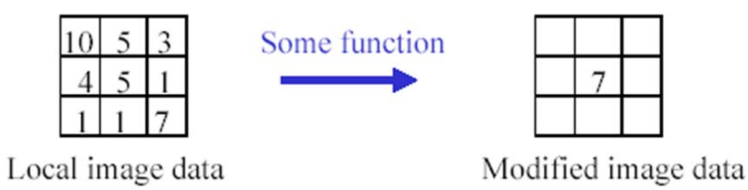
Image Filtering

-Image filtering is about modifying pixels based on neighborhood
-Used for noise reduction and edge detection

What is Image Filtering?

- Modify the pixels in an image based on some function of a local neighborhood of the pixels.



Linear Functions

- Simplest: Linear Filtering
  – Replace each pixel by a linear combination of its neighbors
- The prescription for the linear combination is called the "convolution kernel".

10	5	3
4	5	1
1	1	7

Local image data

0	0	0
0	0.5	0
0	1	0.5

kernel

	7	

Modified image data

Image Filtering

- Image filtering consists of moving the filter mask/kernel from point to point in an image.
- At each point (x,y), the response of the filter is calculated using a predefined relationship:

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

Image Filtering

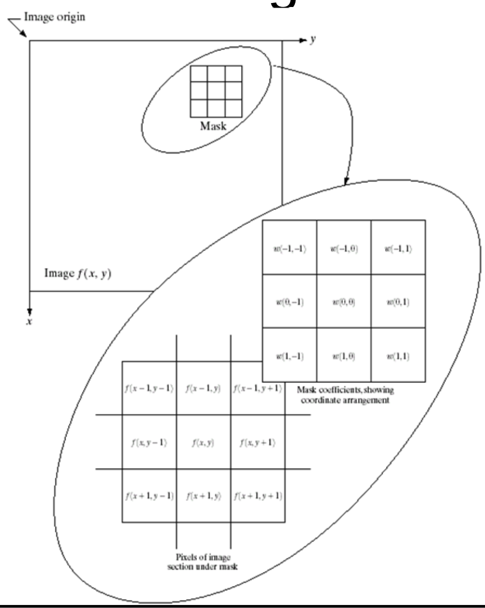


FIGURE 3.32 The mechanics of spatial filtering. The magnified drawing shows a 3×3 mask and the image section directly under it; the image section is shown displaced out from under the mask for ease of readability.

Filtering to Reduce Noise

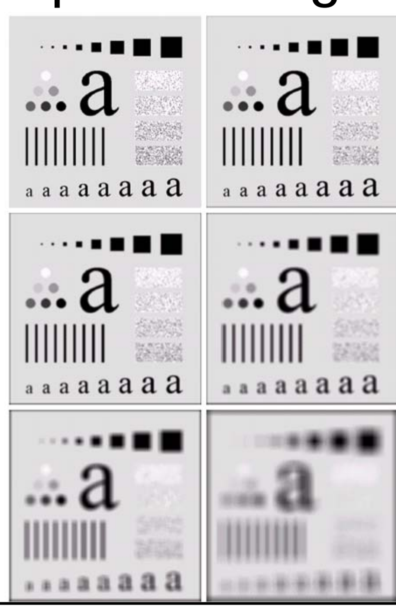
- Noise is what we are not interested in.
- Averaging noise reduces its effect.

Mean (Box/Averaging) Filter

- Mask with positive entries that sum 1.
- Replaces each pixel with an average of its neighborhood.
- Used for blurring and noise reduction.

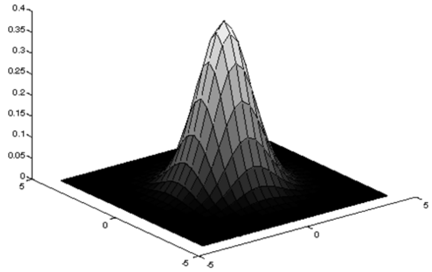
$$\frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Example of Image Smoothing



Gaussian Filter

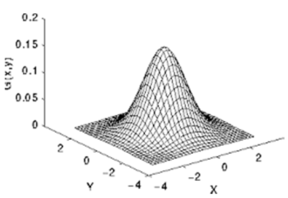
- Rotationally symmetric
- This kernel is an approximation of a Gaussian function
- Weights nearby pixels more than distant ones



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

How to Obtain Kernel Coefficients for Gaussian Filter?

- Two-dimensional Gaussian function: $G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$



- Gaussian function is non-zero everywhere but approaches to zero at about 3σ from the mean. This means we can normally limit the kernel size to contain only values within 3σ of the mean.
- Kernel coefficients are obtained by digitizing the 2D function.

A 5x5 Convolution Kernel of a Gaussian Filter

0.000	0.005	0.011	0.005	0.000
0.005	0.052	0.114	0.052	0.005
0.011	0.114	0.248	0.114	0.011
0.005	0.052	0.114	0.052	0.005
0.000	0.005	0.011	0.005	0.000

- In MATLAB use fspecial()

Types of Noise

- Common types of noise:
  - **Salt and pepper noise**: contains random occurrences of black and white pixels
  - **Impulse noise:** contains random occurrences of white pixels
  - **Gaussian noise**: variations in intensity drawn from a Gaussian normal distribution

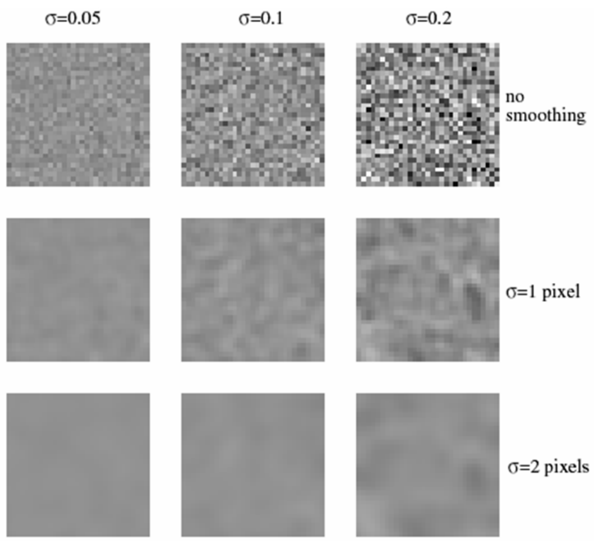

Original


Salt and pepper noise


Impulse noise

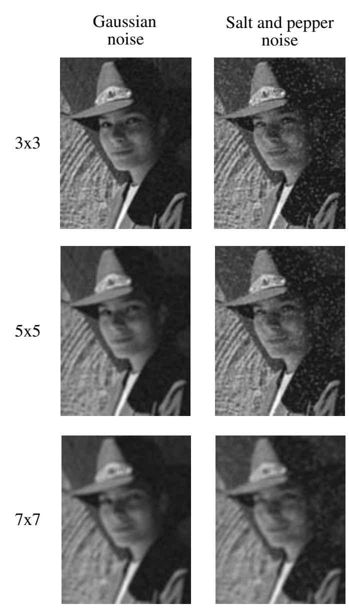

Gaussian noise

Effect of Gaussian Filters of Different Sizes

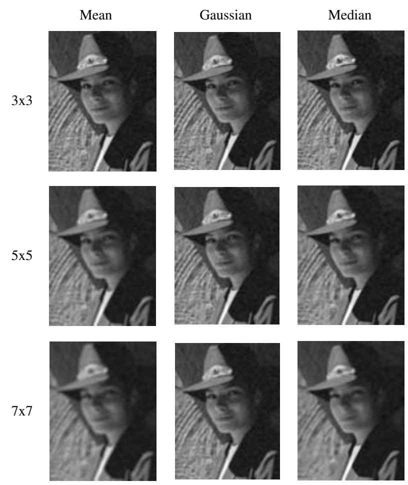


The effects of smoothing:
Each row shows smoothing
with gaussians of different
width;
Each column shows different realizations of an image of gaussian noise.

Effect of Mean Filters of Different Sizes



Effect of Different Filters for Gaussian Noise



Non-linear Filtering

Order-Statistic Filter

- Median filter replaces the gray value of each pixel by the median of the gray levels in a neighborhood of that pixel.
- Median filtering is ideal to eliminate spike-like noise (*impulse noise*, *salt-and-pepper noise*).
- Other order-statistic filters include max filter and min filter.

Properties of Median Filter

- It is a nonlinear filter.
- It is useful in removing isolated lines or pixels while preserving edges. Median filter works well on binary noise but not so well when the noise is Gaussian.
- Its performance is poor when the number of noise pixels is greater than or equal to half the number of pixels in the neighborhood.

Smoothing Filter vs. Median Filter

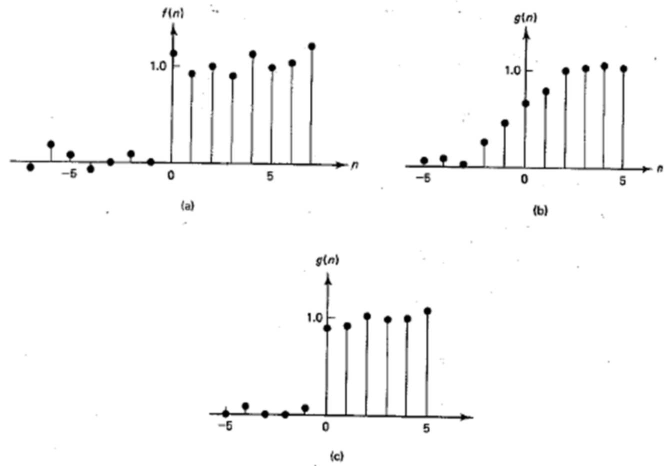


Figure 8.17 Illustration of median filter's tendency to preserve step discontinuities. (a) One-dimensional step sequence degraded by random noise; (b) result of lowpass filtering the sequence in (a) with a 5-point rectangular impulse response; (c) result of applying a 5-point median filter to the sequence in (a).

Smoothing Filter vs. Median Filter

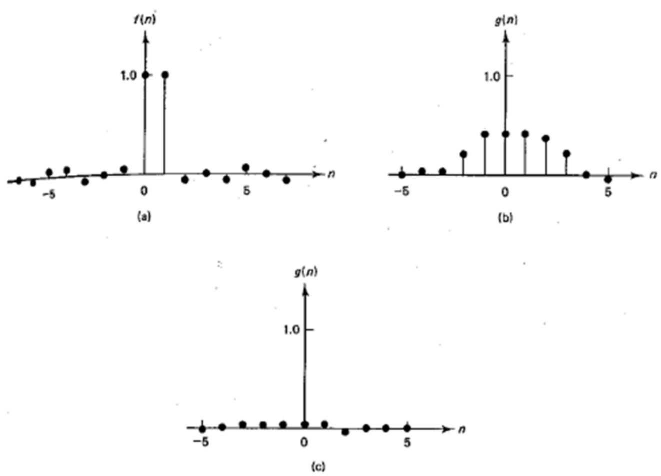


Figure 8.18 Illustration of a median filter's capability to remove impulsive values. (a) One-dimensional sequence with two consecutive samples significantly different from surrounding samples; (b) result of lowpass filtering the sequence in (a) with a 5-point rectangular impulse response; (c) result of applying a 5-point median filter to the sequence in (a).

Example of Using Median Filter

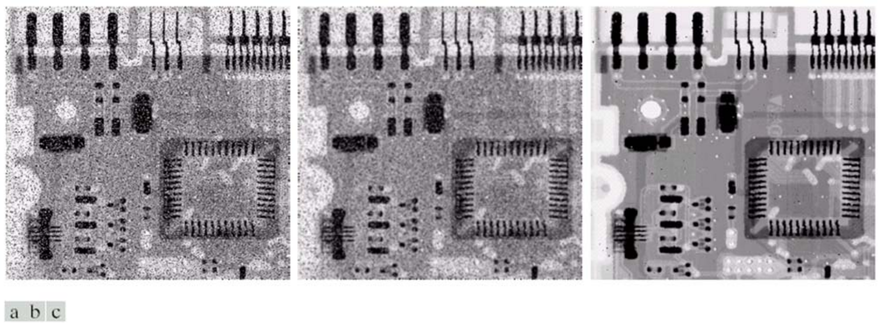
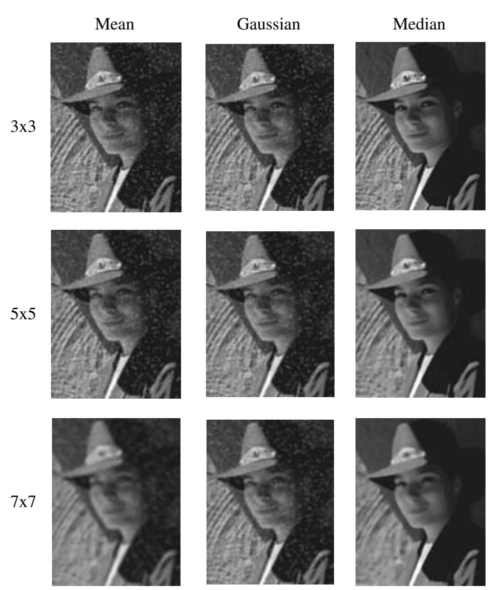


FIGURE 3.37 (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3 × 3 averaging mask. (c) Noise reduction with a 3 × 3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

Comparison: Salt and Pepper Noise



Comparison: Gaussian Noise