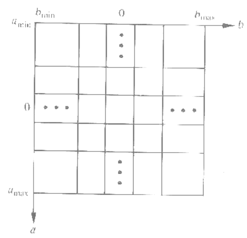


Figure 7.16 Quantization of the parameter plane for use in the Hough transform.

(3).運算數目：(K: increment)

n(n-1)/2 ≒ n^2 finding lines

n(n(n-1))/2 ≒ n^3 comparisons vs. nK computation

(4).直線之 Normal Representation 和參數空間

$x \cos\theta + y \sin\theta = \rho$

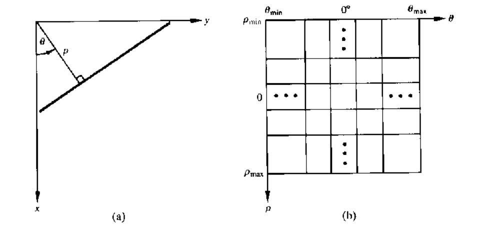


Figure 7.17 (a) Normal representation of a line; (b) quantization of the ρθ plane into cells.

２ ・範例：

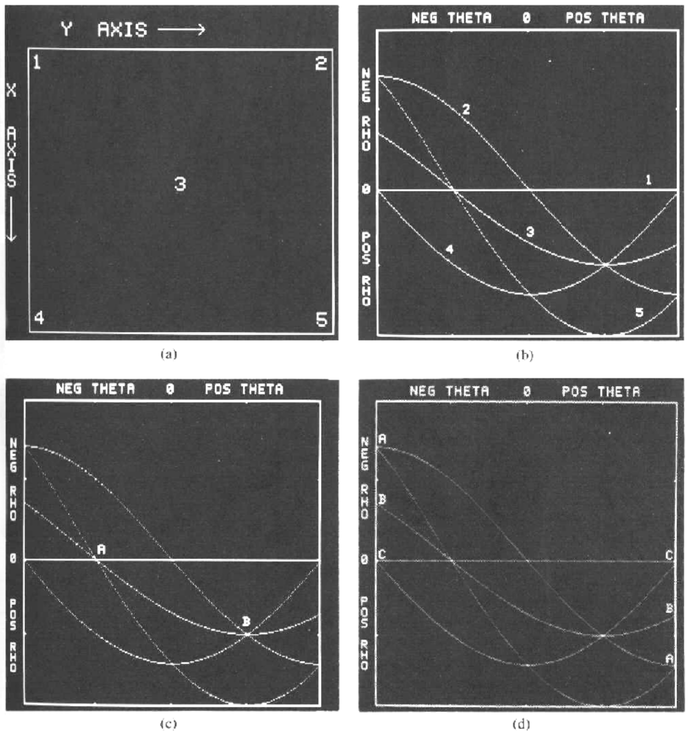


Figure 7.18 *Illustration of the Hough transform. (Courtesy of D. R. Cate, Texas Instruments, Inc.)*

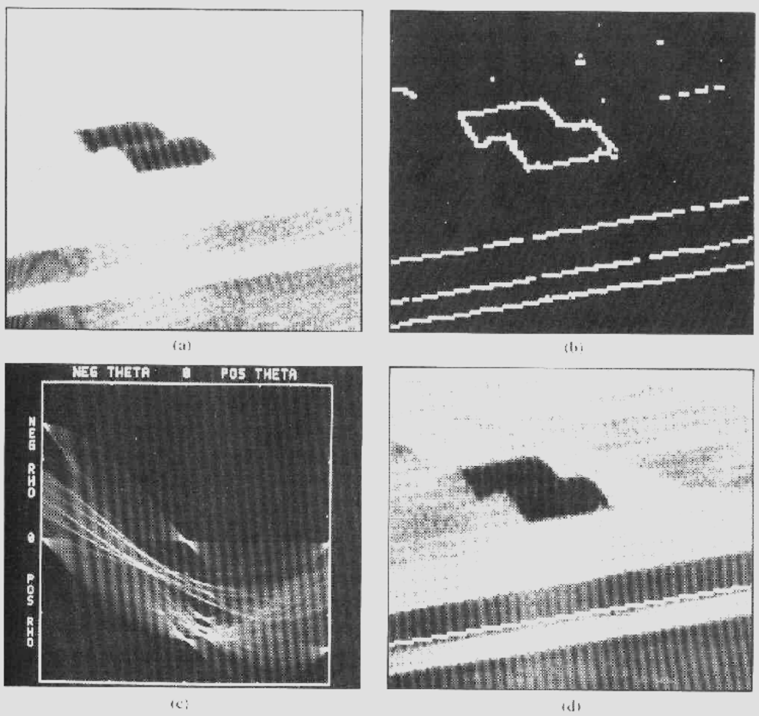
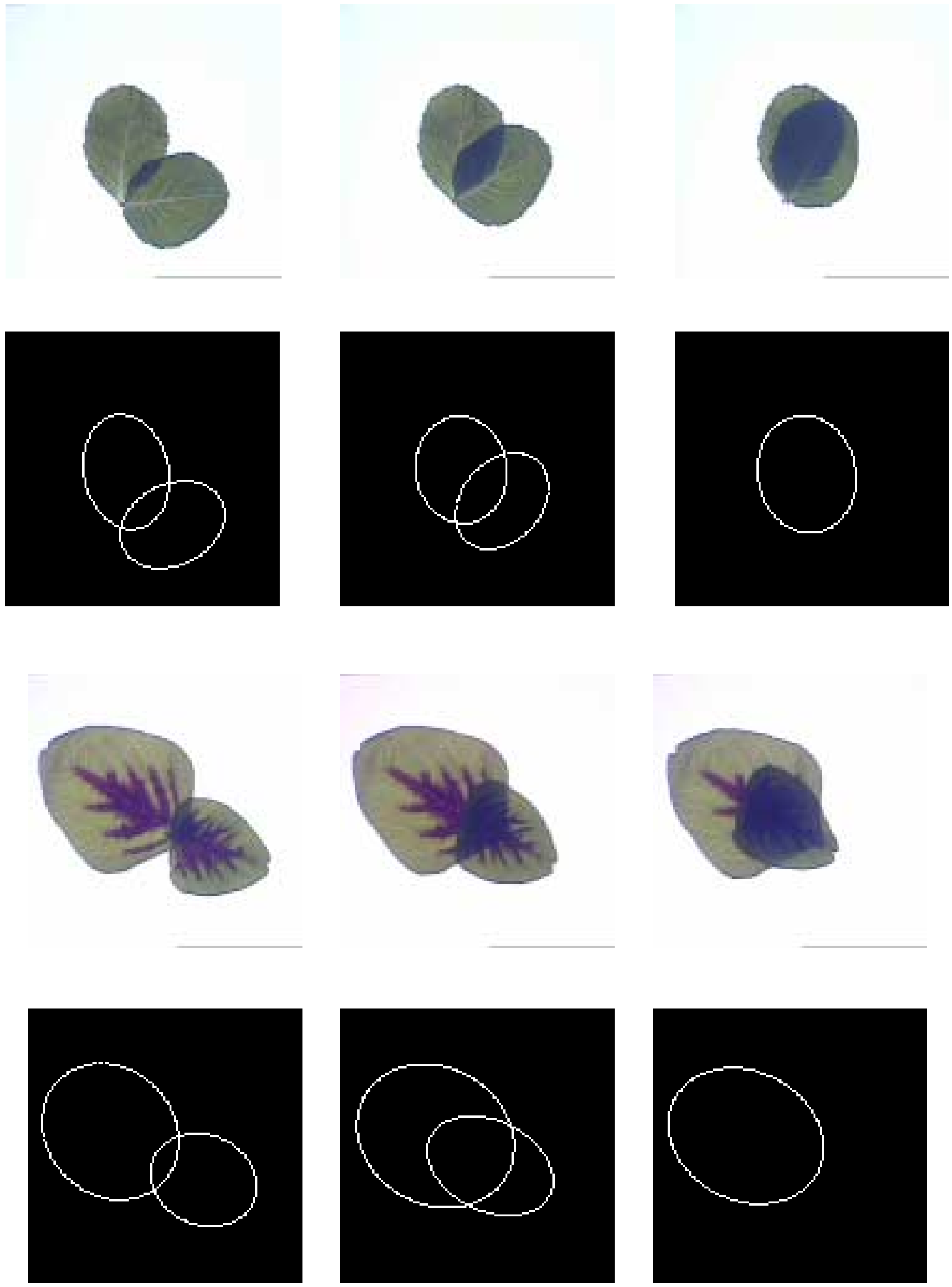


Figure 7.19 *(a) Infrared image; (b) gradient image; (c) Hough transform; (d) linked pixels. (Courtesy of D. R. Cate, Texas Instruments, Inc.)*



三、利用圖論(Graph-Theoretic)技巧進行總體性分析

１．基本定義：

(1). Graph G = (N,A)

(2). Arc $(n_i, n_j) \equiv A$

(3). If an arc is directed from n_i to n_j, n_j is said to be a successor of its parent node n_i

(4). Cost $c(n_i, n_j)$

$$c = \sum_{i=2}^{k} c(n_{i-1}, n_i)$$

(5). Edge element

● ● ●

● p● | ●q

● ● ●

２．Minimum-cost 之搜尋：

c(p,q) = H - [f(p) - f(q)]

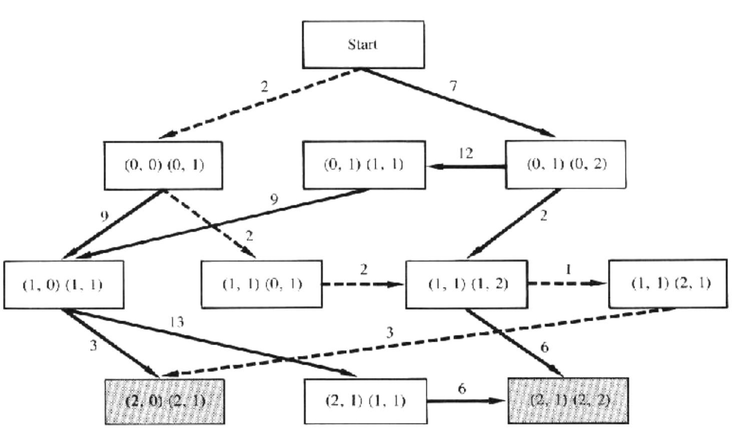


Figure 7.22 *Graph used for finding an edge in the image of Fig. 7.21. The pair (a, b)(c, d) in each box refers to points p and q, respectively. Note that p is assumed to be to the right of the path as the image is traversed from top to bottom. The dashed lines indicate the minimum-cost path. (Adapted from Martelli [1972].)*

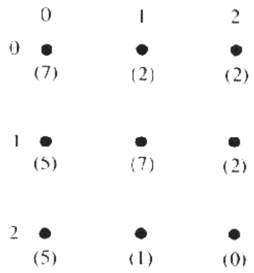


Figure 7.21 *A 3 × 3 image.*

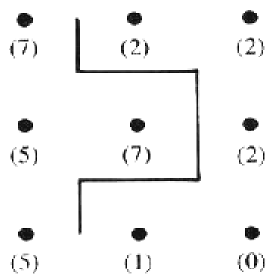


Figure 7.23 *Edge corresponding to the minimum-cost path in Fig. 7.22.*

３・範例：

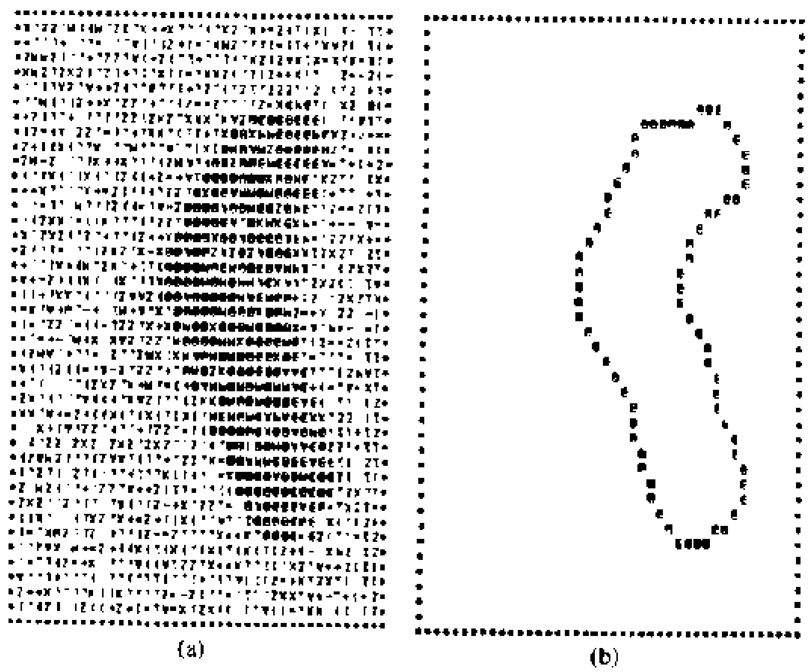


Figure 7.24 *(a) Noisy image; (b) result of edge detection by using the heuristic graph search. (From Martelli [1976].)*

參、分割

一、分割之基本原理：

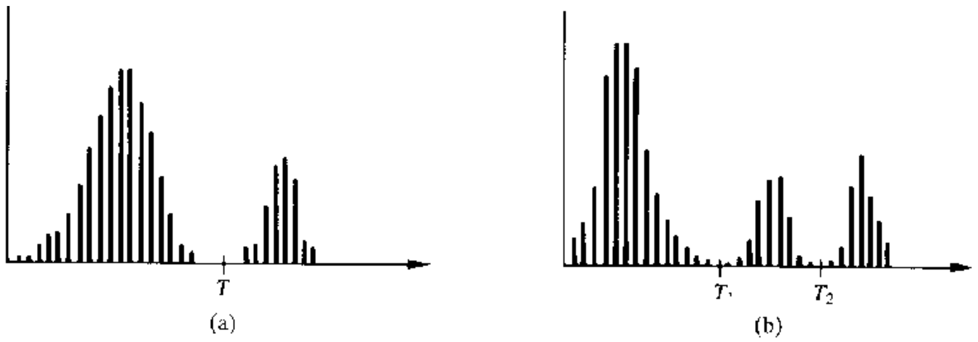


Figure 7.25 Gray-level histograms that can be partitioned by (a) a single threshold and (b) multiple thresholds.

分割乃是針對下列形式的運算函式 T 做測試的一種運算：

T = T[x, y, p(x,y), f(x,y)]

f(x,y)爲灰度值，p(x,y)爲點(x,y)之區域性質。

例如：

$$g(x,y)=\begin{cases}1 & \text{if } \mathrm{f(x,y)>T} \\ 0 & \text{if } \mathrm{f(x,y)\le T}\end{cases}$$

若 T = T[f(x,y)]，則 T 爲總體性分割(Global Threshold)，

若 T = T[f(x,y), p(x,y)]，則 T 爲局部性分割(Local Threshold)，

若 T = T[x,y]，則 T 爲動態分割(Dynamic Threshold)。

二、照明之影響：

影像中物體本來之性質若與背景極易區分，分割之工作則較易進行，但有時亦可能由於照明的不當而使形成的影像中物體和背景難以分割。常用以校正照明不當之步驟爲：

(1).將照明投射到一全白之背景上產生 g(x,y) = k i(x,y)，

(2).令影像 h(x,y) = f(x,y)/g(x,y) = r(x,y)/k。

則 h(x,y)基本上和照明無關而得以輕易分割。

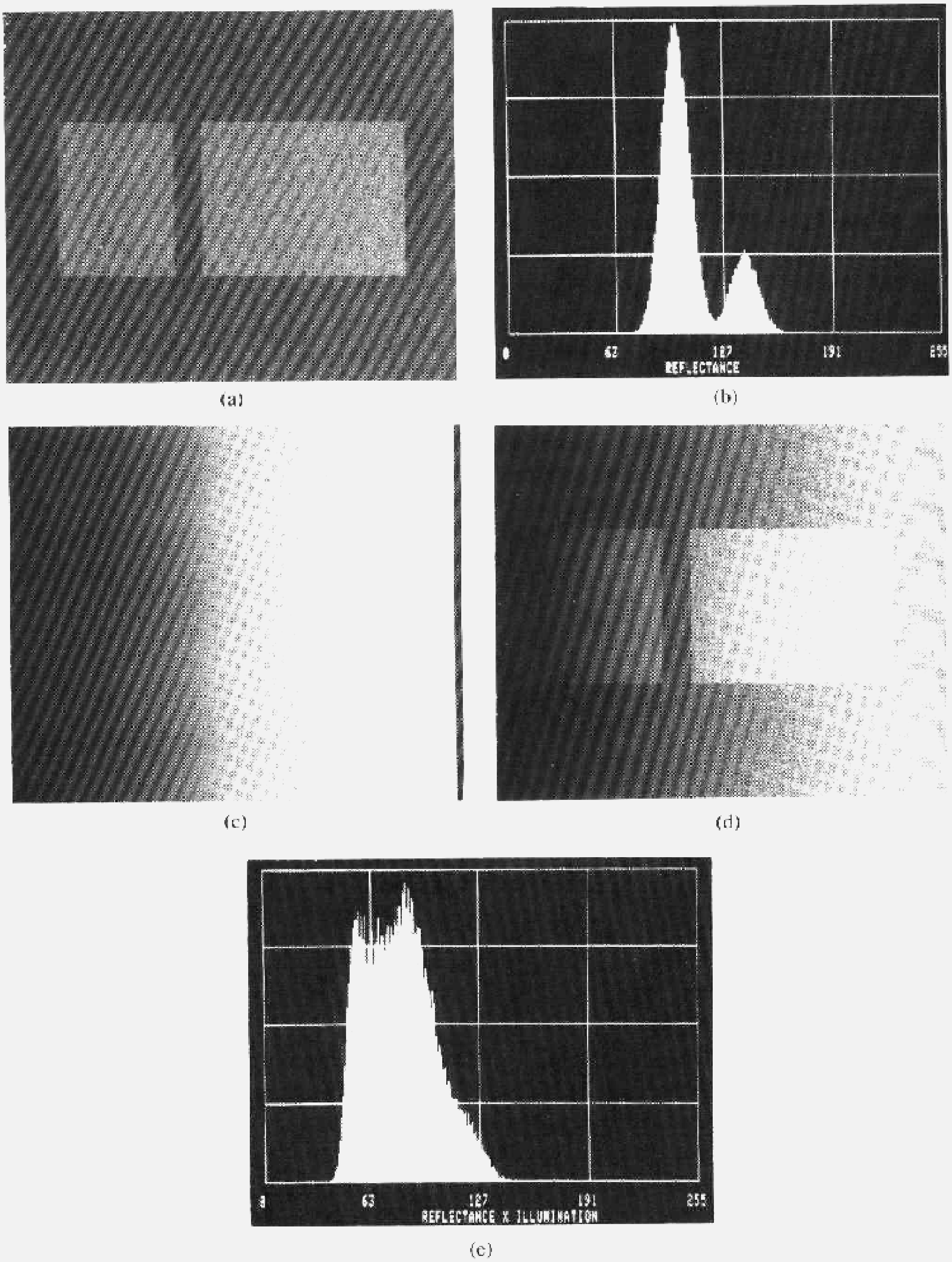


Figure 7.26 *(a) Computer generated reflectance function; (b) histogram of reflectance function; (c) computer generated illumination function; (d) image produced by the product of the illumination and reflectance functions; (e) histogram of image.*

三、整體分割：

１．範例一：

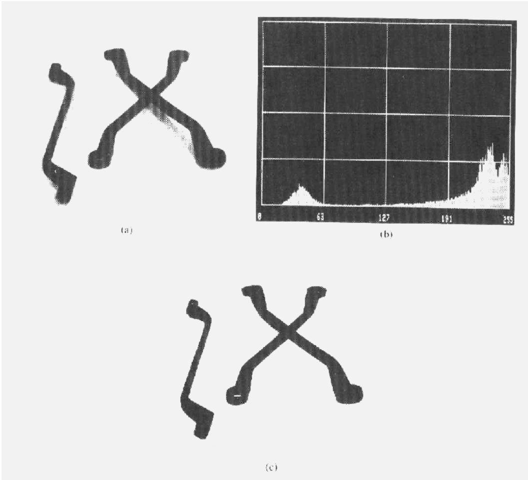


Figure 7.27 Example of global thresholding: (a) original image and (b) its histogram; (c) result of segmentation with $T = 90$. (From Fu, Gonzalez, and Lee [1987].)

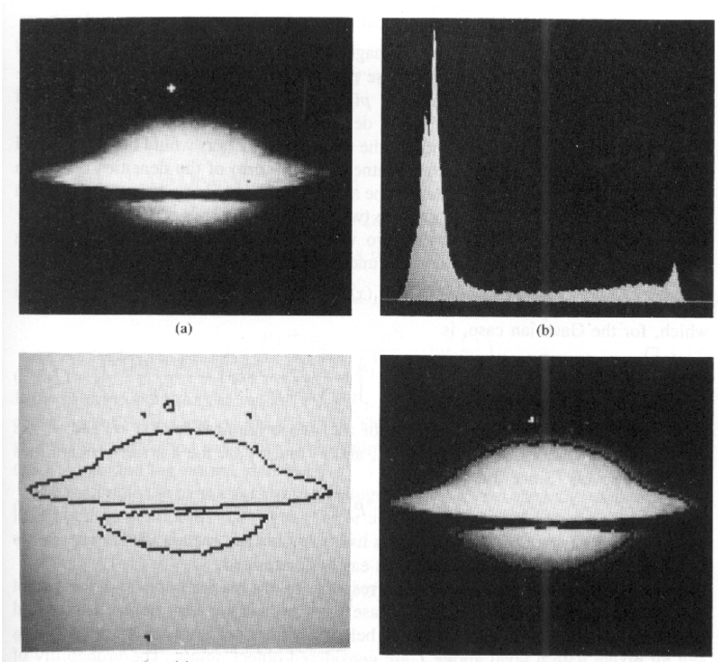
２．範例二：

步驟：(1).選擇適當之 T 值，將灰度值分為兩區。

(2).水平掃描標示 f(x,y)與 f(x,y-1)不屬於同區之點。

(3).垂直掃描標示 f(x,y)與 f(x-1,y)不屬於同區之點。

(4).確定邊緣為符合(2)或(3)條件之點。



四、最佳分割(Optimal Threshold)：

假設一影像之 Histrogram 是由兩個常態分佈組成，則以下之推導即是利用統計方法尋求最佳之分割 T 值。

令　$p(x) = P_1 p_1(x) + P_2 p_2(x)$

$$p(x) = \frac{P_1}{\sqrt{2\pi}\sigma_1} \exp[-\frac{(z-\mu_1)^2}{2\sigma_1^2}] + \frac{P_2}{\sqrt{2\pi}\sigma_2} \exp[-\frac{(z-\mu_2)^2}{2\sigma_2^2}]$$

$P_1 + P_2 = 1$

分割所產生之誤差可以下式評估：

$$E_1(T) = \int_{-\infty}^{T} p_2(z)dz$$

$$E_2(T) = \int_{T}^{\infty} p_1(z)dz$$

$$E(T) = P_2 E_1(T) + P_1 E_2(T)$$

為求 E(T)之最小值，則將上式對 T 微分，可得：

$$P_1 p_1(T) = P_2 p_2(T)$$

由上式可得二次方程式如下：

$$AT^2 + BT + C = 0$$

其中　$A = \sigma_1^2 - \sigma_2^2$

$B = 2(\mu_1 \sigma_2^2 - \mu_2 \sigma_2^2)$

$C = \sigma_1^2 \mu_2^2 - \sigma_2^2 \mu_1^2 + 2\sigma_1^2 \sigma_2^2 \ln(\sigma_2 P_1 / \sigma_1 P_2)$

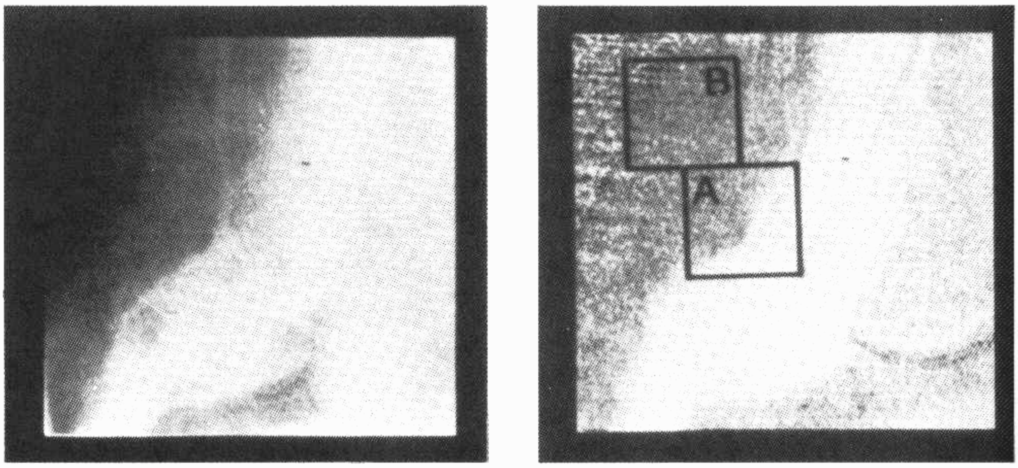
若　$\sigma^2 = \sigma_1^2 = \sigma_2^2$

則

$$T = \frac{\mu_1 + \mu_2}{2} + \frac{\sigma^2}{\mu_1 - \mu_2} \ln(\frac{P_2}{P_1})$$

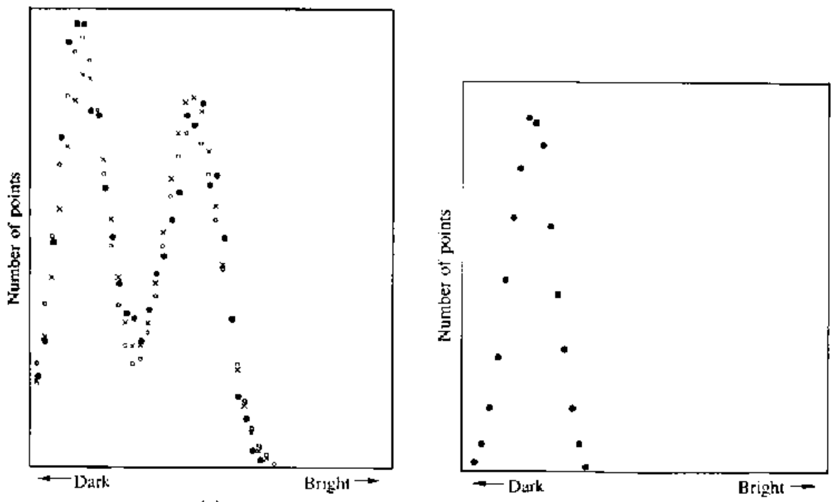
●決定 p(x)中之參數則常利用迴歸的方式求最小平均方差：

$$e_{ms} = \frac{1}{n} \sum_{i=1}^{n} [p(z_i) - h(z_i)]^2$$



(a) (b)

Figure 7.28 *A cardioangiogram before and after processing. (From Chow and Kaneko [1972].)*



(a) (b)

Figure 7.29 *Histograms (black dots) of regions A and B in Fig. 7.28(b). (From Chow and Kaneko [1972].)*

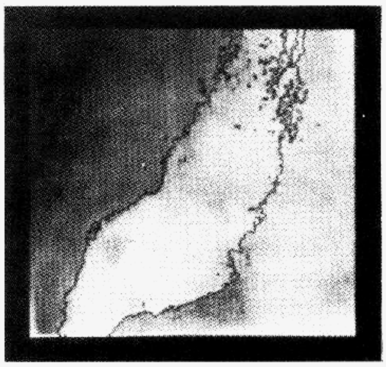


Figure 7.30 *Cardioangiogram showing superimposed boundaries. (From Chow and Kaneko [1972].)*

五、依據邊界特性進行分割

目的：加強 Histrogram 之峰高、谷深及對稱性。

$$s(x,y)=\begin{cases} 0 & \text{if } \nabla \mathrm{f} < \mathrm{T} \\ + & \text{if } \nabla \mathrm{f} \geq \mathrm{T} \text{ and } \nabla^2 f \geq 0 \\ - & \text{if } \nabla \mathrm{f} \geq \mathrm{T} \text{ and } \nabla^2 f < 0 \end{cases}$$

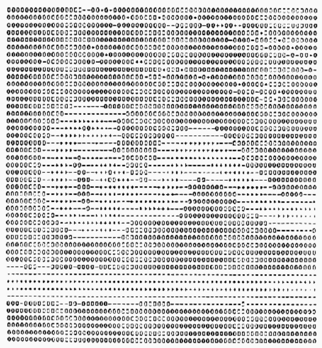
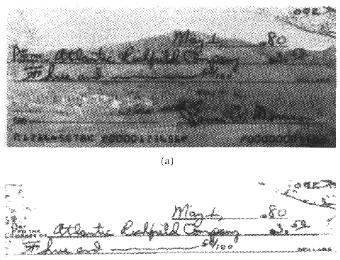


Figure 7.31 *Image of a handwritten stroke coded by using Eq. (7.3-14). (From White and Rohrer [1983].)*



(a) (b)

Figure 7.32 *(a) Original image; (b) segmented image. (From White and Rohrer [1983].)*

六、利用其他變數進行分割

(a) (b) (c)

Figure 7.34 *Segmentation by the multivariable histogram approach.*

肆、區域導向之分割方法

一、基本定義：

令Ｒ爲代表整個影像之區域，則影像分割可視爲將Ｒ分割爲 n 個次區域(Subregion)之過程，同時它也必須滿足以下諸條件：

(a). $\bigcup_{i=1}^{n} R_i = R$,

(b). R_i is a connected region, i = 1,2,...,n,

(c). $R_i \cap R_j = \phi$ for all i and j, $i \neq j$,

(d). $P(R_i)$ = TRUE for i = 1,2,...,n,

(e). $P(R_i \cup R_j)$ = FALSE for $i \neq j$。

其中 P 代表邏輯敘述(Logical Predicate), ϕ爲空集合。

二、以影像元素之聚集進行區域成長(Region Growing)

(a).Seed point。

(b).邏輯敘述。

(c).區域停止成長之法則。

三、區域之分裂(Splitting)與合併(Merging)

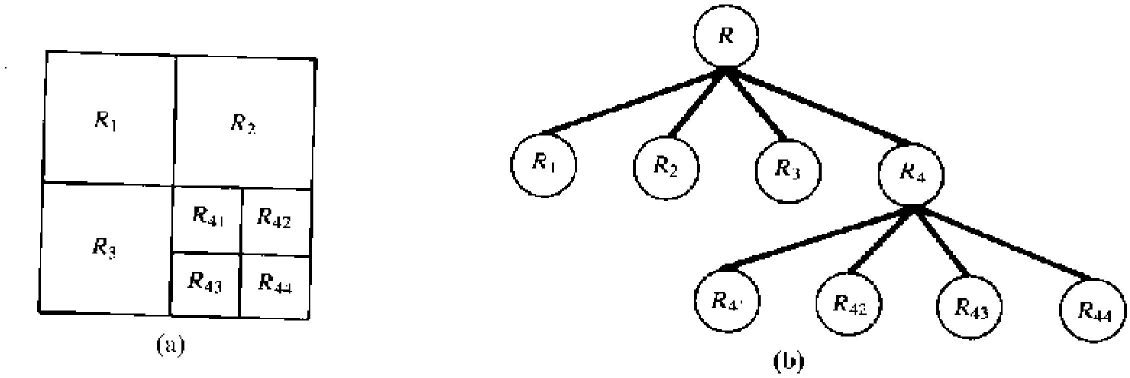


Figure 7.37 *(a) Partitioned image; (b) corresponding quadtree.*

	1	2	3	4	5
1	0	0	5	6	7
2	1	1	5	8	7
3	0	1	6	7	7
4	2	0	7	6	6
5	0	1	5	6	5

(a)

a	a	b	b	b
a	a	b	b	b
a	a	b	b	b
a	a	b	b	b
a	a	b	b	b

(b)

a	a	a	a	a
a	a	a	a	a
a	a	a	a	a
a	a	a	a	a
a	a	a	a	a

(c)

Figure 7.35 *Example of region growing using known starting points: (a) original image array; (b) segmentation result using an absolute difference of less than 3 between intensity levels; (c) result using an absolute difference of less than 8.*

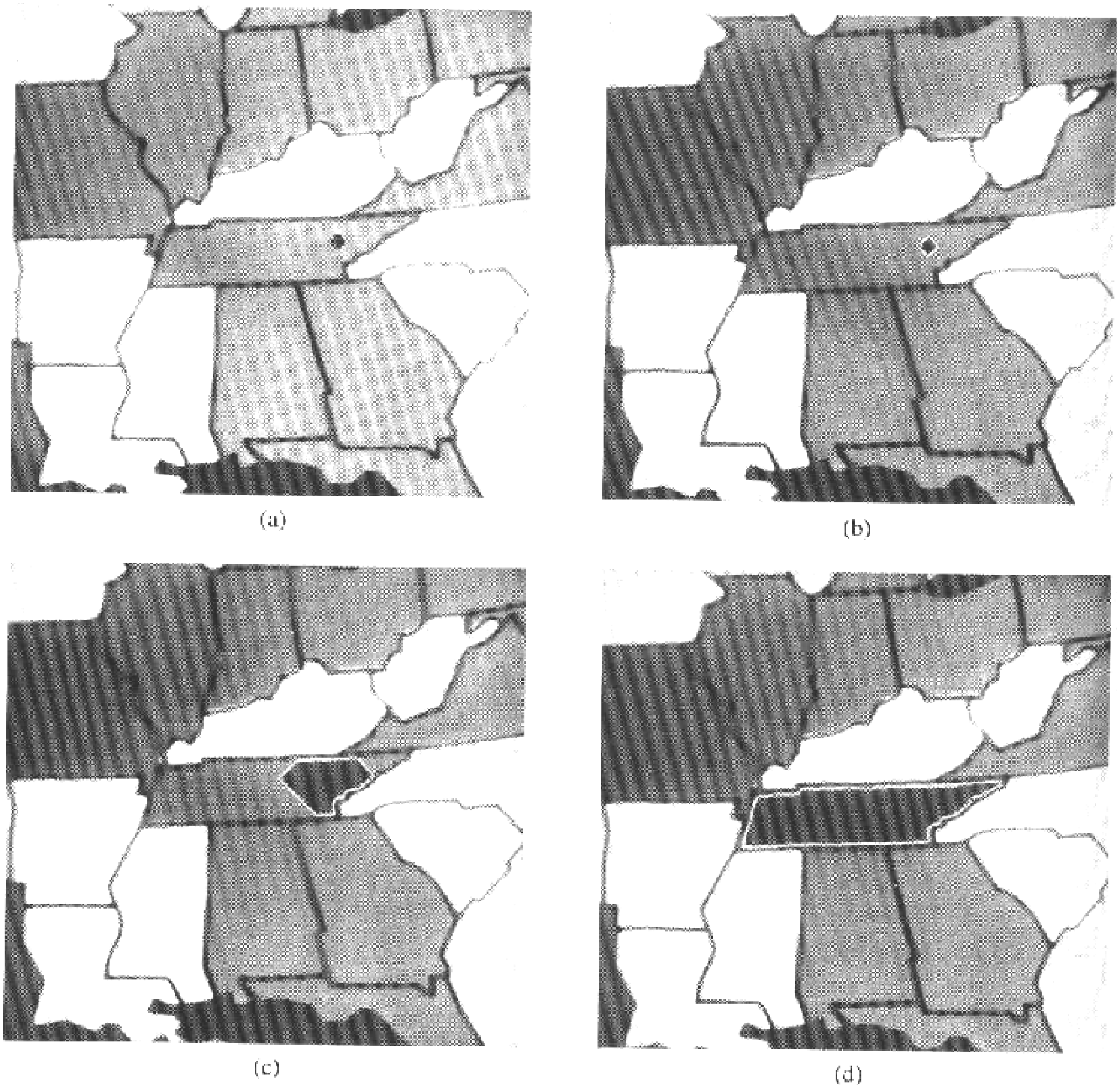


Figure 7.36 *(a) Original image showing seed point; (b) early stage of region growth; (c) intermediate stage of growth; (d) final region.*

１．分裂與合併之法則：

(1).對於任一區域R_i，若 $P(R_i)$ = FALSE 則將其等分成四個不相交之區域。

(2).對於相鄰之二區域R_j與R_k，若 $P(R_j \cup R_k)$ = TRUE，則將二者合併。

(3).當沒有區域可以再合併或分裂時則終止執行。

２．範例：

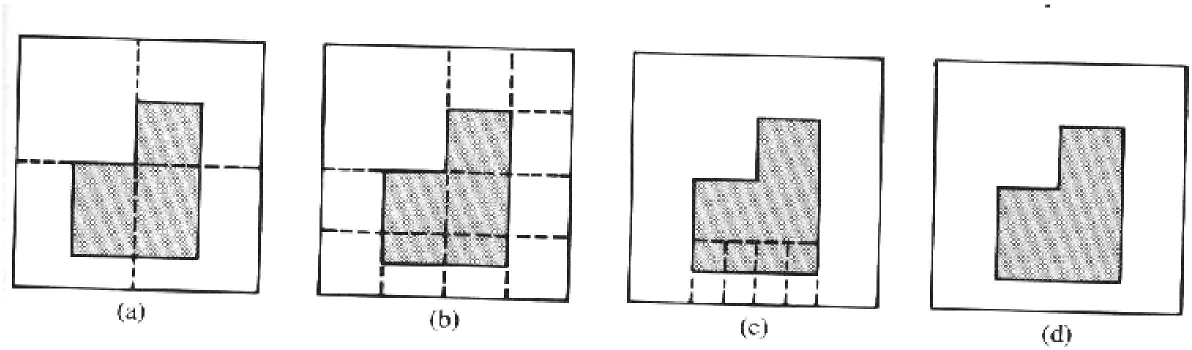


Figure 7.38 *Example of split-and-merge algorithm. (From Fu, Gonzalez, and Lee [1987].)*

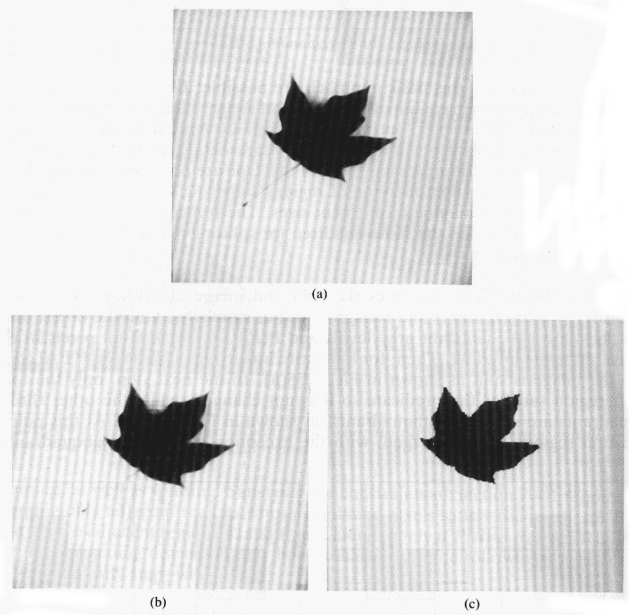


Figure 7.39 *(a) Original image; (b) result of split and merge procedure; (c) result of thresholding Fig. 7.39(b).*

伍、運動在分割上之應用

一、空間領域之技巧(SPATIAL TECHNIQUES)

１．差異影像(Difference Image)

$$d_{ij}(x,y)=\begin{cases}1 & \text{if } \left|f(x,y,t_i)-f(x,y,t_j)\right|>\theta \\ 0 & \text{otherwise}\end{cases}$$

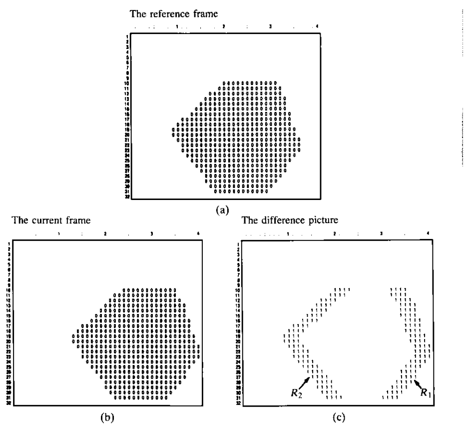


Figure 7.40 (a) Image taken at time t_i; (b) image taken at time t_j; (c) difference image. (From Jain [1981].)

２．累積差異(Accumulative Difference)

(1).AADI,　(2).PADI,　(3).NADI.

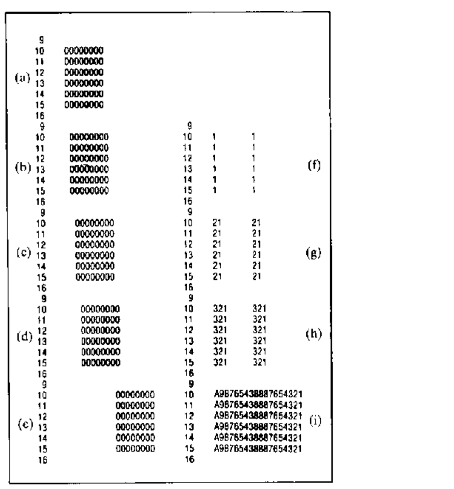


Figure 7.41 (a) Reference image frame; (b)–(e) frames 2, 3, 4, and 11; (f)–(i) accumulative difference images for frames 2, 3, 4, and 11 (the numbers 9–16 on the border are line references only and are not related to this discussion). (From Jain [1981].)

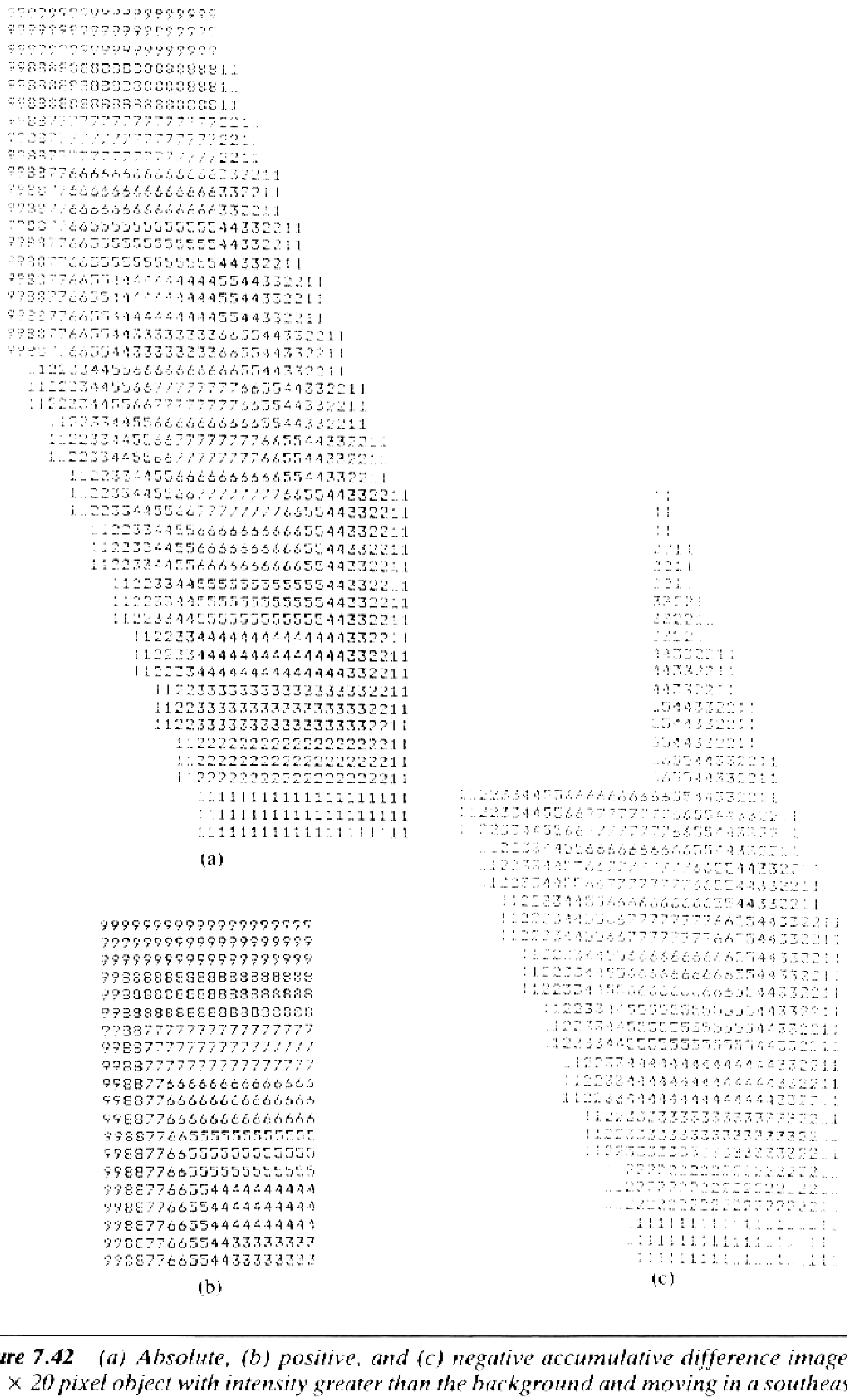
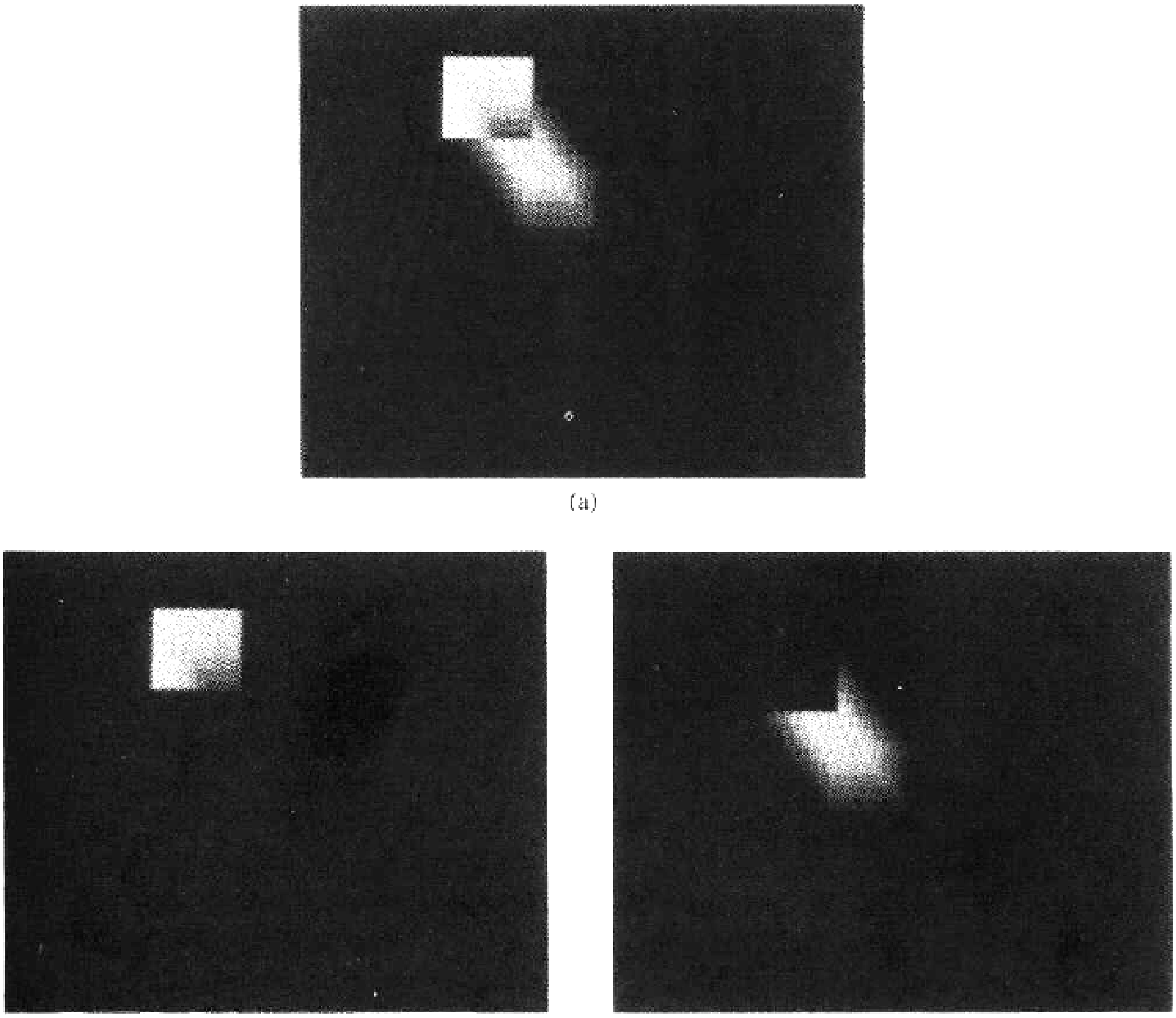


Figure 7.42 *(a) Absolute, (b) positive, and (c) negative accumulative difference images for a 20 × 20 pixel object with intensity greater than the background and moving in a southeasterly direction. (From Jain [1983].)*



(a)

(b) (c)

Figure 7.43 *Intensity-coded accumulative difference images for Fig. 7.42: (a) AADI, (b) PADI, and (c) NADI. (From Jain [1983].)*

二、頻率領域之技巧(Frequency Domain Techniques)

１．點之移動：

$\exp[j2\pi k_1 x'\triangle t]$ $\exp[j2\pi k_1(x'+1)\triangle t]$

在 time = t 時，

$\exp[j2\pi k_1(x'+1)\triangle t] = \cos[2\pi k_1(x'+t)\triangle t] + j\sin[2\pi k_1(x'+t)\triangle t]$

t = 0,1,2,...T-1.

上式之頻率為 k_1

若每一個 frame 間點移動 V_1 pixels (x 方向)，則頻率為 k_1V_1

２．影像中物體之移動：(x,y 方向物體速度之求取)

(1).x,y 方向加權投影之計算

$$g_x(t,k_1)=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y,t)e^{j2\pi k_i x\Delta t} \qquad t=0,1,...,T-1.$$

$$g_y(t,k_2)=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y,t)e^{j2\pi k_2 y\Delta t} \qquad t=0,1,...,T-1.$$

(2).加權投影之傅利葉轉換

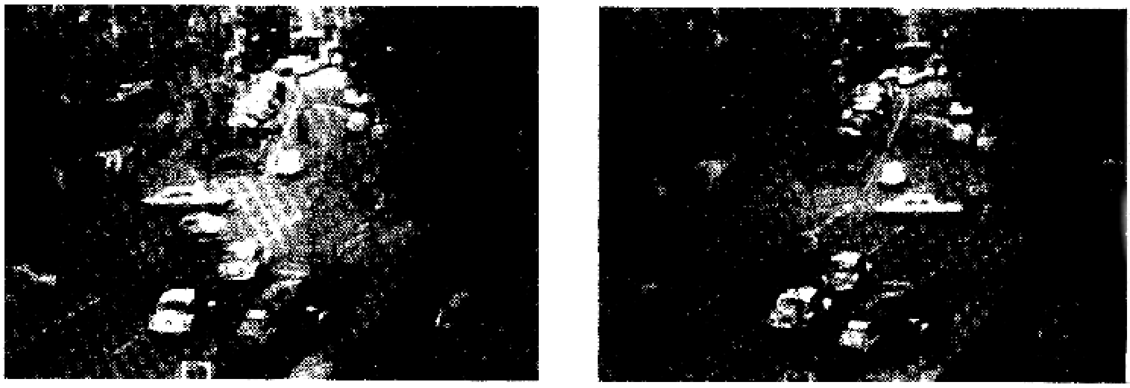
$$G_x(u_1,k_1)=\frac{1}{T}\sum_{t=0}^{T-1} g_x(t,k_1)e^{-j2\pi u_1 t/T} \qquad u_1=0,1,...,T-1.$$

$$G_y(u_2,k_2)=\frac{1}{T}\sum_{t=0}^{T-1} g_y(t,k_2)e^{-j2\pi u_2 t/T} \qquad u_2=0,1,...,T-1.$$

(3).頻率與速度之關係

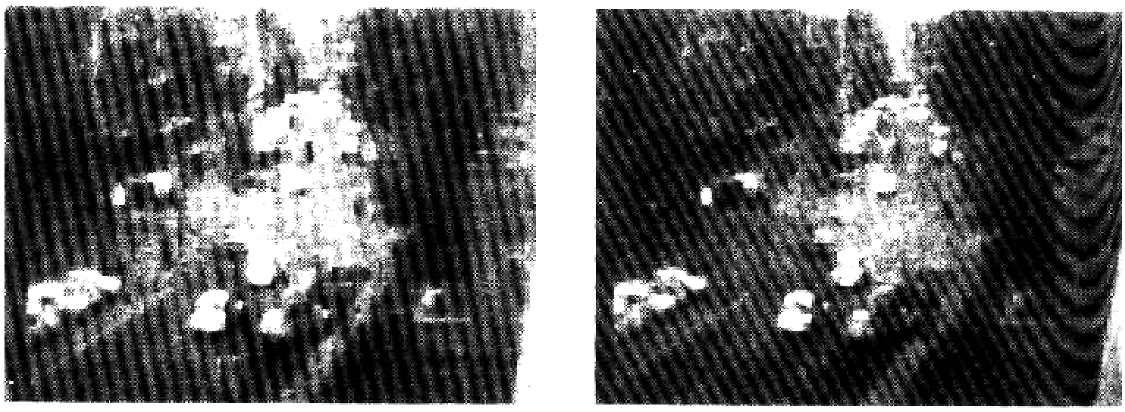
$u_1 = k_1 V_1$, $u_2 = k_2 V_2$

３．參考影像(Reference Image)之建立



(a) (b)

Figure 7.44 *Two image frames of a traffic scene. There are two principal moving objects: a white car in the middle of the picture and a pedestrian on the lower left. (From Jain [1981].)*



(a) (b)

Figure 7.45 *(a) Image with automobile removed and background restored; (b) image with pedestrian removed and background restored. The latter image can be used as a reference. (From Jain [1981].)*

清除移動物體之步驟：

(1).選定序列影像之第一張爲參考影像，

(2).利用 PADI 確定移動物體已完全移出原來之位置，

(3).若物體已移出原來之位置，則原位置之背景灰度值補入第一張影像之相同位置。

４．運動之方向：

$$S_{1x} = \left. \frac{d^2 \ \mathrm{Re}[g_x(t,k_1)]}{dt^2} \right|_{t=n}$$

$$S_{2x} = \left. \frac{d^2 \ \mathrm{Im}[g_x(t,k_1)]}{dt^2} \right|_{t=n}$$

若 S_{1x} 與 S_{2x} 爲同號，則 V_1 爲正號，

若 S_{1x} 與 S_{2x} 爲異號，則 V_1 爲負號，

若 S_{1x} 與 S_{2x} 有一爲零，則考慮 $t = n \pm \triangle t$ 之 g_x

５．範例：

若 T=30, V1=10, frame rate = 2 image/sec,

1 pixel = 0.5 m

則 V1 = (10 pixels)(0.5 m/pixel)(2 frame/sec)/(30 frame)
= 1/3 m/sec

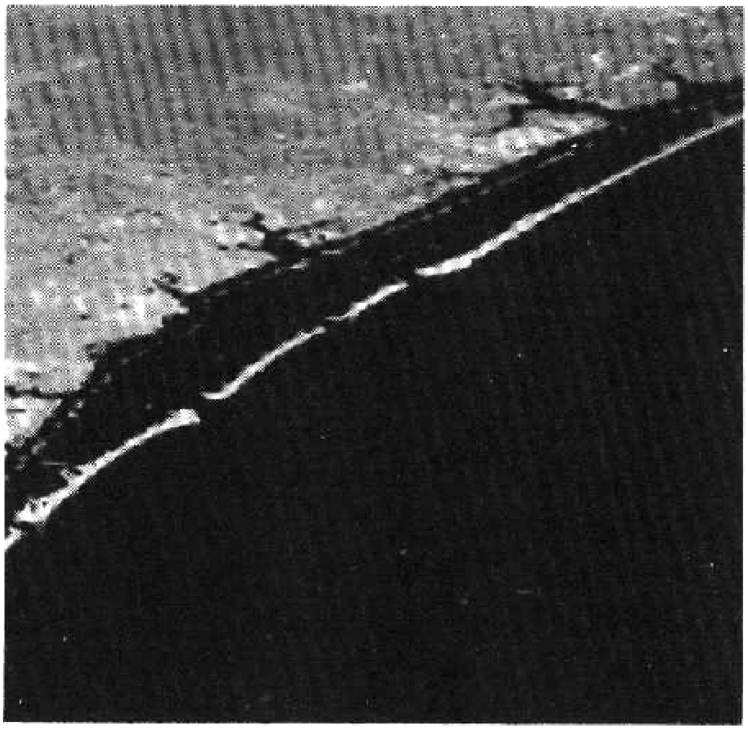


Figure 7.46 LANDSAT frame. (From Cowart, Snyder, and Ruedger [1983].)

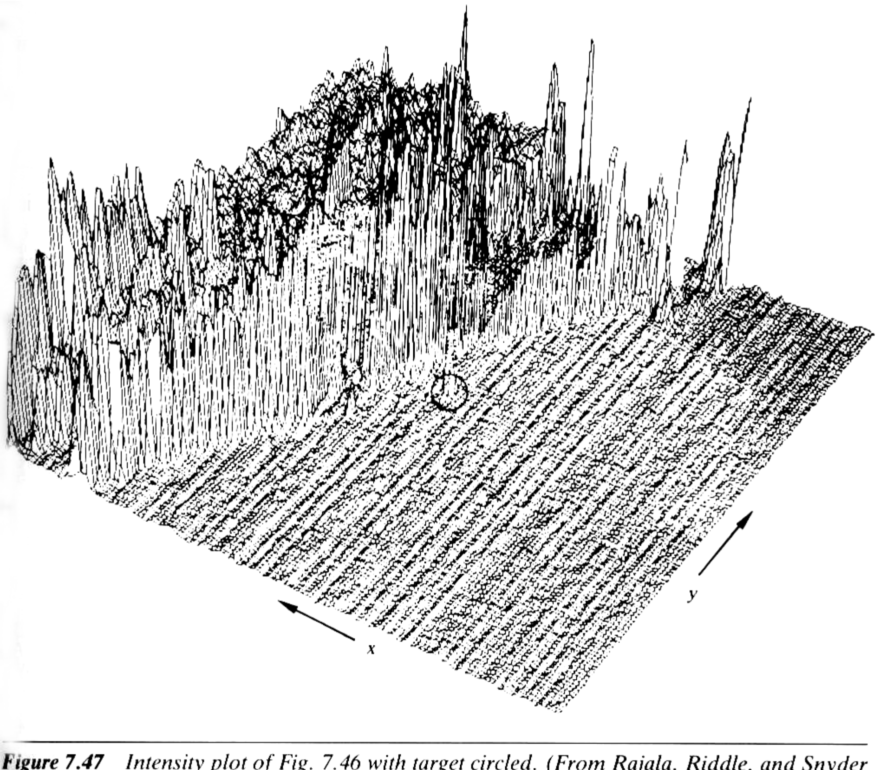


Figure 7.47 *Intensity plot of Fig. 7.46 with target circled. (From Rajala, Riddle, and Snyder [1983].)*

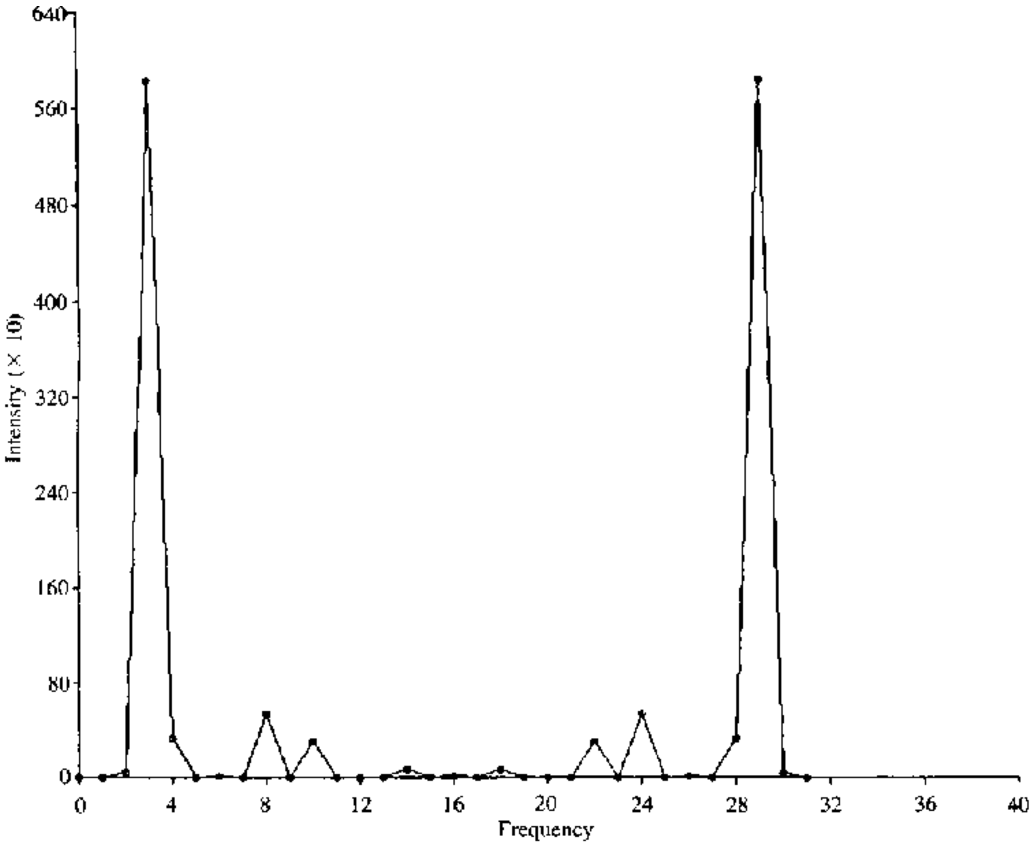


Figure 7.48 Spectrum of Eq. (7.5-5) showing a peak at $u_1 = 3$. (From Rajala, Riddle, and Snyder [1983].)

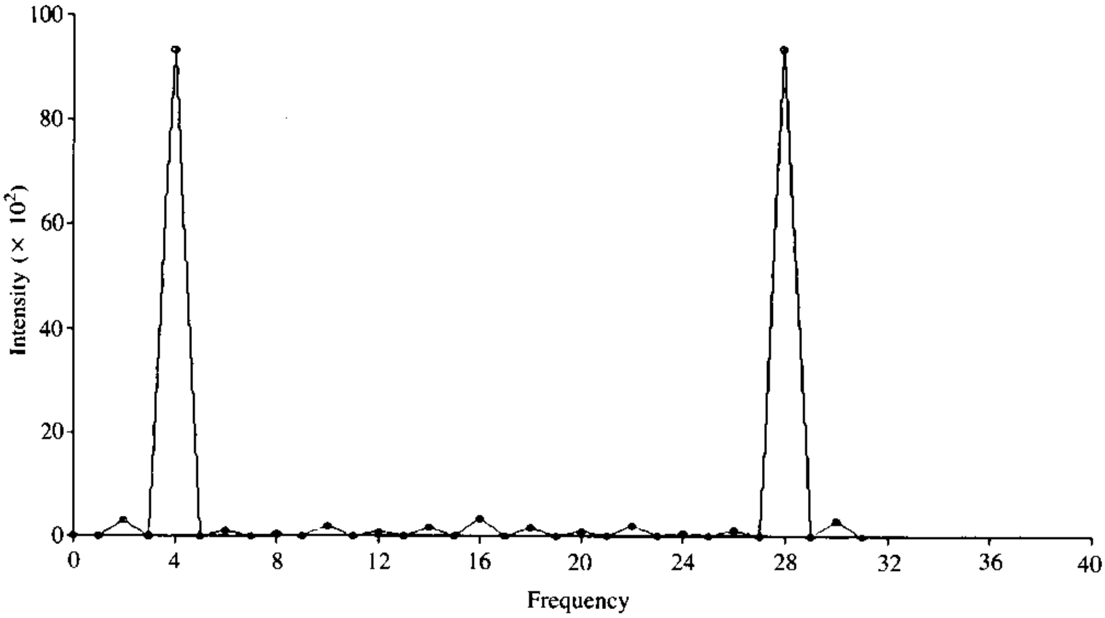


Figure 7.49 *Spectrum of Eq. (7.5-6) showing a peak at $u_2 = 4$. (From Rajala, Riddle, and Snyder [1983].)*