Image Arithmetic

$$g(x,y) = f(x,y) \pm h(x,y)$$

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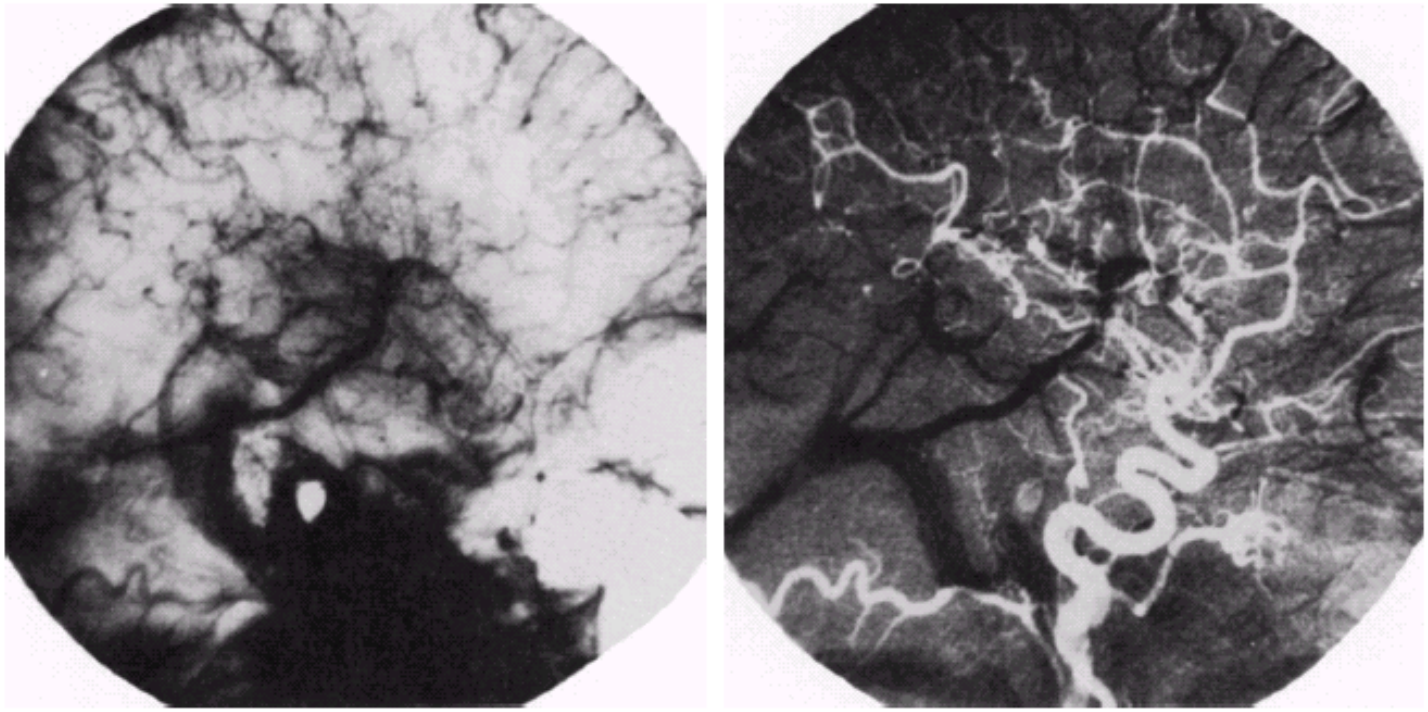
Image Subtraction

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

- Mask mode radiography
  - h(x,y) is the mask

Image Enhancement in the Spatial Domain



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.

Image Averaging

- A noisy image:

$$g(x,y) = f(x,y) + n(x,y)$$

- Averaging M different noisy images:

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

Image Averaging

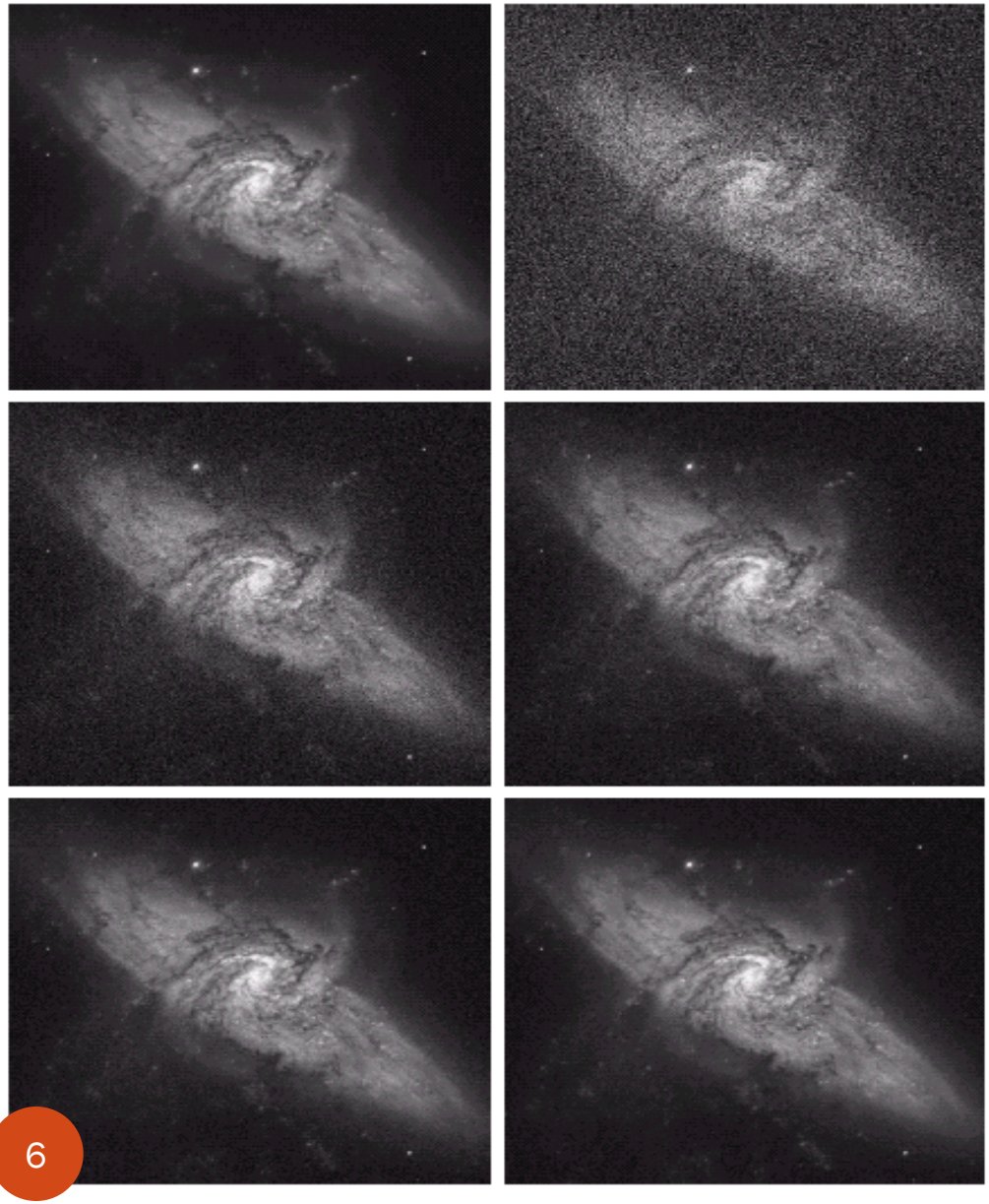
- As M increases, the variability of the pixel values at each location decreases.

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

  - This means that $\bar{g}(x,y)$ approaches $f(x,y)$ as the number of noisy images used in the averaging process increases.

- Registering of the images is necessary to avoid blurring in the output image.

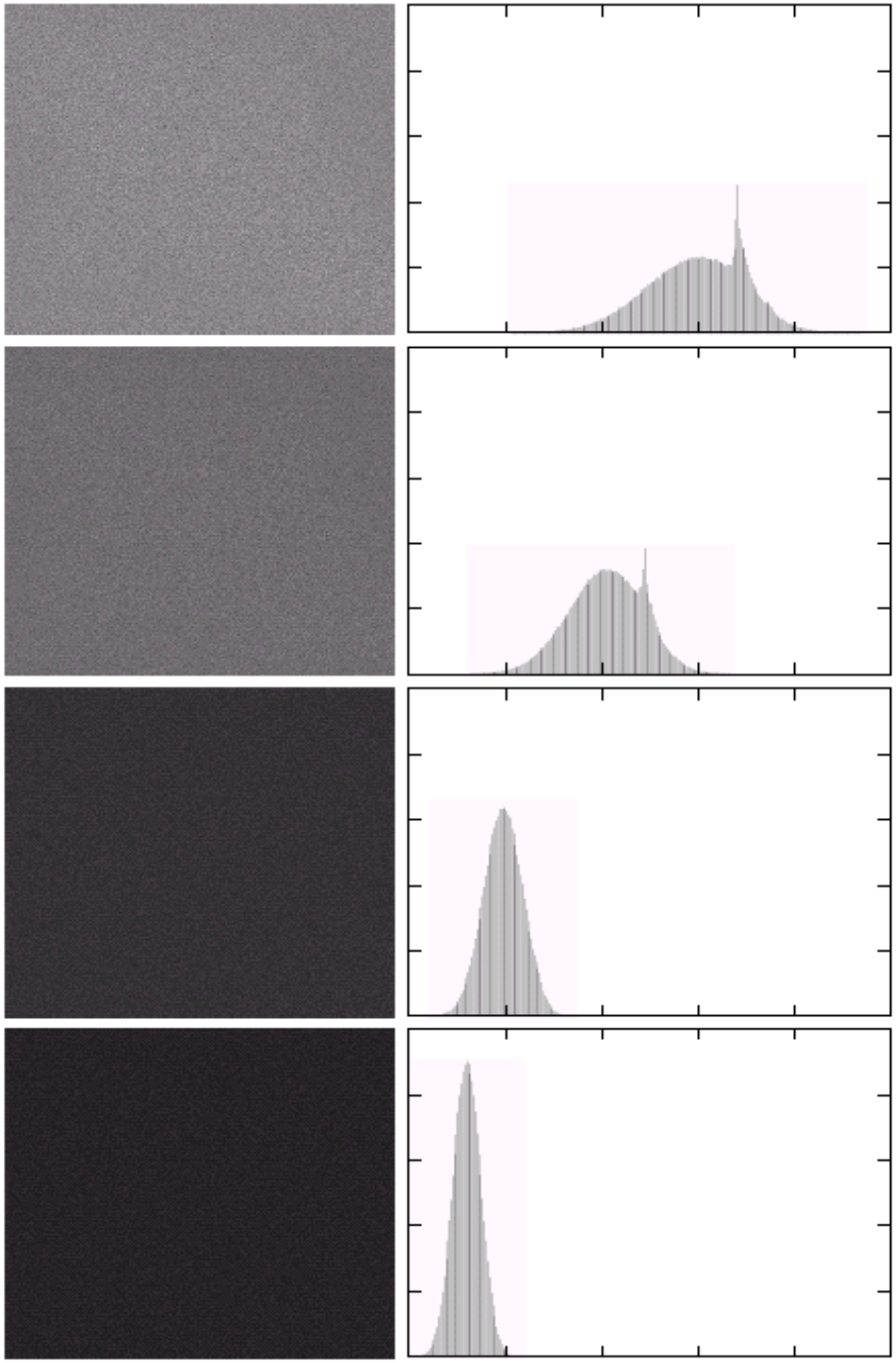
Image Enhancement in the Spatial Domain



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.)

Image Enhancement - Spatial Domain



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.

Local Enhancement

- When it is necessary to enhance details over smaller areas

- To devise transformation functions based on the gray-level distribution in the neighborhood of every pixel

Local Enhancement

- The procedure is:
  - Define a square (or 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 either a histogram equalization or histogram specification transformation function is obtained

Local Enhancement

- This function is finally used to map the gray level of the pixel centered in the neighborhood
- The center is then moved to an adjacent pixel location and the procedure is repeated

Spatial Filtering

- Use of spatial masks for image processing (spatial filters)
- Linear and nonlinear filters
- Low-pass filters eliminate or attenuate high frequency components in the frequency domain (sharp image details), and result in image blurring

Spatial Filtering

- High-pass filters attenuate or eliminate low-frequency components (resulting in sharpening edges and other sharp details)

- Band-pass filters remove selected frequency regions between low and high frequencies (for image restoration, not enhancement)

Spatial Filtering

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

$a=(m-1)/2$ and $b=(n-1)/2$,

m , n (odd numbers)

- For x = 0,1,…,M-1 and y = 0,1,…,N-1
- Also called *Convolution*

Spatial Filtering

- The basic approach is to sum products between the mask coefficients and the intensities of the pixels under the mask at a specific location in the image:

$$R = w_1 z_1 + w_2 z_2 + \ldots + w_9 z_9$$

(for a 3 x 3 filter)

Image Enhancement - Spatial Domain

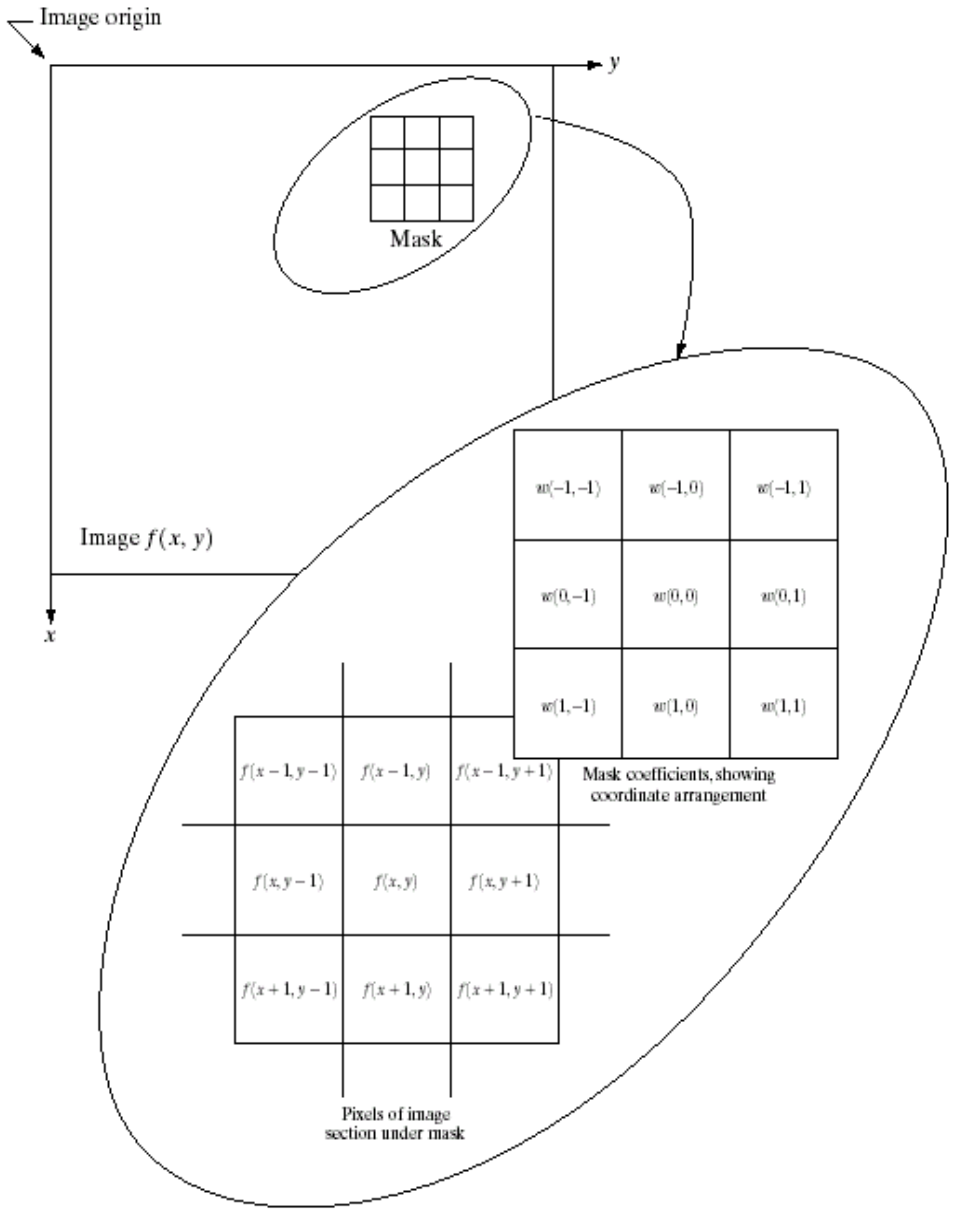


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3×3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

Spatial Filtering

- Non-linear filters also use pixel neighborhoods but do not explicitly use coefficients
  - e.g. noise reduction by median gray-level value computation in the neighborhood of the filter

Smoothing Filters

- Used for blurring (removal of small details prior to large object extraction, bridging small gaps in lines) and noise reduction.

- Low-pass (smoothing) spatial filtering
  - Neighborhood averaging

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

Image Enhancement in the Spatial Domain

FIGURE 3.33 Another representation of a general 3×3 spatial filter mask.

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Image Enhancement in the Spatial Domain

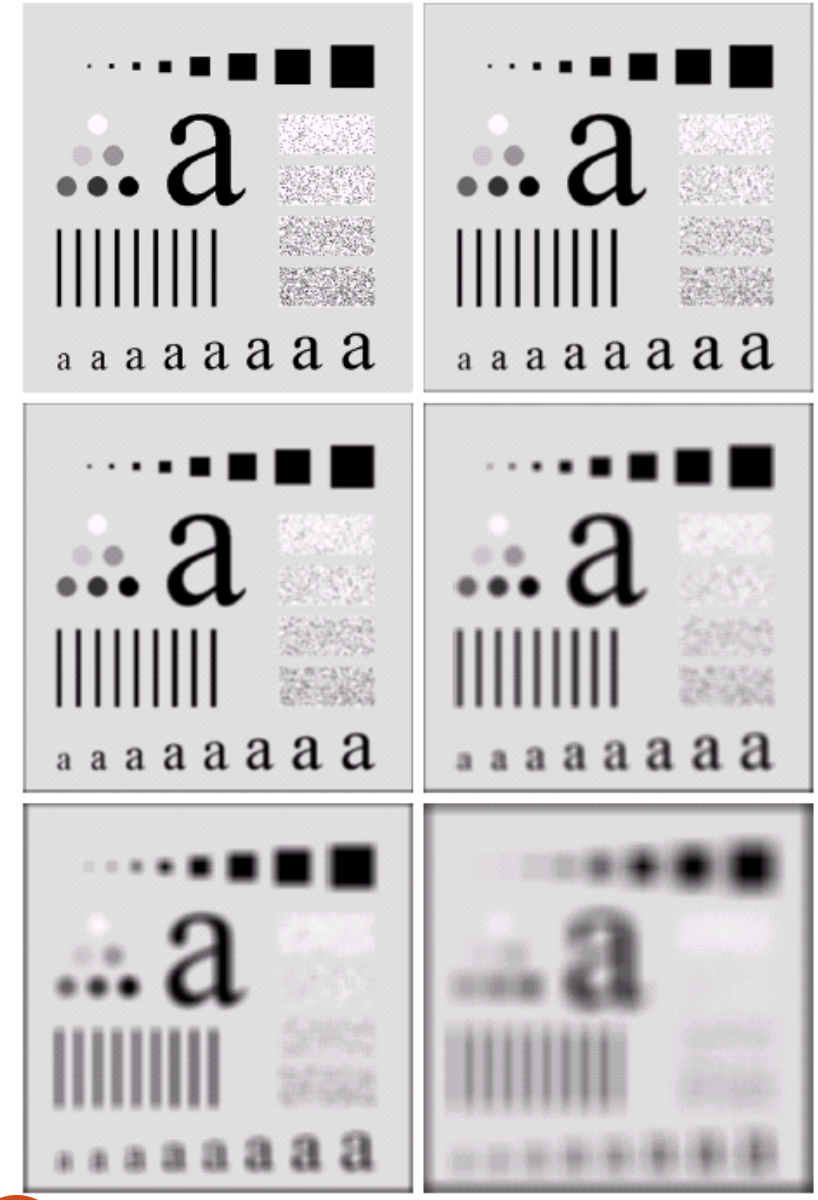
a b

FIGURE 3.34 Two 3×3 smoothing (averaging) filter masks. The constant multiplier in front of each mask is equal to the sum of the values of its coefficients, as is required to compute an average.

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

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

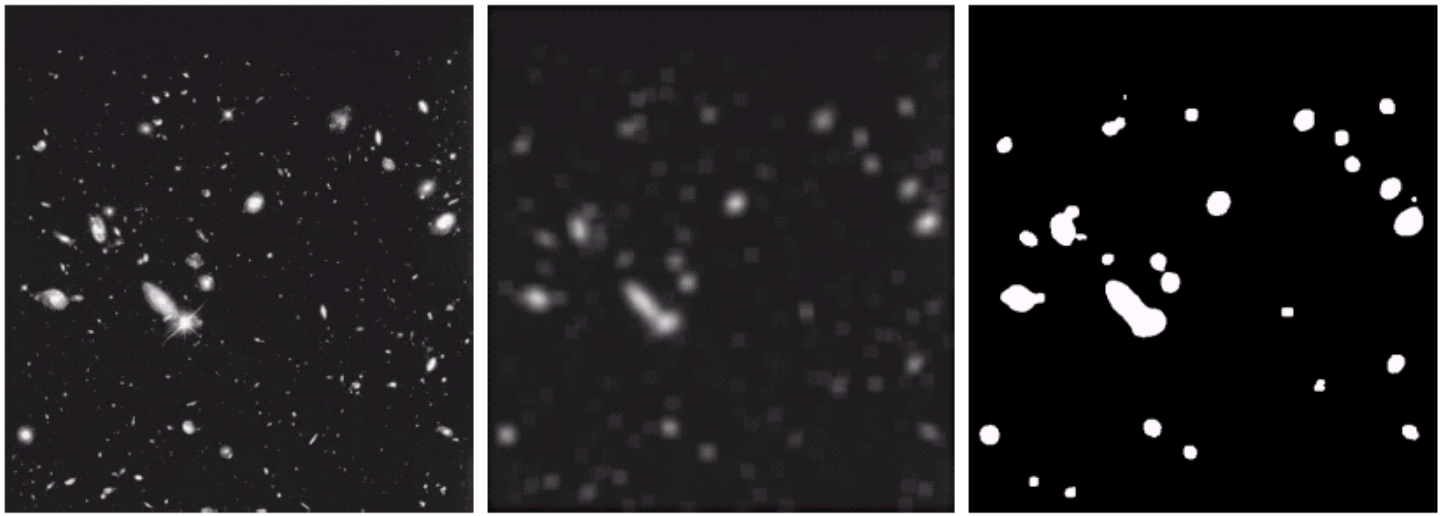
Image Enhancement in the Spatial Domain



a b
c d
e f

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.

Image Enhancement in the Spatial Domain



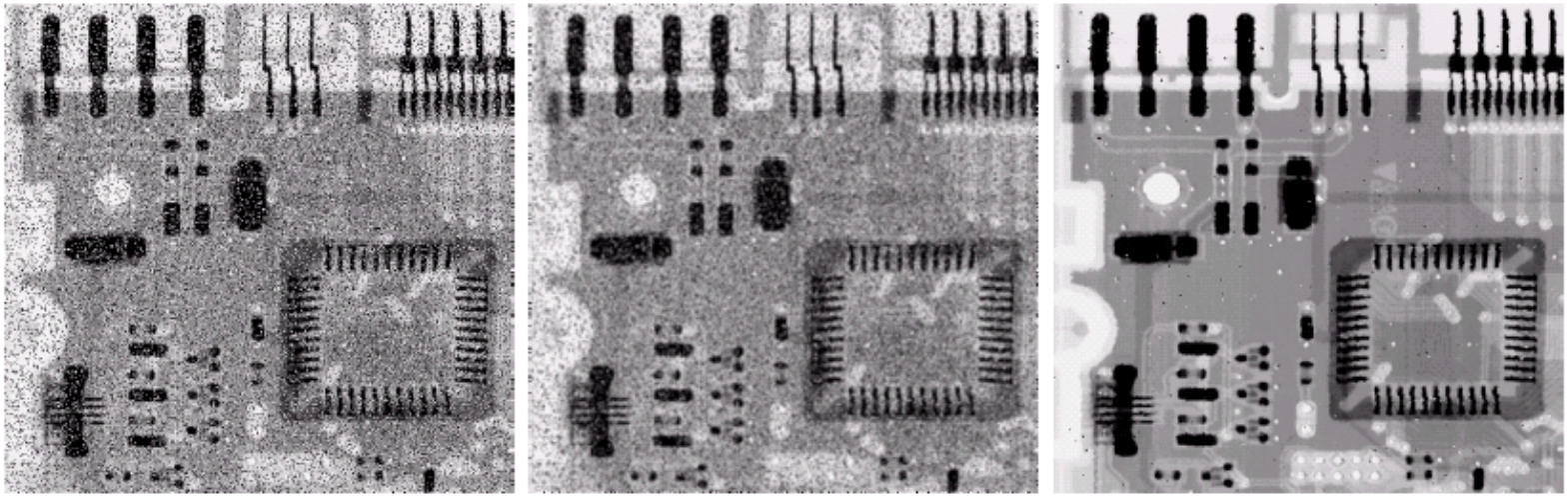
a b c

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.)

Smoothing Filters

- Median filtering (nonlinear)
  - Used primarily for noise reduction (eliminates isolated spikes)
  - The gray level of each pixel is replaced by the median of the gray levels in the neighborhood of that pixel (instead of by the average as before).

Chapter 3
Image Enhancement in the Spatial Domain



a b c

FIGURE 3.37 (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3×3 averaging mask. (c) Noise reduction with a 3×3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

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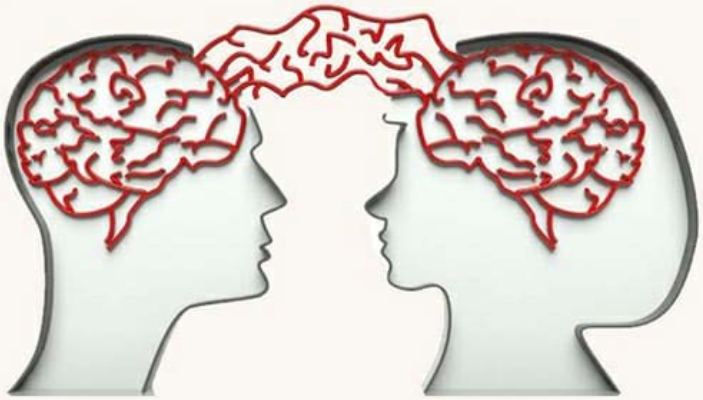

Understanding is deeper than knowledge. There are many people who know you, but there are very few who understand you.

Thanks!

Query Please ?