



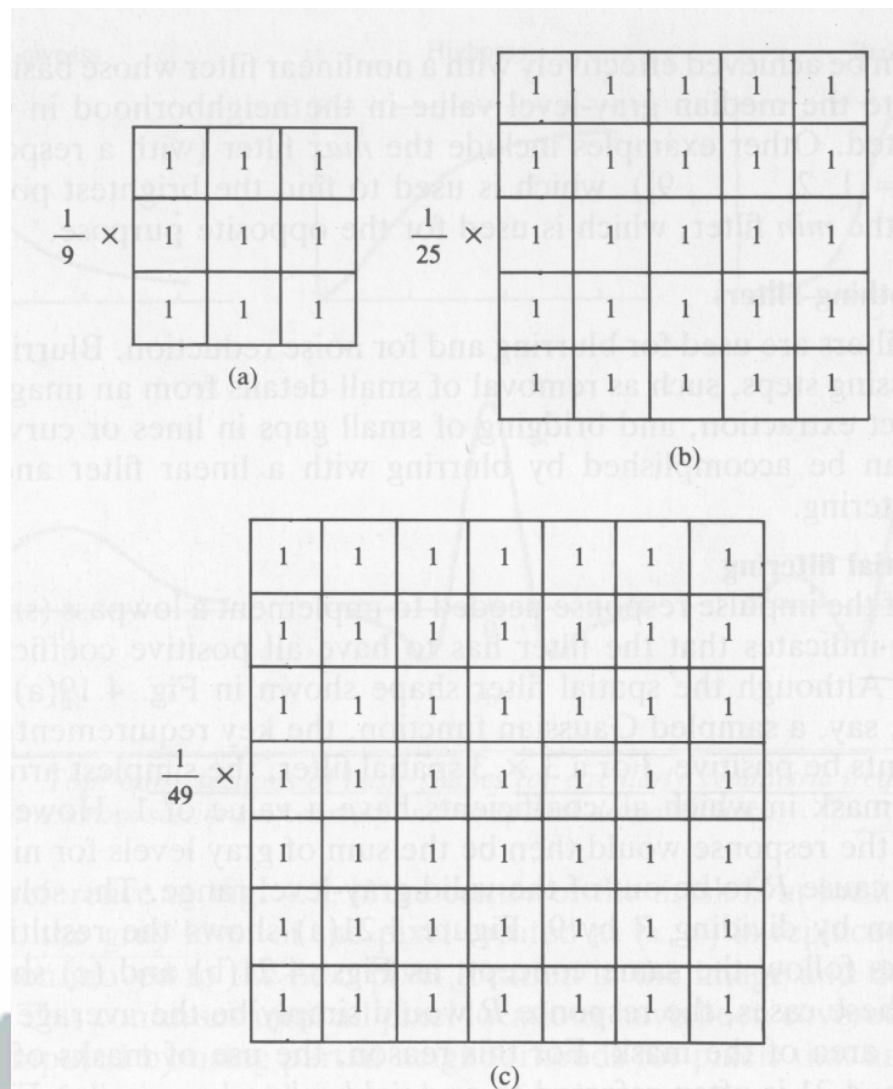
Noise Suppression

- Spatial filters
 - Lowpass spatial filtering
 - Median filtering
- Frequency domain filters
 - Lowpass filtering
 - Band-rejection filtering



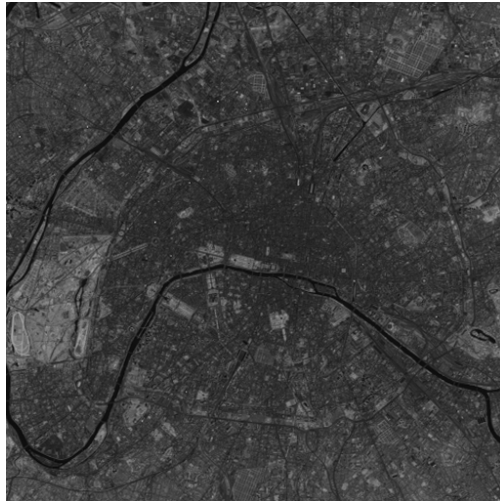
Lowpass Filter

- Blurring and noise reduction (Gaussian noise)

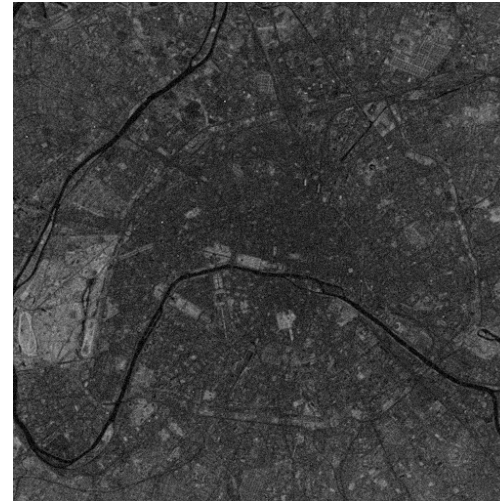


圖片採自Gonzalez, C. R. & Woods, E. R. (1992). Digital Image Processing (p.192). New York: Addison-Wesley.

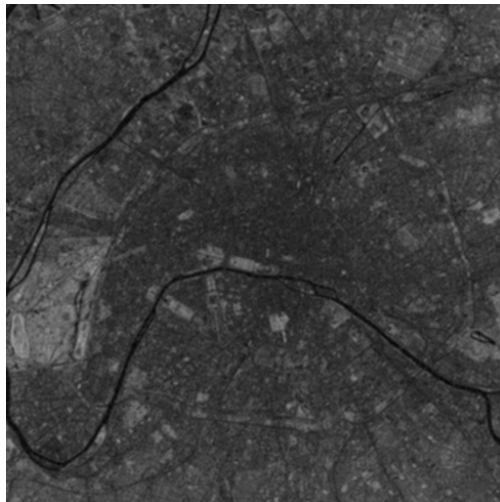
Pattern Computing Laboratory, Center for Space and Remote Sensing Research, NCU.



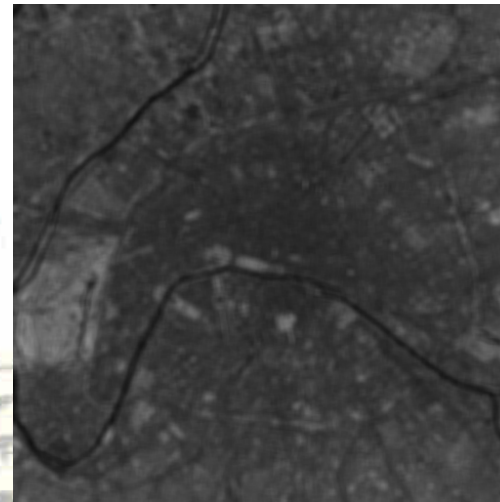
Original



Add Gaussian Noise



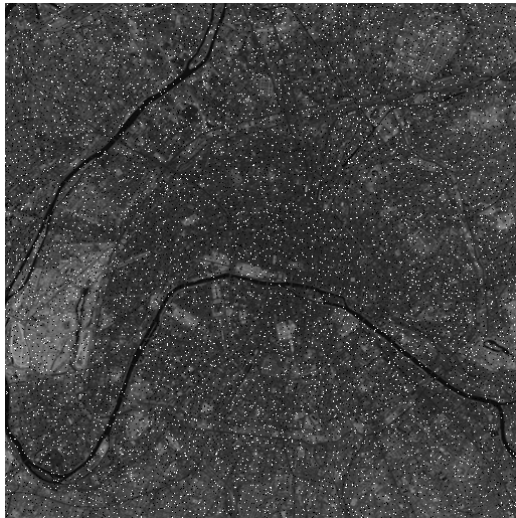
$N = 3$



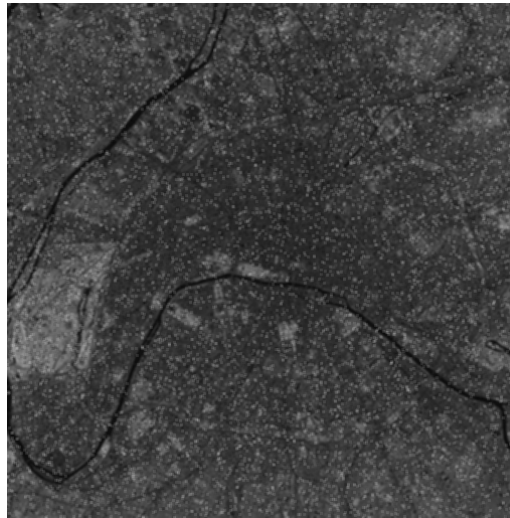
$N = 7$

Median Filter

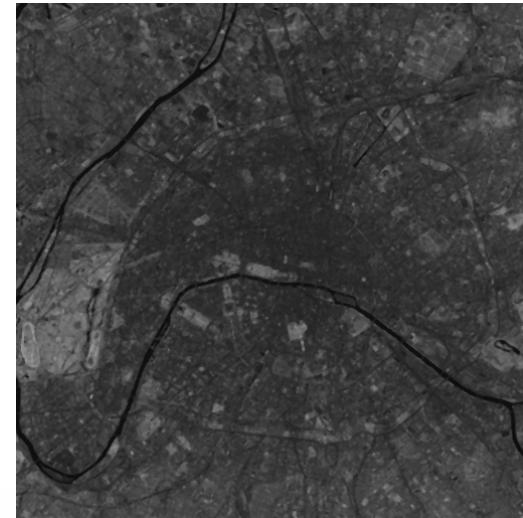
- Salt and Pepper noise
- Median in the mask area



Salt & Pepper noise



Gaussian filter



Medium filter



頻域低通濾波器

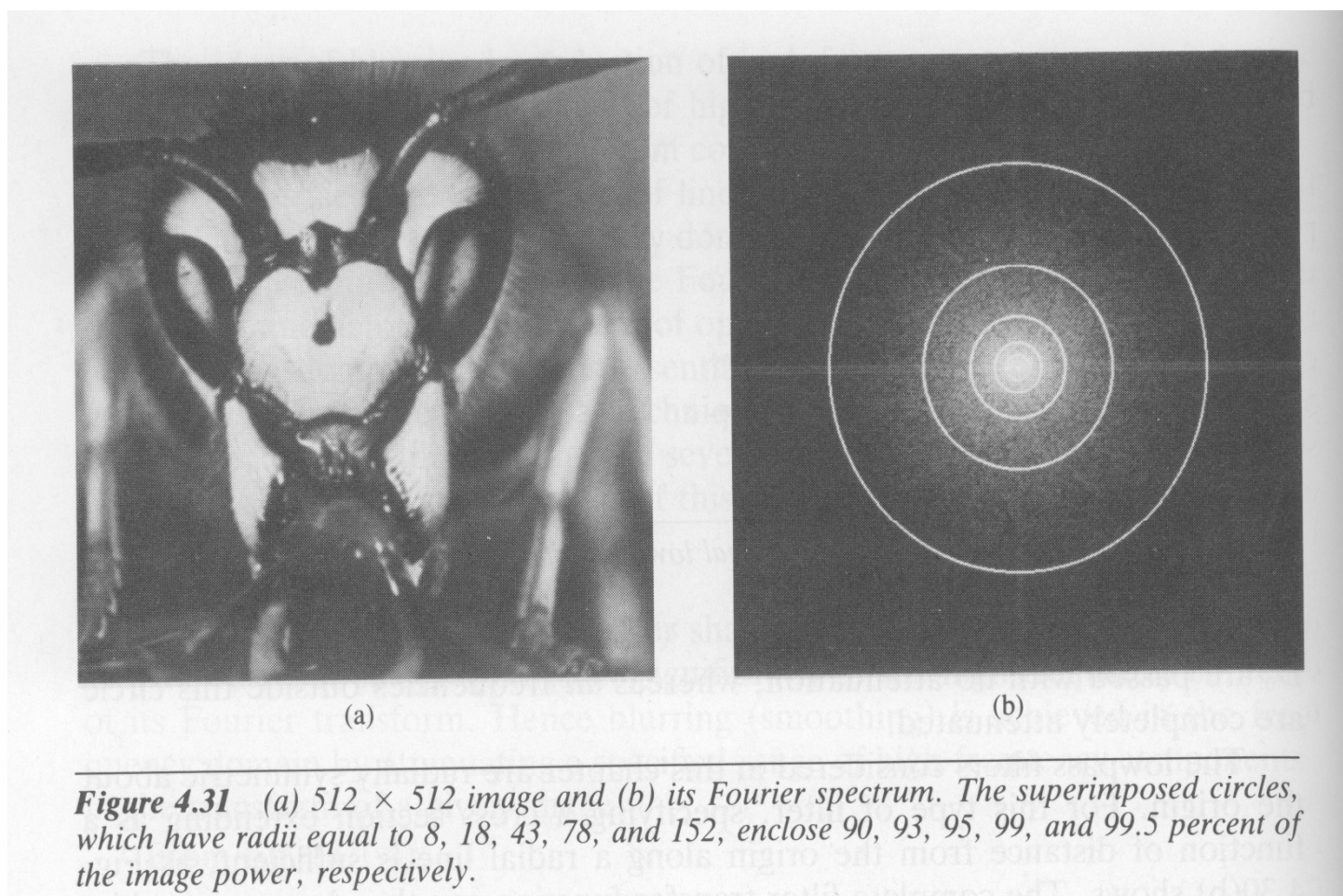
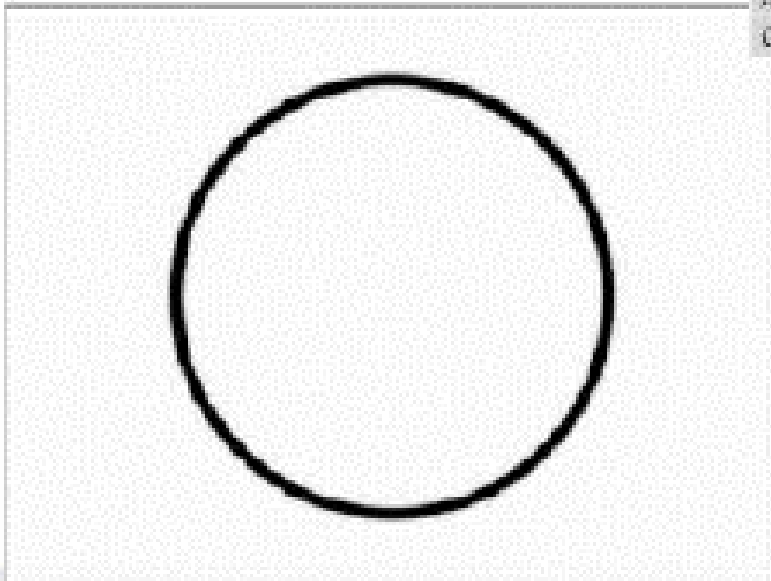
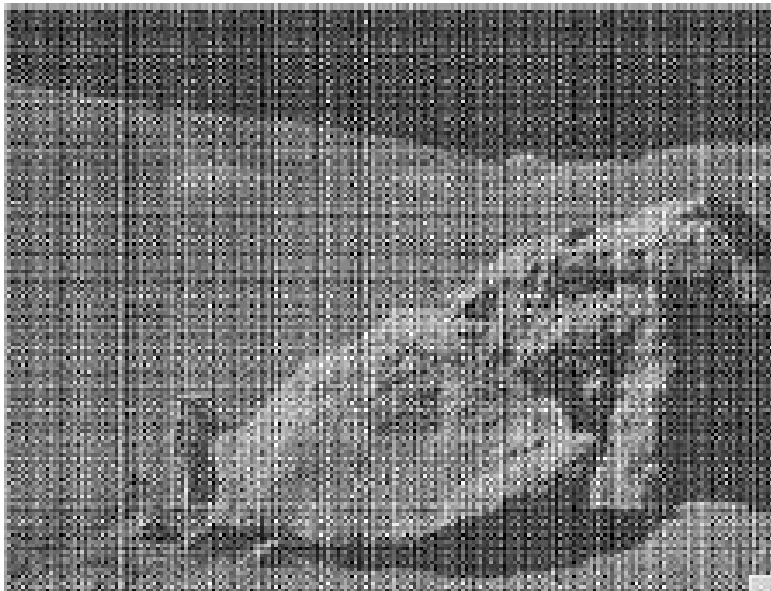


Figure 4.31 (a) 512×512 image and (b) its Fourier spectrum. The superimposed circles, which have radii equal to 8, 18, 43, 78, and 152, enclose 90, 93, 95, 99, and 99.5 percent of the image power, respectively.

圖片採自Gonzalez, C. R. & Woods, E. R. (1992). Digital Image Processing (p.204). New York: Addison-Wesley.



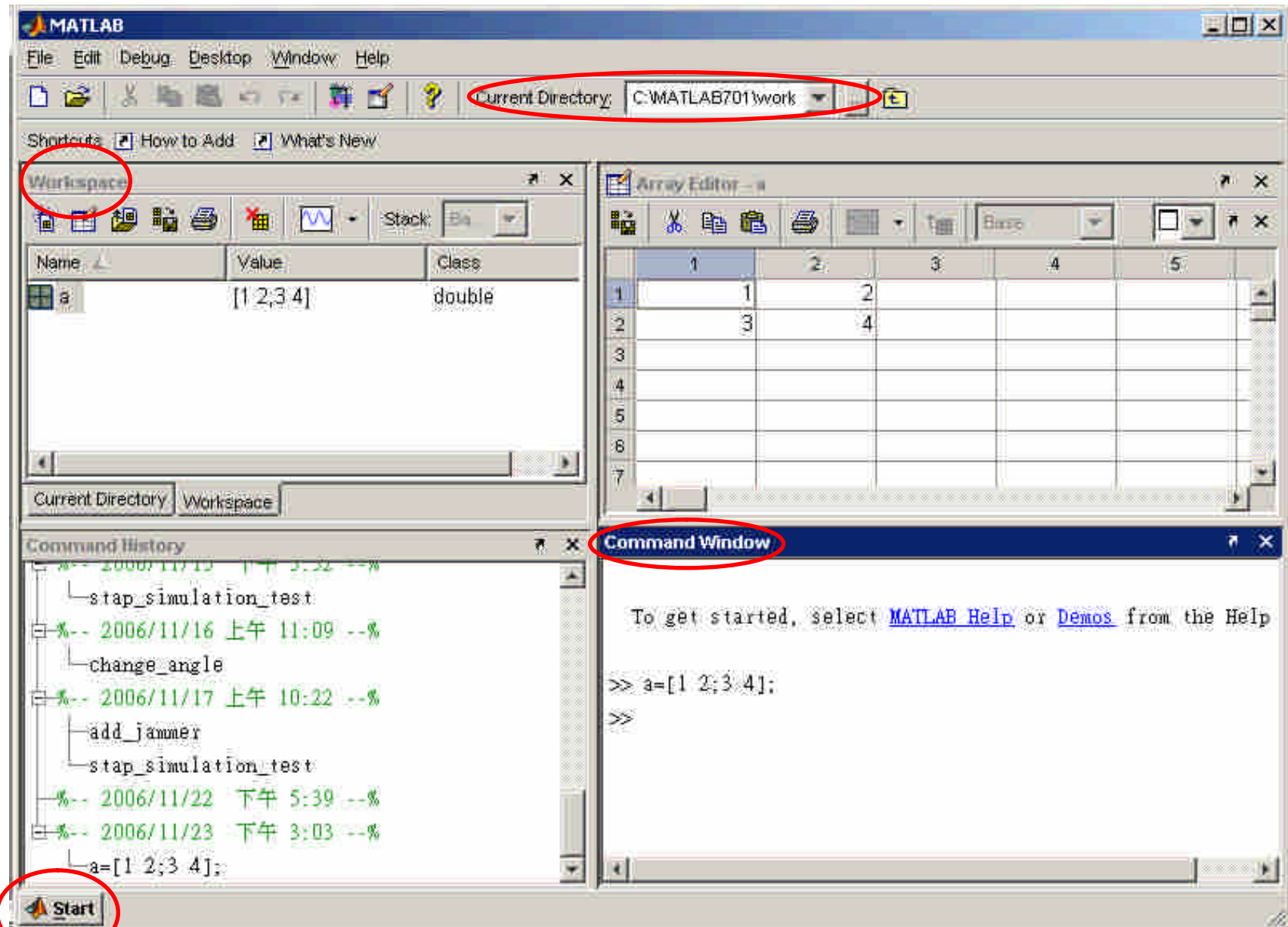
Band Stop Filter



a b
c d

基本影像處理軟體之應用介紹

Matlab視窗環境



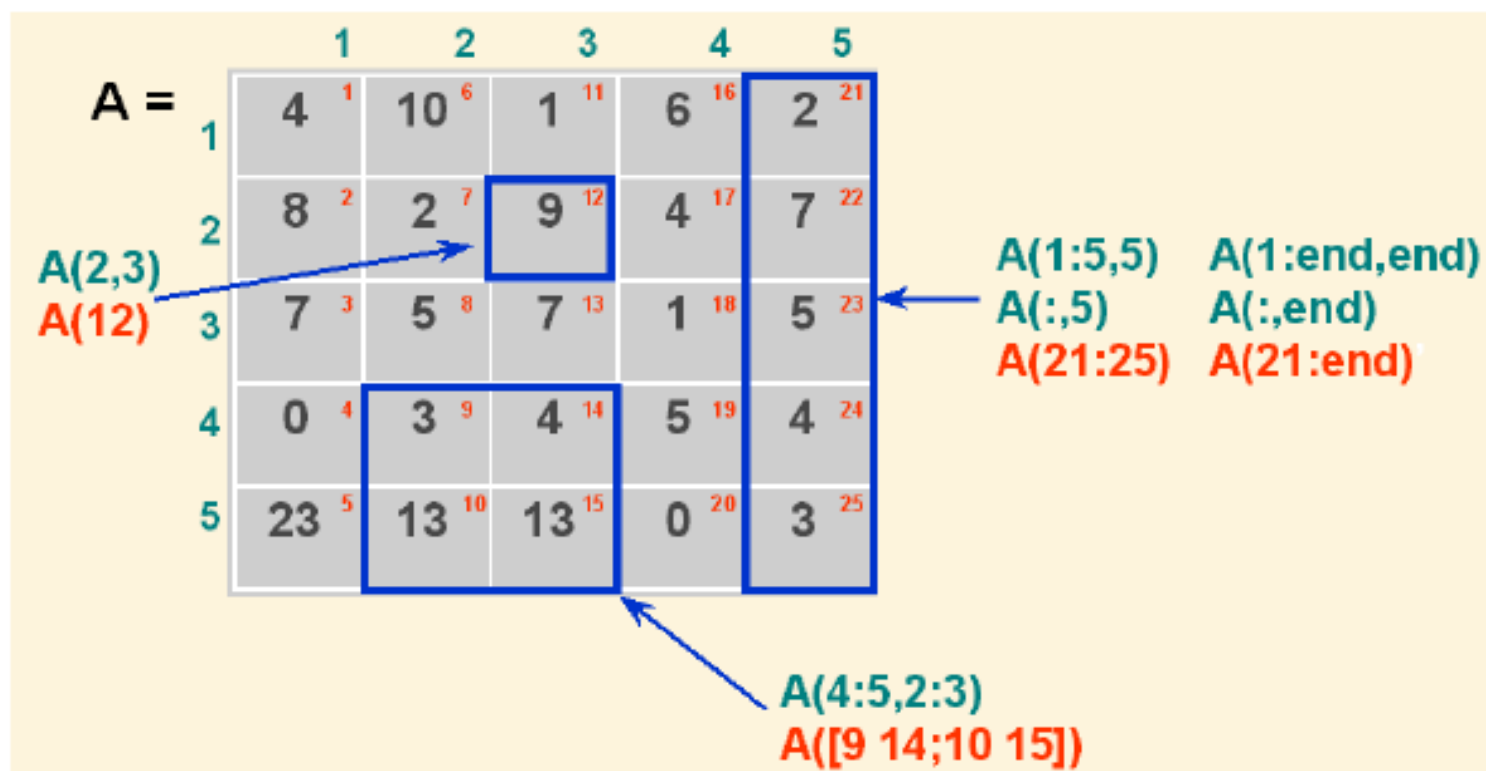
基本概念

1. 程式可撰寫於command window直接執行，或是開啟副檔名為.M的檔案(File→New→M-File)，再將檔名鍵入command window中執行。
2. 程式中命名的參數數值可在Workspace中查詢，雙點擊參數名可查詢詳細資料。
3. 可在Help中(start→Help)查詢指令、工具箱(ToolBox)的使用方法。
4. 逗號和分號皆代表結束敘述，但分號不會將計算結果顯示於command window中。
5. 使用pause可使程式暫時停止執行，ctrl+c 可強制終止程式執行。
6. 將%加在敘述的前面代表此行程式不會執行，可用於註解的添加。

矩陣索引

建立矩陣A

$A = [4 \ 10 \ 1 \ 6 \ 2; \ 8 \ 2 \ 9 \ 4 \ 7; \ 7 \ 5 \ 7 \ 1 \ 5; \ 0 \ 3 \ 4 \ 5 \ 4; \ 23 \ 13 \ 13 \ 0 \ 3];$



矩陣運算

- 矩陣相加

```
>> A = [12 34 56 20];  
>> B = [1 3 2 4];  
>> C = A + B  
C =13 37 58 24
```

- 矩陣相乘

```
>> A = [1; 2];  
>> B = [3, 4, 5];  
>> C = A*B  
C =3 4 5  
    6 8 10
```

- 矩陣內元素對元素運算

```
>> A = [12; 45];  
>> B = [2; 3];  
>> A.*B  
ans =24  
      135  
>> A./B  
ans =6  
      15  
>> A.^2  
ans =144  
      2025
```

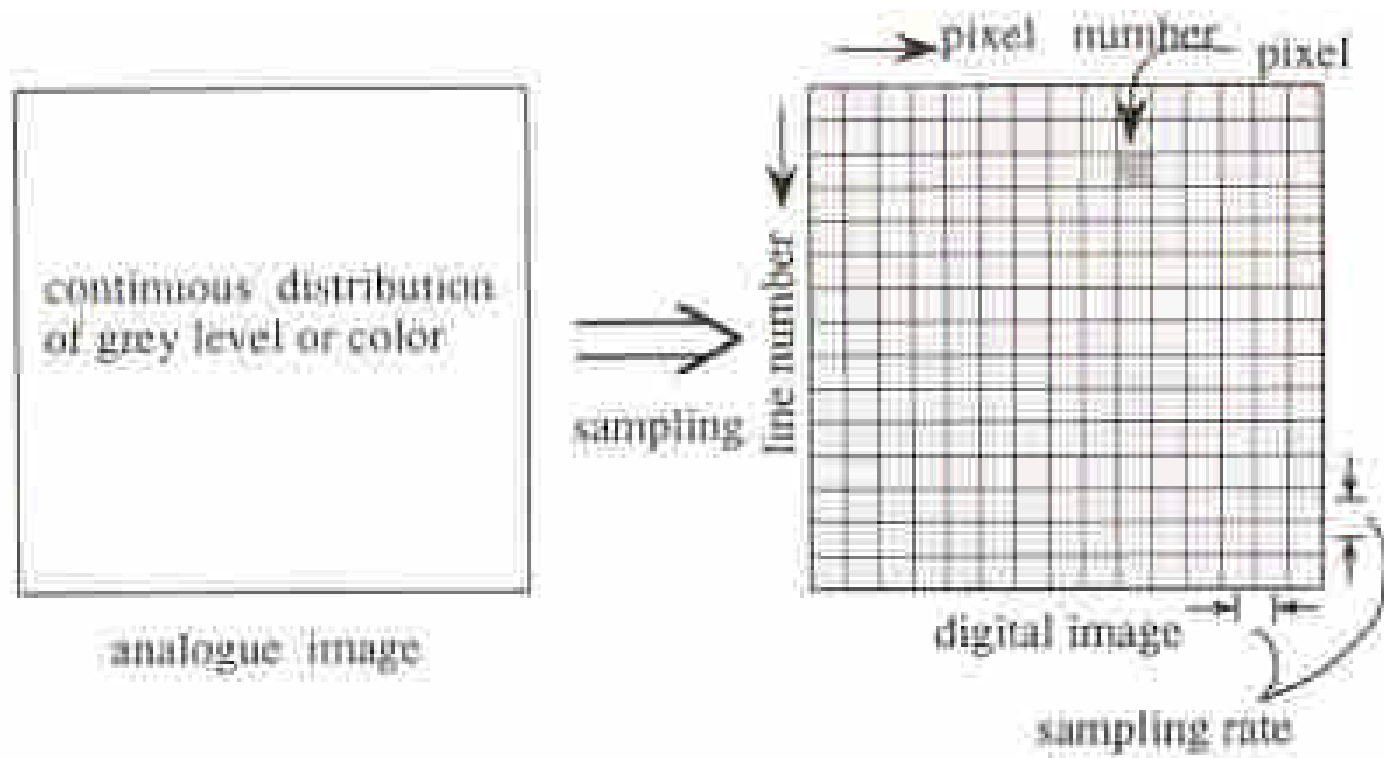
常用數學函數

函數	說明
abs(x)	純量的絕對值或向量的長度
angle(z)	複數 z 的相角 (Phase Angle)
sqrt(x)	開平方
real(z)	複數 z 的實部
imag(z)	複數 z 的虛部
exp(x)	自然指數 e^x
pow2(x)	2 的指數 2^x
log(x)	以 e 為底的對數，即自然對數或 $\ln(x)$
log2(x)	以 2 為底的對數 $\log_2(x)$
log10(x)	以 10 為底的對數 $\log_{10}(x)$

常用統計指令

函數	說明
<code>min(x)</code>	向量 x 的元素的最小值
<code>max(x)</code>	向量 x 的元素的最大值
<code>mean(x)</code>	向量 x 的元素的平均值
<code>median(x)</code>	向量 x 的元素的中位數
<code>std(x)</code>	向量 x 的元素的標準差
<code>diff(x)</code>	向量 x 的相鄰元素的差
<code>sort(x)</code>	對向量 x 的元素進行排序 (Sorting)
<code>length(x)</code>	向量 x 的元素個數
<code>norm(x)</code>	向量 x 的歐氏 (Euclidean) 長度
<code>sum(x)</code>	向量 x 的元素總和

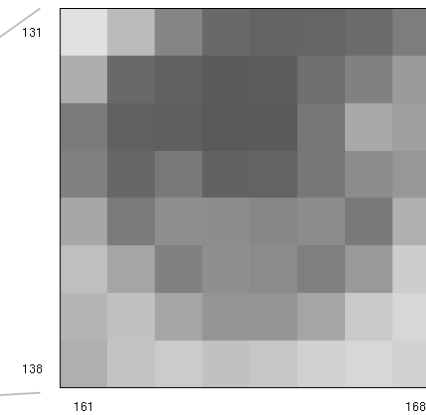
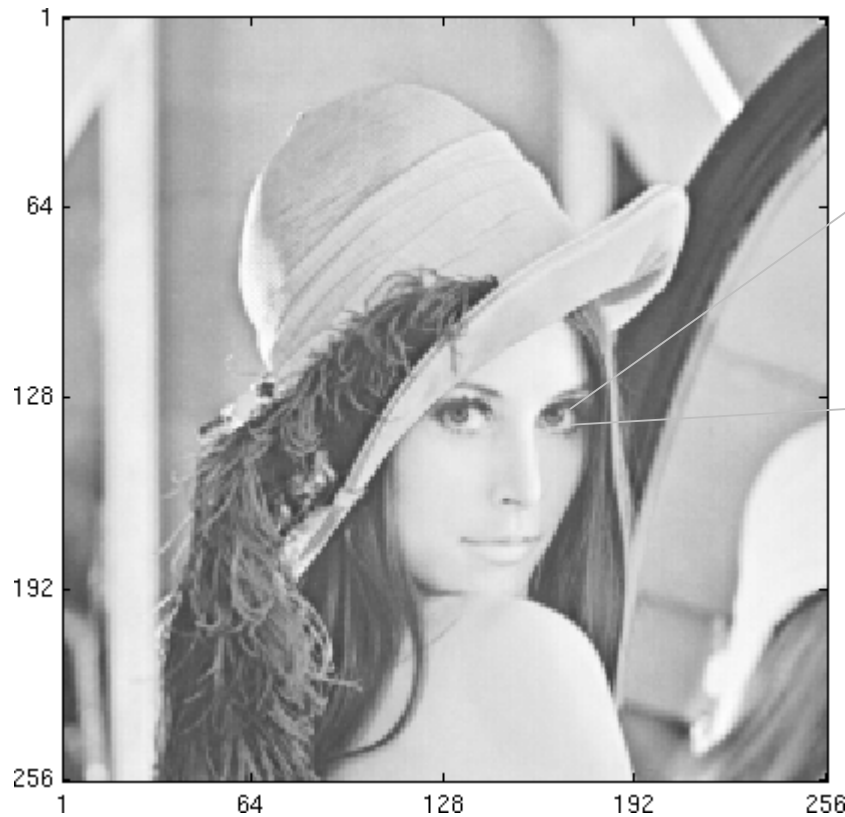
數位影像(類比影像→數位影像)



數位影像範例

```
>> load lena.dat  
>> image(lena)  
>> colormap(gray(256))
```

```
>> image(lena(131:138,161:168))
```



```
>> lena(131:138,161:168)
```

225	187	134	105	100	101	107	126
174	105	97	92	94	112	129	156
124	97	96	89	92	119	170	159
129	103	122	98	100	120	142	152
167	124	143	142	136	142	122	175
191	166	130	143	139	128	154	205
181	194	166	149	149	166	202	215
176	196	203	194	200	209	215	209

基本影像顯示

```
clear all; %清除所有參數
```

```
data=imread( 'slash.bmp' );%將檔名為slash的圖檔讀進並命名為data  
的矩陣，尺寸為270*192
```

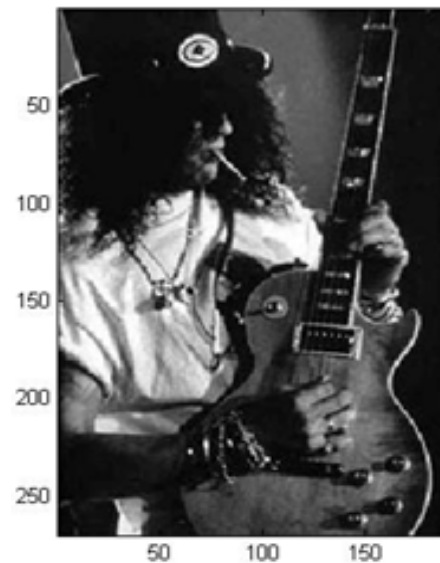
```
data_gray=rgb2gray(data); %將影像從RGB轉為灰階影像
```

```
data_gray=double(data_gray); %將資料型態從unit8轉為double型式
```

```
imagesc(data_gray), colormap(gray); %將影像顯示為灰階影像
```



Original image



Gray image

Image Enhancement

- Point Operation
- Mask Operation
- Fourier Transform
- Color Process

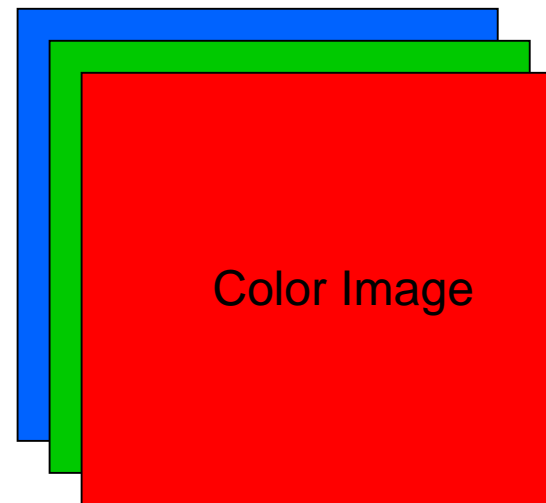
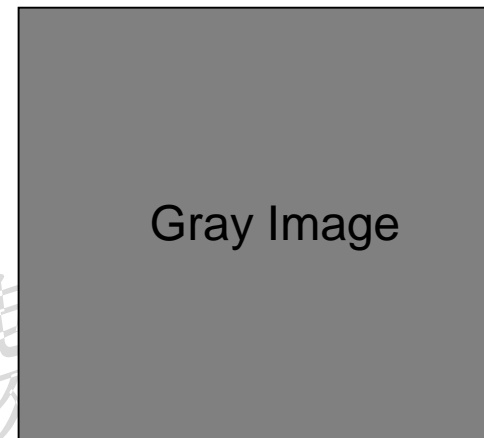
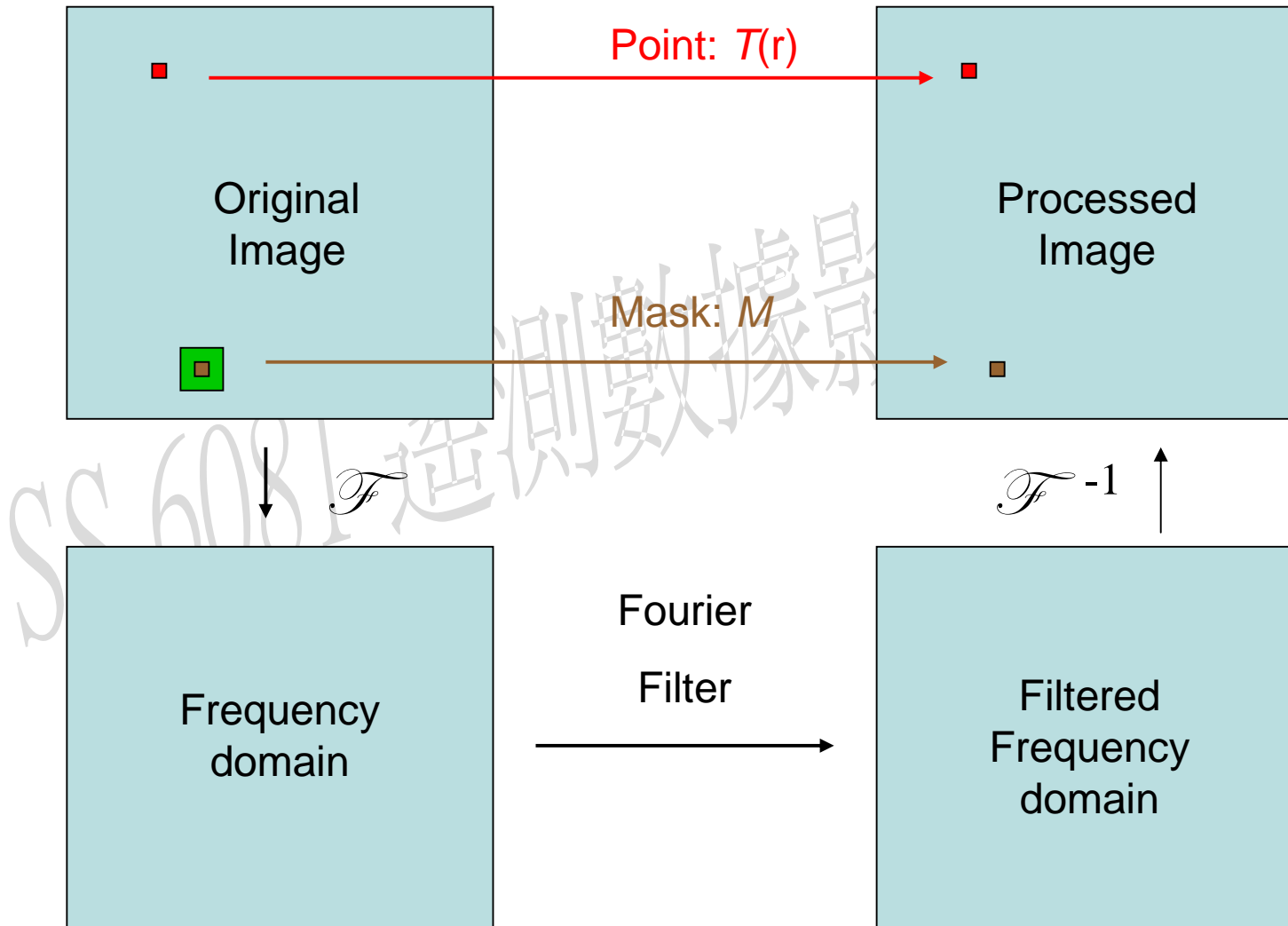


Image Enhancement



Point operation

- Image Negative
- Contrast Stretching
- Gray level slicing
- Histogram operations

SS 6081 遙測數據影像處理 I

Gray-level transformation

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

Where $f(x, y)$ is an original image

$g(x, y)$ is the transformed image

T is a gray-level transformation

Point processing:

These techniques are referred to as point processing if enhancement at any point only depends on its gray-level

Some basic gray level transformations

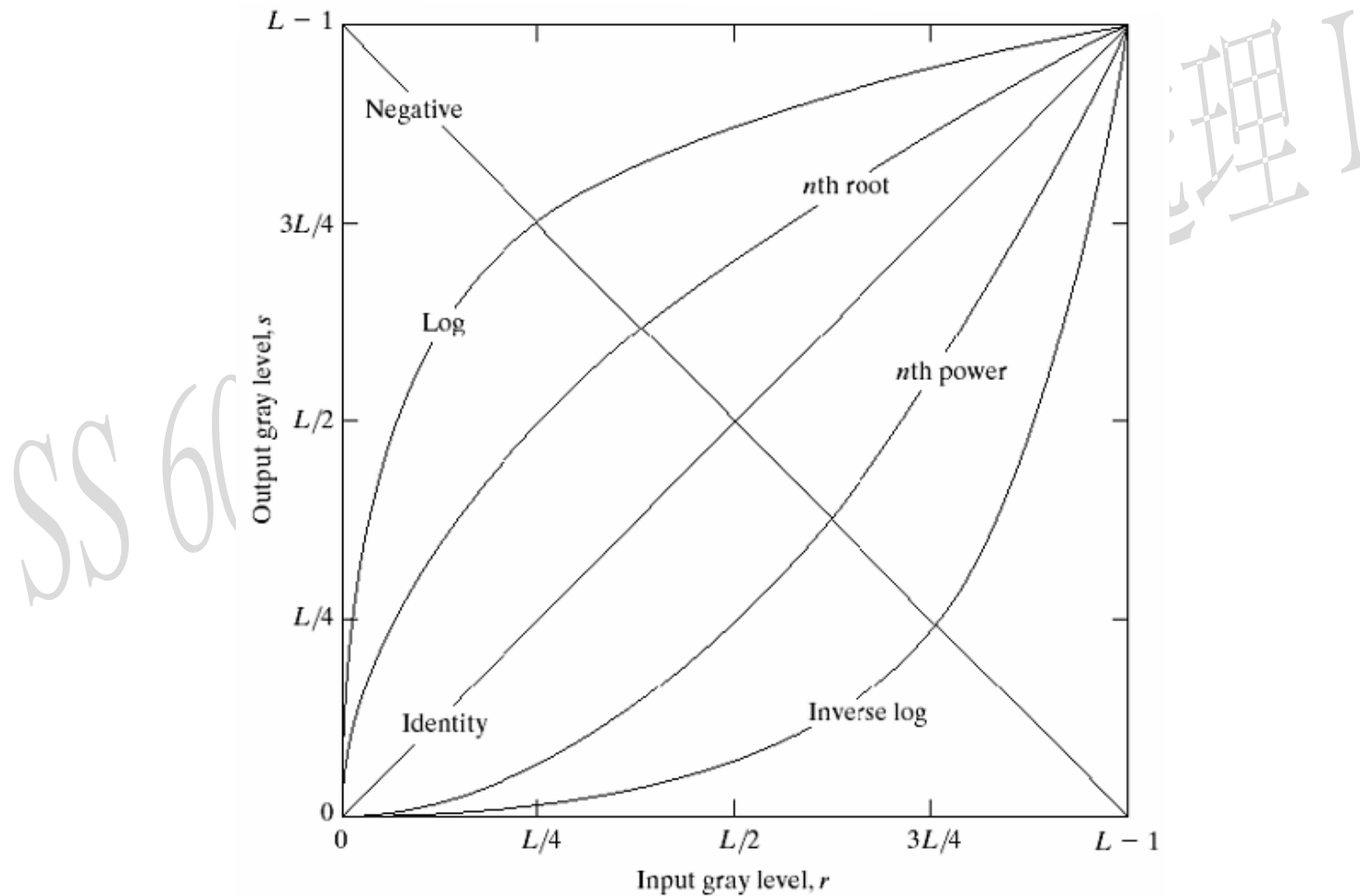
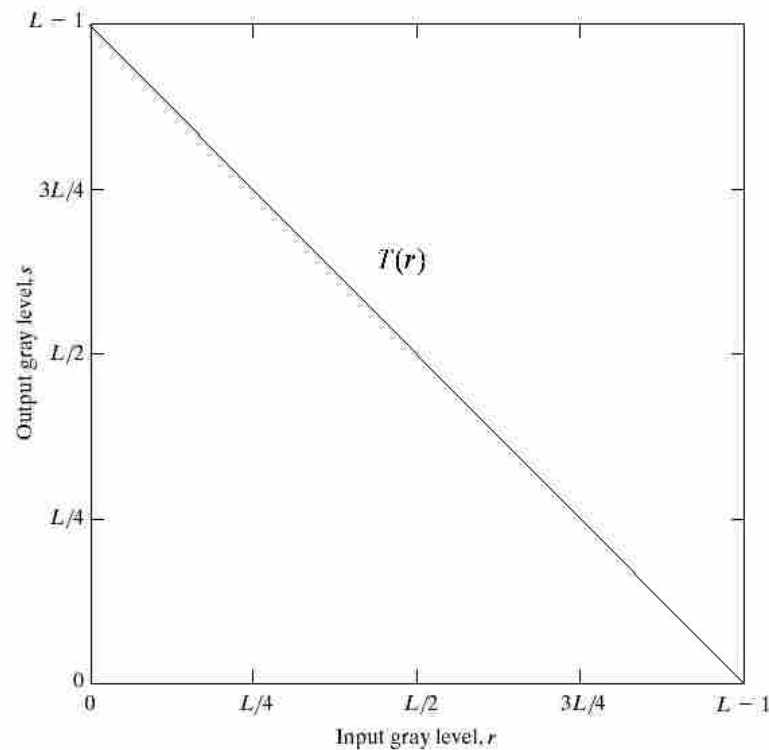


Image negatives

The negative of an image with gray levels in the range $[0, L-1]$ is obtained by the following expression

$$s = L - 1 - r.$$



Transformation function

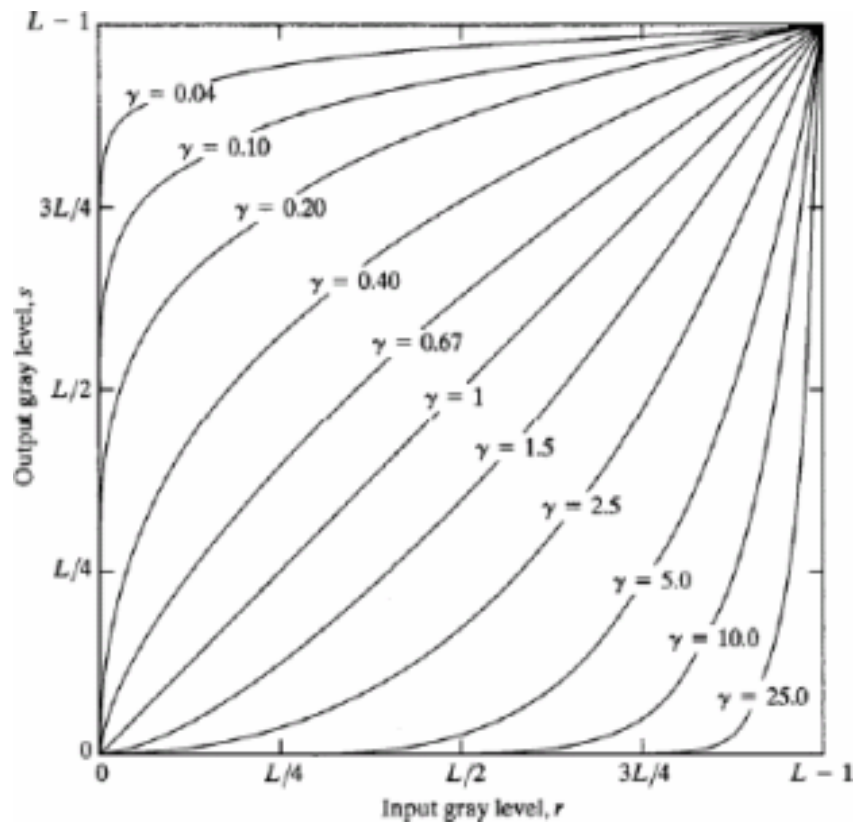


Original Image



Negative Transformation

Power-law transformations



Power-law transformations have the basic form

$$s = cr^\gamma$$

or

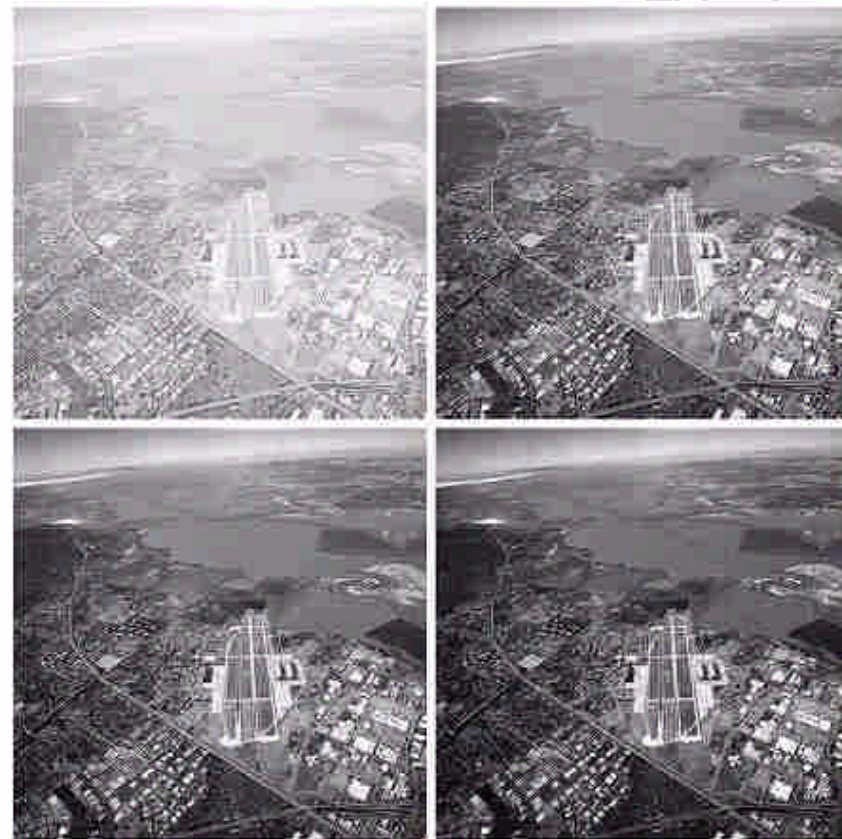
$$s = c(r + \epsilon)^\gamma$$

where c and r are constants, γ and c are positive integer.

Power-Law Transformation for general-purpose contrast manipulation

- (a) original image
- (b) $c=1$ $\gamma=3.0$
- (c) $c=1$ $\gamma=4.0$
- (d) $c=1$ $\gamma=5.0$

$\gamma=3.0$ to 4.0 is best looking (a)



(b)

(c)

(d)

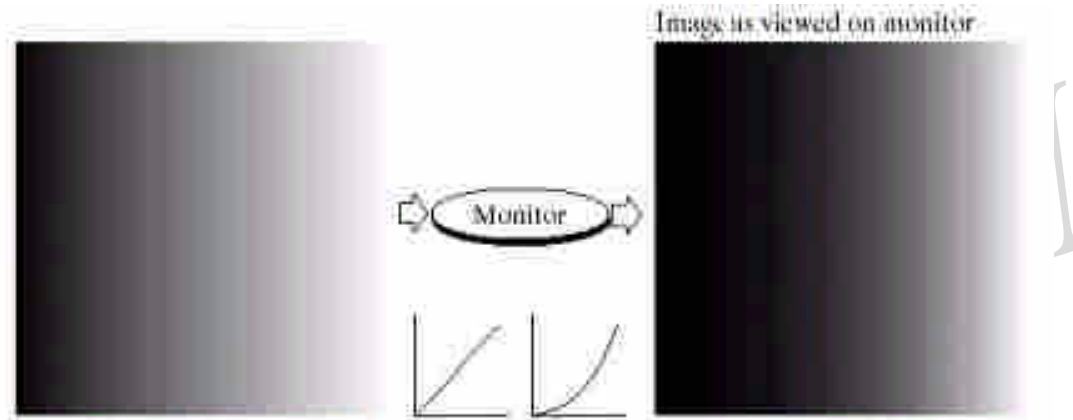
Gamma correction

- A variety of devices used for image capture, printing, and display respond according to a power law.
- Gamma correction:
The process to correct the power-law response phenomena is called gamma correction.
- Ex: CRT
intensity-to-voltage response is a power function. ($\gamma = 1.8$ to 2.5)
=> Gamma correction is performed by inverse power function:

$$s = r^{1/2.5} = r^{0.4}$$

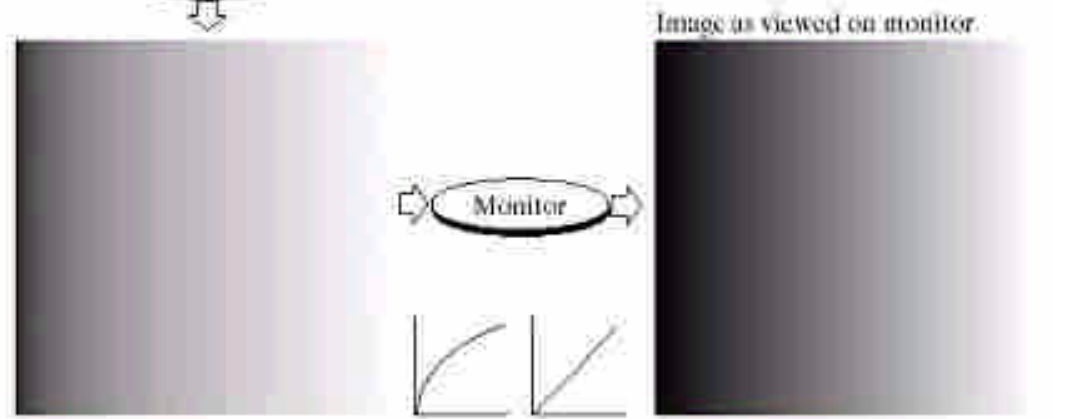
Gamma correction

Before correction



Gamma correction

After correction

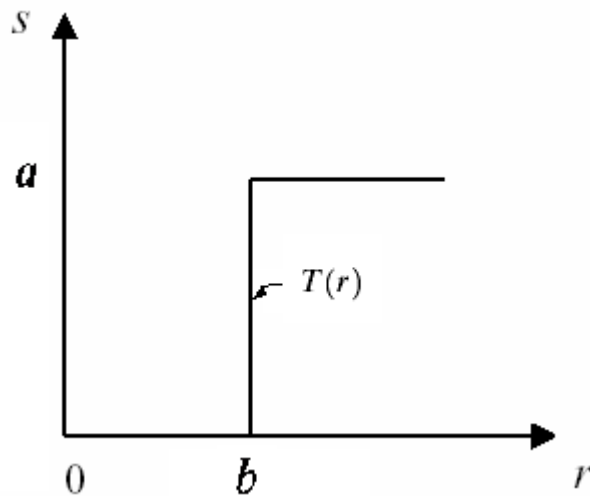


SS 6081

Contrast stretching

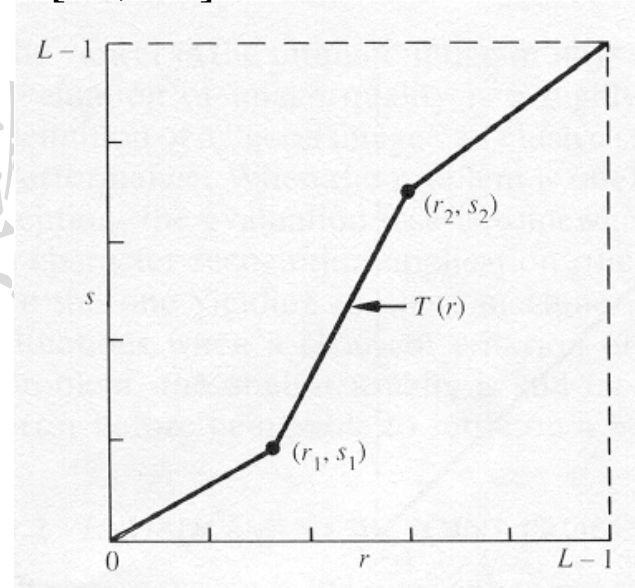
- Increasing the dynamic range of the gray-level

Suppose you are interested in stretching the input intensity values in the interval $[r_1, r_2]$:



$S=0$ if $r < b$
 $S=a$ if $r \geq b$

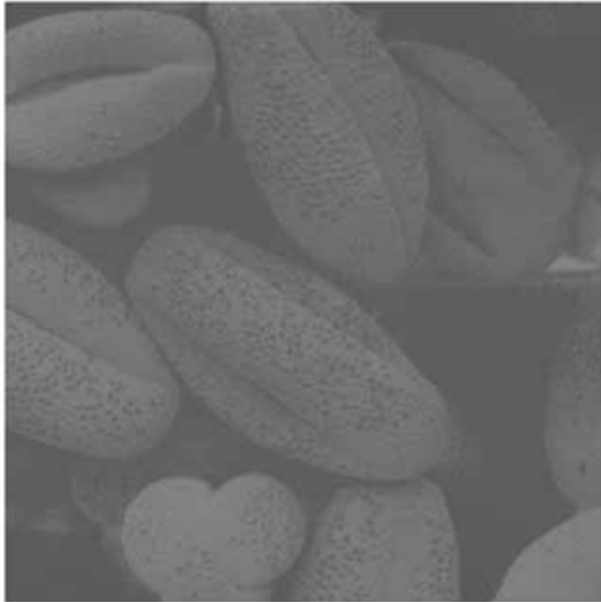
(a)



Note that $(r_1 - r_2) < (s_1 - s_2)$. The gray values in the rang $[r_1, r_2]$ is stretched into the rang $[s_1, s_2]$.

(b)

Example



Original Image



Image processed by
transformation function (a)



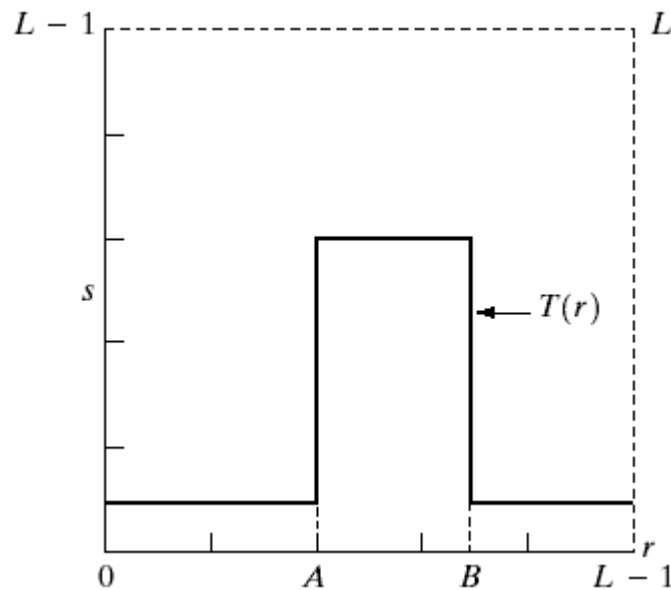
Image processed by
transformation function (b)

$$(r_1, s_1) = (r_{\min}, 0)$$

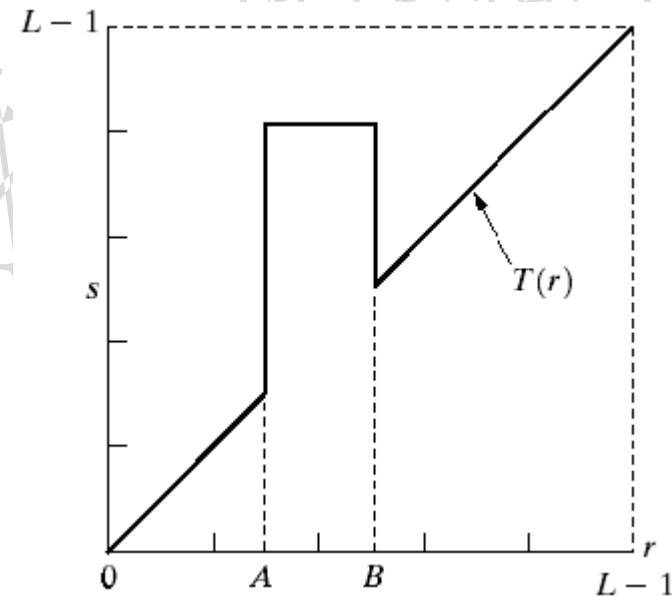
$$(r_2, s_2) = (r_{\max}, L-1)$$

Gray-Level Slicing

- Highlighting a specific range of gray levels in an image

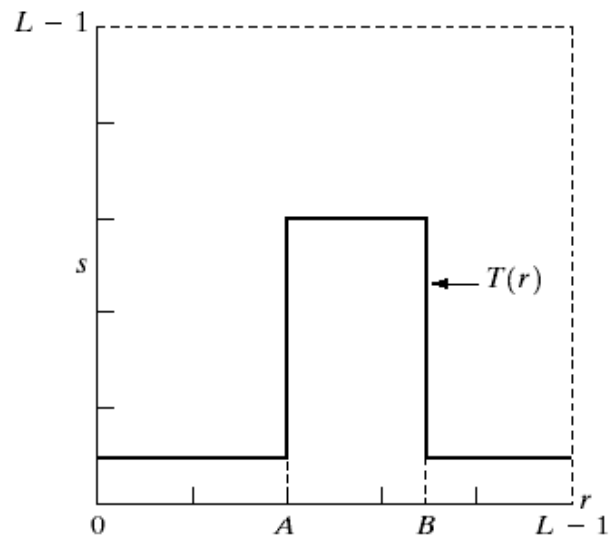


Highlight range $[A,B]$ and reduce all others to a constant level

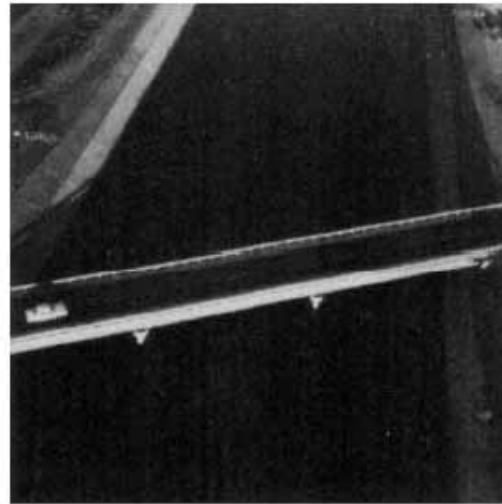


Highlight range $[A,B]$ but preserve all other levels

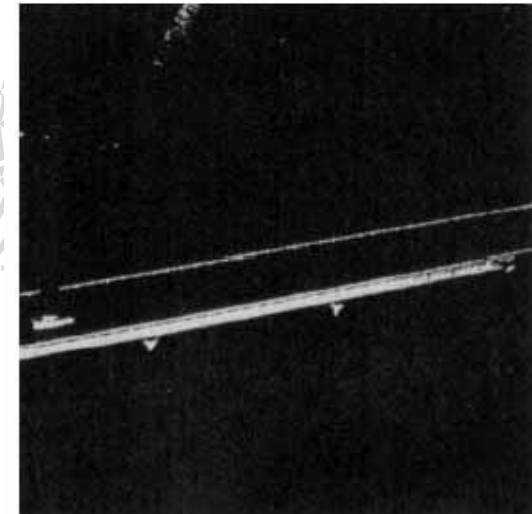
Example



(a)

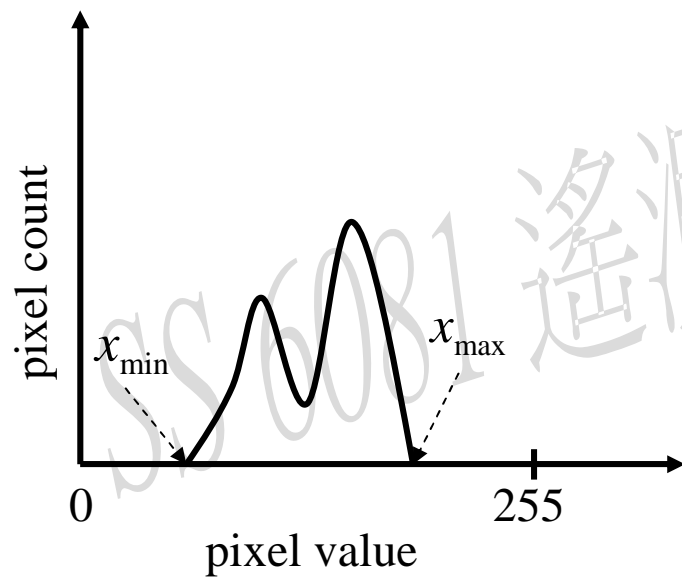


Original Image

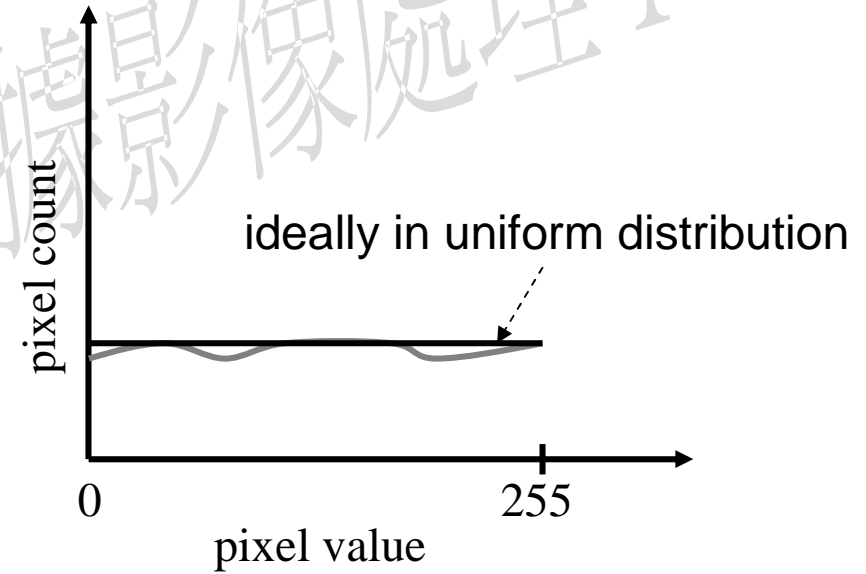
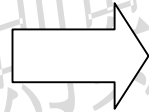


After transformation by
(a) Function

Histogram Equalization

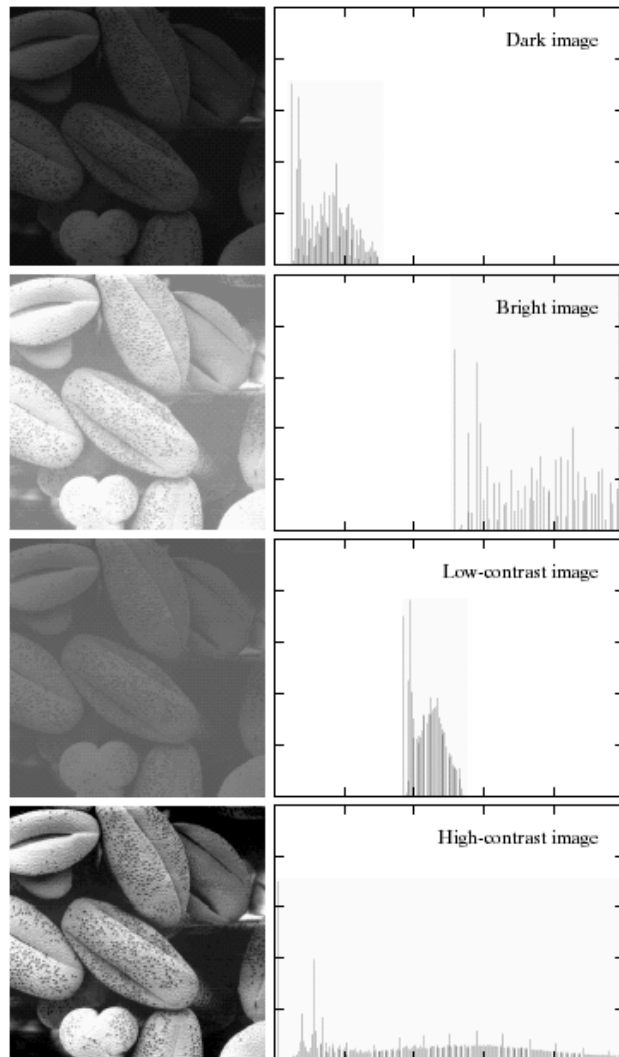


Original histogram



Enhanced histogram

Histogram Equalization



The histogram of a digital image with gray levels in the range $[0, L-1]$ is a discrete function

$$h(r_k) = n_k$$

where r_k is the k th gray level and n_k is the number of pixels in the image having gray level r_k . A normalized histogram is given by

$$P_r(r_k) = \frac{n_k}{n}, \text{ and } \sum_k P_r(r_k) = 1$$

a b

FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Histogram Equalization

By the transformation: $s = T(r)$

Conditions:

- (1) $T(r)$ is single-valued and monotonically increasing
- (2) $0 \leq r \leq 1$ for $0 \leq T(r) \leq 1$

The inverse transformation from s back to r is denoted

$$r = T^{-1}(s), 0 \leq s \leq 1$$

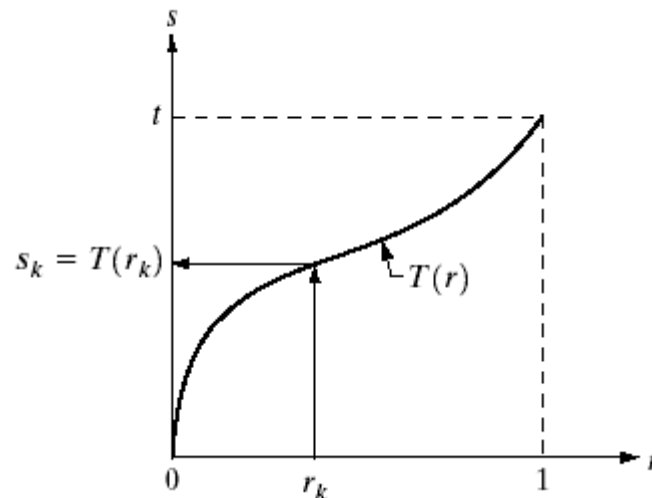


FIGURE 3.16 A gray-level transformation function that is both single valued and monotonically increasing.

Histogram Equalization

The gray levels in an image may be viewed as random variables in the interval $[0, 1]$. Let $P_r(r)$ and $P_s(s)$ denote the probability density functions of random variables r and s , respectively.

The probability density function $P_s(s)$ of the transformed variable s can be obtained using a rather simple formula:

$$p_s(s) = p_r(r) \left| \frac{dr}{ds} \right|$$

A transformation function of particular importance in image processing has the form

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

Histogram Equalization

$$\begin{aligned} \frac{ds}{dr} &= \frac{dT(r)}{dr} \\ &= \frac{d}{dr} \left[\int_0^r p_r(w) dw \right] \Rightarrow p_s(s) = p_r(r) \left| \frac{dr}{ds} \right| \Rightarrow \\ &= p_r(r) \qquad \qquad \qquad p_s(s) = p_r(r) \left| \frac{dr}{ds} \right| \\ & \qquad \qquad \qquad = p_r(r) \left| \frac{1}{p_r(r)} \right| \\ & \qquad \qquad \qquad = 1 \quad 0 \leq s \leq 1 \end{aligned}$$

the form of $P_s(s)$ given above as a *uniform* probability density function.

Discrete type

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

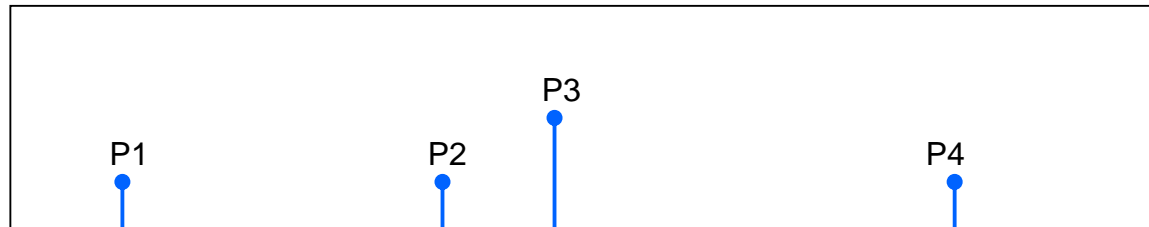
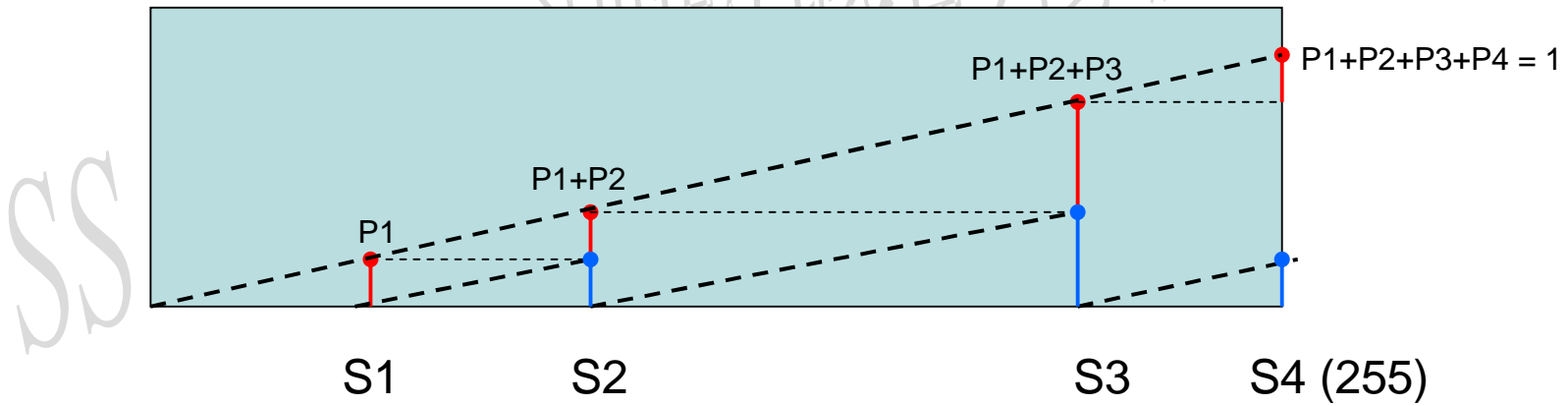
$$\begin{aligned} s_k = T(r_k) &= \sum_{j=0}^k p_r(r_j) \\ &= \sum_{j=0}^k \frac{n_j}{n} \quad k = 0, 1, 2, \dots, L - 1 \end{aligned}$$

Where n is the total number of pixels in the image, n_k is the number of pixels that have gray level r_k , and L is the total number of possible gray levels in the image.



$$\text{slope} = \frac{p_1}{S_1 - 0} = \frac{p_1 + p_2}{S_2 - 0} = \dots = \frac{p_1 + p_2 + p_3 + p_4}{S_4 - 0} = \frac{1}{255}$$

$$\text{slope} = \frac{p_1}{S_1 - 0} = \frac{p_2}{S_2 - S_1} = \dots = \frac{p_4}{S_4 - S_3} = \frac{1}{255}$$



same result

Example:

- Consider an 8-level 64 x 64 image with gray values (0, 1, ..., 7). The normalized gray values are (0, 1/7, 2/7, ..., 1). The normalized histogram :

$$s_k = T(r_k) = \sum_{j=0}^k p_r(r_j)$$

$$0 \leq k \leq L-1$$

k	r_k	n_j	$P(r_k) = n_k / n$
0	0	30	0.0036
1	1/7	50	0.0061
2	2/7	100	0.0122
3	3/7	1500	0.1829
4	4/7	2300	0.2804
5	5/7	4000	0.4878
6	6/7	200	0.0243
7	1	20	0.0024

• Applying the transformation, $s_k = T(r_k) = \sum_{j=0}^k p_r(r_j)$ we have

$$s_0 = \sum_{j=0}^0 \frac{n_j}{n} = \frac{n_0}{n} = \frac{30}{8200} = 0.0037 \approx \frac{0}{7}$$

$$s_1 = \sum_{j=0}^1 \frac{n_j}{n} = \frac{n_0 + n_1}{n} = \frac{30 + 50}{8200} = \frac{80}{8200} = 0.0098 \approx \frac{0}{7}$$

$$s_2 = \sum_{j=0}^2 \frac{n_j}{n} = \frac{n_0 + n_1 + n_2}{n} = \frac{30 + 50 + 100}{8200} = \frac{180}{8200} = 0.022 \approx \frac{0}{7}$$

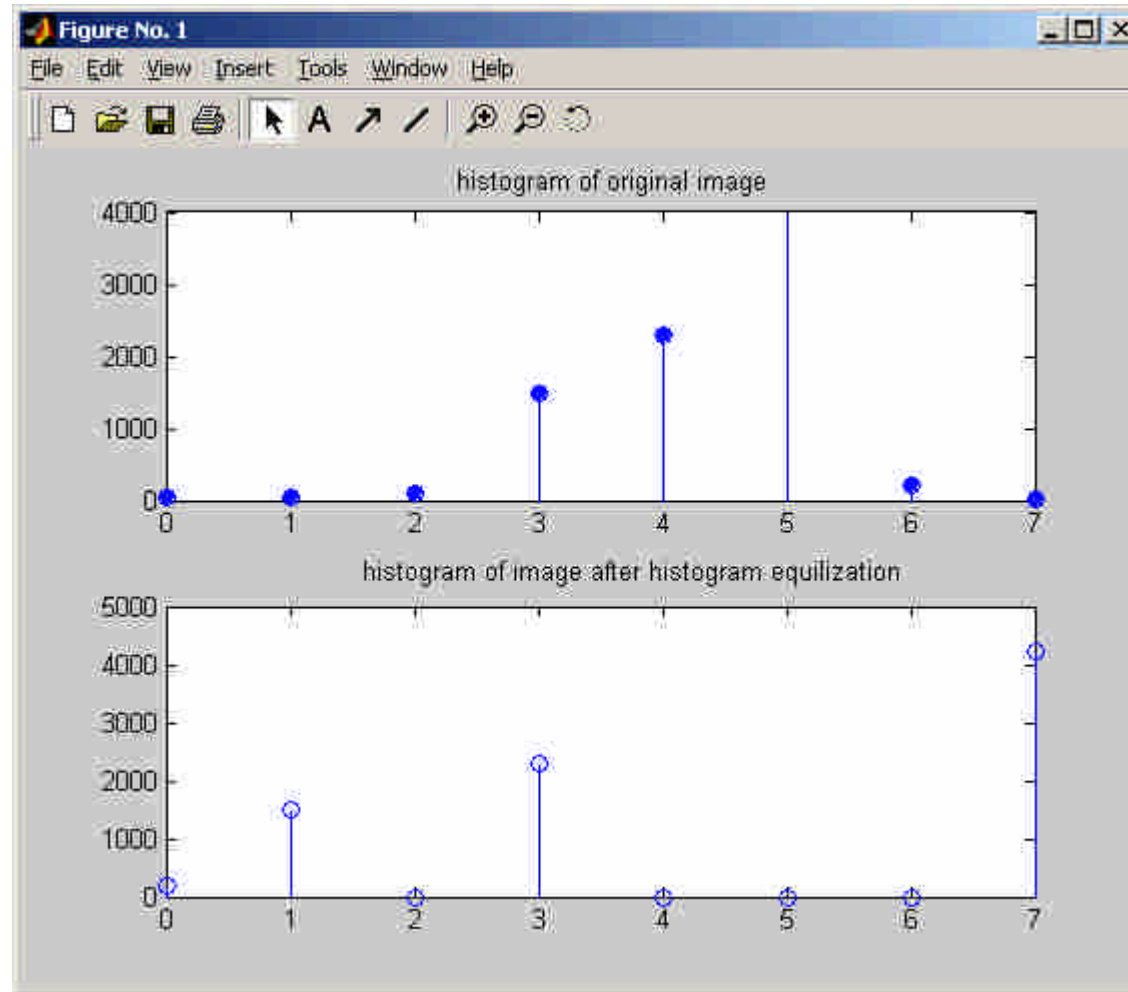
$$s_3 = \sum_{j=0}^3 \frac{n_j}{n} = \frac{30 + 50 + 100 + 1500}{8200} = \frac{1680}{8200} = 0.205 \approx \frac{1}{7}$$

$$s_4 = \sum_{j=0}^4 \frac{n_j}{n} = \frac{30 + 50 + 100 + 1500 + 2300}{8200} = \frac{3980}{8200} = 0.485 \approx \frac{3}{7}$$

$$s_5 = \sum_{j=0}^5 \frac{n_j}{n} = \frac{30 + 50 + 100 + 1500 + 2300 + 4000}{8200} = \frac{7980}{8200} = 0.973 \approx \frac{7}{7}$$

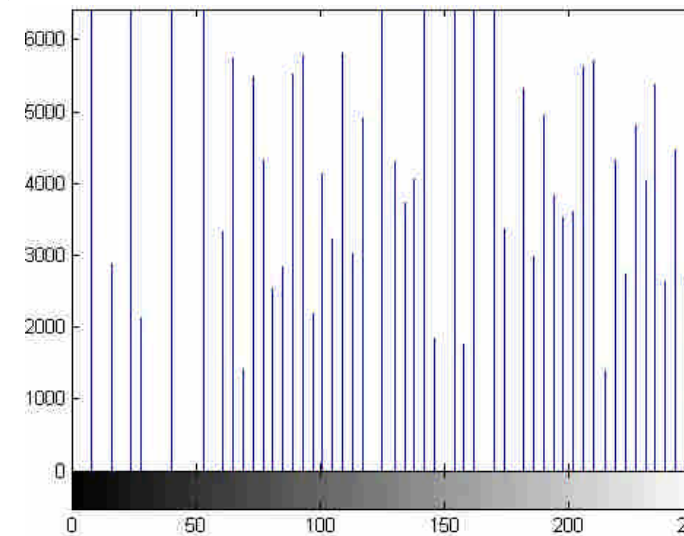
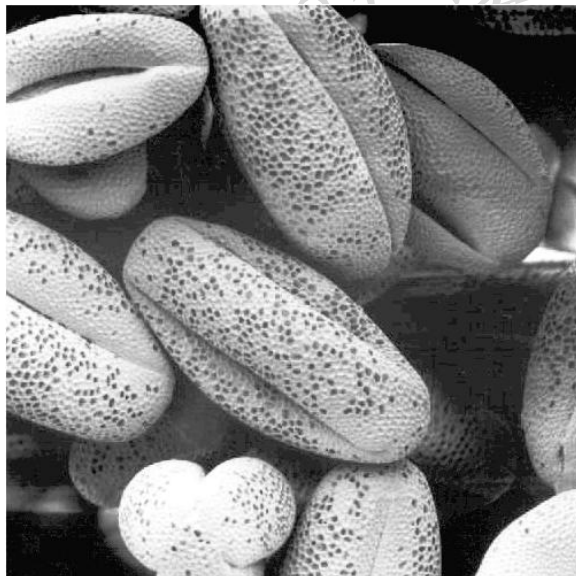
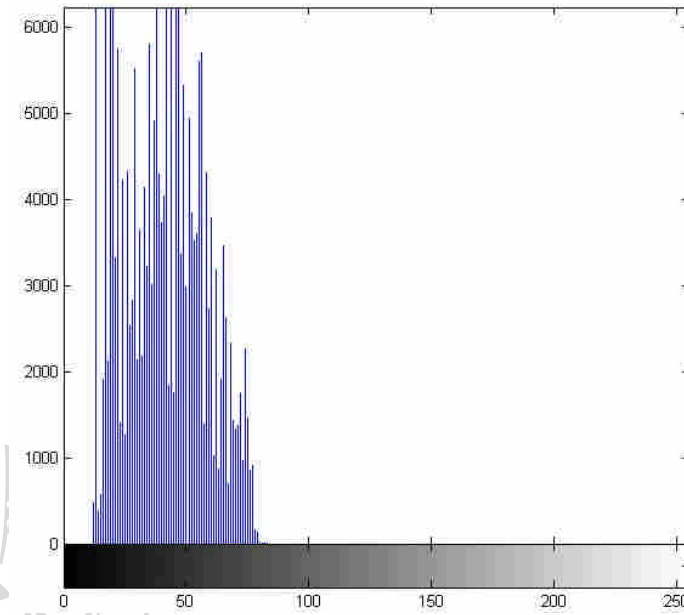
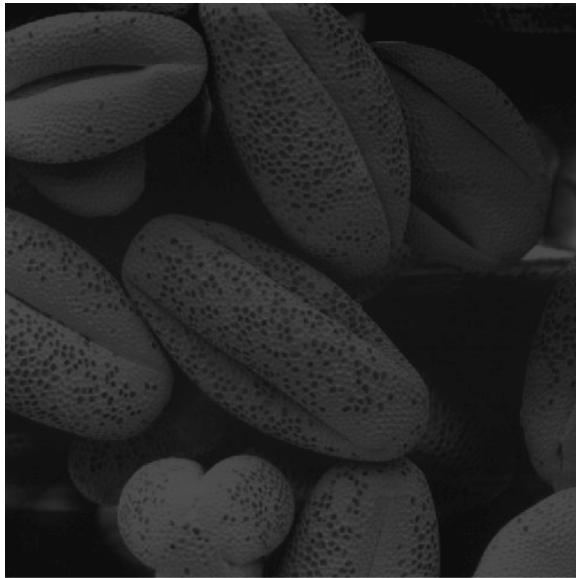
$$s_6 = \sum_{j=0}^6 \frac{n_j}{n} = \frac{30 + 50 + 100 + 1500 + 2300 + 4000 + 200}{8200} = \frac{8180}{8200} = 0.998 \approx \frac{7}{7}$$

$$s_7 = \sum_{j=0}^7 \frac{n_j}{n} = \frac{30 + 50 + 100 + 1500 + 2300 + 4000 + 200 + 20}{8200} = \frac{8200}{8200} = 1 \approx \frac{7}{7}$$



k	n_j	$\sum_{j=0}^k n_j$	$\sum_{j=0}^k \frac{n_j}{n}$	$s_k = (L-1) \sum_{j=0}^k \frac{n_j}{n}$
0	30	30	0.0037	0.0256
1	50	80	0.0098	0.0683
2	100	180	0.0220	0.1537
3	1500	1680	0.2050	1.4241
4	2300	3980	0.4854	3.3976
5	4000	7980	0.9732	6.8122
6	200	8180	0.9976	6.9830
7	20	8200	1.0000	7.0000

Example



Histogram Equalization

- Histogram equalization may not always produce desirable results, particularly if the given histogram is very narrow. It can produce false edges and regions. It can also increase image “graininess” and “patchiness.”

