What is spatial image filter

- Image filter is an N*M operator, with center at w(0,0)
- w(i, j) is coefficient

3x3 image filter

w(-1,+1)	w(0, +1)	w(+1,+1)
w(-1,0)	w(0,0)	w(+1,0)
w(-1,-1)	w(0,-1)	w(+1,-1)

Image filtering (1)

- A typical spatial filtering process is as follows
  - Move the filter from point to point in an image
  - At each point (x,y), calculate the response of the filter
- Response of filtering is calculated by convolution

$$f * w = \sum_{\substack{(a,b)\in w \\ (x-a,y-b)\in f}} f(x-a, y-b)w(a,b)$$

Image filtering (2)

- Convolution includes three steps:
  1. Position the center of the filter at the first pixel of an image and flip the filter.
  2. Calculate the inner product between the filter and the sub-image covered by the filter.
  3. Slide to next pixel, repeat steps 2 and 3 until the whole image is processed

Lowpass filtering (1)

- Low pass image filters are used in image smoothing
  - Reduce noise
  - Image may become blurred
- Example:
  - Average filter
  - Guassian filter

Lowpass filtering (2)

- Average filter:

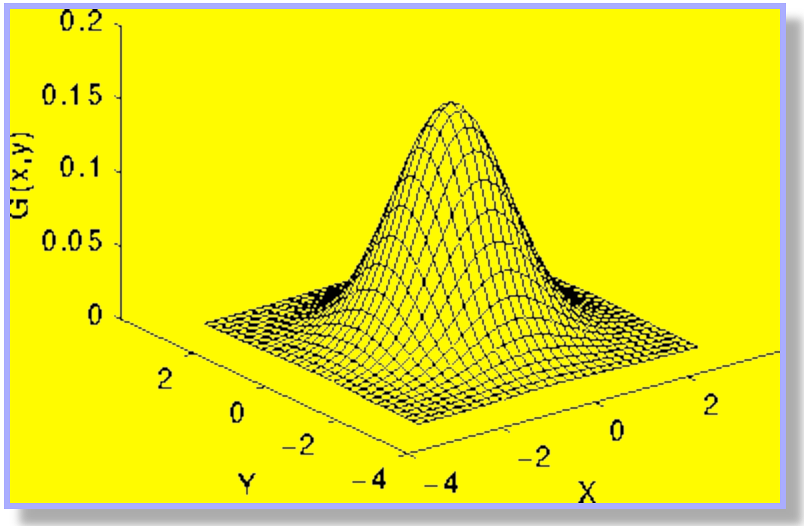
$$1/9 * \begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}$$

1

- Gaussian filter:

$$1/16 * \begin{array}{|c|c|c|} \hline 1 & 2 & 1 \\ \hline 2 & 4 & 2 \\ \hline 1 & 2 & 1 \\ \hline \end{array}$$

2-D Continuous Gaussian filter



Example of smoothing

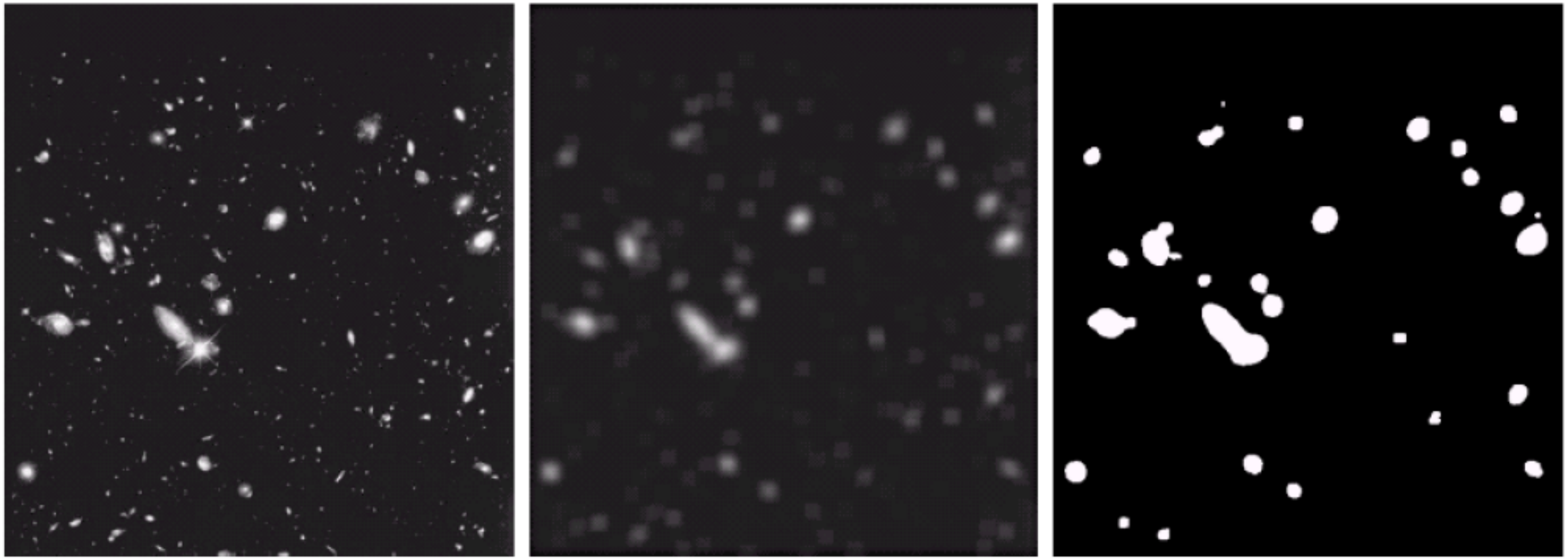


FIGURE 3.36 (a) Image from the Hubble Space Telescope. (b) Image processed by a 15 × 15 averaging mask. (c) Result of thresholding (b). (Original image courtesy of NASA.)

Median Filter

- Median filtering is to replace each pixel value in an image by the median of its neighborhood
- Procedure of Median filtering (filter size nxm):
  - Sort the pixel values in the *nxm* sub-image, centered at (*x*,*y*), to find the median;
  - Replace the pixel value *f(x,y)* by the median.

Gaussian vs. Median

Source

Gaussian

Median (5 X 5)

Edge detection (1)

- Highpass filtering is used to sharpen the image or detect the edges
- What is edge?
  - Gray level discontinuity
  - An important concept related to edge detection -- **Gradient**

Edge detection (2)

- Gradient is defined as a vector

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

- Gradient reflects the degree of change of gray levels in x and y directions
- An edge is detected if the gradient is larger than a threshold

1st order digital edge detector

Robert's operator

1	0
0	-1

0	1
-1	0

Prewitt's operator

-1	-1	-1
0	0	0
1	1	1

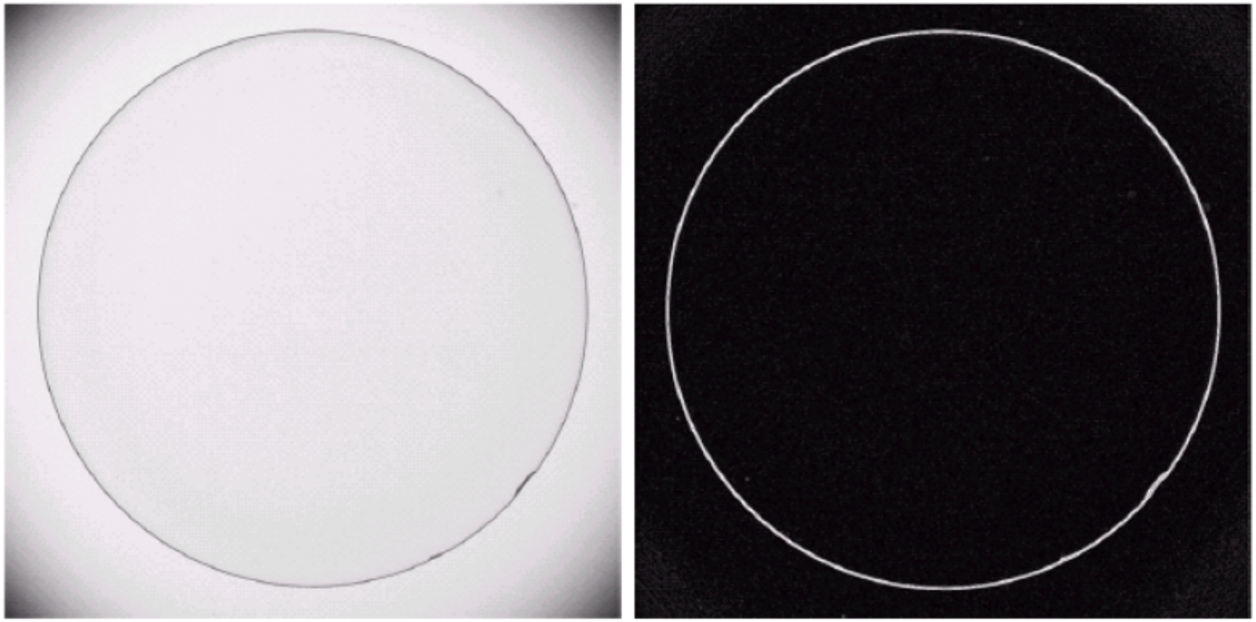
-1	0	1
-1	0	1
-1	0	1

Sobel's operator

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

An example of edge detection



a b

FIGURE 3.45 Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock). (b) Sobel gradient. (Original image courtesy of Mr. Pete Sites, Perceptics Corporation.)