

ECE 468 / CS 519: Digital Image Processing

Spatial Filtering

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Outline

- MATLAB
- Smoothing spatial filters (Textbook: 3.5)

MATLAB

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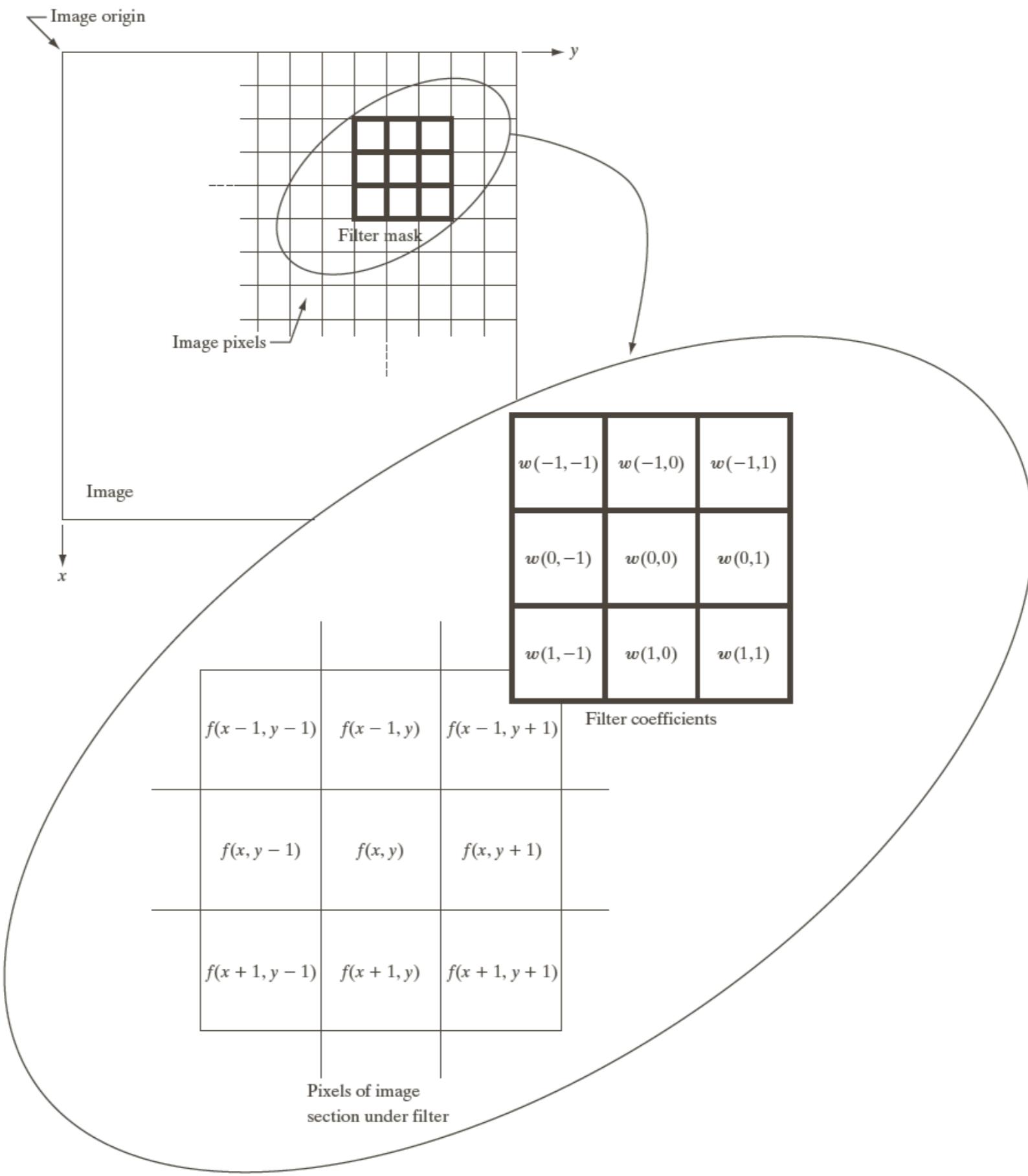
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 - `hspec` - counts of equally spaced intensity values in [0,255]

Linear Spatial Filtering

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

Linear Spatial Filtering



Correlation vs. Convolution

- Correlation:

1. Move the filter mask to a location
2. Compute the sum of products
3. Go to 1.

$$w(x, y) \star f(x, y) = \sum_{i=-a}^a \sum_{j=-b}^b w(i, j) f(x + i, y + j)$$

- Convolution:

1. Rotate the filter mask by 180 degrees
2. Correlation

$$w(x, y) \star f(x, y) = \sum_{i=-a}^a \sum_{j=-b}^b w(i, j) f(x - i, y - j)$$

Example: Correlation vs. Convolution

		Padded f							
		0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0
↙ Origin		$f(x, y)$							
0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	$w(x, y)$	0	0	0	0
0	0	1	0	0	1	2	3	0	0
0	0	0	0	0	4	5	6	0	0
0	0	0	0	0	7	8	9	0	0
(a)					(b)				
↖ Initial position for w		Full correlation result							
1	2	3	0	0	0	0	0	0	0
4	5	6	0	0	0	0	0	0	0
7	8	9	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	9	8
0	0	0	0	1	0	0	0	6	5
0	0	0	0	0	0	0	0	3	2
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
(c)					(d)				

Example: Correlation vs. Convolution

Full correlation result

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	9	8	7	0	0	0
0	0	0	6	5	4	0	0	0
0	0	0	3	2	1	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

(d)

Cropped correlation result

0	0	0	0	0
0	9	8	7	0
0	6	5	4	0
0	3	2	1	0
0	0	0	0	0

(e)

Example: Correlation vs. Convolution

Origin	$f(x, y)$
0 0 0 0 0	
0 0 0 0 0	$w(x, y)$
0 0 1 0 0	1 2 3
0 0 0 0 0	4 5 6
0 0 0 0 0	7 8 9

(a)

Rotated w	Full convolution result
9 8 7	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
6 5 4	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
3 2 1	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0	0 0 0 0 0 0 0 0 1 2 3 0 0 0 0 0
0 0 0 0 1 0 0 0 0	0 0 0 0 4 5 6 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0	0 0 0 7 8 9 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(f) (g)

Example: Correlation vs. Convolution

Cropped correlation result

0	0	0	0	0
0	9	8	7	0
0	6	5	4	0
0	3	2	1	0
0	0	0	0	0

Cropped convolution result

0	0	0	0	0
0	1	2	3	0
0	4	5	6	0
0	7	8	9	0
0	0	0	0	0

Gaussian Filter

$$N(x, y) = \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right)$$

3x3 filter:

$$w_1 = N(-1, -1), w_2 = N(-1, 0), \dots w_9 = N(1, 1)$$

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Smoothing Filter -- Low Pass Filter

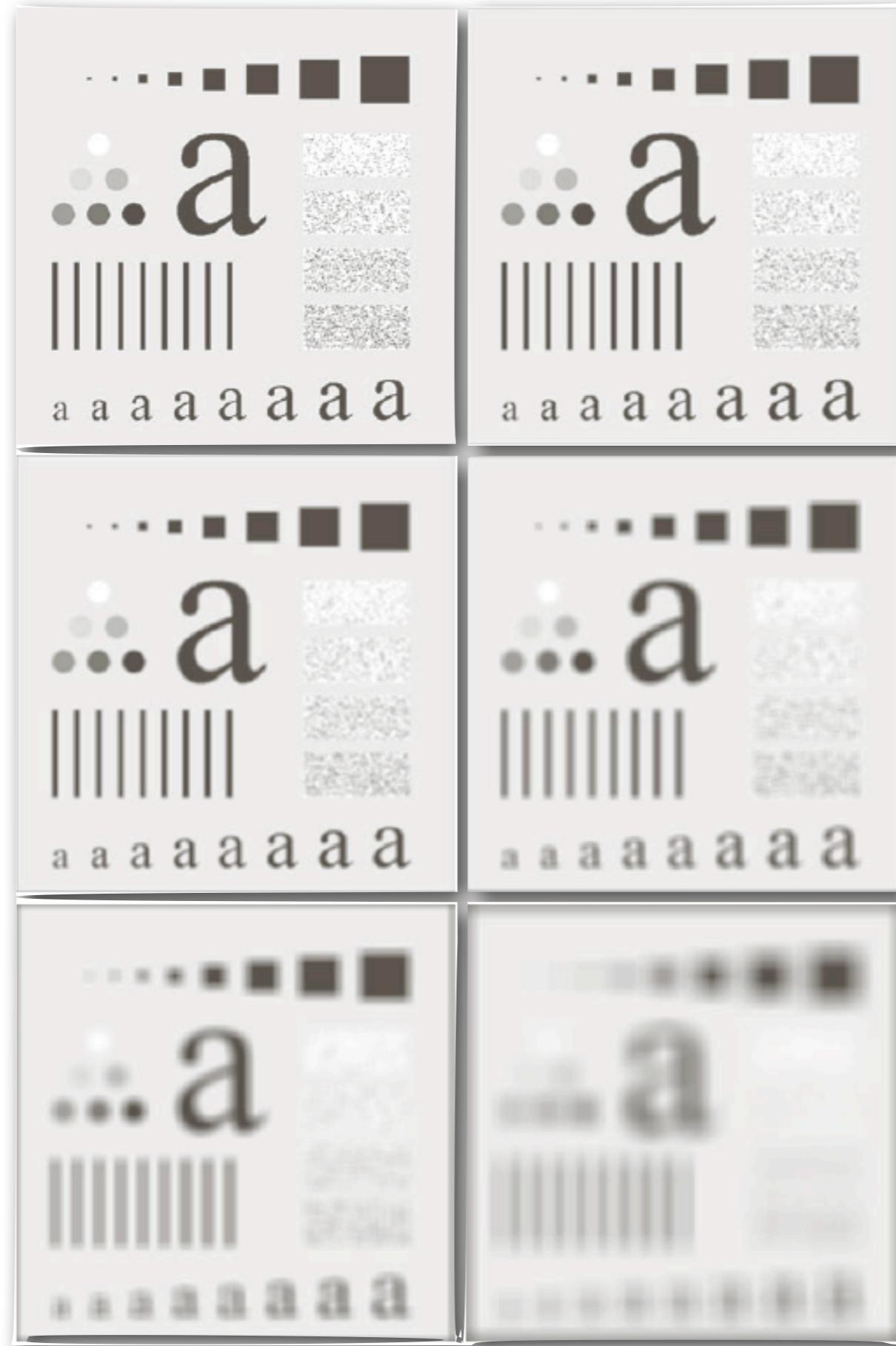
$$\frac{1}{9} \times \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

spatial averaging

$$\frac{1}{16} \times \begin{array}{|c|c|c|} \hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

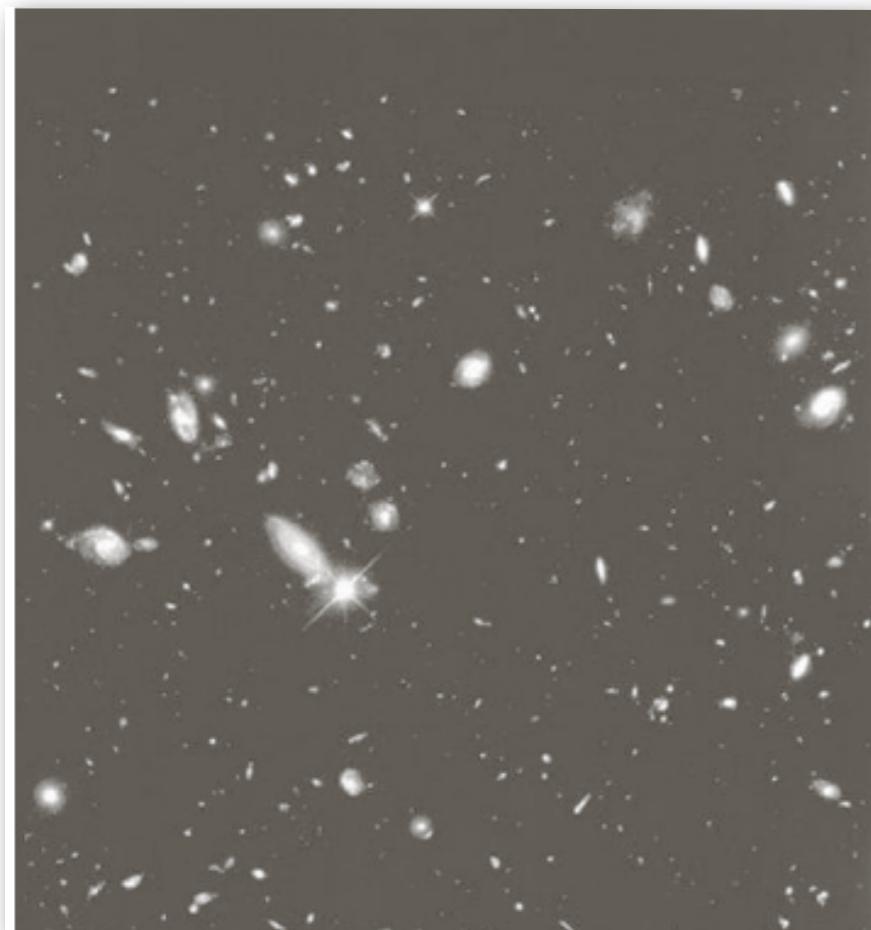
weighted averaging

Example: Smoothing Filter

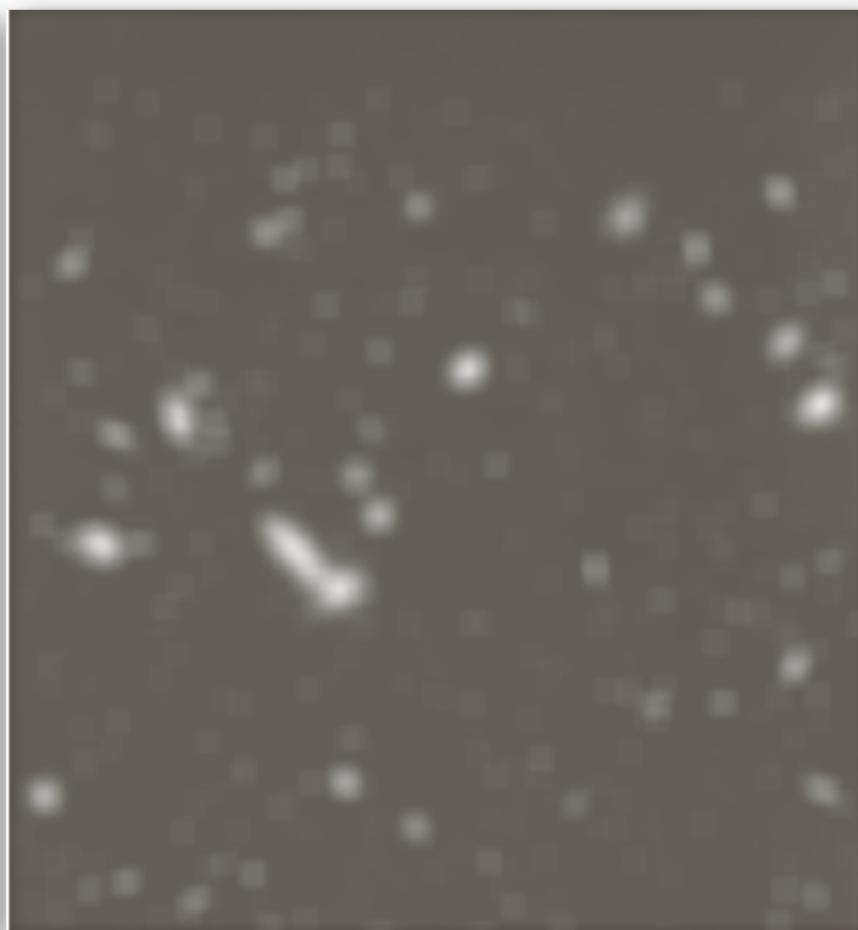


Application of Smoothing

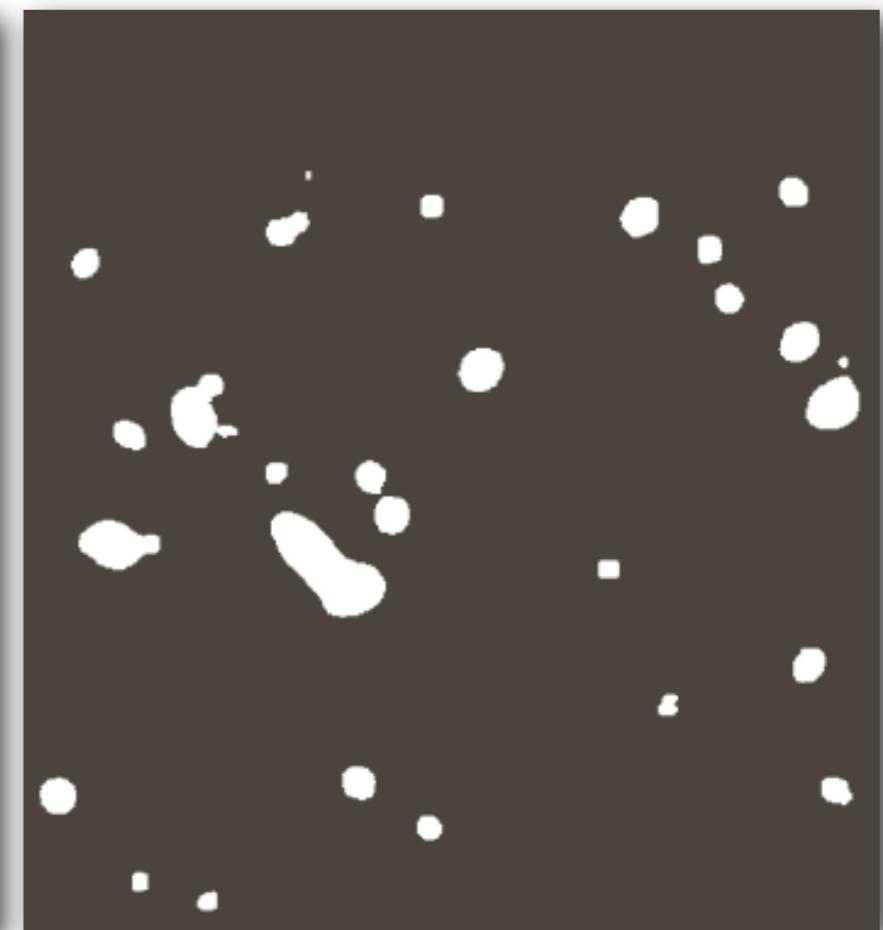
an image from Hubble space telescope



input

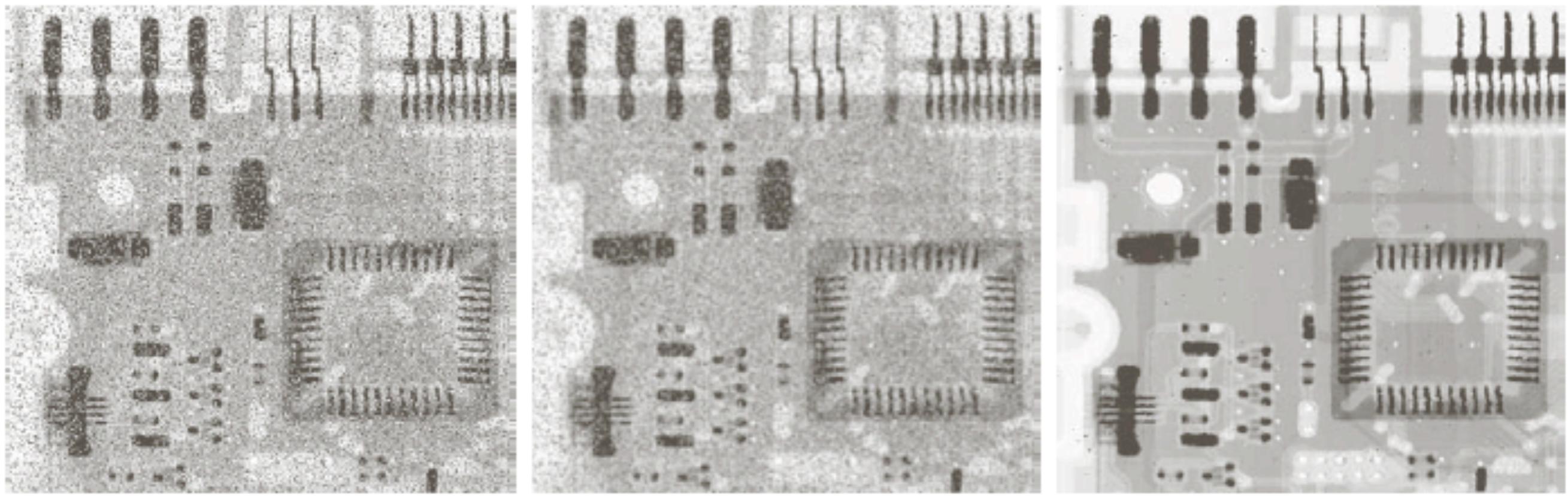


output



thresholded

Application of Smoothing



a b c

FIGURE 3.35 (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.)