Image Processing

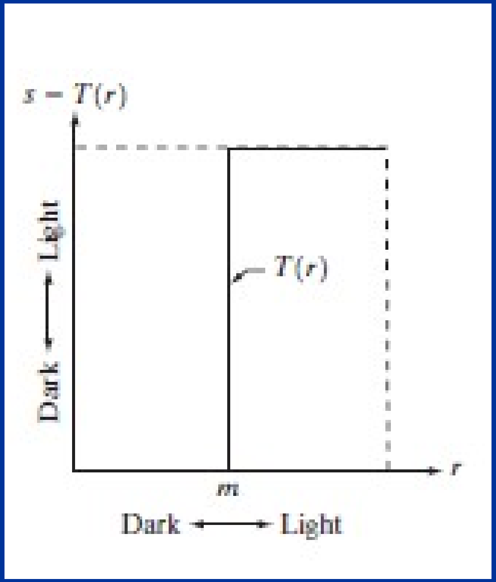
Lecture 5

Introducing Image Processing

Image Enhancement in the Spatial Domain

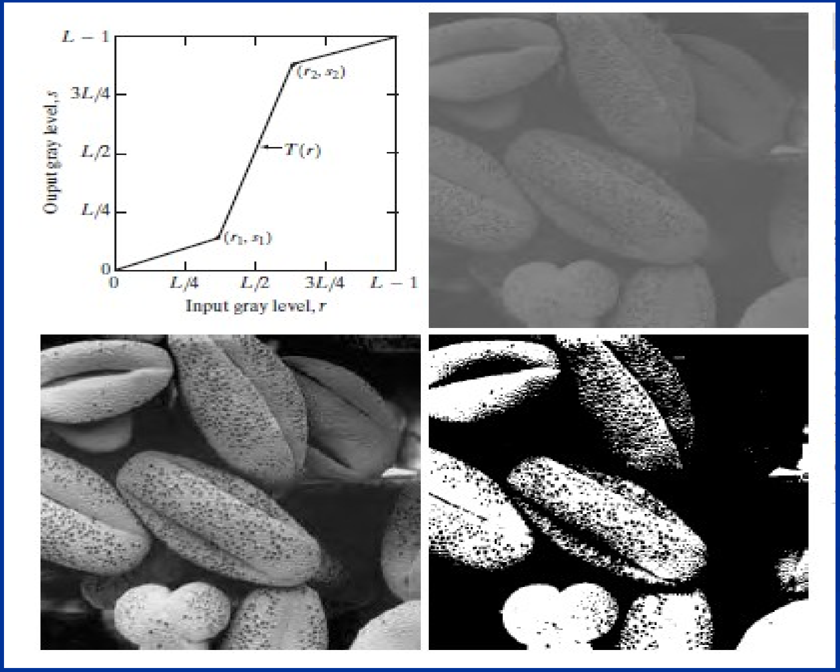
Piecewise-Linear Transformation Functions

- Thresholding : In this transformation, the pixels are categorized according to thresholds into categories and each category has its own gray level




Piecewise-Linear Transformation Functions

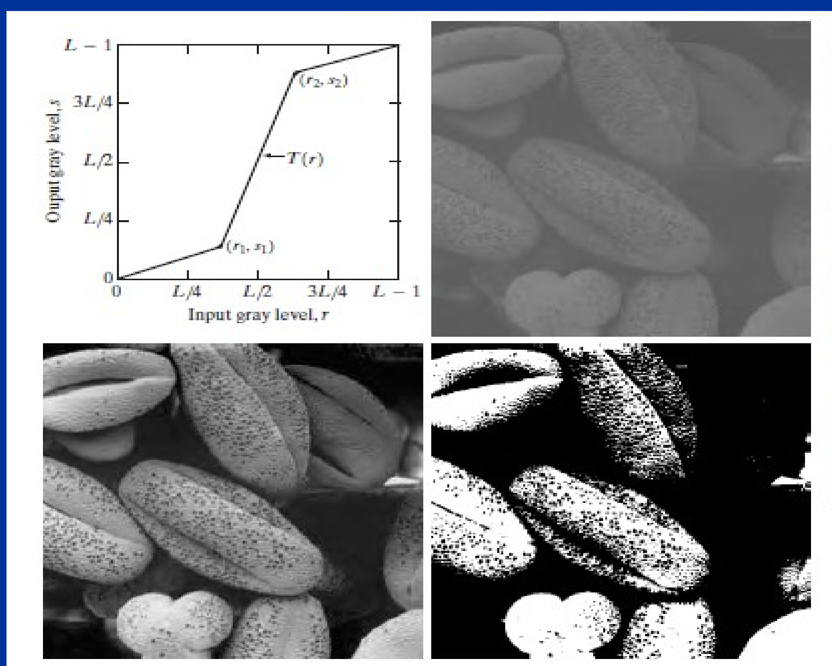
- **Contrast stretching :** The idea behind contrast stretching is to increase the dynamic range of the gray levels in the image being processed



Intermediate Intermediate values of r1, s1 and r2, s2 produce various degrees of spread in the gray levels of the output image, thus affecting its contrast

Piecewise-Linear Transformation Functions

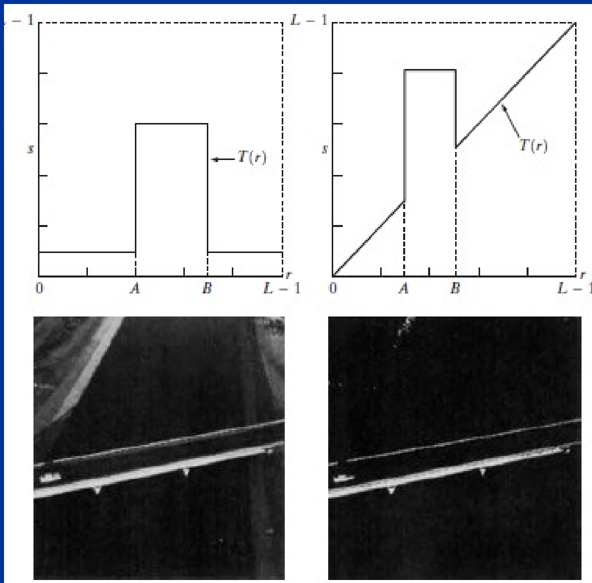
- تمديد التباين: الفكرة وراء امتداد التباين هي زيادة النطاق الديناميكي لمستويات الرمادي في الصورة التي تتم معالجتها.



Intermediate Intermediate values of r1, s1 and r2, s2 produce various degrees of spread in the gray levels of the output image, thus affecting its contrast

Piecewise-Linear Transformation Functions

- **Gray-level slicing: is a** Highlighting of a specific range of gray levels in an image and it often is desired for applications include enhancing features

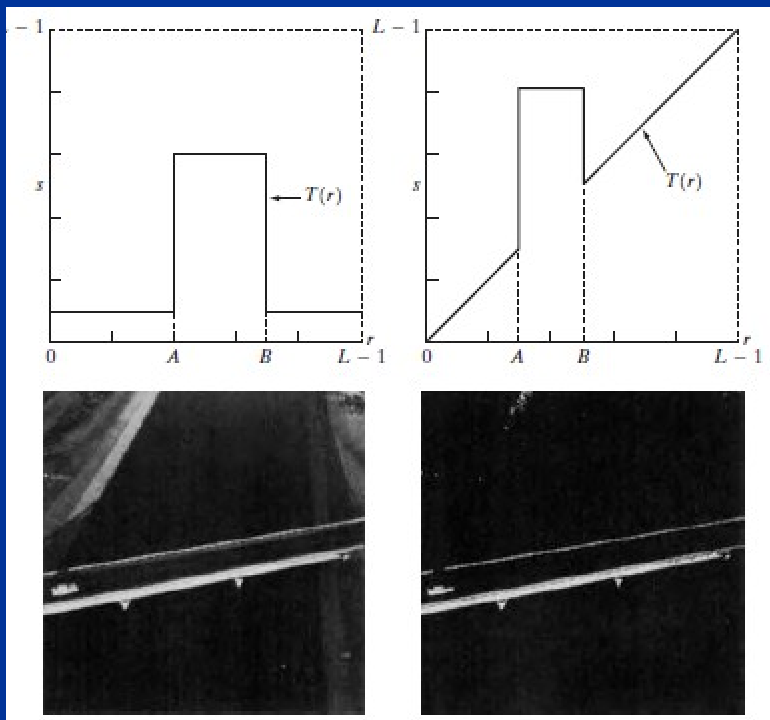


a b
c d

FIGURE 3.11 (a) This transformation highlights range [A, B] of gray levels and reduces all others to a constant level. (b) This transformation highlights range [A, B] but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).

Piecewise-Linear Transformation Functions

- تقطيع المستوى الرمادي: هو تمييز نطاق معين من مستويات الرمادي في صورة ما وغالبًا ما يكون مطلوبًا للتطبيقات التي تتضمن ميزات محسنة.

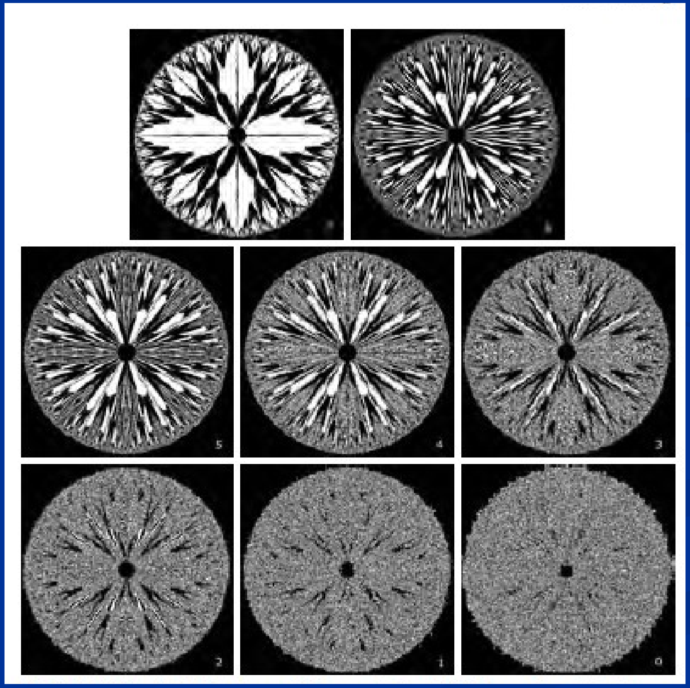


a b
c d

FIGURE 3.11 (a) This transformation highlights range [A, B] of gray levels and reduces all others to a constant level. (b) This transformation highlights range [A, B] but preserves all other levels. (c) An image. (d) Result of using the transformation in (a).

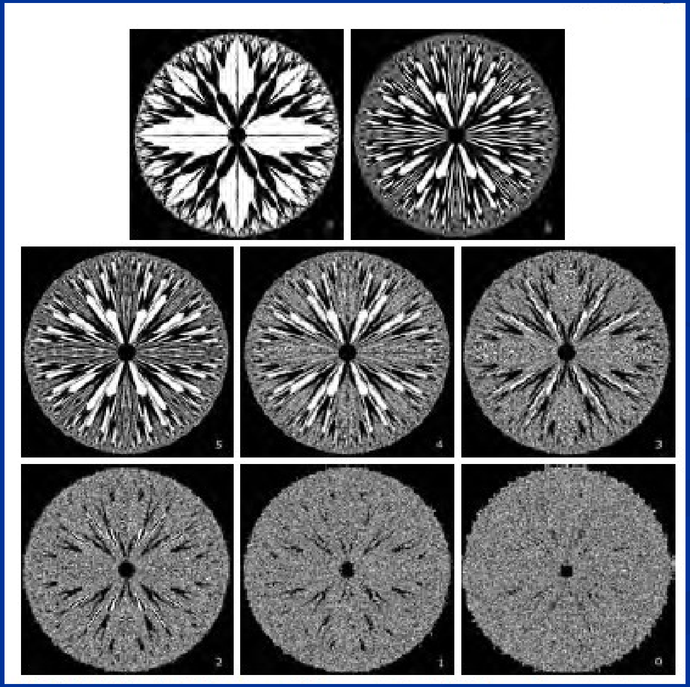
Piecewise-Linear Transformation Functions

- **Bit-plane slicing :** Instead of highlighting gray-level ranges, highlighting the contribution made to total image appearance by specific bits might be desired.



دوال التحويل الخطي المتقطع

- تقطيع مستوى البت: بدلاً من إبراز نطاقات المستوى الرمادي ، قد يكون من المرغوب فيه إبراز المساهمة التي تم إجراؤها لمظهر الصورة الكلي بواسطة وحدات بت معينة

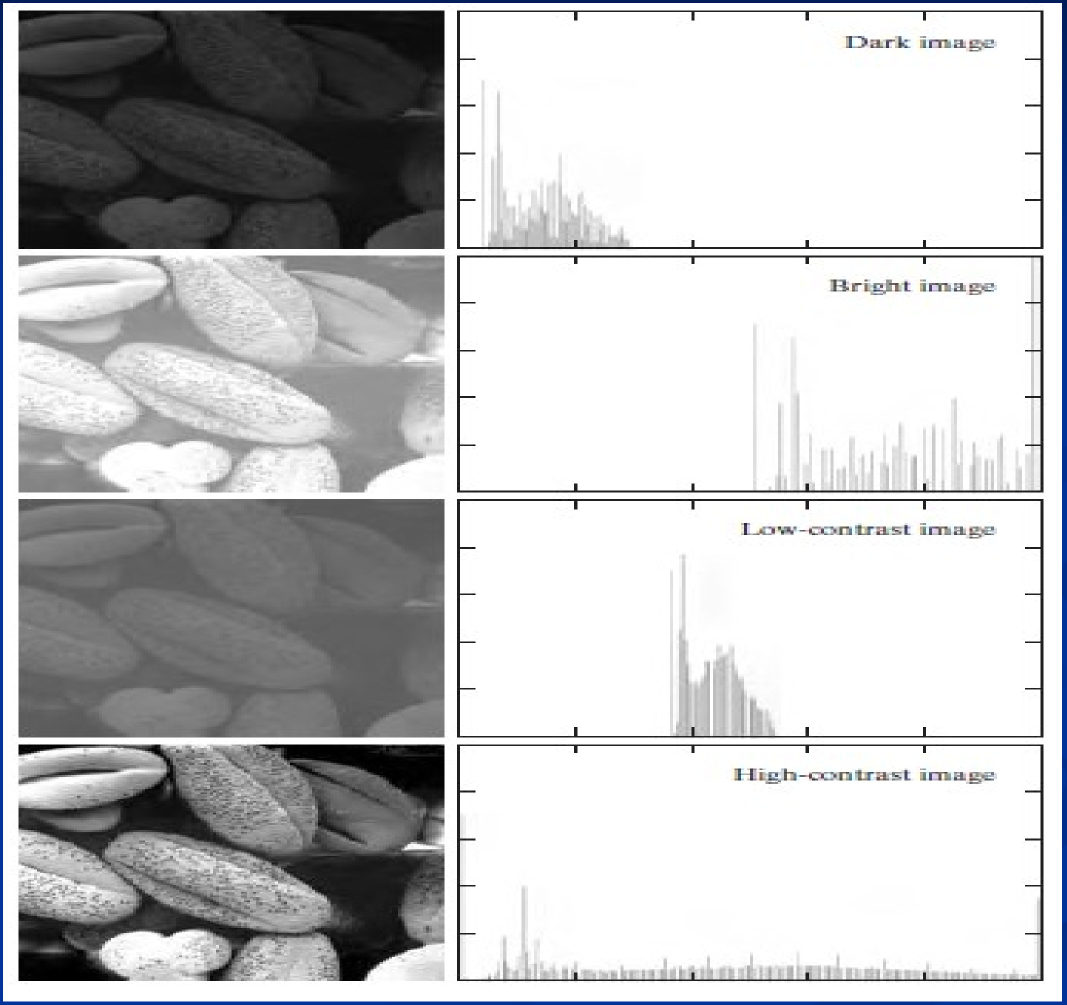


Histogram Processing

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 kth gray level and n_k is the number of pixels in the image having gray level r_k. It is common practice to normalize

image, denoted by n. Thus, a normalized histogram is given by $p(r_k) = n_k/n$, for $k = 0, 1, \ldots, L-1$. Loosely speaking, $p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k. Note that the sum of all components of a normalized histogram is equal to 1.

Histogram Processing



Histogram Processing

- Histograms are the basis for numerous spatial domain processing enhancement techniques.
- They provide useful image statistics which are useful in image compression and segmentation.
- Histograms are simple to calculate in software and also lend themselves to economic hardware implementations, thus making them a popular tool for real-time image processing

معالجة الرسم البياني

- الرسوم البيانية هي الأساس للعديد من تقنيات تحسين معالجة المجال المكاني.
- أنها توفر إحصاءات صور مفيدة في ضغط الصور وتقسيمها.
- من السهل حساب الرسوم البيانية في البرامج ، كما أنها مناسبة لتطبيقات الأجهزة الاقتصادية ، مما يجعلها أداة شائعة لمعالجة الصور في الوقت الفعلي

Histogram Processing

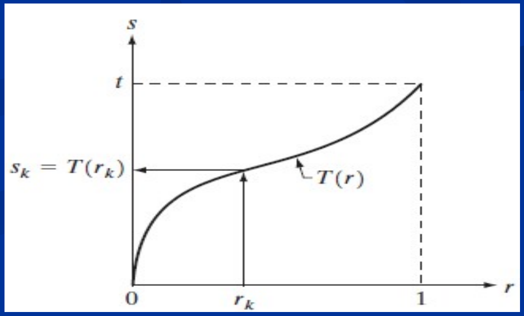
- **Histogram Equalization :**
- *Let r* has been normalized to the interval [0, 1]. Our Transformation : s=T(r) *where* 0 <= r <= 1

$T(r)$ satisfies the following conditions:

(a) $T(r)$ is single-valued and monotonically increasing in the interval $0 \leq r \leq 1$; and

(b) $0 \leq T(r) \leq 1$ for $0 \leq r \leq 1$.

- The inverse transformation from *s* back to *r* is denoted : s=T^{-1}(r) *where* 0 <= r <= 1



Histogram Equalization

- The probability of occurrence of gray level r_k :

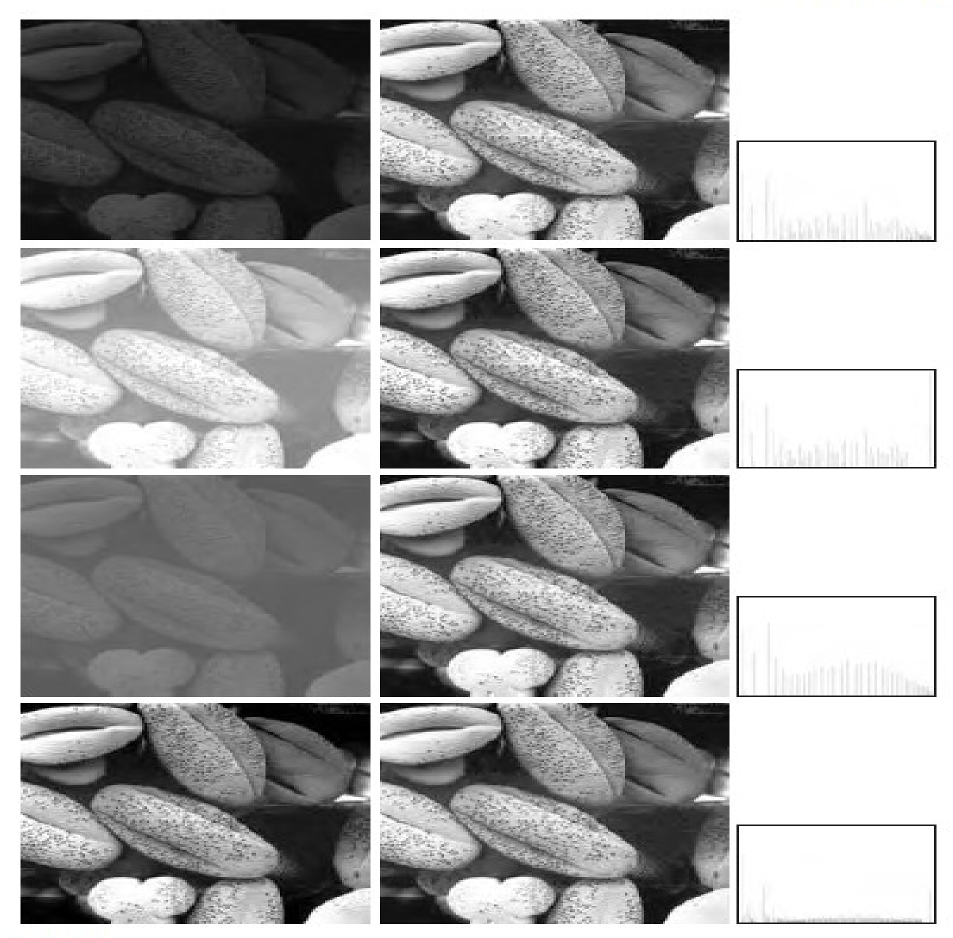
$$p_r(r_k) = \frac{n_k}{n} \qquad k = 0, 1, 2, \ldots, L-1$$

- The transformation function of histogram equalization is :

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

- Does the above formula satisfy the (a) and (b) conditions ?
- The inverse transformation: $r_k = T^{-1}(s_k) \qquad k = 0, 1, 2, \ldots, L-1$

Histogram Equalization



Local enhancement

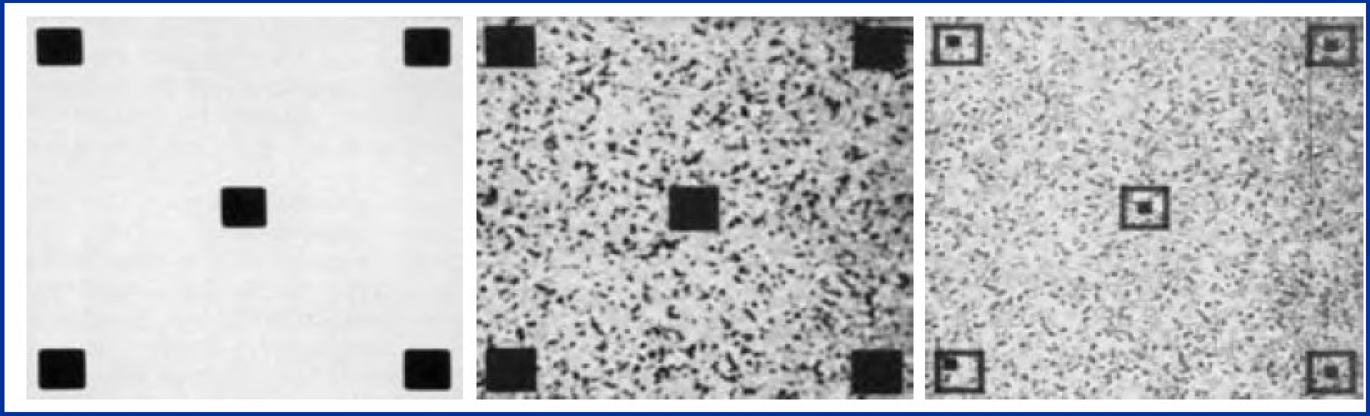
- *In global*, the pixels are modified by a transformation function based on the gray-levels of entire image.
- There are cases in which it is necessary to enhance details over small areas in an image
- The solution is to do transformation functions based on the gray-levels of the neighborhood of every pixel in the image.
- This is called local enhancement.

التحسين للمحلي

- بشكل عام ، يتم تعديل وحدات البكسل بواسطة وظيفة التحويل بناءً على مستويات الرمادي للصورة بأكملها.
- هناك حالات يكون فيها من الضروري تحسين التفاصيل على مساحات صغيرة في الصورة
- الحل هو القيام بوظائف التحويل بناءً على مستويات الرمادي لجوار كل بكسل في الصورة.
- هذا يسمى التحسين المحلي.

Local enhancement

- The procedure is to define a rectangular neighborhood and move the center of this area from pixel to pixel.
- At each location, the histogram of the points in the neighborhood is computed and a histogram equalization transformation function is obtained.



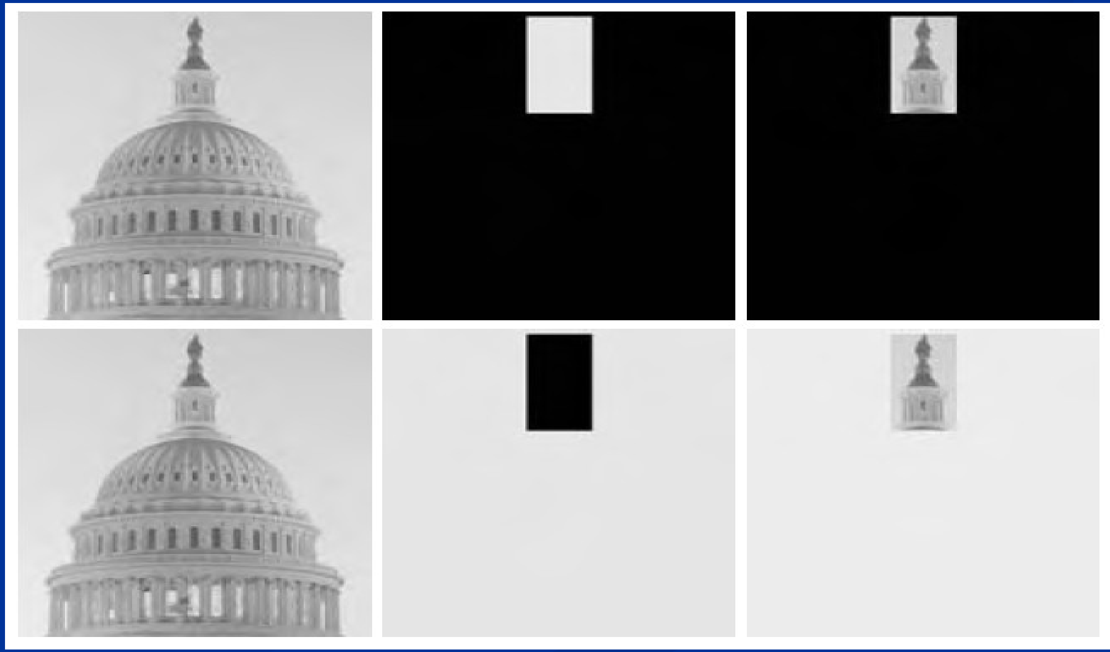
Enhancement Using Arithmetic/Logic Operations

- Arithmetic/logic operations are performed on a pixel-by-pixel basis between two or more images (NOT, which is performed on a single image)

Logic Operations:

AND ,

OR

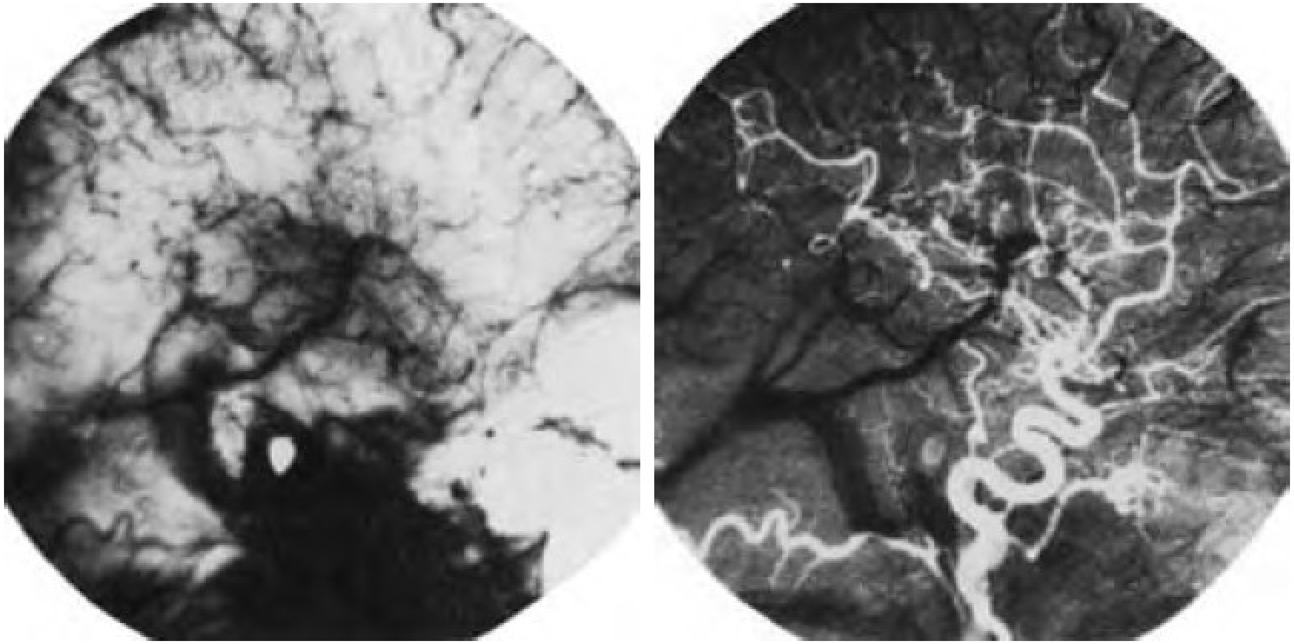


Enhancement Using Arithmetic/Logic Operations

- Image Subtraction :

The difference between two images $f(x, y)$ and $h(x, y)$, expressed as

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



a b

FIGURE 3.29 Enhancement by image subtraction. (a) Mask image. (b) An image (taken after injection of a contrast medium into the bloodstream) with mask subtracted out.

Enhancement Using Arithmetic/Logic Operations

- Image Averaging :

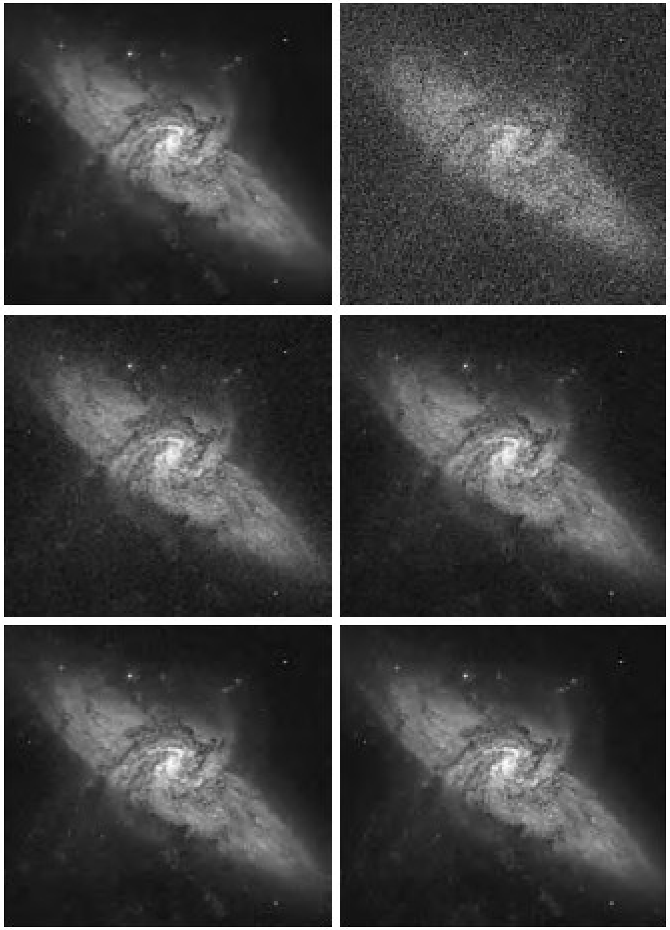
$$\bar{g}(x, y) = \frac{1}{K} \sum_{i=1}^{K} g_i(x, y)$$

- Image noise can be done using :

$$g(x, y) = f(x, y) + \eta(x, y)$$

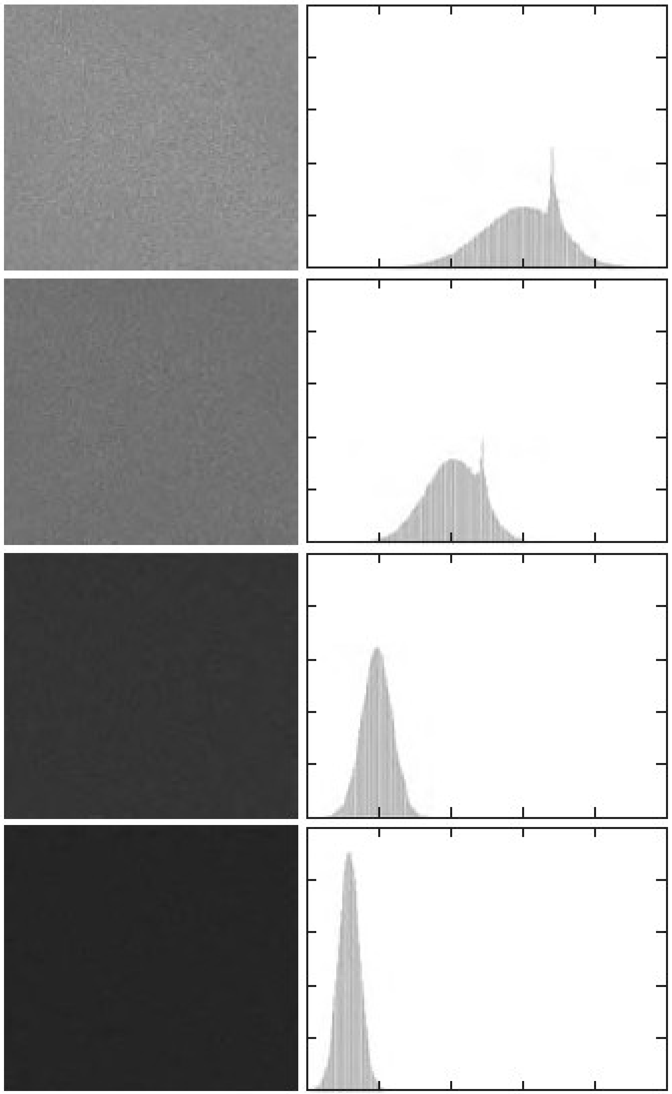
- Where k represent number of images.
- The expected image :

$$E\{\bar{g}(x, y)\} = f(x, y)$$



a b
c d
e f

FIGURE 3.30 (a) Image of Galaxy Pair NGC 3314. (b) Image corrupted by additive Gaussian noise with zero mean and a standard deviation of 64 gray levels. (c)–(f) Results of averaging $K = 8, 16, 64$, and 128 noisy images. (Original image courtesy of NASA.)



a b

FIGURE 3.31 (a) From top to bottom: Difference images between Fig. 3.30(a) and the four images in Figs. 3.30(c) through (f), respectively. (b) Corresponding histograms.

Basics of Spatial Filtering

- The linear filter with the filter mask at point (x,y) is :

$$R = w(-1,-1)f(x-1,y-1) + w(-1,0)f(x-1,y) + \cdots + w(0,0)f(x,y) + \cdots + w(1,0)f(x+1,y) + w(1,1)f(x+1,y+1),$$

- which is the sum of products of the mask coefficients with the corresponding pixels directly under the mask

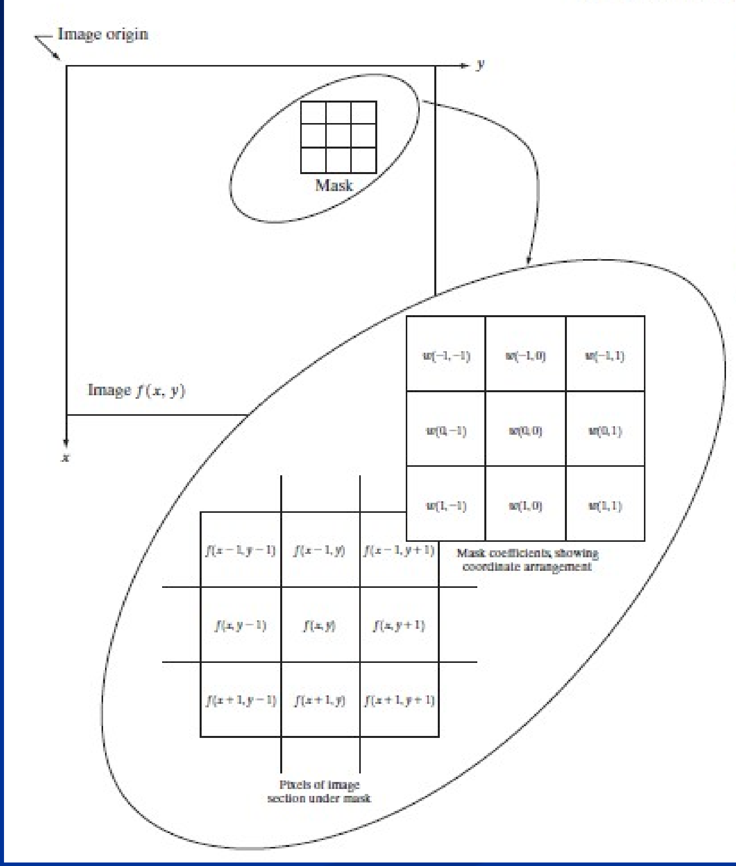


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3 × 3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

In general, linear filtering of an image f of size $M \times N$ with a filter mask of size $m \times n$ is given by the expression:

$$g(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x + s, y + t) \qquad (3.5\text{-}1)$$

where, from the previous paragraph, $a = (m - 1)/2$ and $b = (n - 1)/2$. To generate a complete filtered image this equation must be applied for $x = 0, 1,$

Basics of Spatial Filtering

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

$$
\begin{aligned}
R &= w_1 z_1 + w_2 z_2 + \dots + w_{mn} z_{mn} \\
&= \sum_{i=1}^{mn} w_i z_i
\end{aligned}
$$

$$
\begin{aligned}
R &= w_1 z_1 + w_2 z_2 + \dots w_9 z_9 \\
&= \sum_{i=1}^{9} w_i z_i .
\end{aligned}
$$

Smoothing Spatial Filters

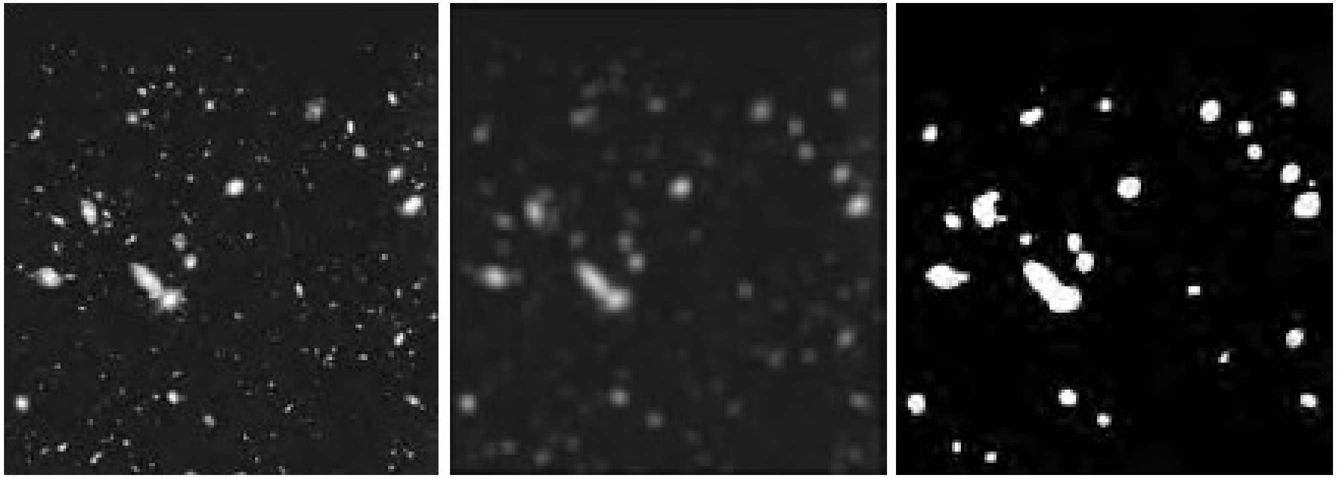
- **Smoothing Linear Filters :** is used to remove small details in images (noise reduction) or to blur images.

$$\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \qquad \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

$$g(x, y) = \frac{\sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x+s, y+t)}{\sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t)}$$

$$R = \frac{1}{9} \sum_{i=1}^{9} z_i,$$

FIGURE 3.35 (a) Original image, of size 500 × 500 pixels. (b)–(f) Results of smoothing with square averaging filter masks of sizes $n = 3, 5, 9, 15,$ and 35, respectively. The black squares at the top are of sizes 3, 5, 9, 15, 25, 35, 45, and 55 pixels, respectively; their borders are 25 pixels apart. The letters at the bottom range in size from 10 to 24 points, in increments of 2 points; the large letter at the top is 60 points. The vertical bars are 5 pixels wide and 100 pixels high; their separation is 20 pixels. The diameter of the circles is 25 pixels, and their borders are 15 pixels apart; their gray levels range from 0% to 100% black in increments of 20%. The background of the image is 10% black. The noisy rectangles are of size 50 × 120 pixels.



a b c

FIGURE 3.36 (a) Image from the Hubble Space Telescope. (b) Image processed by a 15×15 averaging mask. (c) Result of thresholding (b). (Original image courtesy of NASA.)