1 緒論

一張圖片勝過千言萬語

無名氏

前　言

人們對於數位影像處理方法的興趣來自於兩個主要的應用領域：改善影像資訊供人理解之用，以及處理影像資料供自動機器感知所需的儲存、傳輸與表示。本章有幾個目標：(1) 定義我們所稱影像處理的領域範圍；(2) 從歷史的觀點來看此領域的起源；(3) 藉由檢視一些主要的應用領域瞭解影像處理的最新發展；(4) 簡要的討論用在數位影像處理上的方法；(5) 瀏覽典型的通用影像處理系統的組成部分；以及 (6) 提供何處有與影像處理相關的書籍與文獻。

Fundamental Steps in digital image processing

Image acquisition

Image enhancement

Image restoration

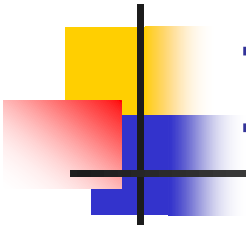
Color image processing

Compression

Morphological processing

Segmentation

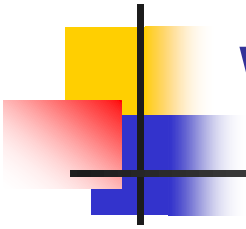
Recognition



Introduction

- One picture is worth more than ten thousand words.

=> Richness of image content



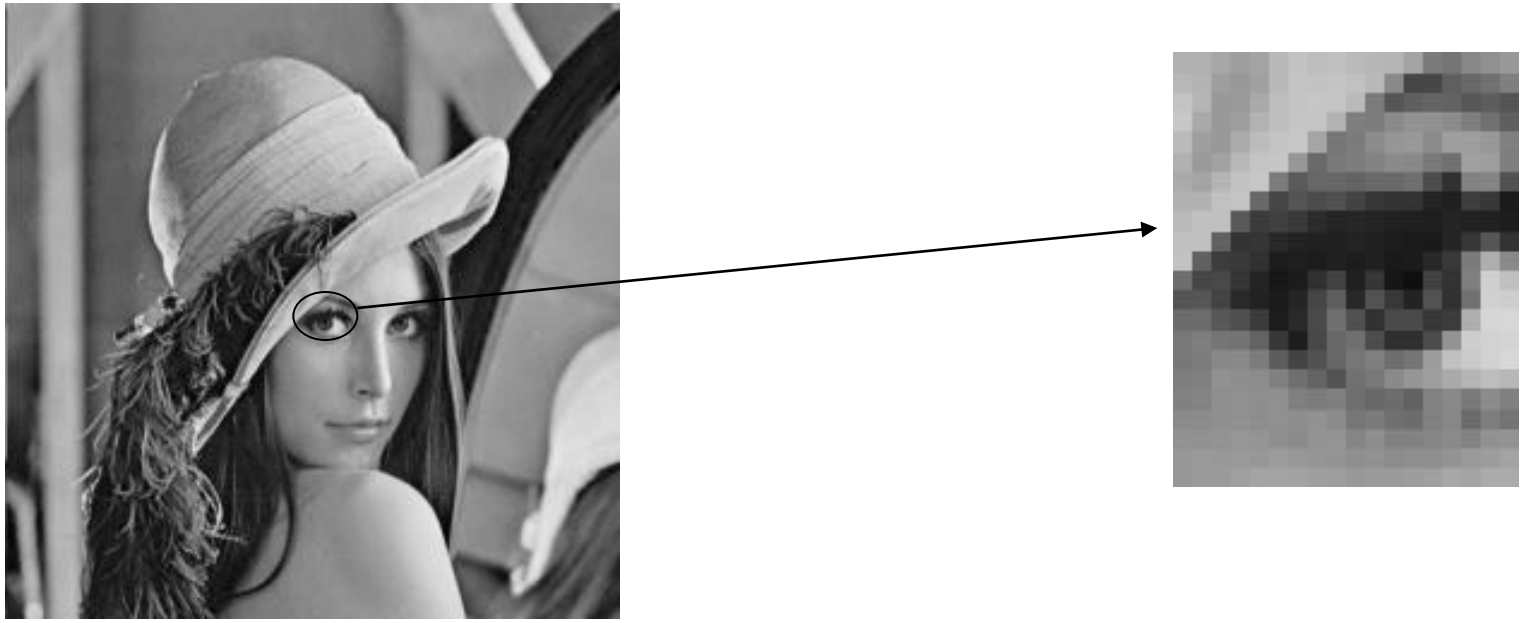
Why digital image processing?

- Motivation:
- Improvement of pictorial information for human interpretation
- Processing of image data for storage, transmission, and representation for autonomous machine perception

What is digital image?

- An image: 2-d function
  - I=f(x,y)
  - I: intensity (or Gray level)
  - (x,y): coordinate
  - When (x,y) and I are finite and discrete quantities -> digital image
  - pixels(像素), picture elements, image elements, pels

Pixels



Notice: pixel is not a square!

Representing digital images

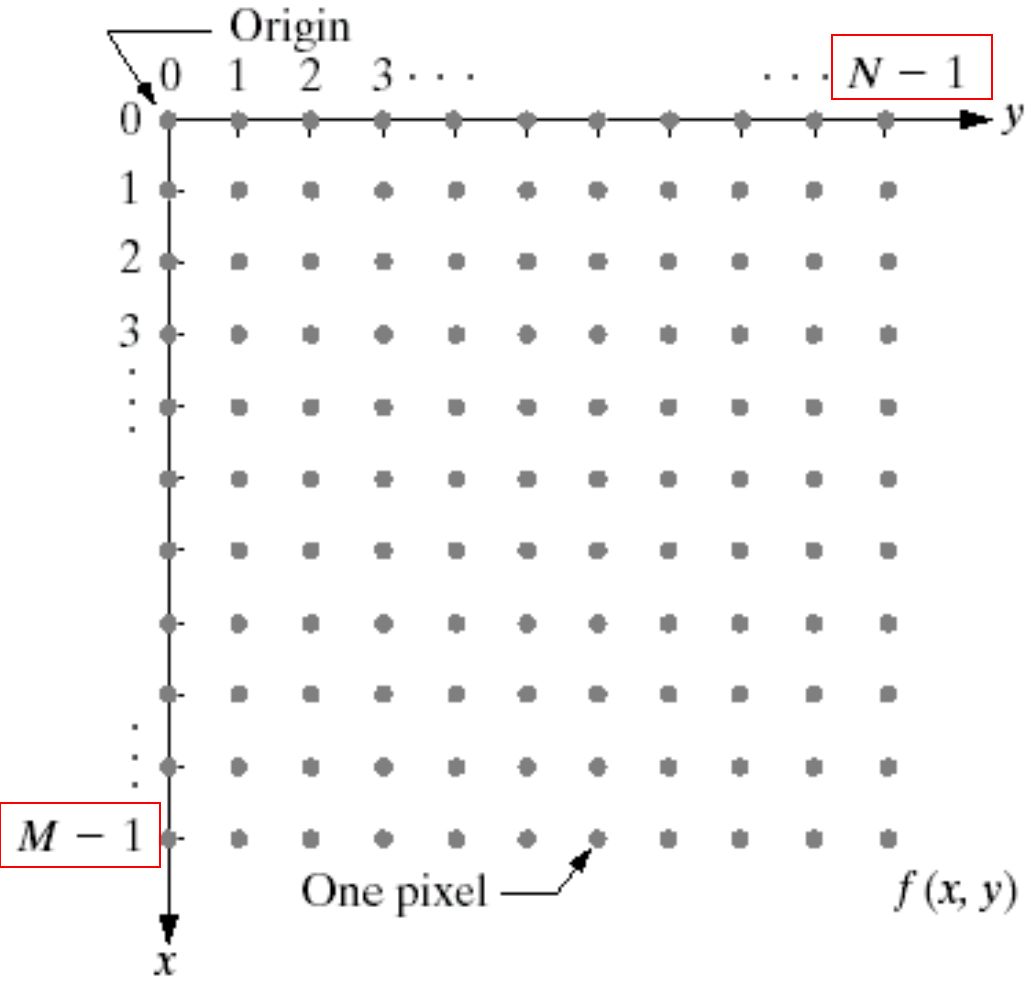


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

Representing digital images (cont.)

- Matrix form

$$\begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,N-1) \\ f(1,0) & f(0,1) & \dots & f(1,N-1) \\ & & \dots & \\ & & \dots & \\ f(M-1,0) & f(M-1,1) & \dots & f(M-1,N-1) \end{bmatrix}_{M \times N}$$

bits to store the image = M x N x k

gray level = 2^k

Side story of Lena

1972 playboy: Miss Nov.

1997 Lena

Origins of digital image processing

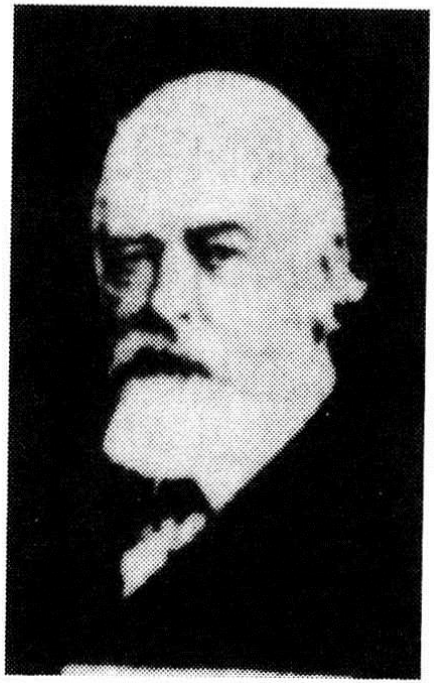
- Newspaper industry in 1920s
- Telegraph printer, 5 gray levels

Specialized printing equipment coded pictures for cable transmission and then reconstructed them at the receiving end.

圖 1.1
用具有特殊字型的電報印表機由經編碼的帶子中在 1921 年所產生的一張數位圖片 (McFarlane[1])。

圖 1.2

1922 年由打孔帶所得的數位影像，它是在訊號兩次跨越大西洋後產生的。可以看出某些錯誤(McFarlane)。

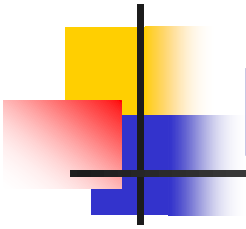


Origins of digital image processing (cont.)

- 15-tone in 1929

FIGURE 1.3
Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

The rising of digital image processing



- Digital image processing
  - Digital image + digital computer processing
- Modern digital computers
  - 1940, John von Neumann

The rising of digital image processing (cont.)

- 1960s, for space program
- Jet Propulsion Lab(Pasadena, CA) in 1964

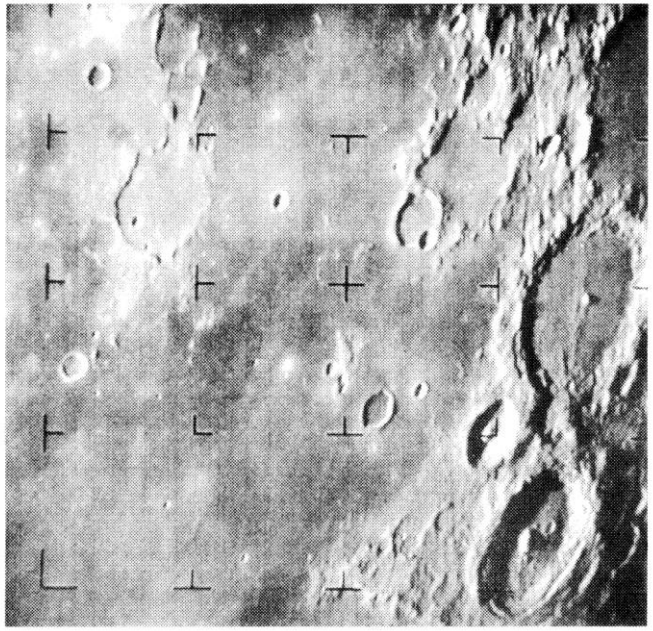


圖 1.4
由美國太空船上所取得的第一張月球圖片。航行者 7 號在 1964 年東部白晝時間的 7 月 31 號上午 9:09 亦即大約在登入月球表面 17 分鐘之前，拍攝這張影像。

a b
c d

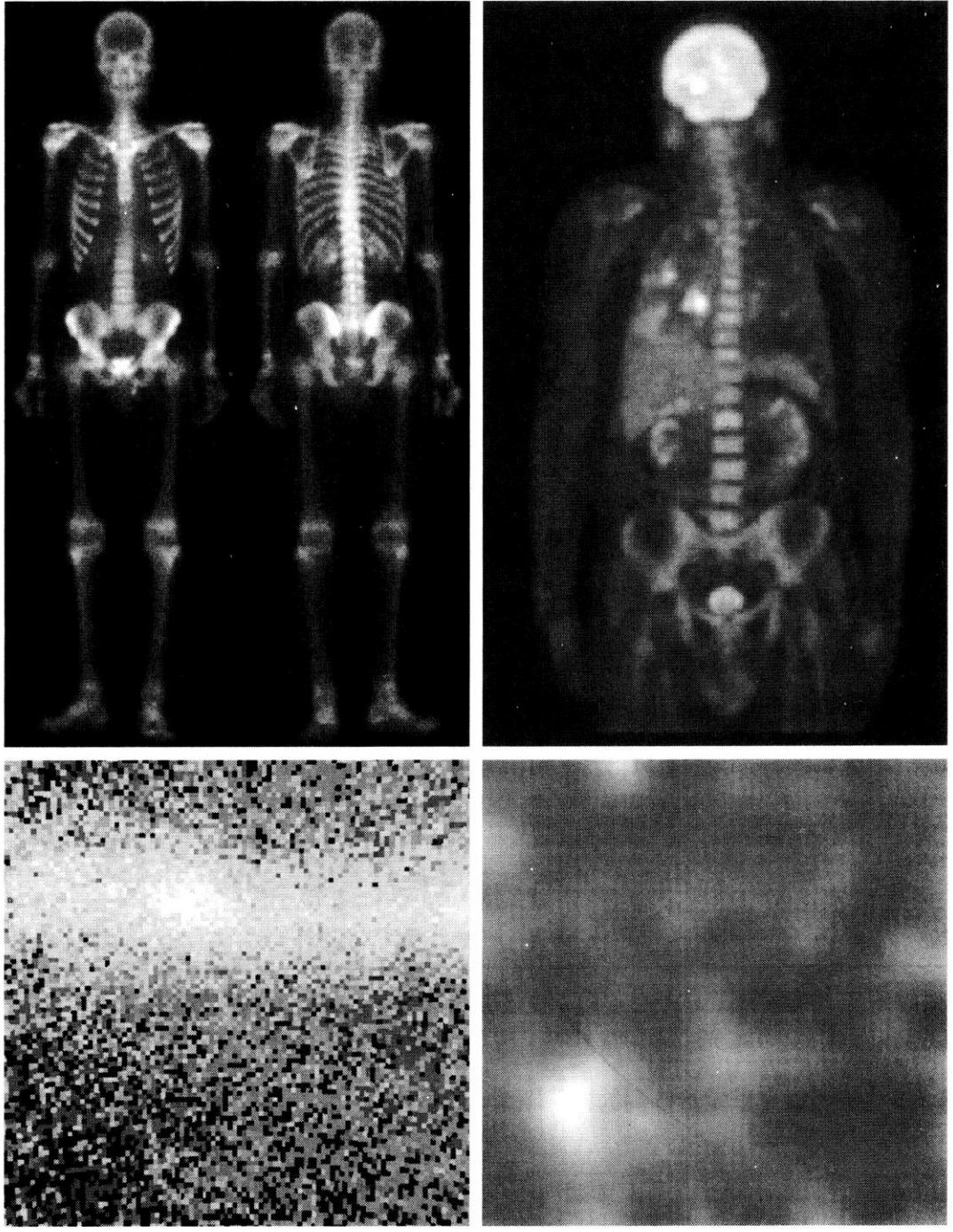
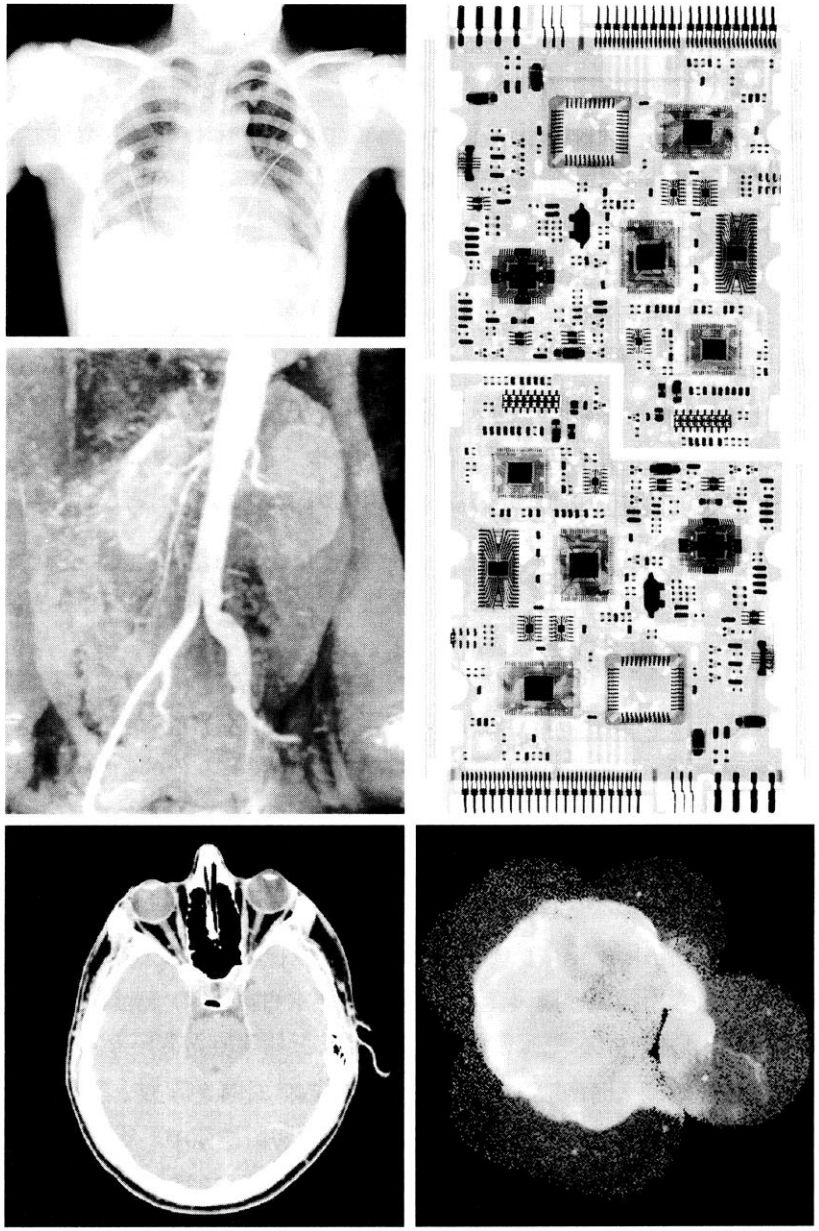


圖 1.6
gamma 射線成像的例子：(a) 骨頭掃描；(b) 正電子斷層攝影；(c) 天鵝座星環；(d) 從核子反影器的閥所取得的 gamma 射線（亮點）影像。（影像提供者：(a) G.E. 醫學系統；(b) Dr. Michael E. Casey, CTI PET 系統；(c) NASA；(d) 密西根大學的 Zhong He 和 David K. Wehe 教授。）

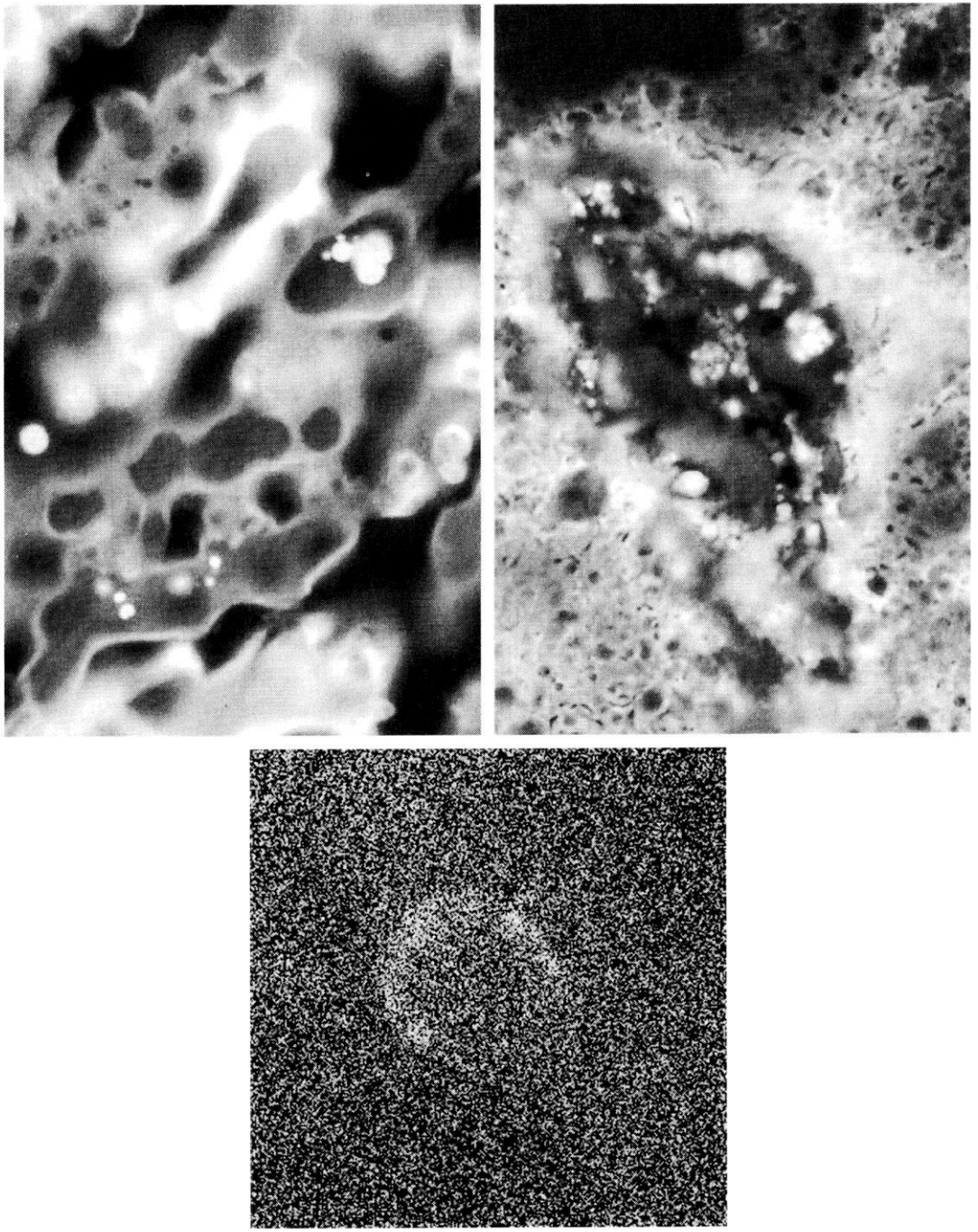


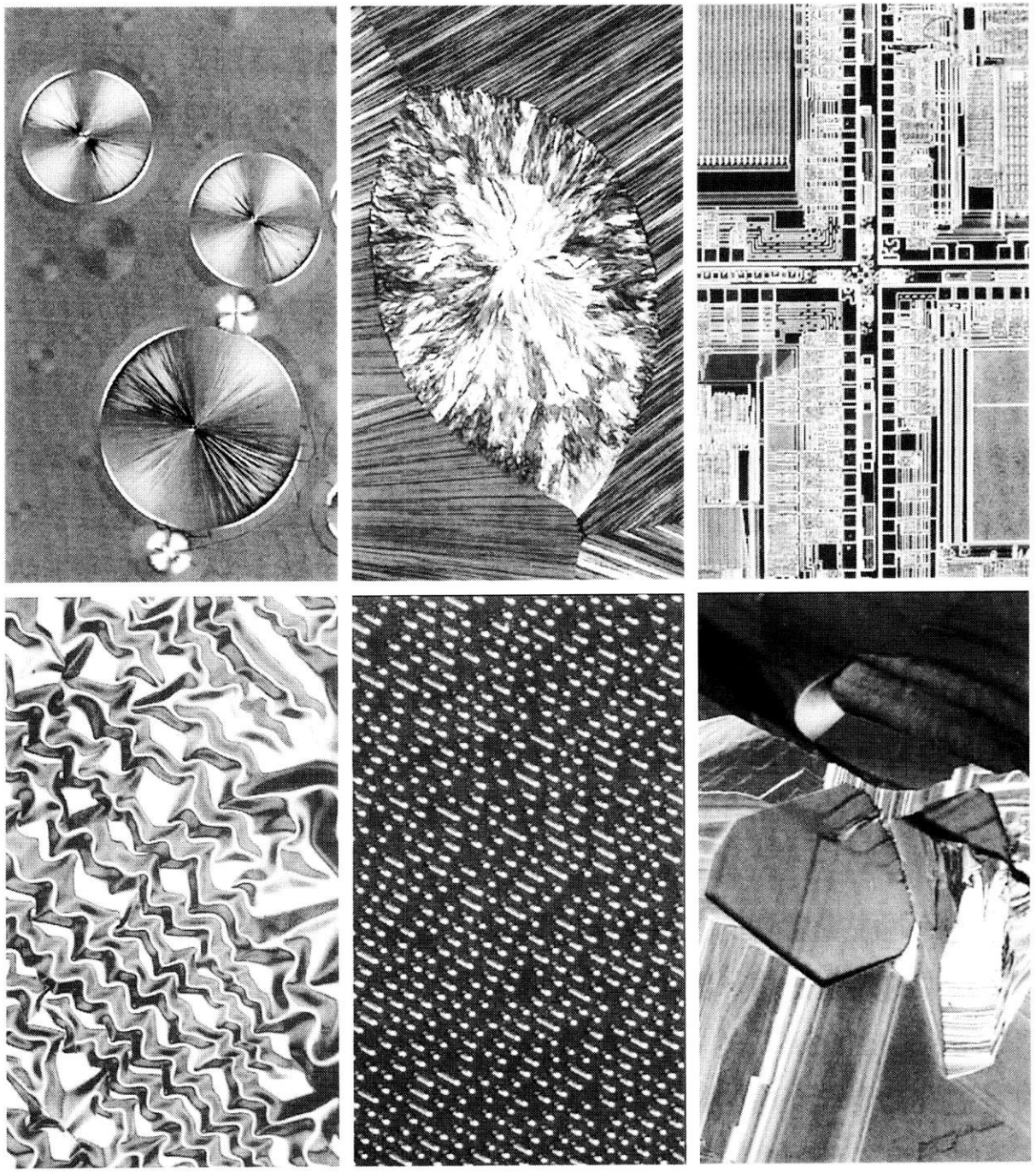
a d
b e
c

圖 1.7 X 光成像的例子：(a) 胸部 X 光；(b) 動脈血管圖；(c) 頭部 CT 切片；(d) 電路板；(e) 天鵝星座 ((a) 和 (c) 的影像由凡德比爾大學醫學中心之放射學與放射科學部門的 Dr. David R. Pickens；(b) 的影像由密西根大學醫學院之解剖科學部門的 Dr. Thomas R. Gest；(d) 的影像由 Lixi 公司的 Joseph E. Pascente 先生，以及 (e) NASA 所提供。)

a b
c

圖 1.8
紫外線成像的例子：(a)正常玉黍蜀；(b) 有黑穗病的玉黍蜀；(c) 天鵝座星環 ((a) 和 (b) 的影像由佛羅里達州立大學 Dr. Michael W. Davidson，(c) 的影像由 NASA 提供。)





a b c
d e f

圖 1.9

光顯微鏡影像的例子：(a) Taxol（抗癌因子）放大 250 倍；(b) 膽固醇放大 40 倍；(c) 微處理機放大 60 倍；(d) 氧化鎳薄膜放大 600 倍；(e) CD 表面放大 1750 倍；(f) 有機超導體放大 450 倍。（影像由佛羅里達州立大學的 Dr. Michael W. Davidson 所提供。）

表 1.1
NASA 的 LANDSAT 衛星上的熱感頻帶

頻帶號碼	名　　稱	波長 (μm)	特徵與用途
1	可見藍	0.45-0.52	最大的水穿透力
2	可見綠	0.52-0.60	適用於量測植物的活力
3	可見紅	0.63-0.69	草木鑑別
4	近紅外線	0.76-0.90	物種與海岸線圖標示
5	中紅外線	1.55-1.75	土壤與草木的水氣含量
6	熱紅外線	10.4-12.5	土壤水氣；熱感圖標示
7	中紅外線	2.08-2.35	礦物圖標示

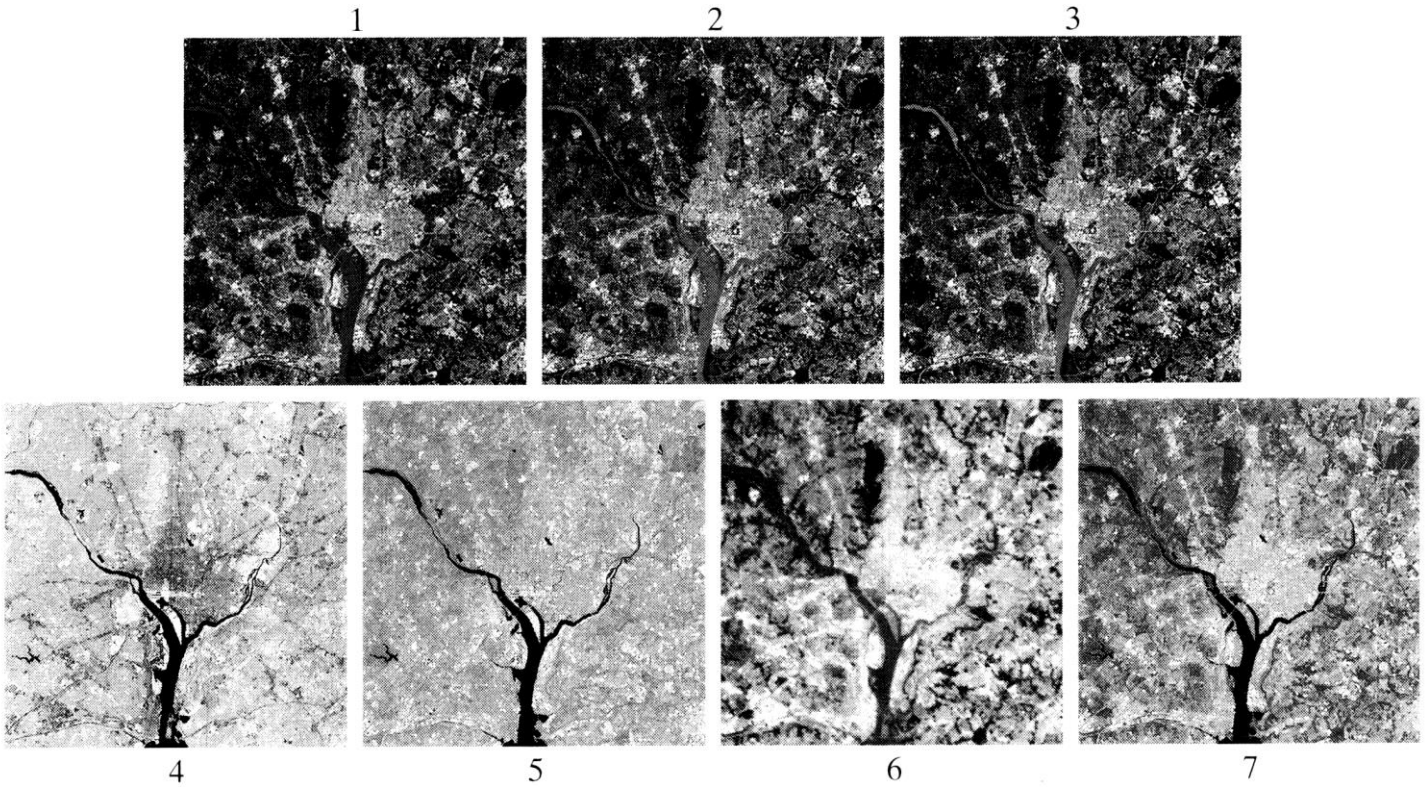


圖 1.10　華盛頓特區的 LANDSAT 衛星影像，其中的數字指表 1.1 中的熱感頻帶。(影像由 NASA 提供。)

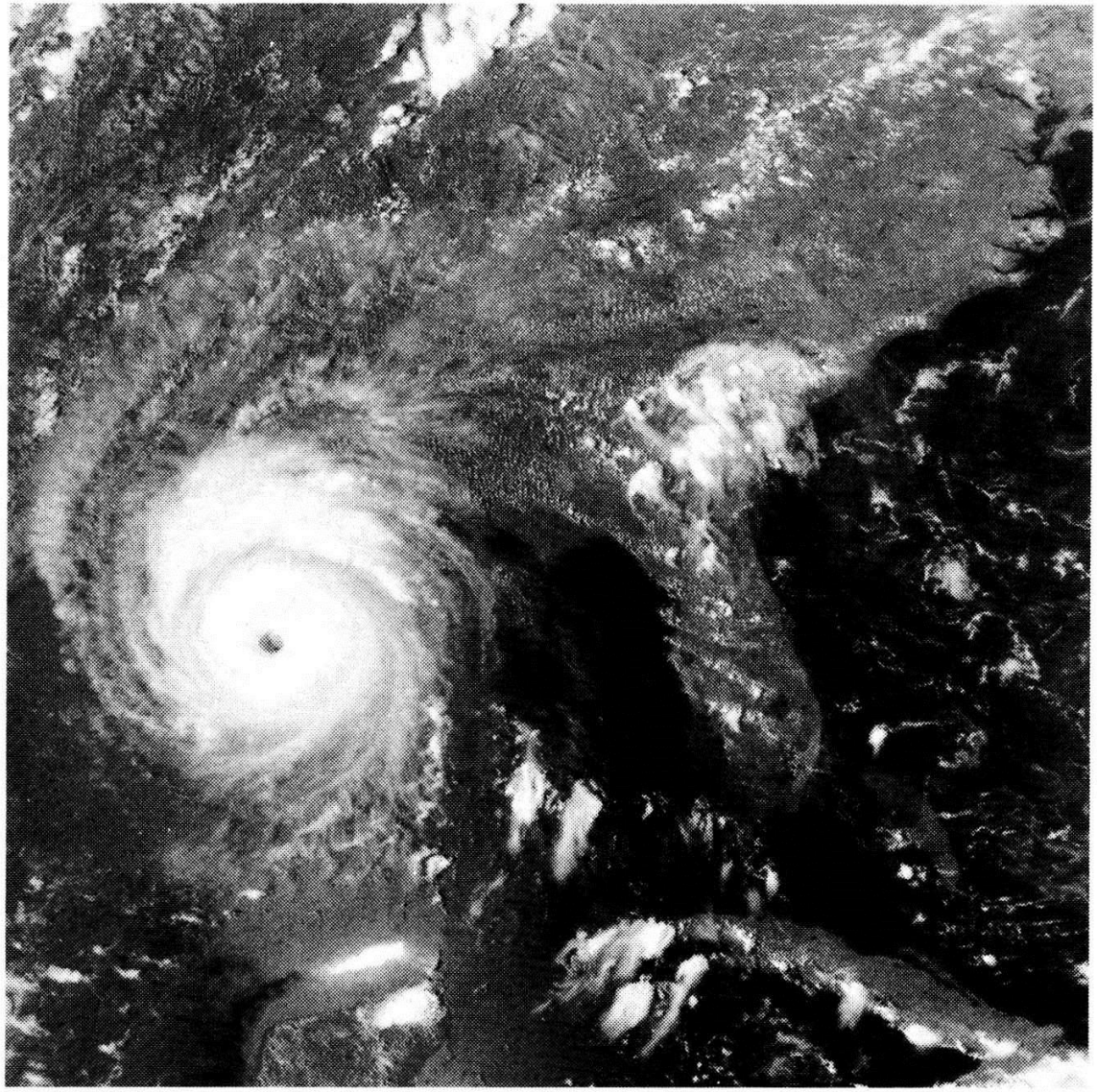


圖 1.11
由 NOAA GEOS (Geostationary Environmental Operational Satelliate) 感應器所取 Andrew 颱風的多頻譜影像。(影像由 NOAA 所提供。)

圖 1.12
美洲的紅外線衛星影像，其中小的灰色地圖提供參考之用。(由 NOAA 提供。)

圖 1.13
世界上其他有人居住部分的紅外線衛星影像，其中小的灰色地圖提供參考之用。(由 NOAA 提供。)

a b
c d
e f

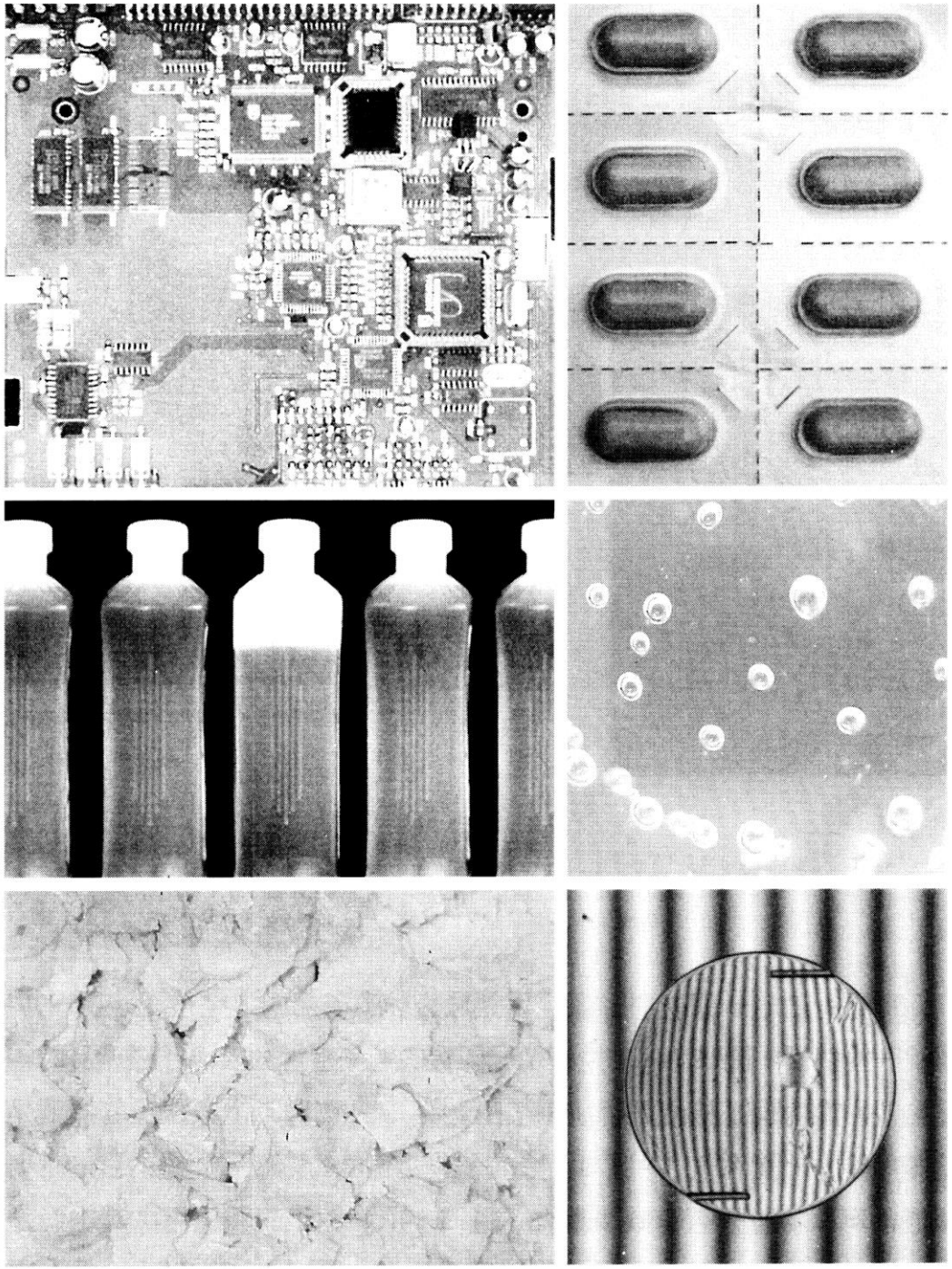
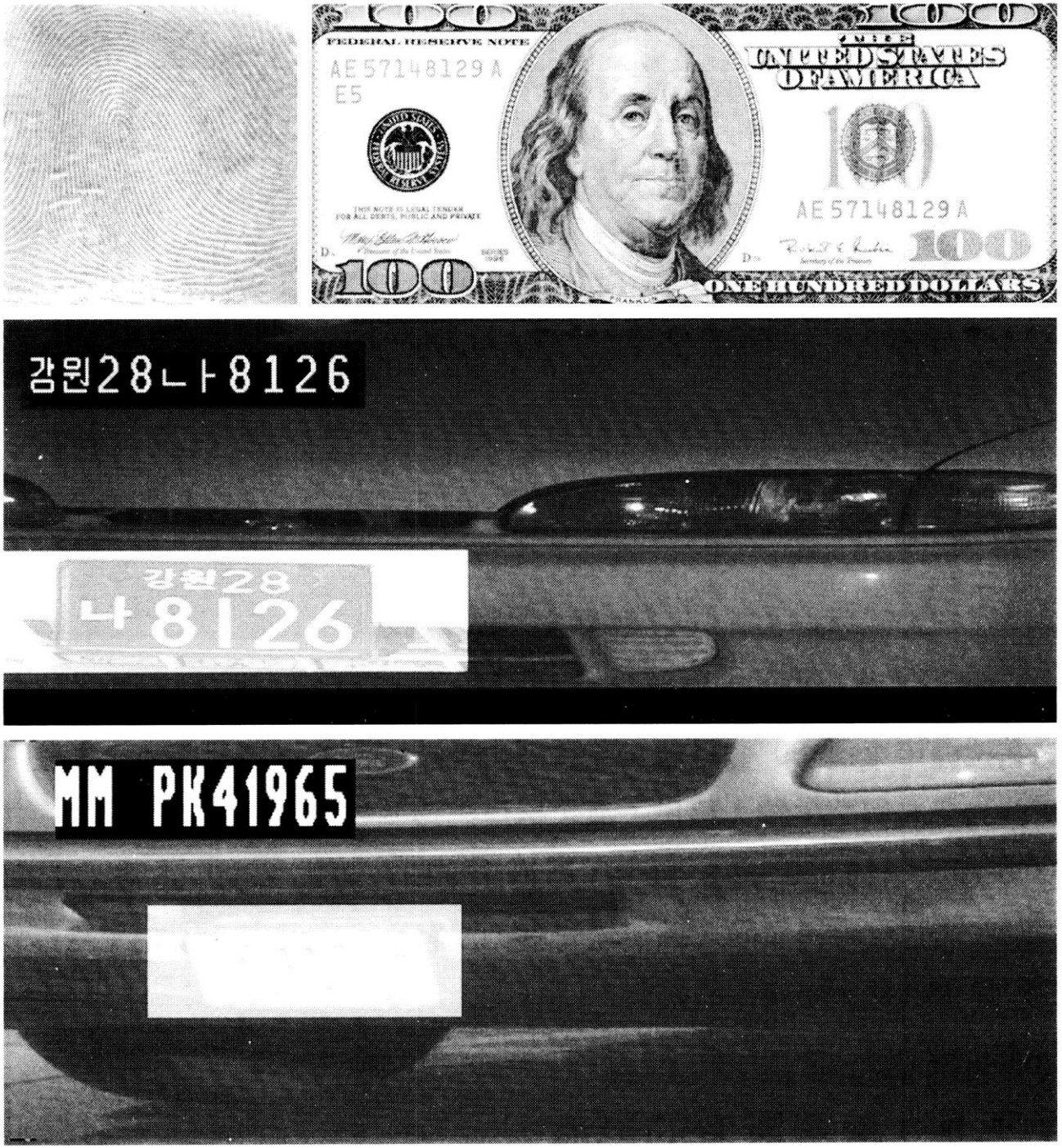


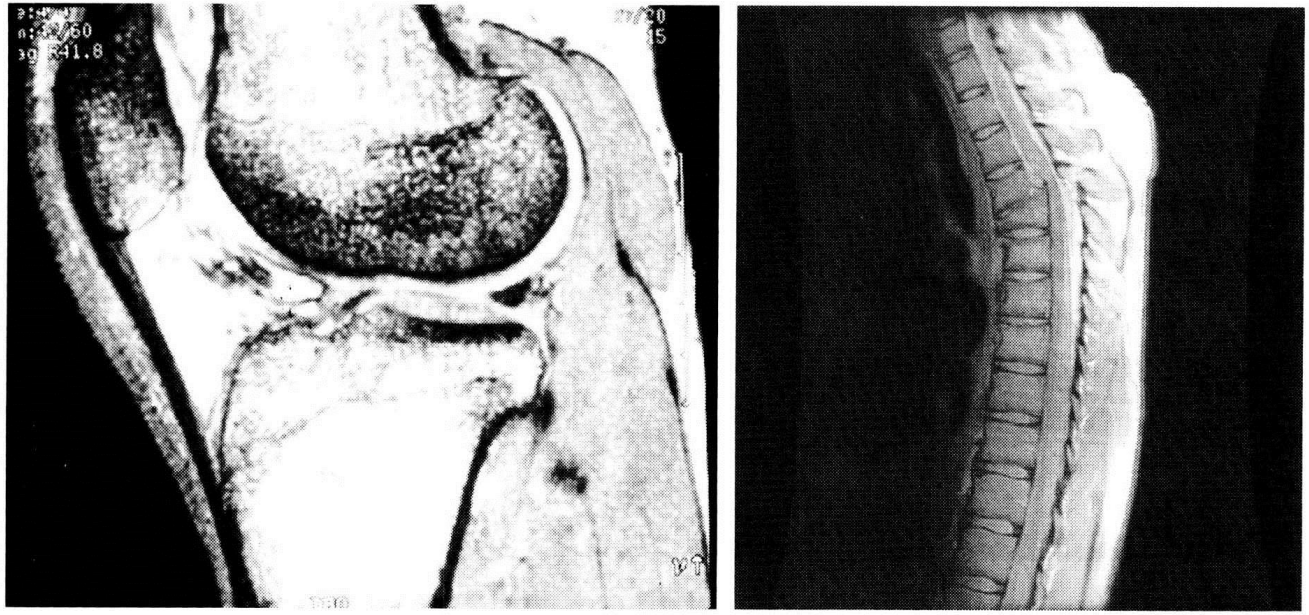
圖 1.14
常用數位影像處理檢視製造產品的一些例子：(a) 電路板的控制器；(b) 包裝的藥丸；(c) 瓶子；(d) 透明塑膠產品的氣泡；(e) 麥片；(f) 眼內移植的影像。(圖 (f) 由 Perceptics 公司的 Pete Sites 先生所提供。)



a b
c
d

圖 1.15
視覺頻譜成像的一些額外例子：(a) 拇指的紋路；(b) 紙幣；(c) 和 (d) 表示車牌自動讀取。(圖 (a) 由 National Institute of Standards and Technology 所提供；圖 (c) 由 Perceptics 公司的 Dr. Juan Herrera 提供。)

圖 1.16
西藏東南方山區的太空雷達影像。(由 NASA 所提供。)



a b

圖 1.17
人類的 (a) 膝蓋骨和 (b) 脊椎骨的 MRI 影像。(影像 (a) 由密西根大學醫學院解剖科學部門的 Dr. Thomas R. Gest 提供。圖 (b) 由凡德比爾大學醫學中心的放射學和放射線科學部門的 Dr. David R. Pickens 提供。)

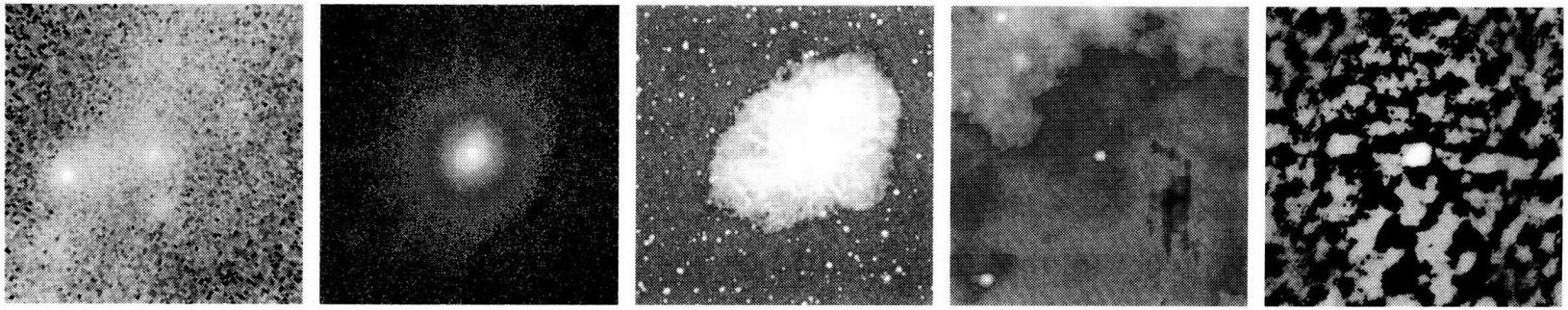
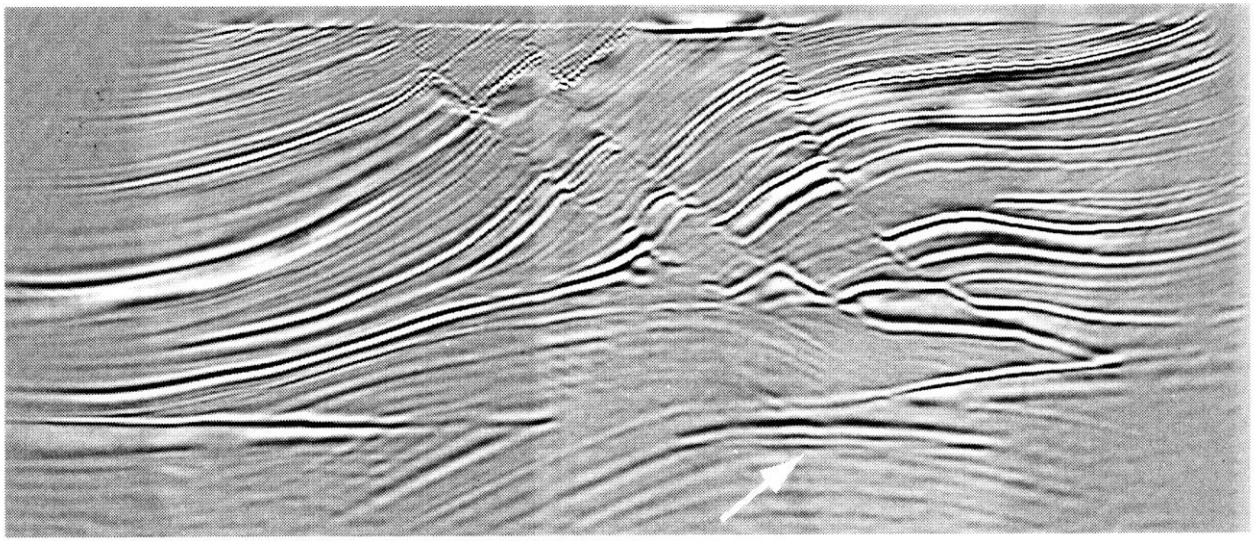
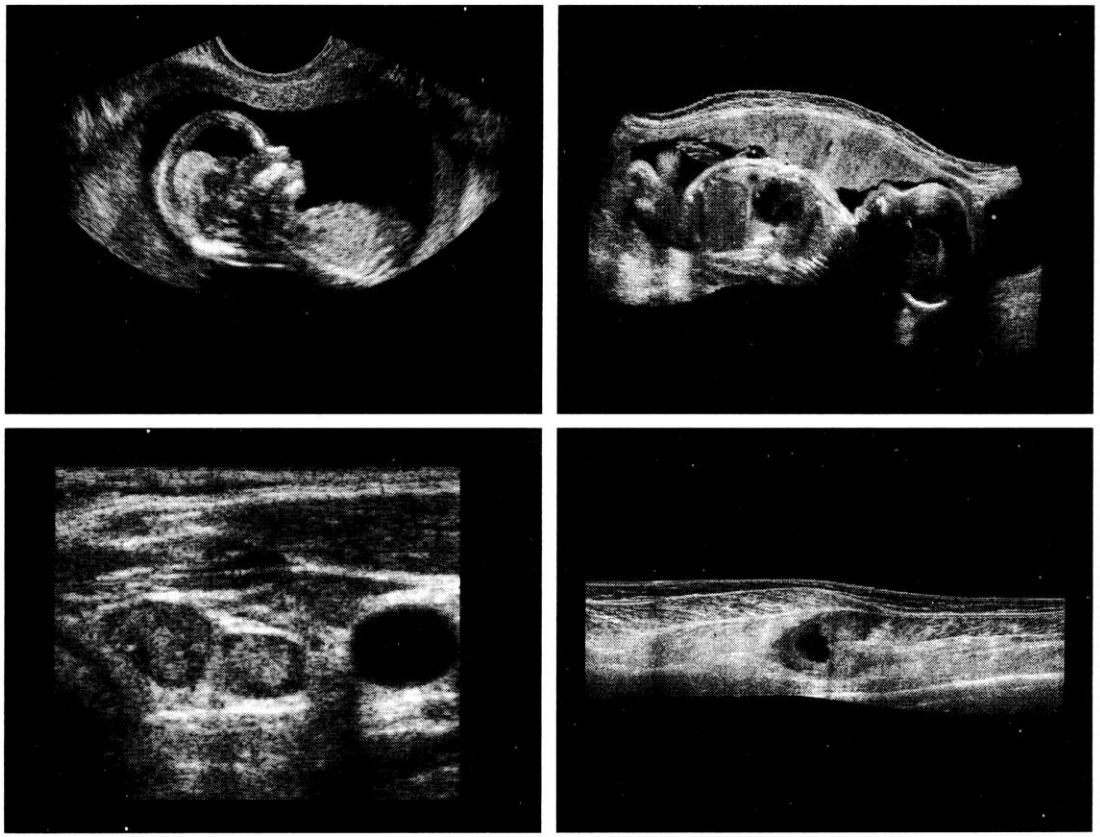


圖 1.18 涵蓋無線電波頻帶的巨蟹座星雲 (在影像的中心) 的影像。(由 NASA 提供。)

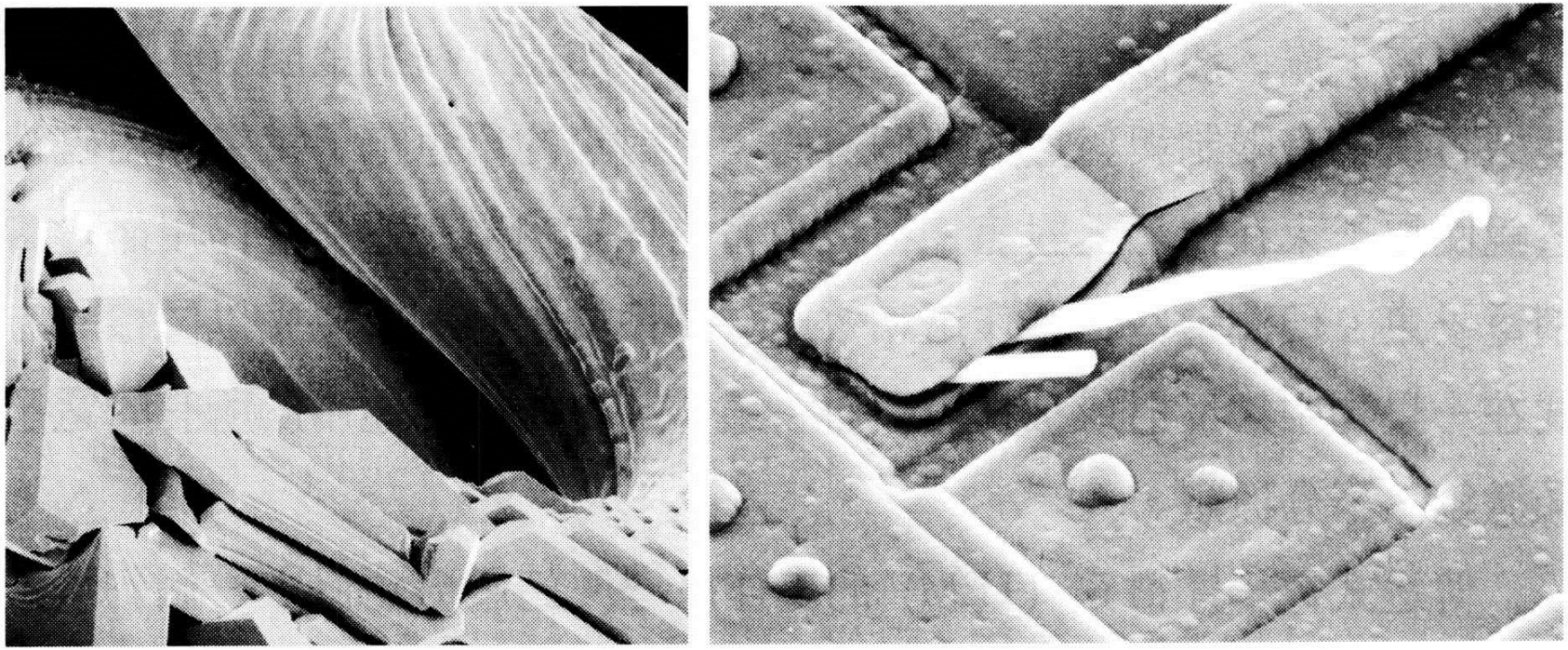
圖 1.19
地震模型的剖面影像。箭頭指向碳化氫（油及/或氣體）火山岩。（由桑地亞國家實驗室的 Dr. Curtis Ober 所提供。）





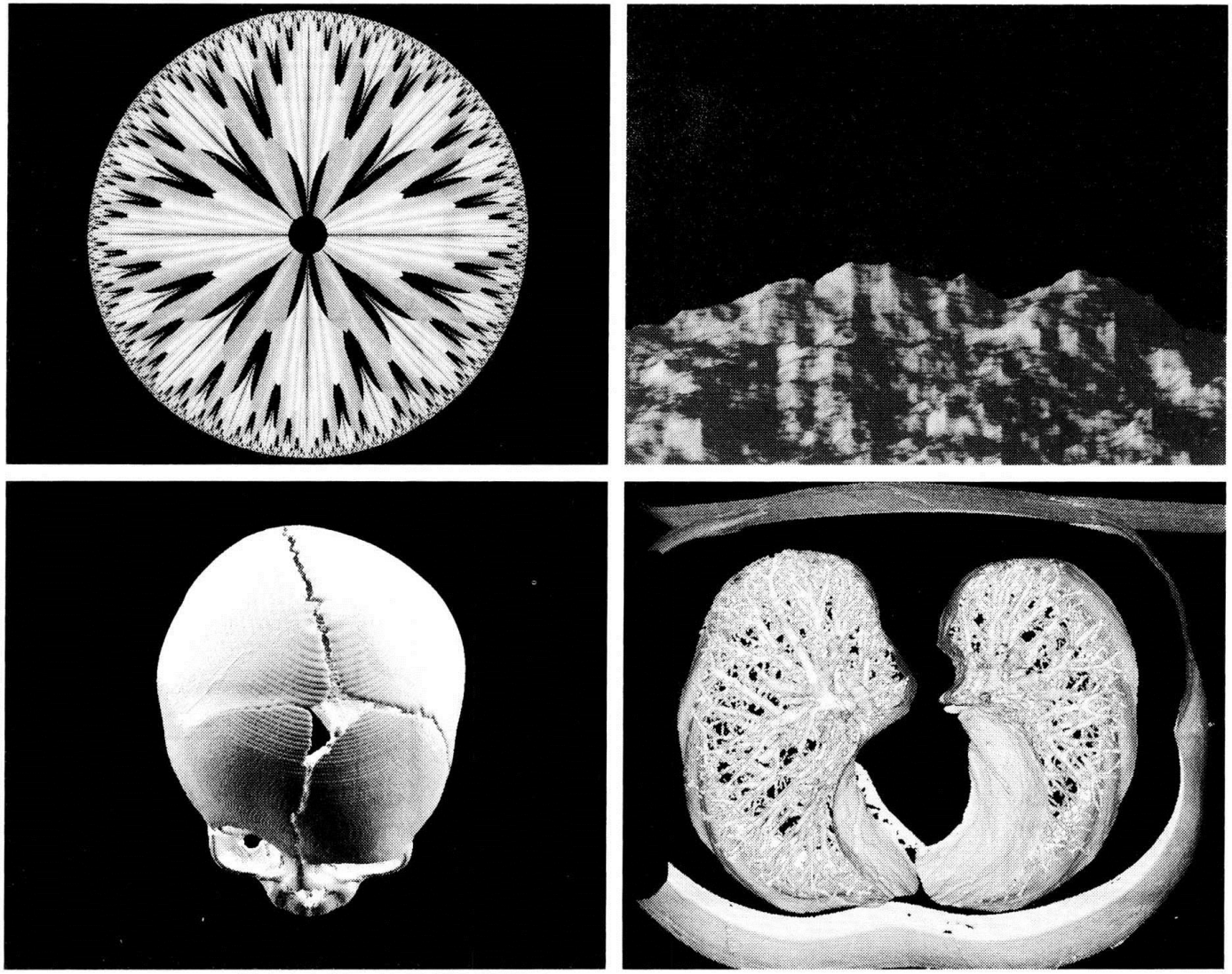
a b
c d

圖 1.20
超音波成像的例子。(a) 嬰兒；(b) 檢視嬰兒的另一面；(c) 甲狀軟骨；(d) 顯示受損的肌肉層。（由西門子醫學系統公司的超音波組所提供。）



a b

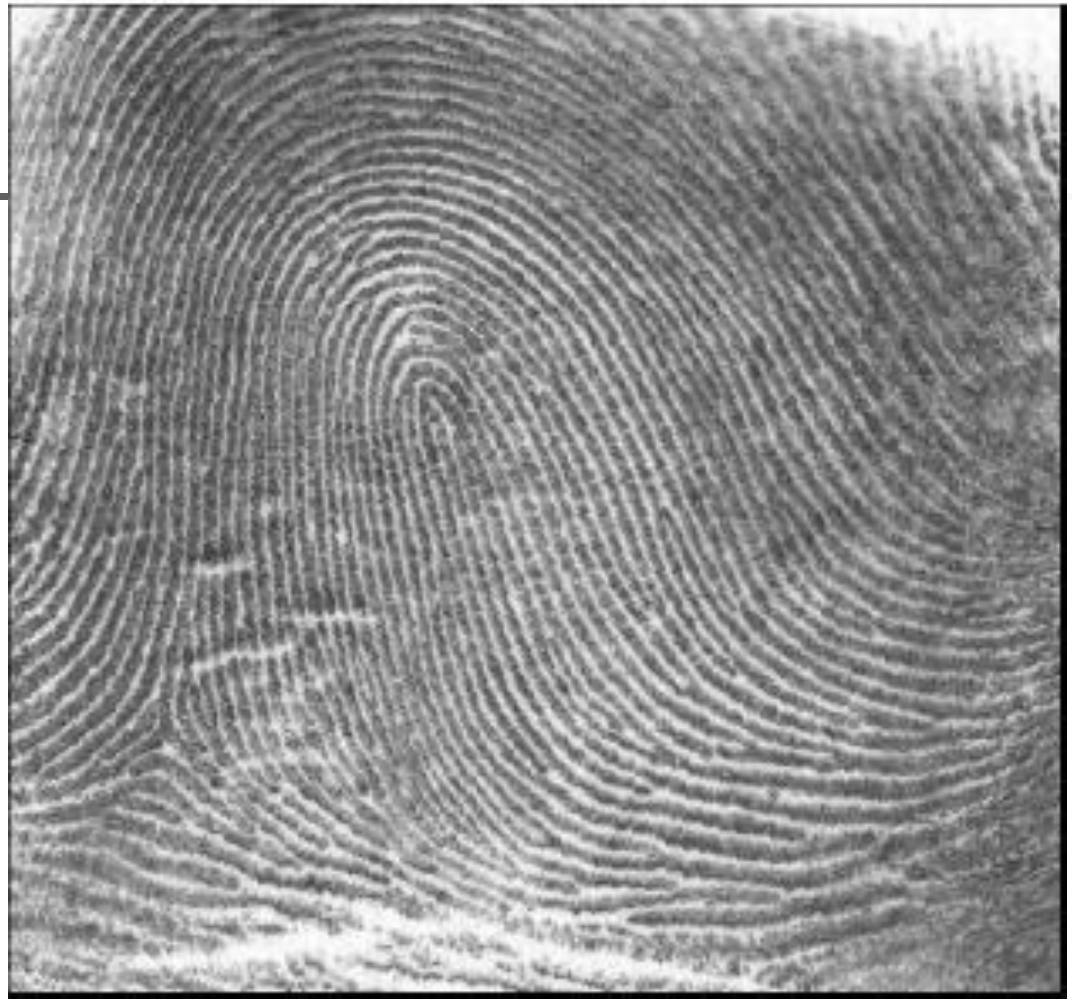
圖 1.21 (a) 250 倍鎢絲燈下的熱損害 SEM 影像；(b) 2500 倍損壞的積體電路 SEM 影像。白色纖維是來自於熱的破壞所產生的氧化物。(圖 (a) 由 Oregon 大學 Eugene 校區的地質學科學部門的 Michael Shaffer 先生所提供；圖 (b) 由加拿大 Mcmaster 大學 Dr. J. M. Hudak 提供。)



a b
c d

圖 1.22

(a) 和 (b) 是碎形影像；(c) 和 (d) 由圖中所示之物體的 3-D 電腦模型所產生。(圖 (a) 和圖 (b) 由 Swarthmore 學院的 Melissa D. Binde 女士所提供；圖 (c) 和 (d) 由 NASA 所提供。)



fingerprint image

Image from video

License Plate reader

Face morphing

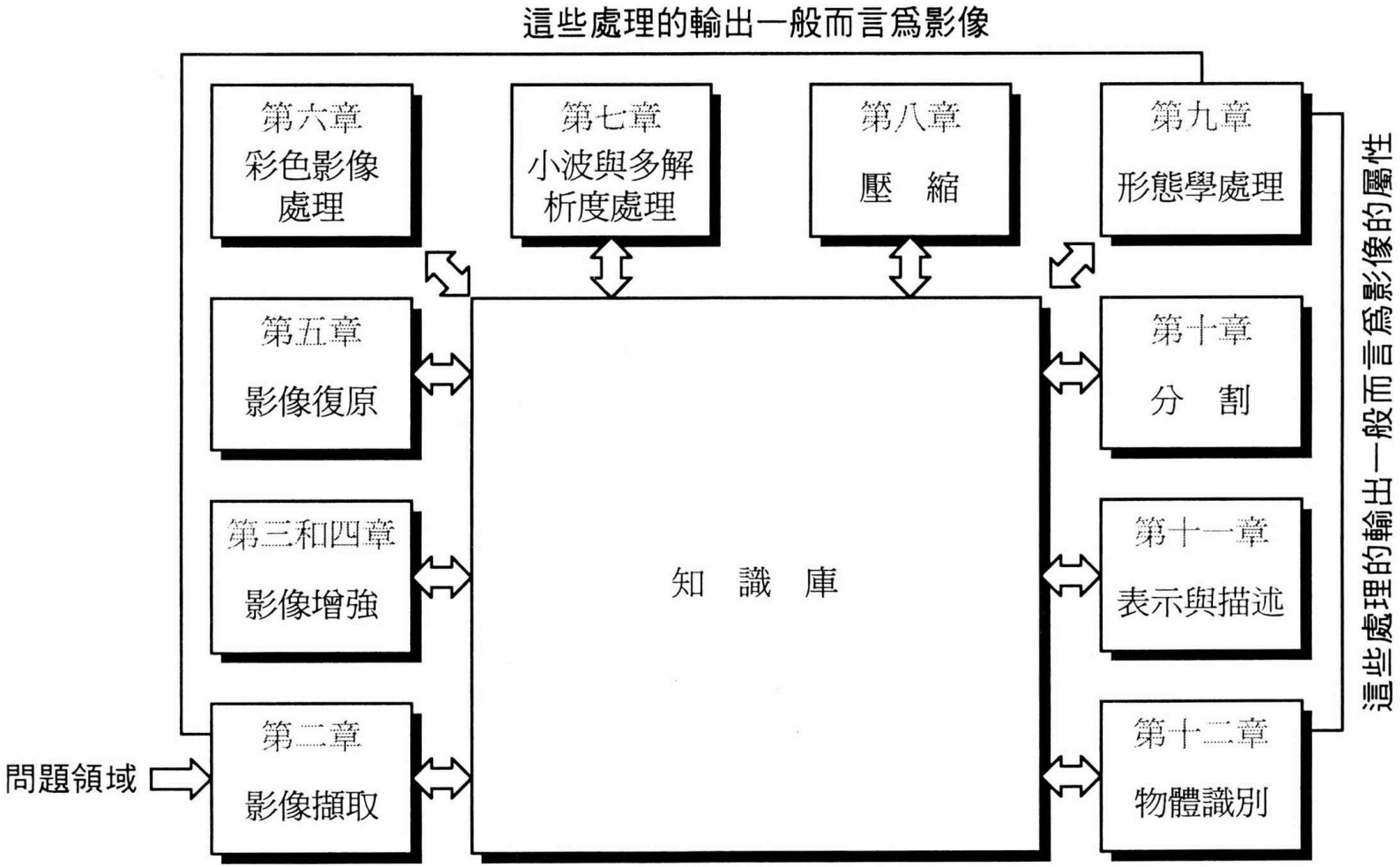


圖 1.23　數位影像處理的基本步驟。

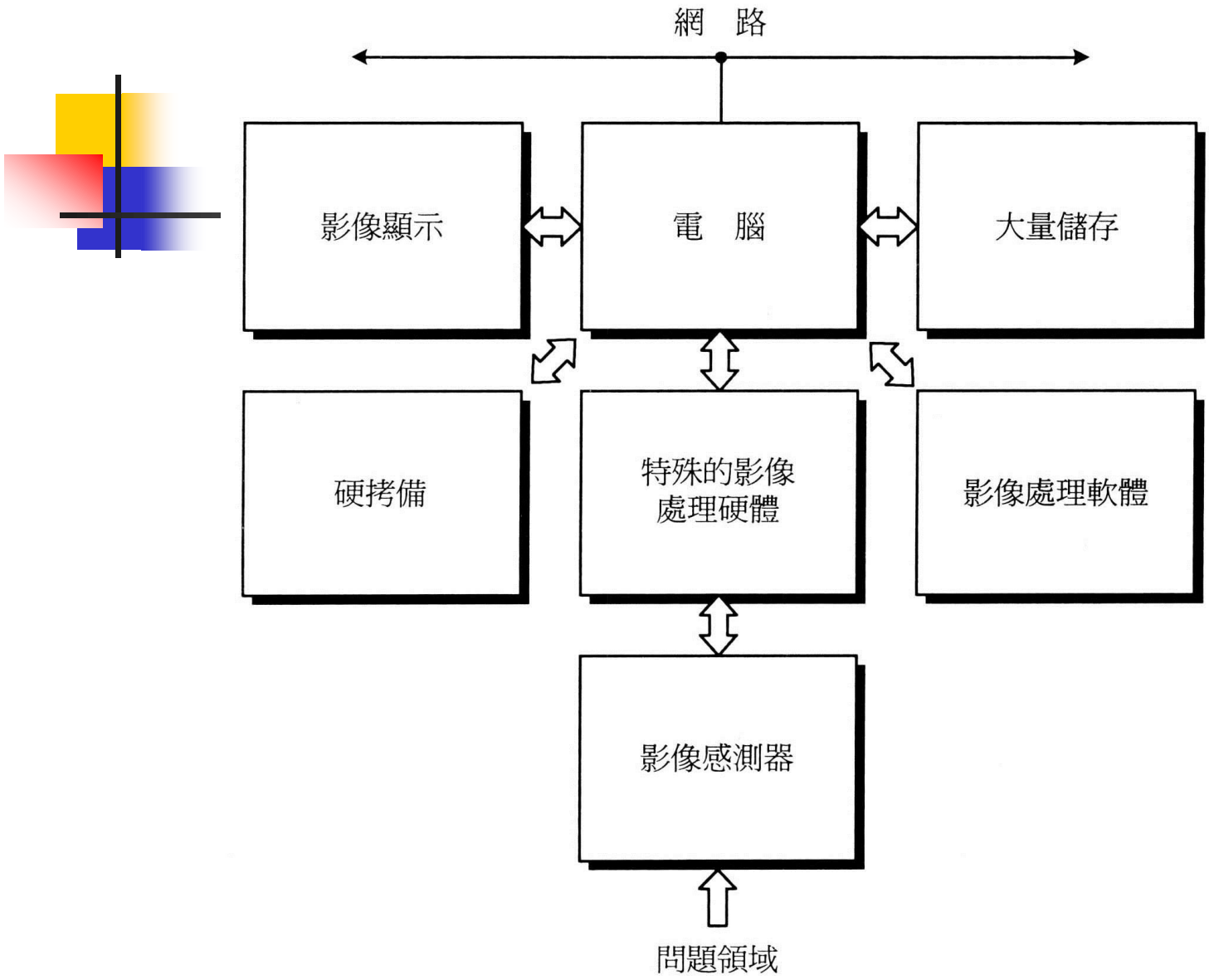
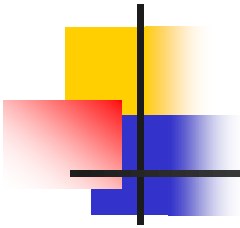


圖 1.24
一般用途影像處理系統的組成成分。

Sources of digital images



- Electromagnetic(EM) energy 電磁波
- Acoustic imaging 超音波
- Synthetic (computer-generated) imaging

EM images

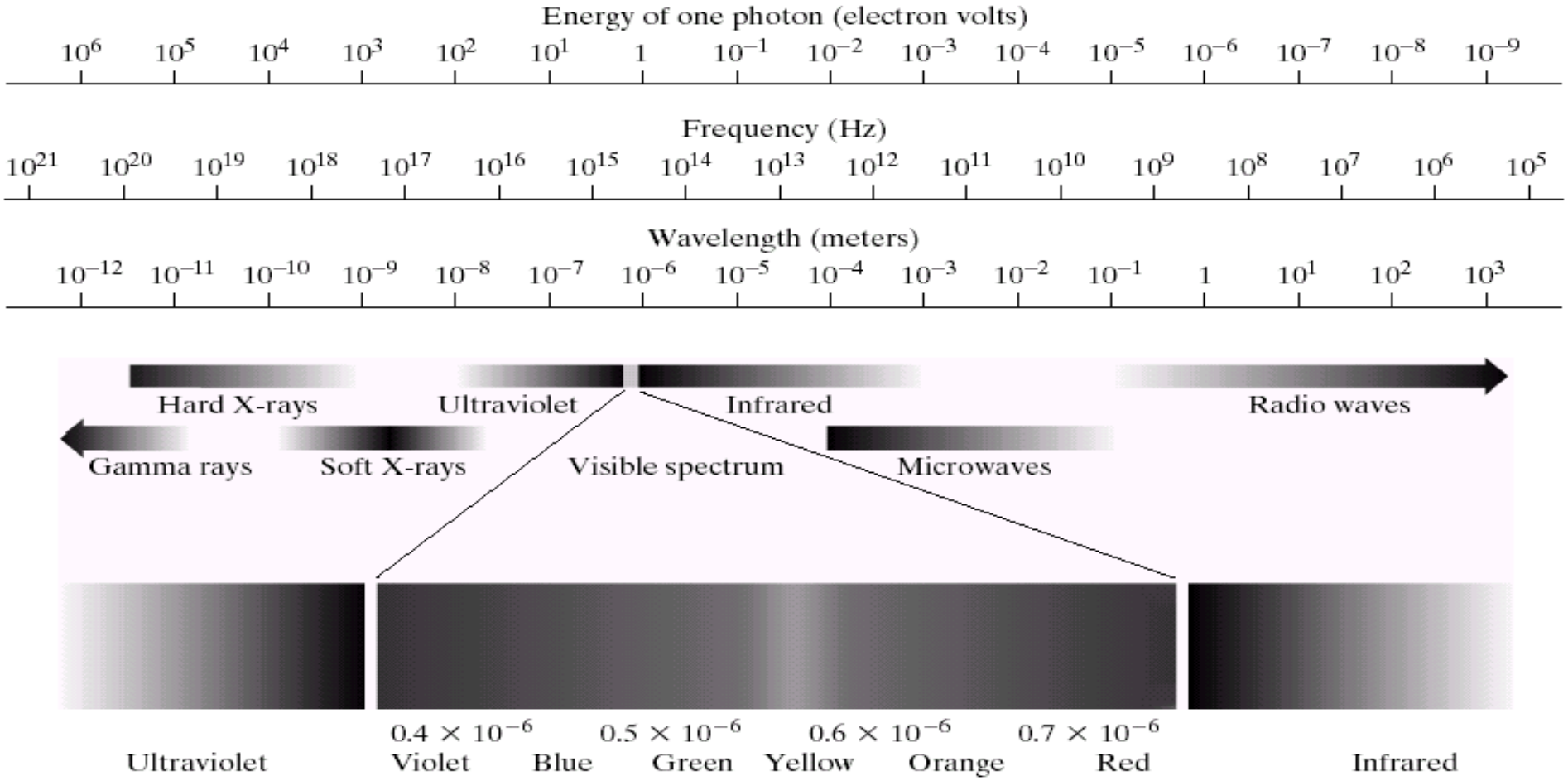


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Image acquisition

Image display

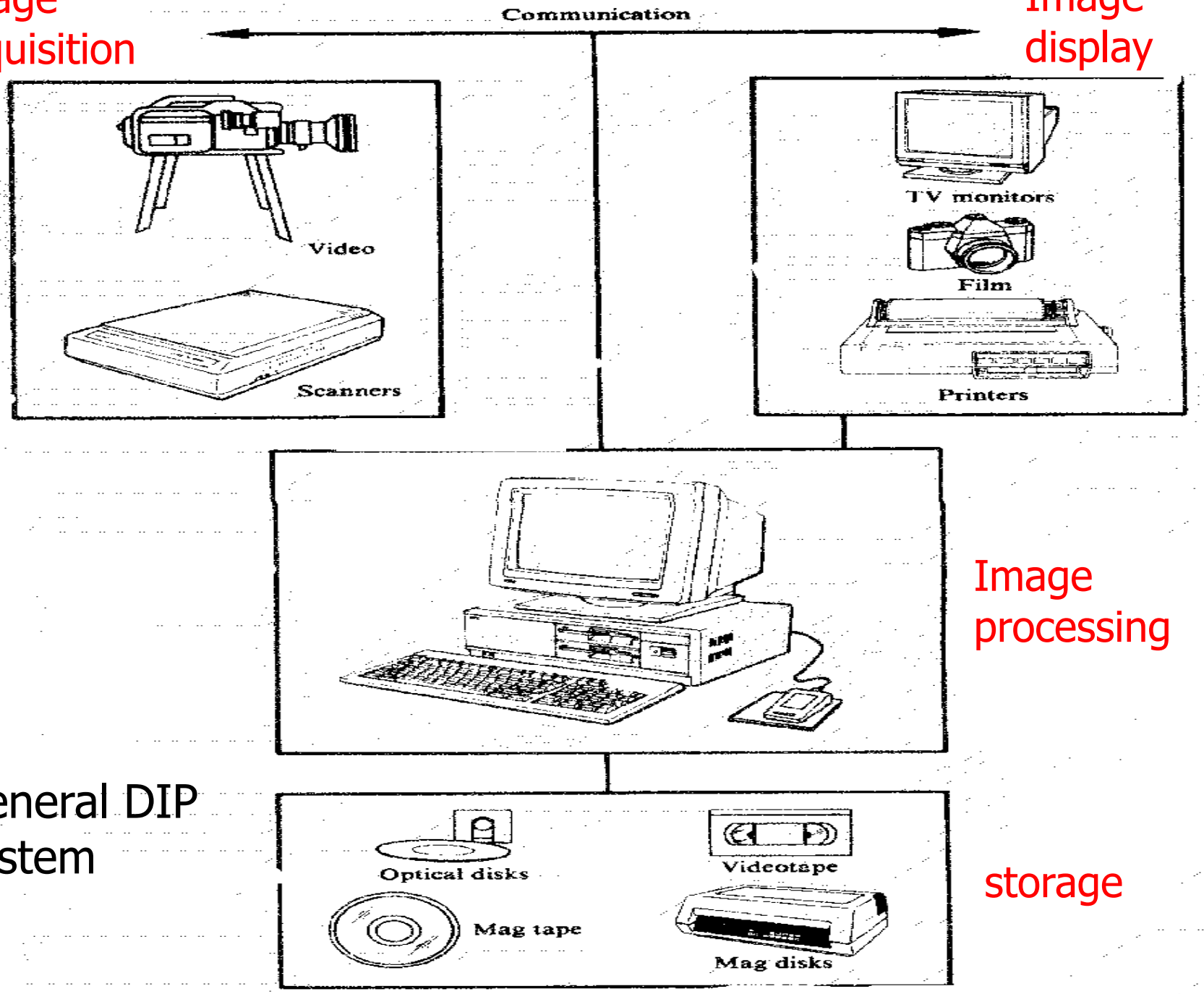


Image processing

storage

General DIP system

Introduction To Digital Image Processing With Matlab

- Matlab is an abbreviation of Matrix Laboratory.
- It is a popular Mathematical Programming Environment used extensively in Education as well as in Industry.
- The trick behind Matlab is that *everything is represented in the form of arrays or matrices.*
- Mathematical Operations starting from simple algebra to complex calculus may be conveniently carried out using this environment.
- The main use of Matlab in Image Processing 2 is for algorithm implementations.
- Code developed in Matlab can be converted into C, C++ or Visual C++.

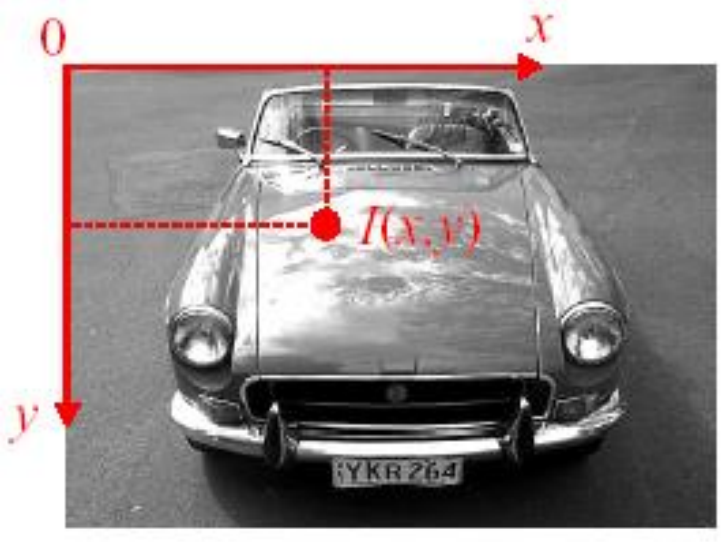
Matlab Basics

- Matrix Manipulation:
  - Addressing of individual element
  - Complete Row Addressing
  - Complete Column Addressing
  - Transpose
  - Fliplr and Flipud
- Saving and Loading Data
- Concept of Function and m-Files
- Concept of Path

- Useful Commands:
  - Whos
  - Help
  - Clear
  - Path
  - Cd
  - Dir
  - lookfor

Image Processing in Matlab

Image Representation



- An image **I** is a *matrix* of pixel values
- Pixel value at $\mathbf{p} = [x,y]^T$ is $\mathbf{I}(\mathbf{p})$ or $\mathbf{I}(x,y)$
- Origin is top left corner
  - **I** is a matrix
  - **p** is a vector
  - x, y, $\mathbf{I}(\mathbf{p})$, $\mathbf{I}(x,y)$ are scalars

Note in Matlab `I(r,c)` refers to the *r*th row and the *c*th column of **I.**

- The image processing may be done simply by matrix calculation or matrix manipulation.
- Image may be displayed with *imshow* command.

Image Processing in Matlab

Image I/O

- You can open an image as a matrix using *imread* command.
  - The matrix may simply be m x n form or it may be 3 dimensional array or it may be an indexed matrix, depending upon image type.
- Changed image may then be saved with *imwrite* command.

Some Matlab Resources:

- Getting started with MATLAB
  http://www.mathworks.com/access/helpdesk/help/techdoc/learn_matlab/learn_matlab.shtml

- MATLAB tutorial
  http://www.math.mtu.edu/~msgocken/intro/intro.html
  http://amath.colorado.edu/scico/tutorials/matlab/

- MATLAB helpdesk
  http://www.mathworks.com/access/helpdesk/help/helpdesk.shtml

- MATLAB Primer
  ftp://ftp.eng.auburn.edu/pub/sjreeves/matlab_primer_40.pdf

Example of condition 1 may include: (1)Image sharpening.

圖1.1 影像銳利化 (a) 原始影像 (b) 銳利化結果

(2)Removing noise from an image.

圖1.2 去除影像雜訊 (a) 原始影像 (b) 去除雜訊結果

(3)Image deblurring.

圖 1.3 去除影像模糊現象 (a) 原始影像 (b) 去除模糊現象結果

Example of condition 2 may include:
(1)Obtain the edges of an image.

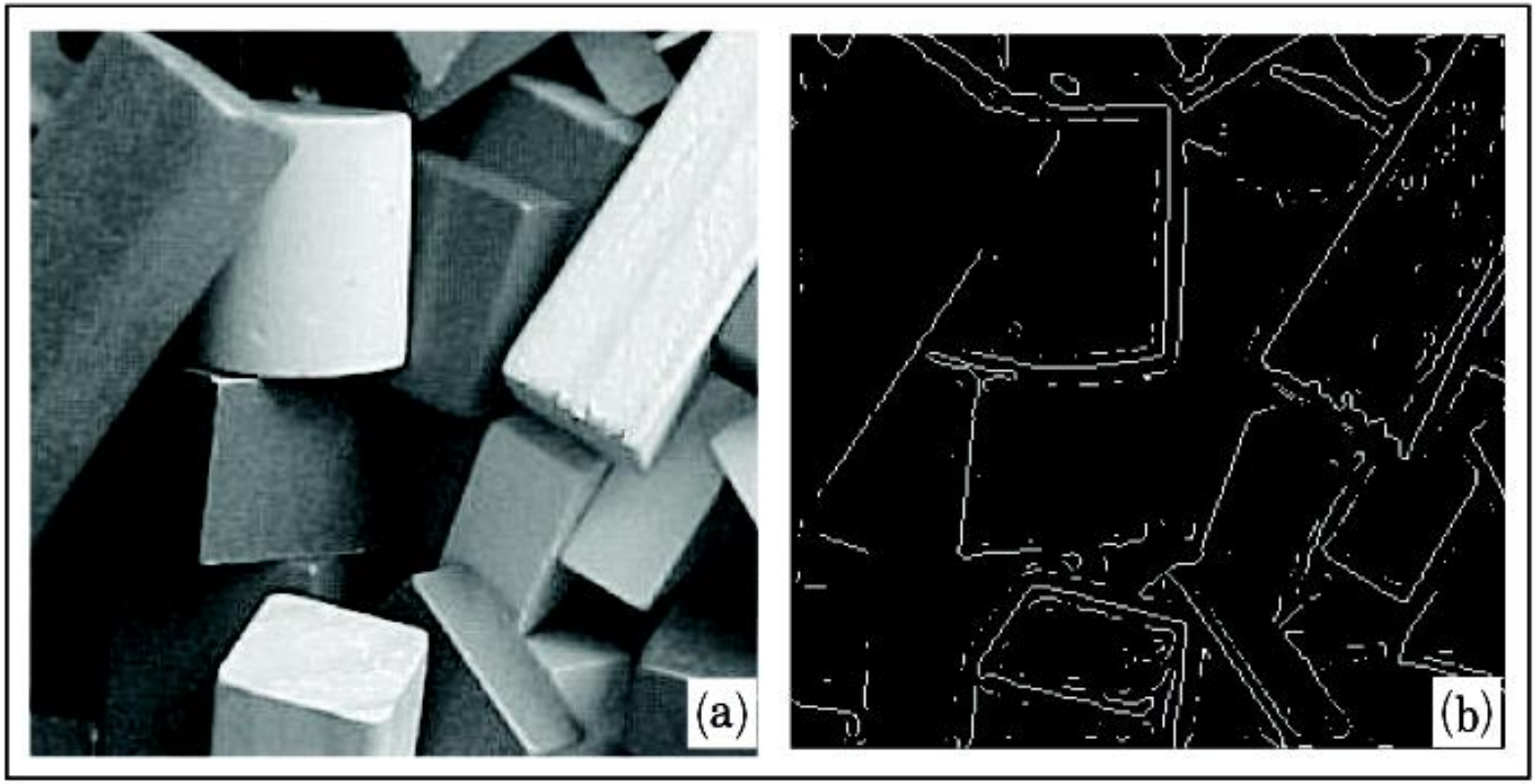


圖1.4 取得影像邊緣線條 (a) 原始影像 (b) 物體邊緣線條

(2)Removing detail from an image.

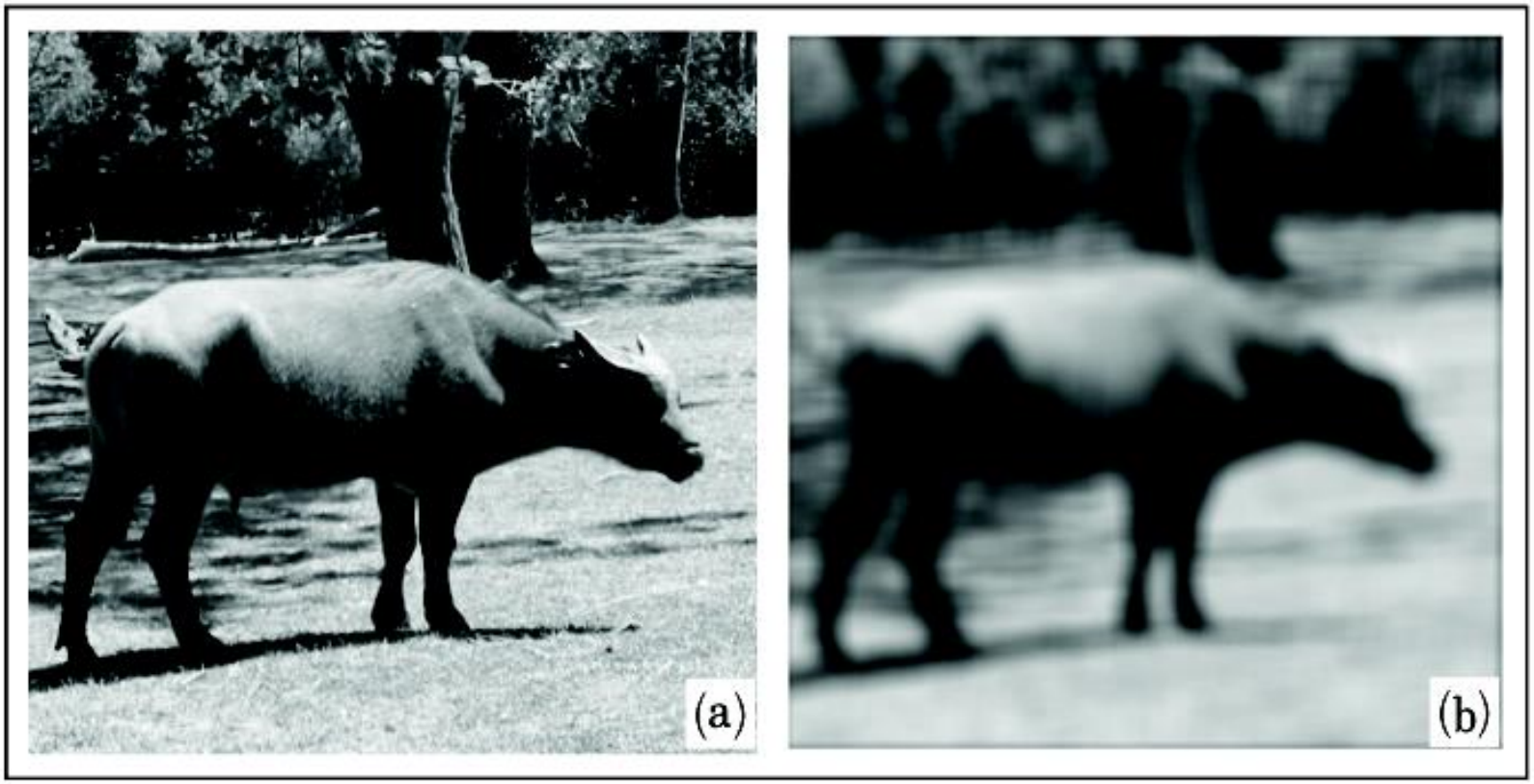


圖 1.5 影像模糊化 (a) 原本影像 (b) 模糊化後去除細節結果

圖 1.6 函數取樣—次取樣

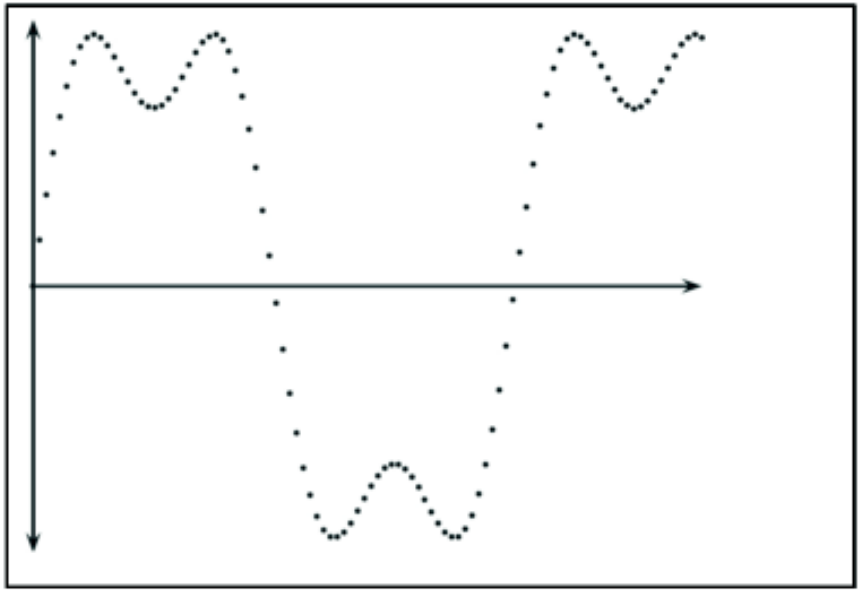


圖 1.7 函數取樣：使用更多取樣點

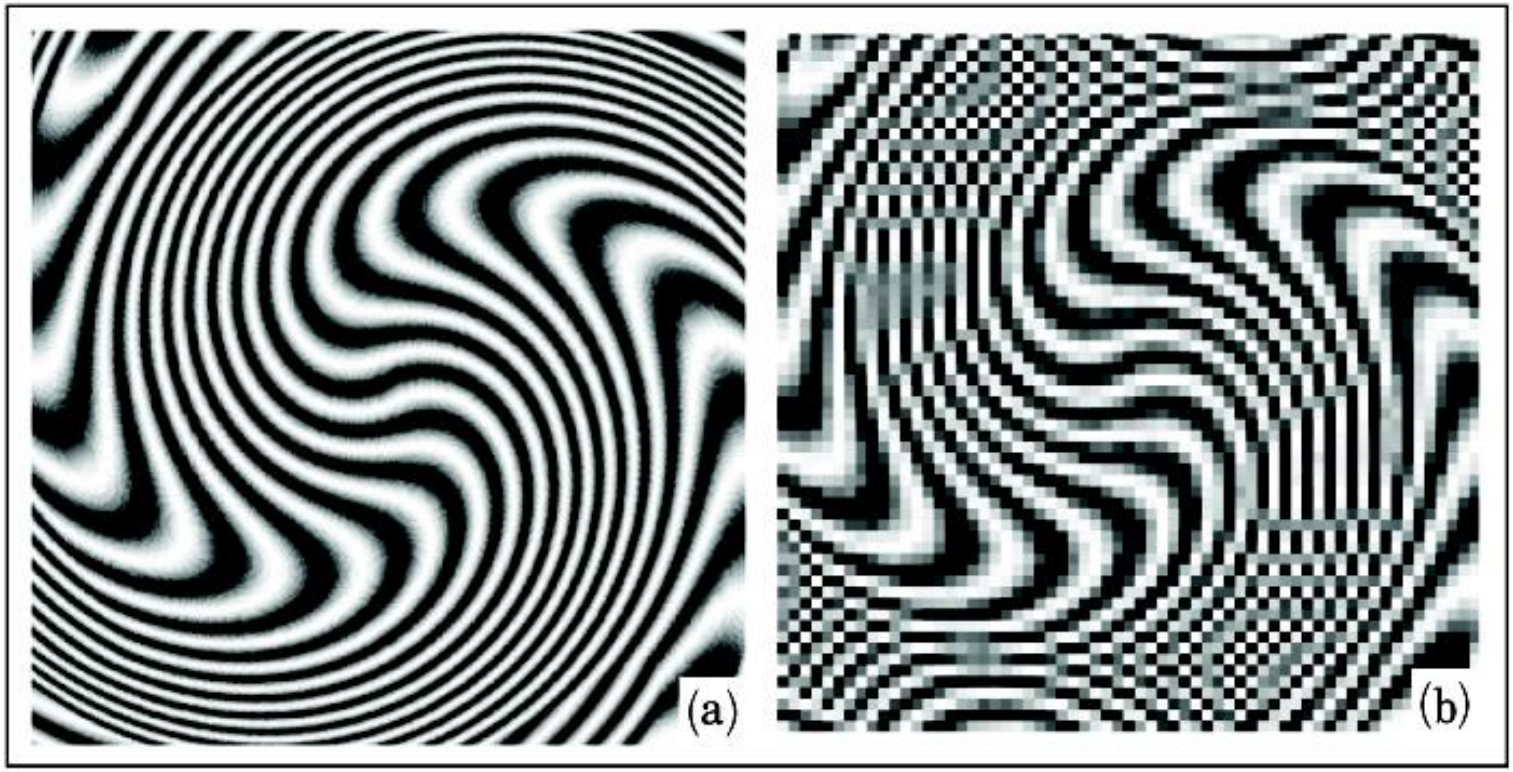


圖 1.8 取樣的效果 (a) 正確取樣，無混疊
(b) 低度取樣版本，有混疊現象

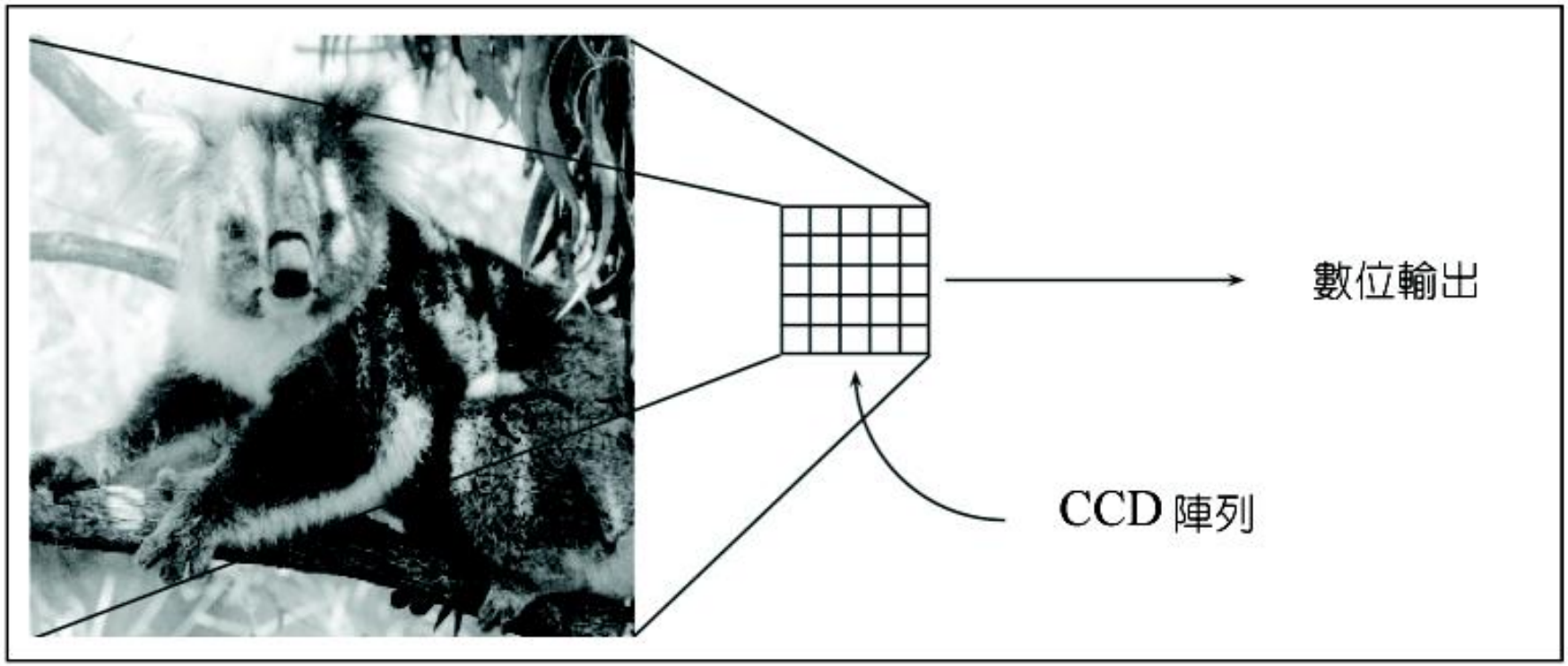


圖1.9 原始景象使用CCD 陣列擷取影像

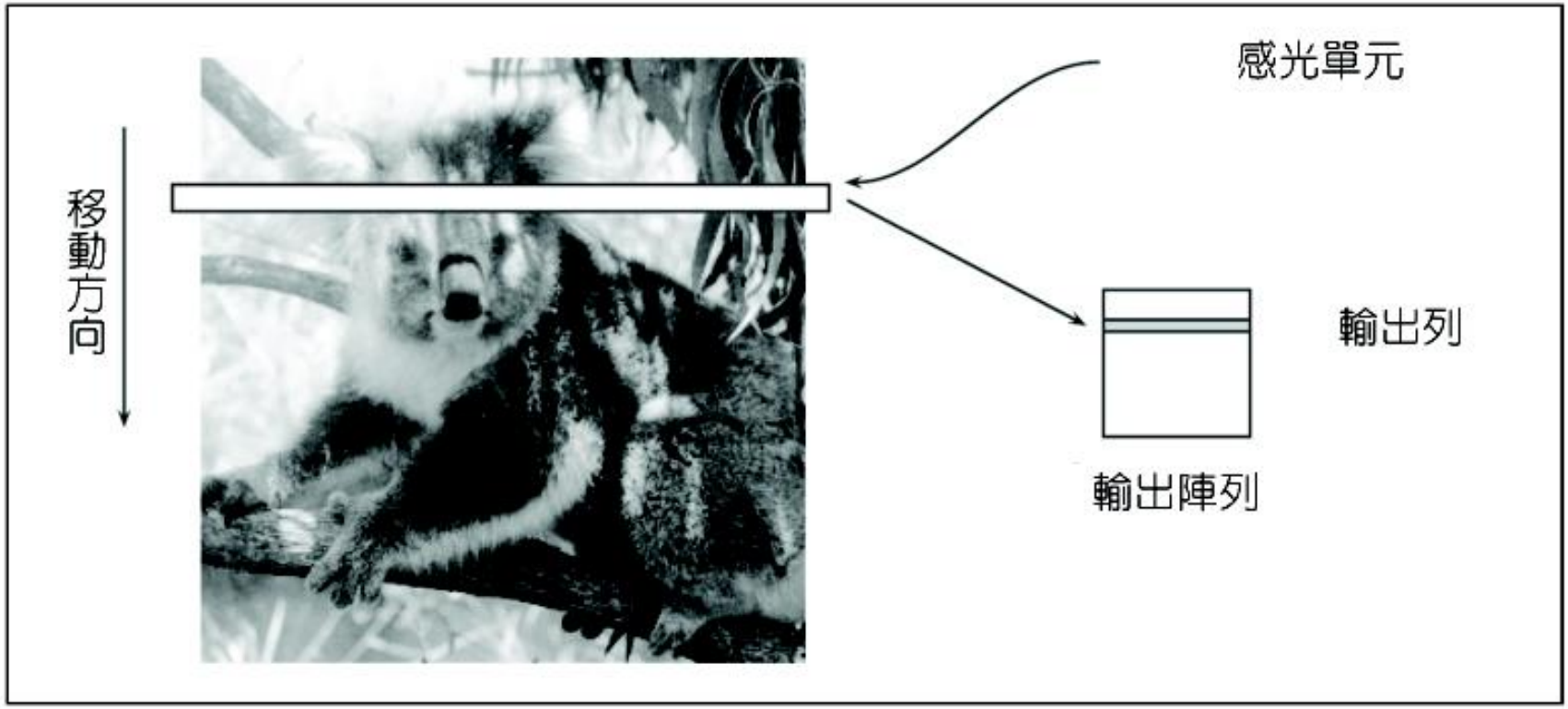


圖 1.10 原始景象使用CCD 掃描器擷取影像

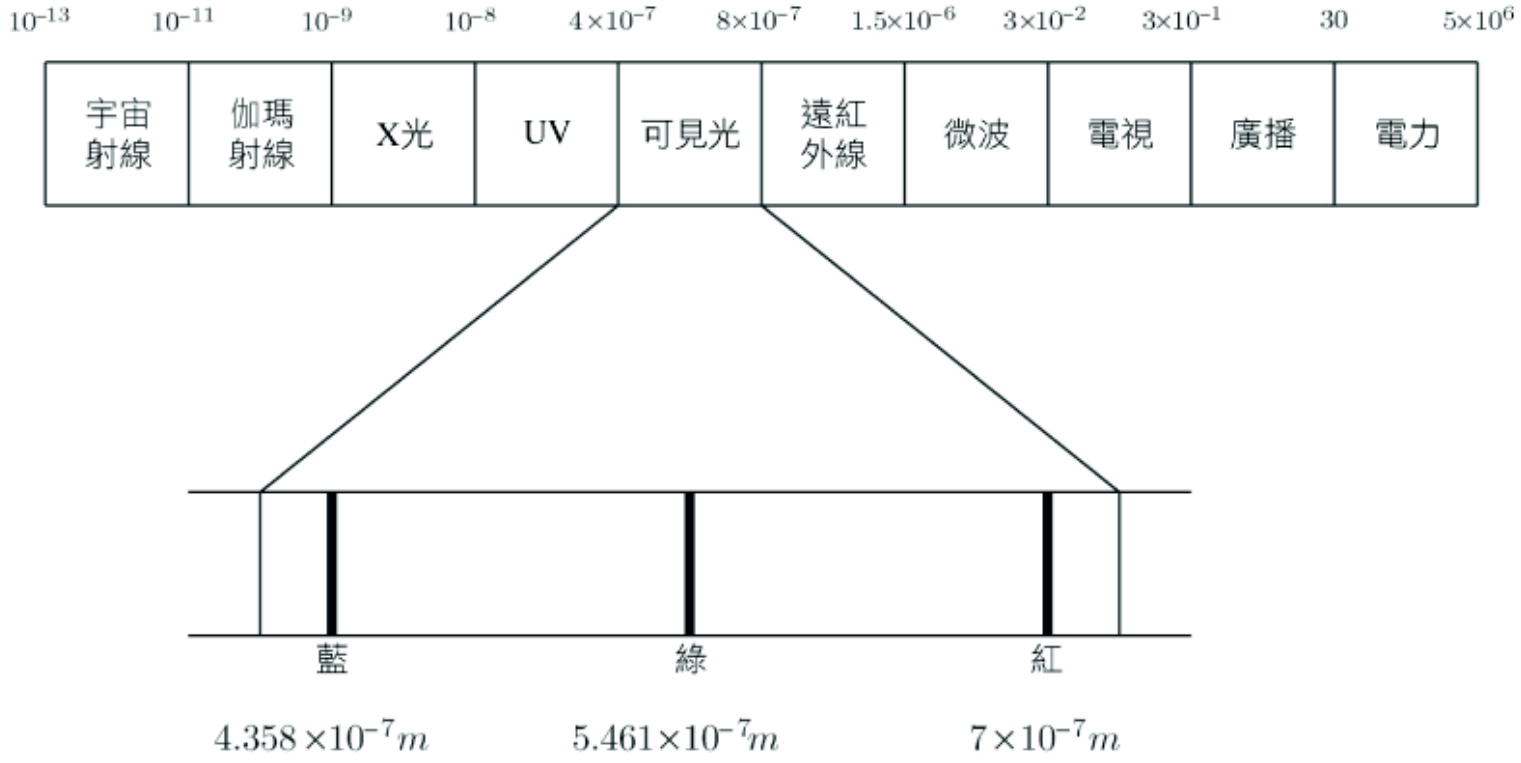

10^{-13}
10^{-11}
10^{-9}
10^{-8}
4×10^{-7}
8×10^{-7}
1.5×10^{-6}
3×10^{-2}
3×10^{-1}
30
5×10^{6}
宇宙射線
伽瑪射線
X光
UV
可見光
遠紅外線
微波
電視
廣播
電力
藍
綠
紅
$4.358\times10^{-7}m$
$5.461\times10^{-7}m$
$7\times10^{-7}m$

圖 1.11 電磁波頻譜

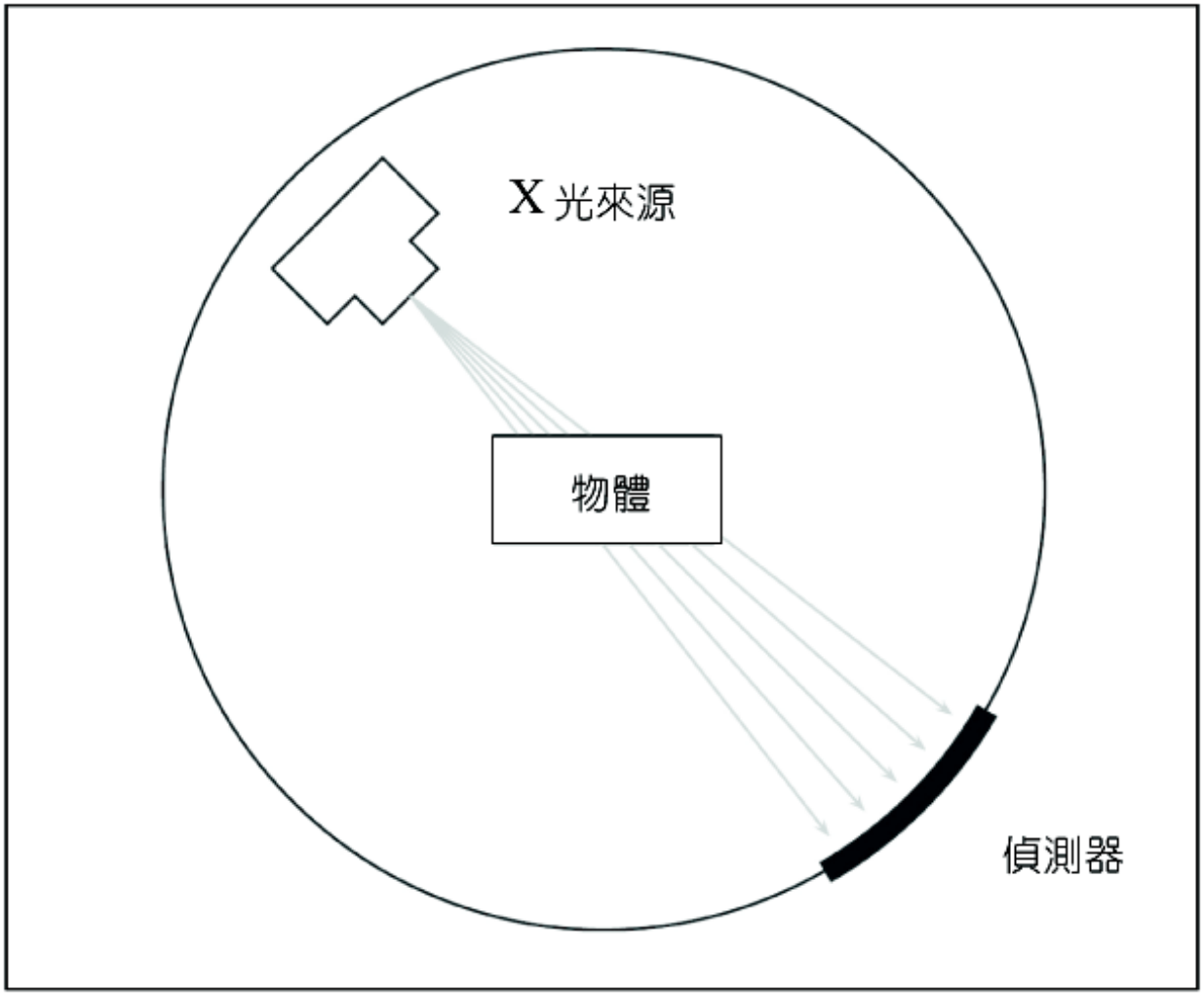


圖 1.12 X 光斷層攝影法

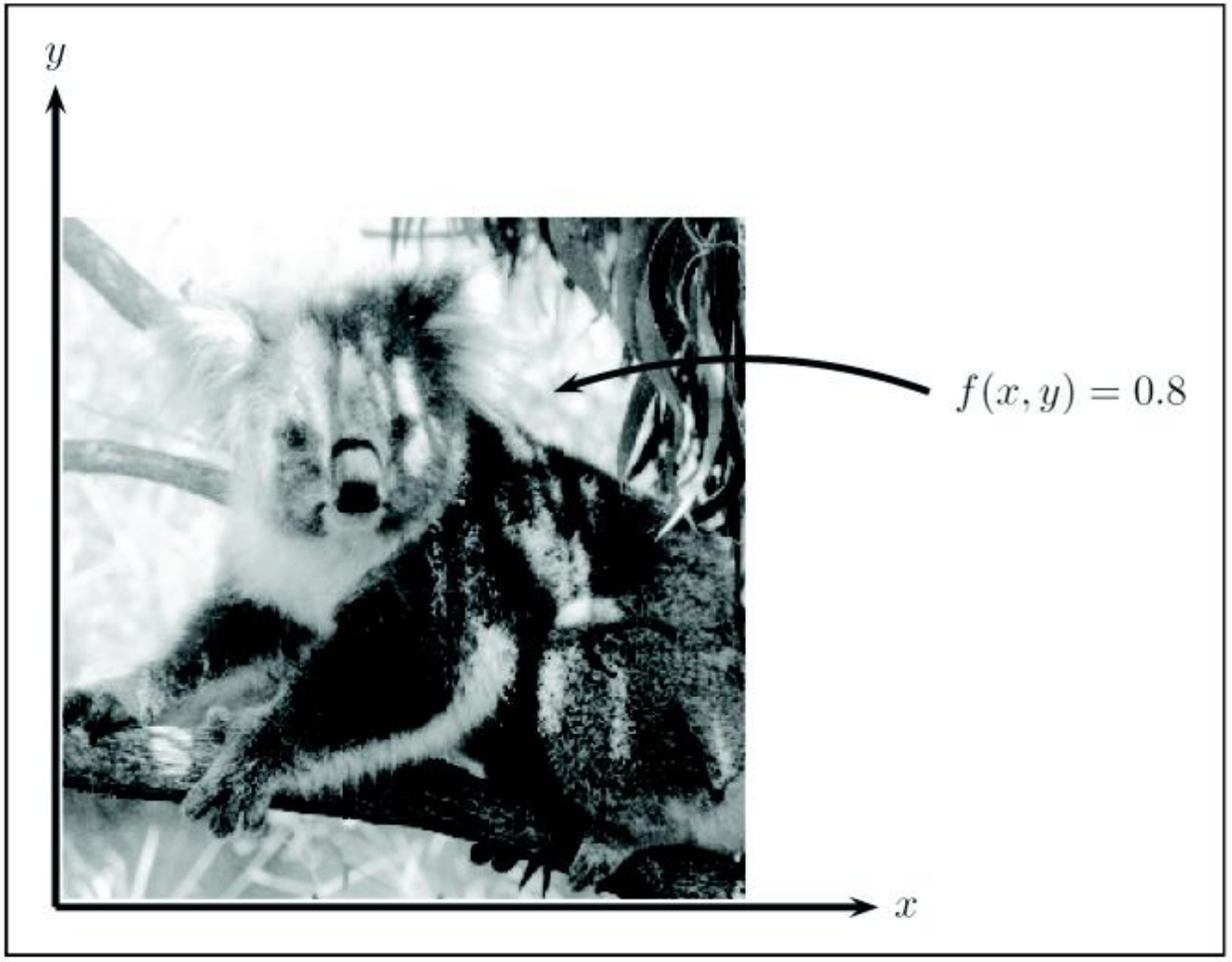


圖 1.13 影像視為函數

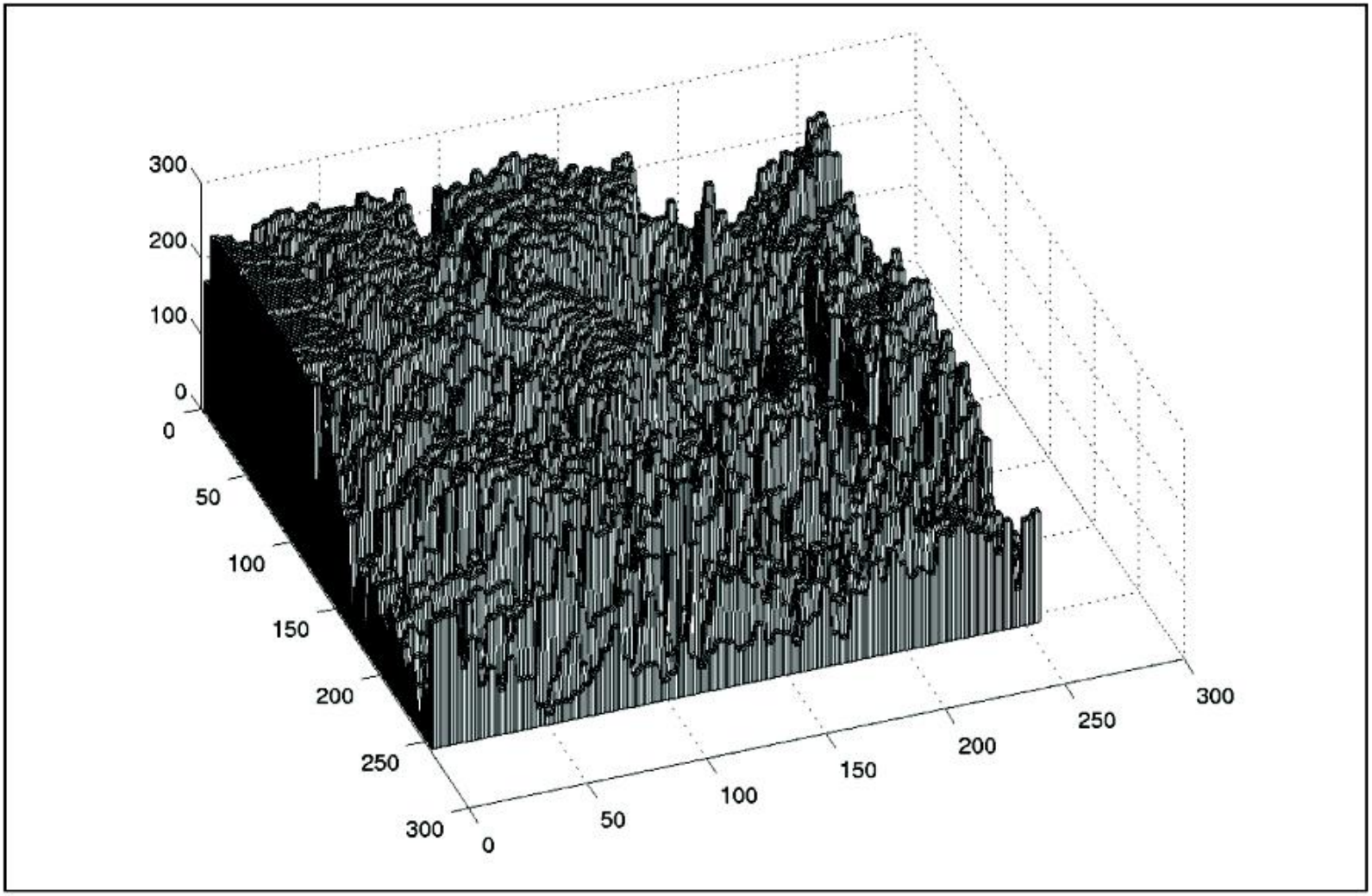


圖1.14 圖1.13之二維變數函數製圖

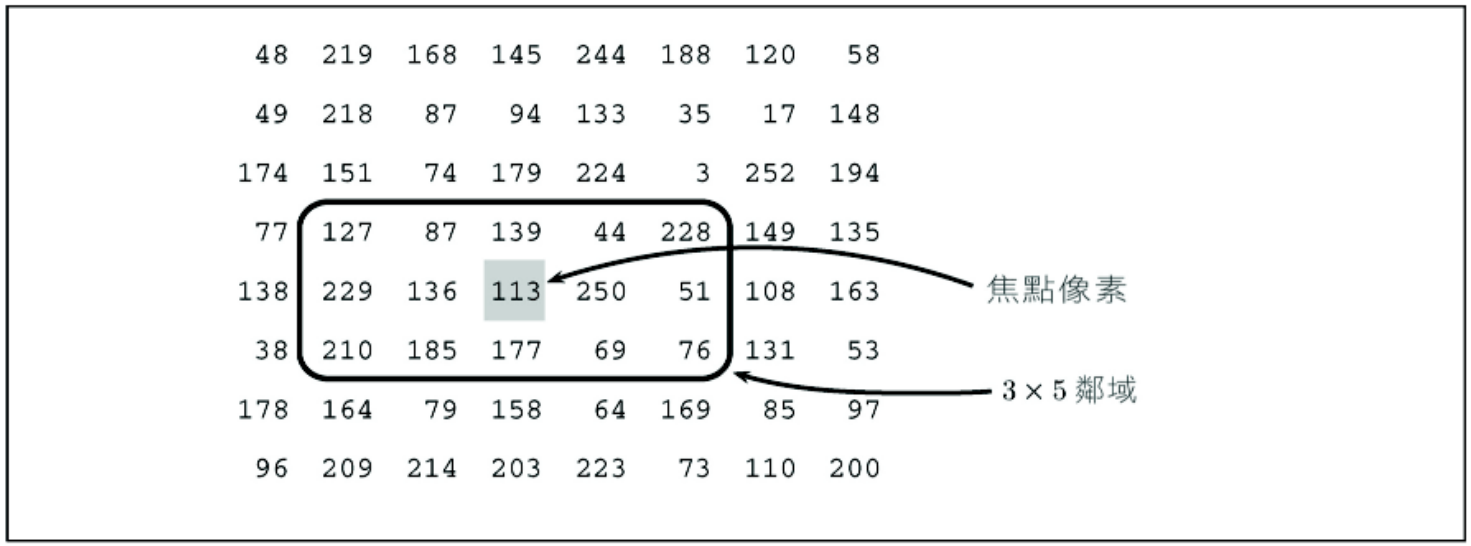

48 219 168 145 244 188 120 58
49 218 87 94 133 35 17 148
174 151 74 179 224 3 252 194
77 127 87 139 44 228 149 135
138 229 136 113 250 51 108 163
38 210 185 177 69 76 131 53
178 164 79 158 64 169 85 97
96 209 214 203 223 73 110 200
焦點像素
3 × 5 鄰域

圖1.15 像素及其鄰域

Types of digital images

- 1.Binary:Each pixel is just black or white.

  Images for which a binary representation may be suitable include text , fingerprints ,or

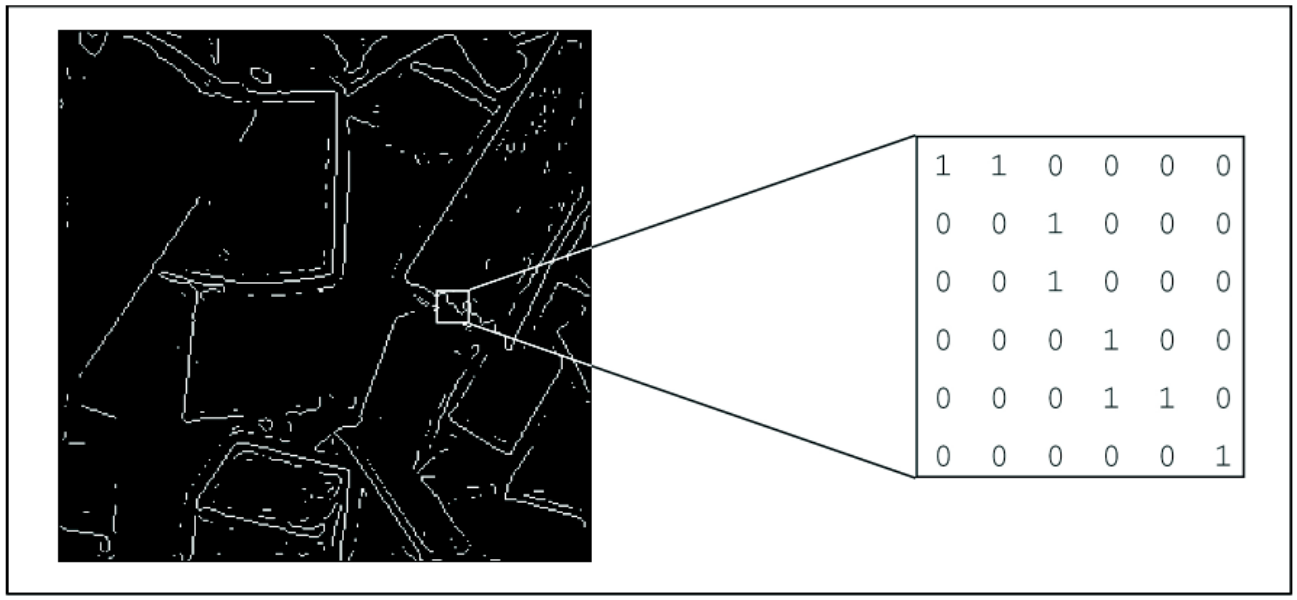


圖1.16 二元數位影像

- 2.Grayscale:Each pixel is a shade of gray, normally from 0(black) to255(white).

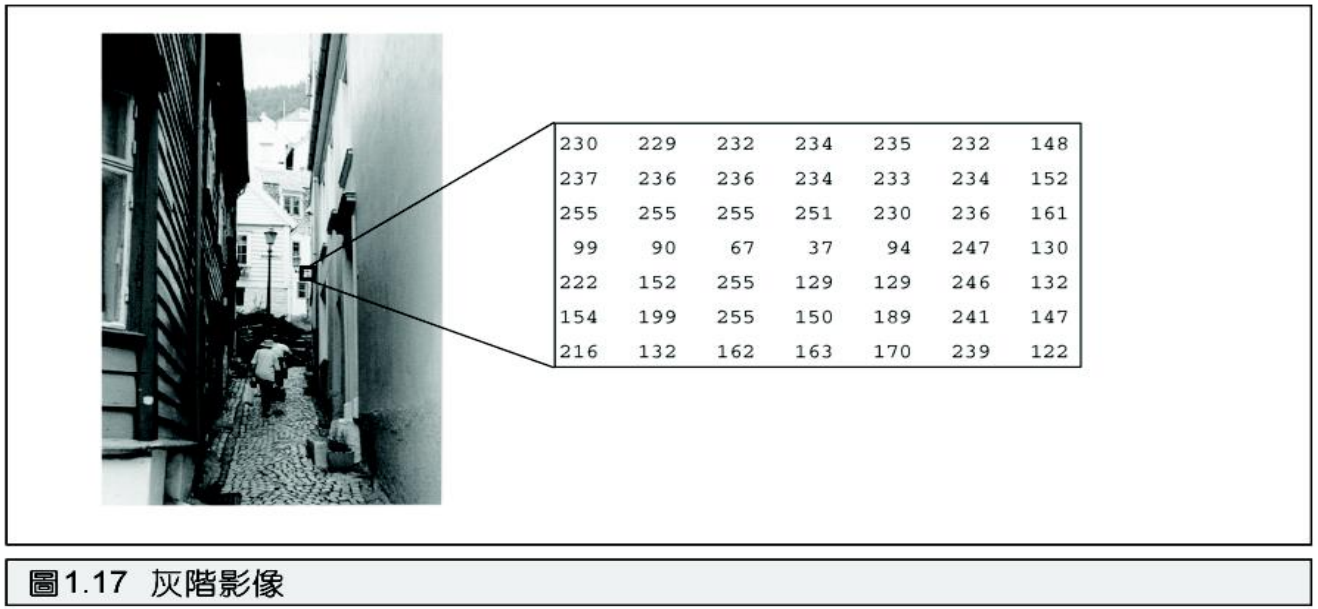


圖1.17 灰階影像

- 3.The color or red-green-blue:Here each pixel has a particular color, that color being described by the amount of red, green, and blue in it.Each of this compoments has a range 0-255.

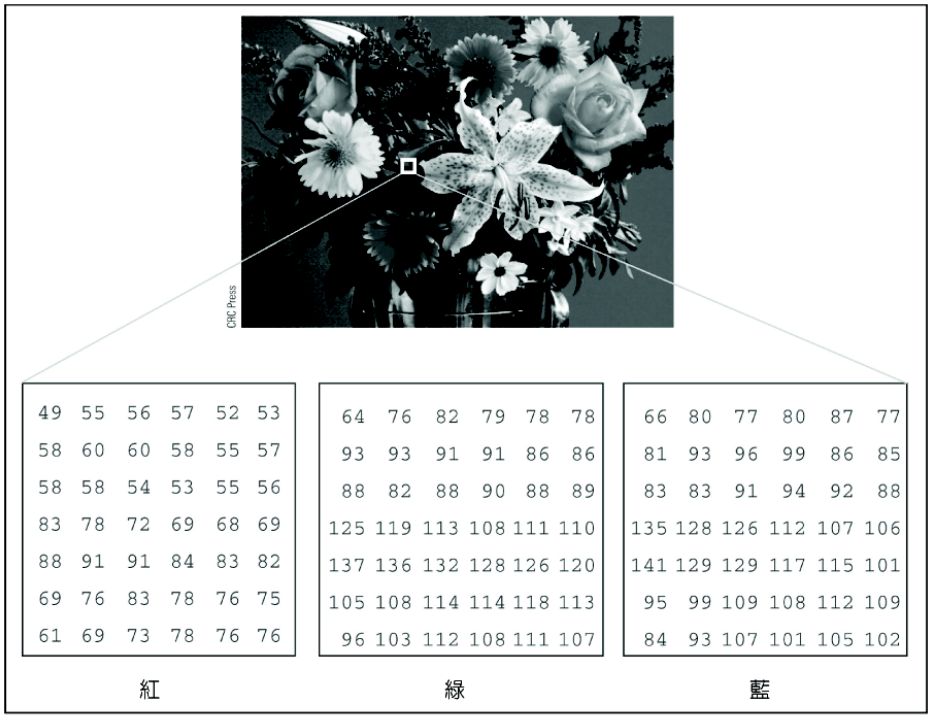
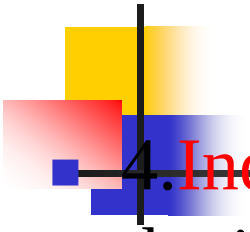


圖1.18 全彩影像



- 4. Indexed: For convenience of storage and file handling, the image has an associated colormap, which is simply a list of all the colord used in that image. Each pixel has a value that does not give its color,but an index to the color in the map.

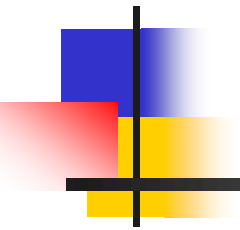
6	10	15	12
5	11	20	10
4	6	10	7

indices

0.1211	0.1211	0.1416
0.1807	0.2549	0.1729
0.2197	0.3447	0.1807
0.1611	0.1768	0.1924
0.2432	0.2471	0.1924
0.2119	0.1963	0.2002

…

Colormap



Chapter2 Images and matlab

導言

2 影像與MATLAB

Grayscale images

- Matlab example:
  - w=imread('tires.tif');
  - figure, imshow(w), pixval on
- figure: create a window to place graphic object.
- imshow: display matrix.
- pixval on: turns on the pixel values in our figure.
- c * r = p

columns row gray value

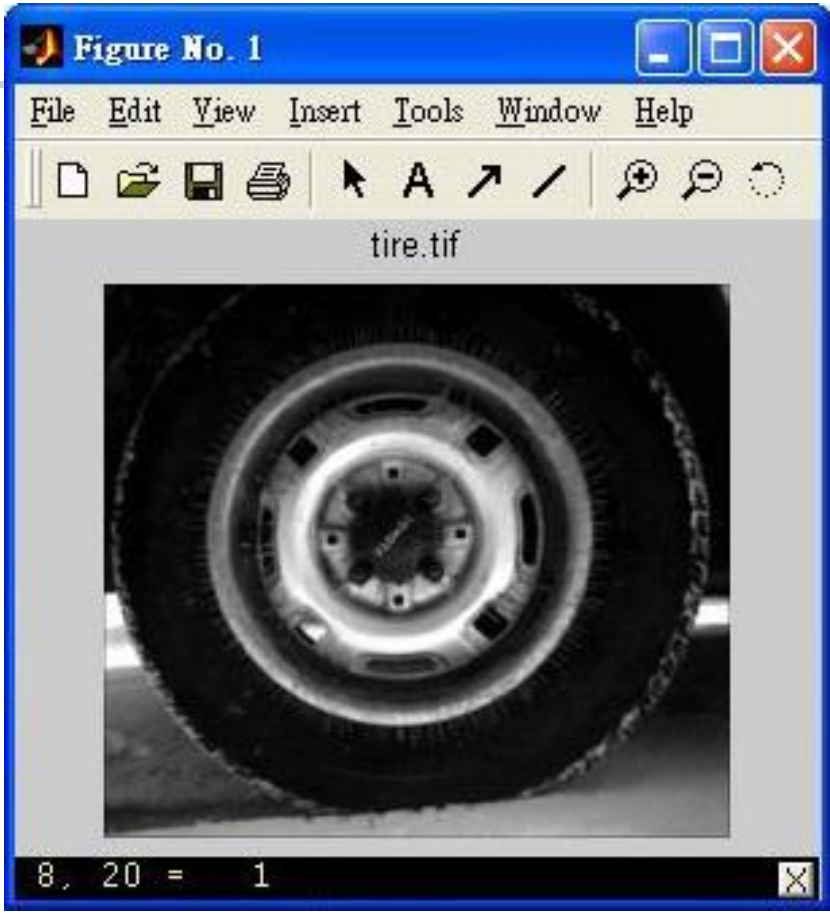


圖2.1 執行了pixval on 指令的袋熊影像

```
w=imread('wombats.tif');
figure, imshow(w), pixval on
```

OR

```
imshow('wombats.tif')
```

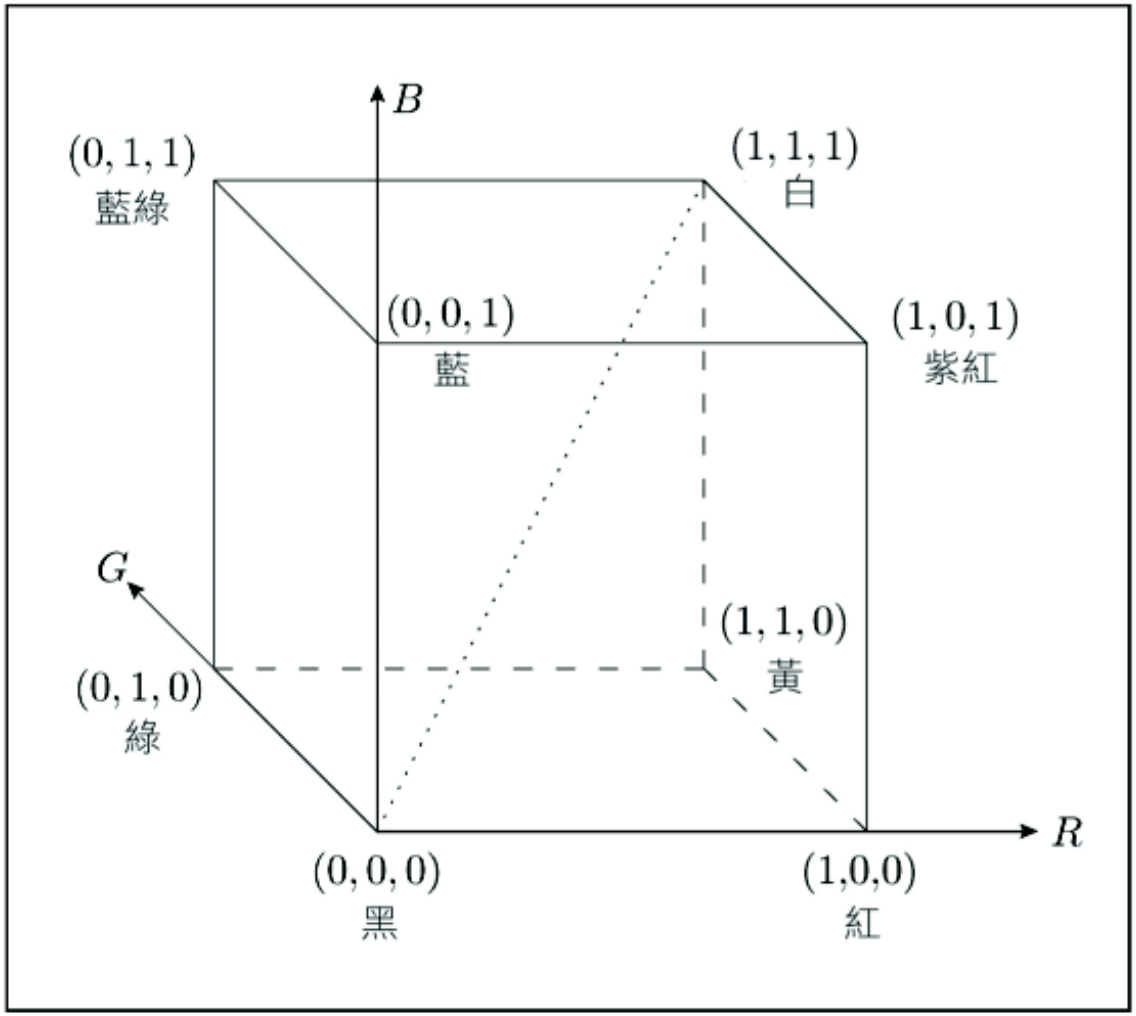


圖 2.2 RGB 色彩模型色彩立方體

```
a=imread('autumn.tif');
>> figure, imshow(a),pixval on
```


```
>> size(a)

ans =

   206   345     3
```

```
>> a(100,200,:)

ans(:,:,1) =   ans(:,:,2) =   ans(:,:,3) =

   75             25             30
```

OR

```
>> impixel(a,200,100)

ans =

   75    25    30
```

RGB (true color) images

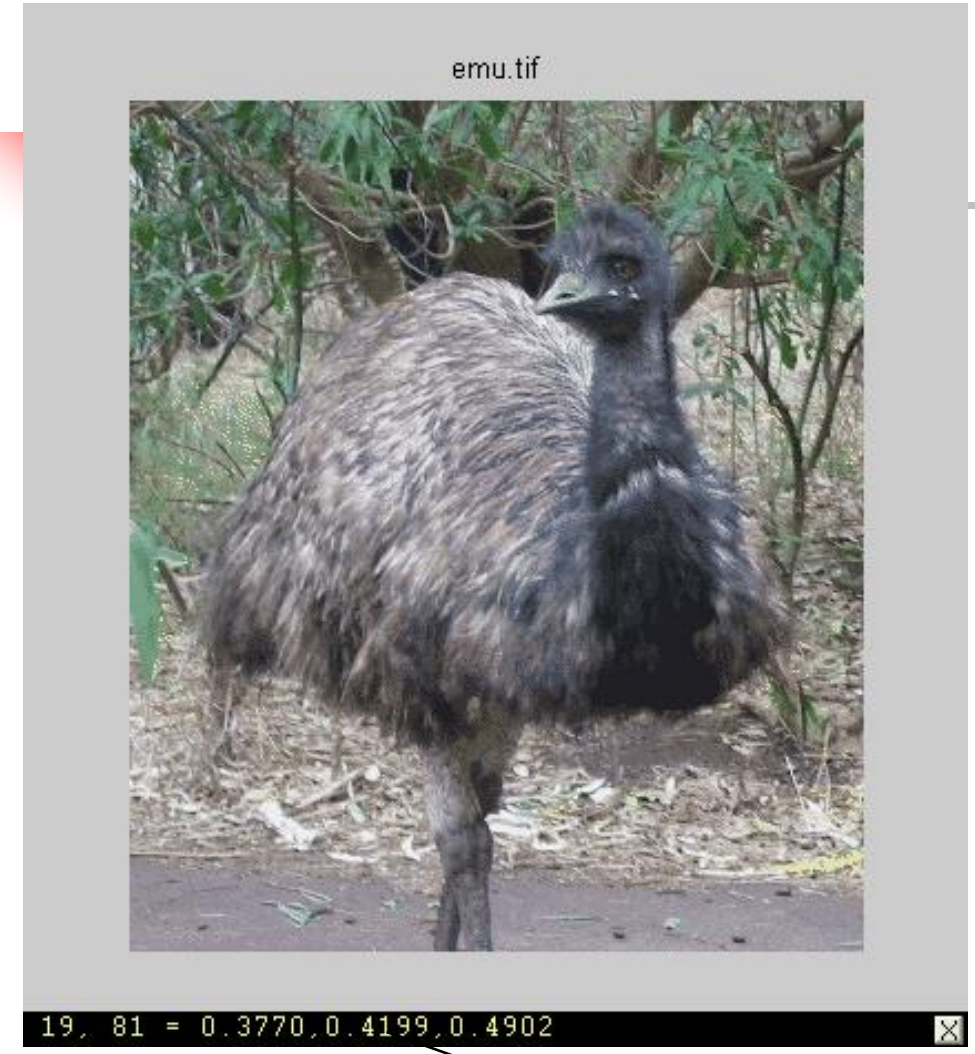
- Matlab example:
  - w=imread('lily.tif');
  - figure, imshow(w), pixval on
  - size(w)

  = 186 230 3

  rows columns pages
  - w(100,200,2)=179
  - w(100,200,1:3)=w(100,200,:)

2.3 Indexed Color Images

<<figure, imshow('emu.tif'), pixval on



Three fractions are between 0 and 1
Why?

2.3 Indexed Color Images

- MATLAB 最常處理的影像格式為索引影像（Indexed Images）
- 顯示此類型影像的語法如下：

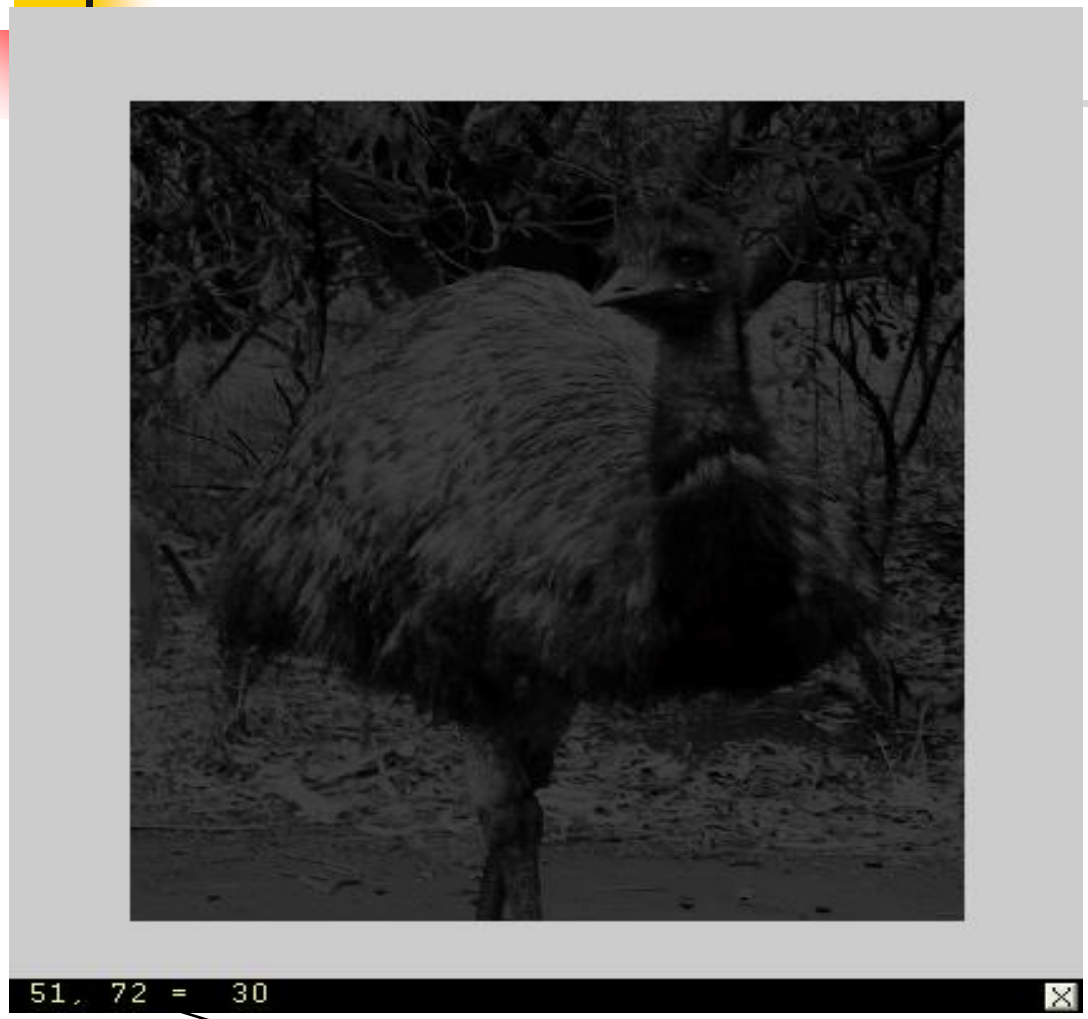
  image(X)

  colormap(map)

  其中X為影像的資料矩陣，map為色盤矩陣。
- 色盤矩陣的大小為Kx3，每個橫列由三個元素所組成，分別是R(紅) 、G(綠)、B(藍) ，每個元素的範圍為0~1
- X的值為1~K，也就是當X(i, j)的值為p，則像素點(i, j)的顏色為map(p, :)這一列的值所決定。

2.3 Indexed Color Images

```
>> em=imread('emu.tif');
>> figure, imshow(em), pixval on
```



em is being interpreted as a sigle grayscale image

2.3 Indexed Color Images

In fact, the image emu.tif is an example of an indexed image

Color map index

```
>> [em,emap]=imread('emu.tif');
>> figure,imshow(em,emap),pixval on
```

OR

```
<<figure, imshow('emu.tif'), pixval on
```

```
>> em(1:5)

ans =

    15    26    16    11    19
```

Indices

```
>> emap(1:5)

ans =

    0.1211    0.1807    0.2197    0.1611    0.2432
```

Color map

Indexed color image

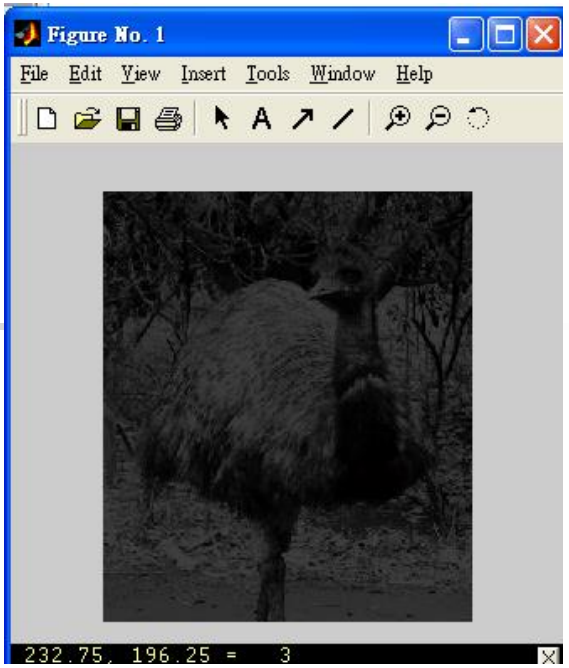
6	10	15	12
5	11	20	10
4	6	10	7

indices

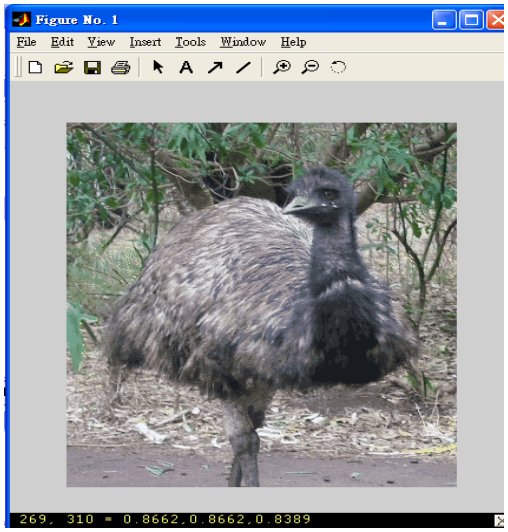
0.1211	0.1211	0.1416
0.1807	0.2549	0.1729
0.2197	0.3447	0.1807
0.1611	0.1768	0.1924
0.2432	0.2471	0.1924
0.2119	0.1963	0.2002
…		

colormap

- Matlab example:
  - w=imread(‘emu.tif’);
  - figure, imshow(w), pixval on



- Matlab example:
  - [w,wmap]=imread(‘emu.tif’);
  - figure, imshow(w, wmap), pixval on



Digital Image Representation

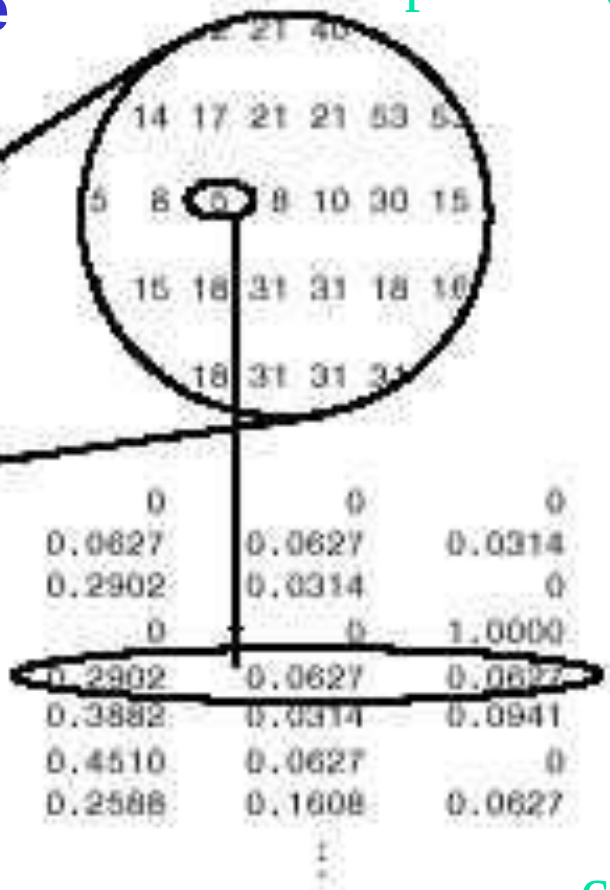
Indexed Images: using colour Maps

- An efficient way of storing colour image information is as an *indexed image*.
  - Indexed images have an associated *colour map.*
  - This is a 3 column matrix, each row contains RGB colour information for a particular colour used in the image.
  - The colour of each pixel is stored as an *index* referring to a row of the colour map.
- **Matlab function:**

```
colormap
```

Structure of an indexed image

pointer (indices)



colormap

Color values store in the colormap

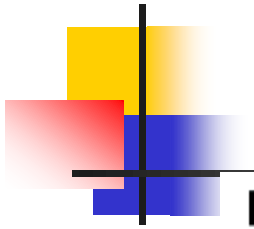
Grayscale and binary image

- imfinfo(‘cameraman.tif’);

```
Filename: [1x49 char]
FileSize: 65240
Format: 'tif'
FormatVersion: []
Width: 256
Height: 256
BitDepth: 8
ColorType: 'grayscale'
```

imfinfo(‘text.tif’);

```
Filename: [1x44 char]
FileSize: 3474
Format: 'tif'
FormatVersion: []
Width: 256
Height: 256
BitDepth: 1
ColorType: 'grayscale'
```



■表2.1 MATLAB 的資料類型

資料型態	描述	範圍
int8	8 位元整數	-128~127
uint8	8 位元無號整數	0~255
int16	16 位元整數	-32768~32767
uint16	16 位元無號整數	0~65535
double	雙精度浮點數	與電腦硬體相關

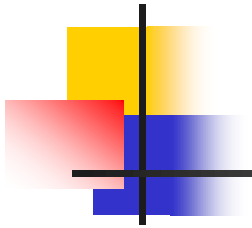
■表2.2 MATLAB 影像轉換

函數	用途	格式
ind2gray	索引轉灰階	y = ind2gray （x,map ）
gray2ind	灰階轉索引	[y,map] = gray2ind (x)
rgb2gray	RGB 轉灰階	y = rgb2gray (x)
gray2rgb	灰階轉RGB	y = gray2rgb (x)
rgb2ind	RGB 轉索引	[y,map] = rgb2ind
ind2rgb	索引轉RGB	y = ind2rgb （x,map ）

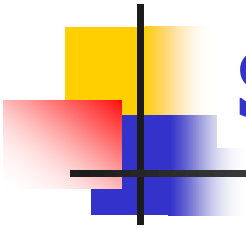
Get information about image

- imfinfo(‘emu.tif’);

```
Filename: 'emu.tif'
FileSize: 119804
Format: 'tif'
FormatVersion: []
Width: 331
Height: 384
BitDepth: 8
ColorType: 'indexed'
```



END



Switching Image Representation

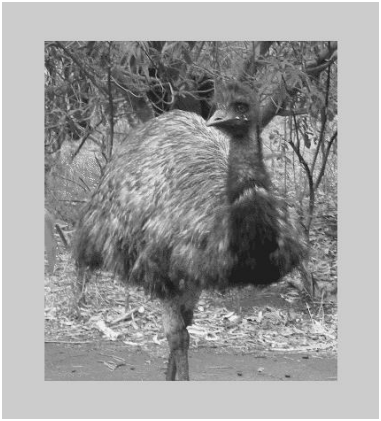
Operation:	**Matlab command:**
Convert between intensity/indexed/RGB format to binary format	dither()
Convert between intensity format to indexed format.	gray2ind()
Convert between indexed format to intensity format.	ind2gray()
Convert between indexed format to RGB format.	ind2rgb()
Convert a regular matrix to intensity format by scaling.	mat2gray()
Convert between RGB format to intensity format.	rgb2gray()
Convert between RGB format to indexed format.	rgb2ind()

Question

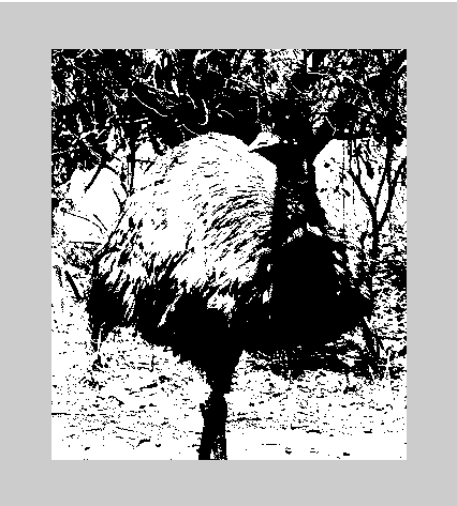
indexed format

RGB format

gray format



binary format



Example

```
[i,map] = imread('emu.tif');
imshow(i);
i1 = ind2rgb(i,map);
figure;  imshow(i1)
i2= ind2gray(i,map);
figure;  imshow(i2)
i3 = im2bw(i,map,0.5);
figure;  imshow(i3)
```

圖片2位元化

```
[i,map] = imread('engineer.tif');
% img = imread(imgPath, 'jpg'); %讀取圖片
level = graythresh(i); %取得標準差
bwimg = im2bw(i,level); %二位元化
figure; imshow(bwimg);
```