

# Edge Detection

Image Processing

CSE 166

Lecture 15

# Announcements

- Assignment 6 is due May 23, 11:59 PM
- Assignment 7 will be released May 23
  - Due Jun 1, 11:59 PM
- Reading
  - Chapter 10: Image segmentation I: edge detection, thresholding, and region detection
    - Sections 10.1, 10.2, and 10.3

# Image segmentation

- General approach
  1. Spatial filtering
  2. Additional processing
  3. Thresholding
- Global thresholding (simplest)

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{otherwise} \end{cases}$$

where

$T$  is threshold value

# Image segmentation

Input

Edges

Segmentation



Edge-based



Region-based

# Derivatives in 1D

- Forward difference

$$\frac{\partial f(x)}{\partial x} = \frac{f(x + \Delta x) - f(x)}{\Delta x}$$

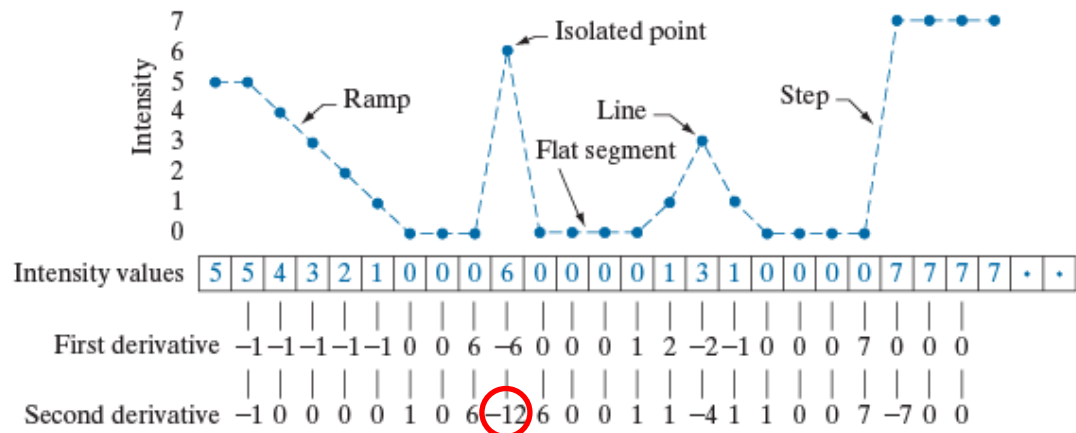
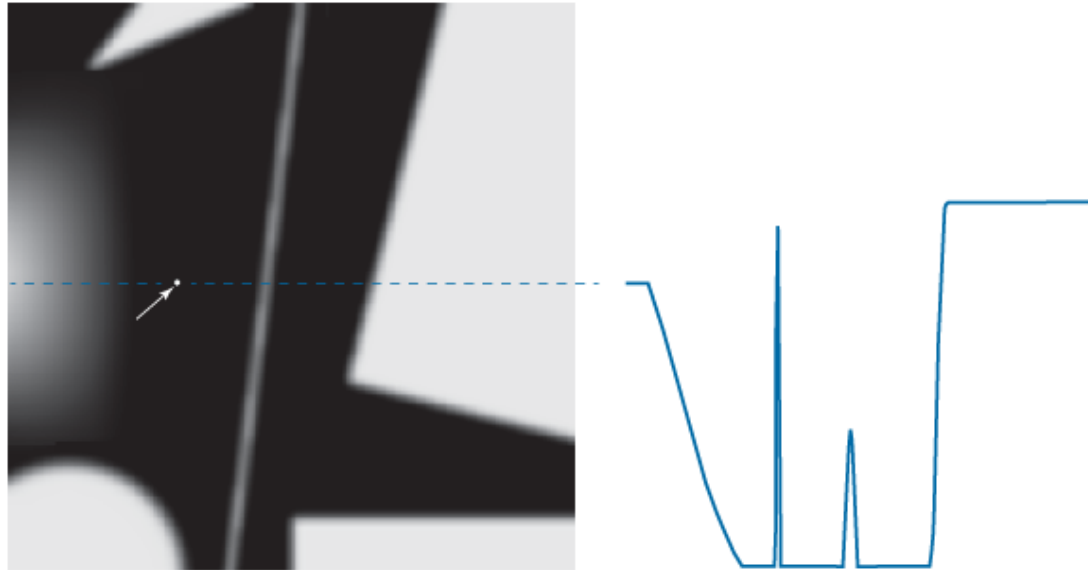
- Backward difference

$$\frac{\partial f(x)}{\partial x} = \frac{f(x) - f(x - \Delta x)}{\Delta x}$$

- Central difference

$$\frac{\partial f(x)}{\partial x} = \frac{f(x + \Delta x) - f(x - \Delta x)}{2\Delta x}$$

# Image derivatives



# Detection of isolated points

1	1	1
1	-8	1
1	1	1

Laplacian  
(second derivative)



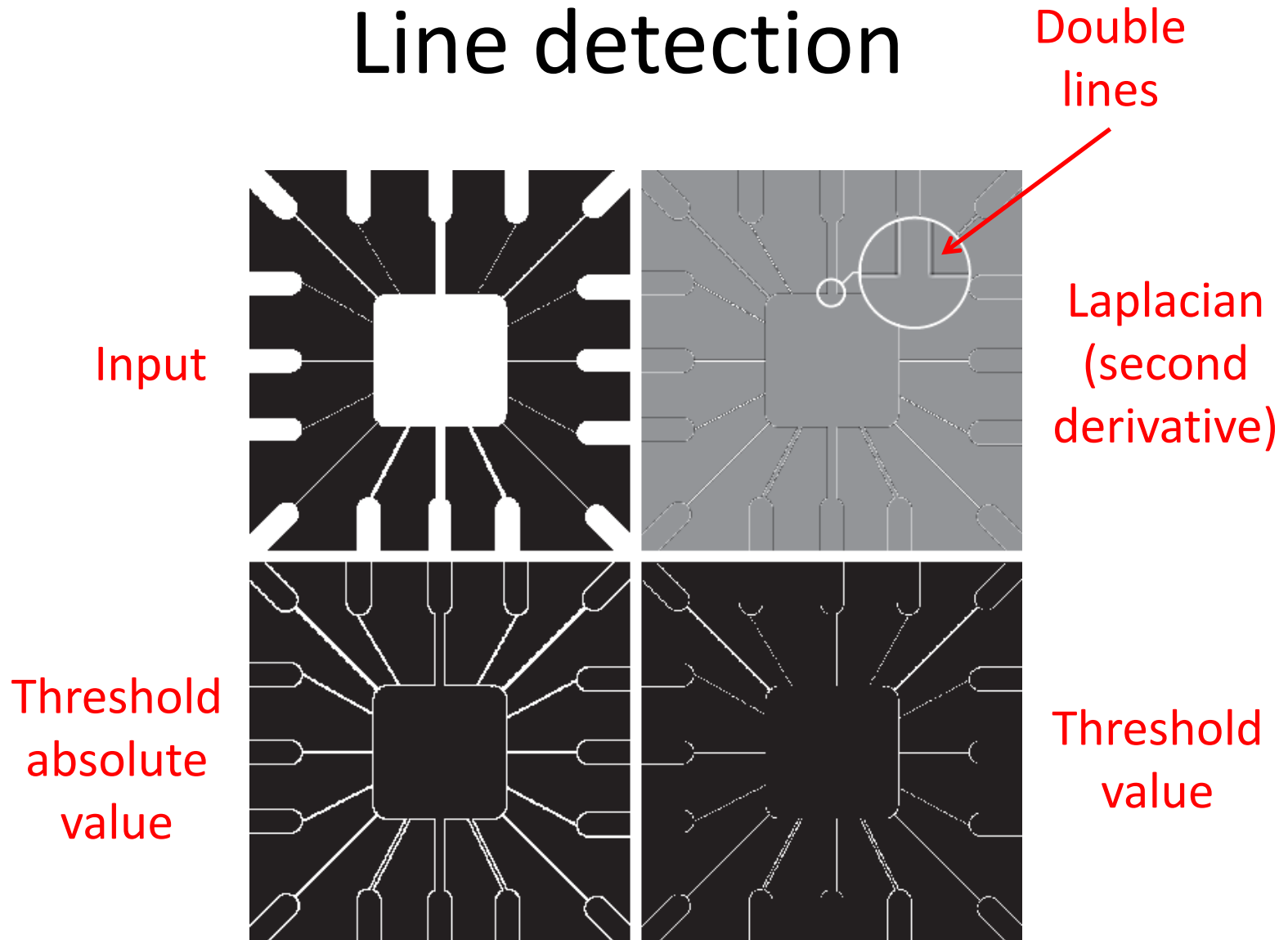
Input



Threshold  
absolute  
value

Segmentation

# Line detection





# Line detection, specific directions

-1	-1	-1	2	-1	-1	-1	2	-1	-1	-1	2
2	2	2	-1	2	-1	-1	2	-1	-1	2	-1
-1	-1	-1	-1	-1	2	-1	2	-1	2	-1	-1

Horizontal

+45°

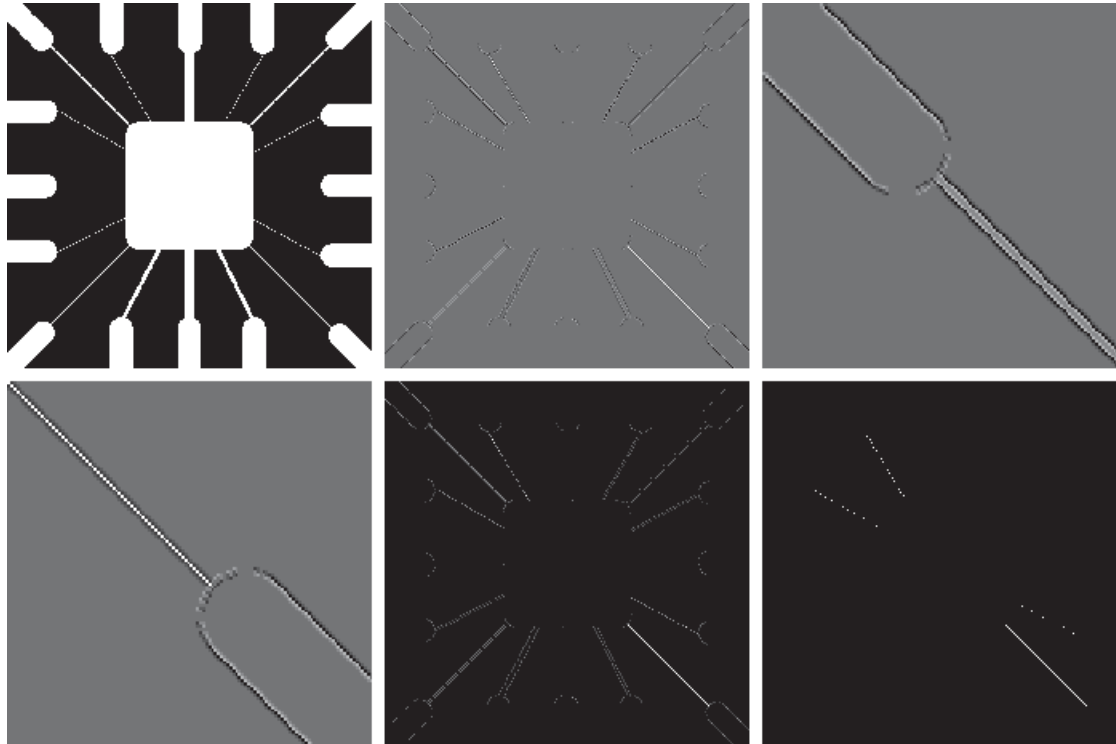
Vertical

-45°

Spatial filters

# Line detection, specific directions

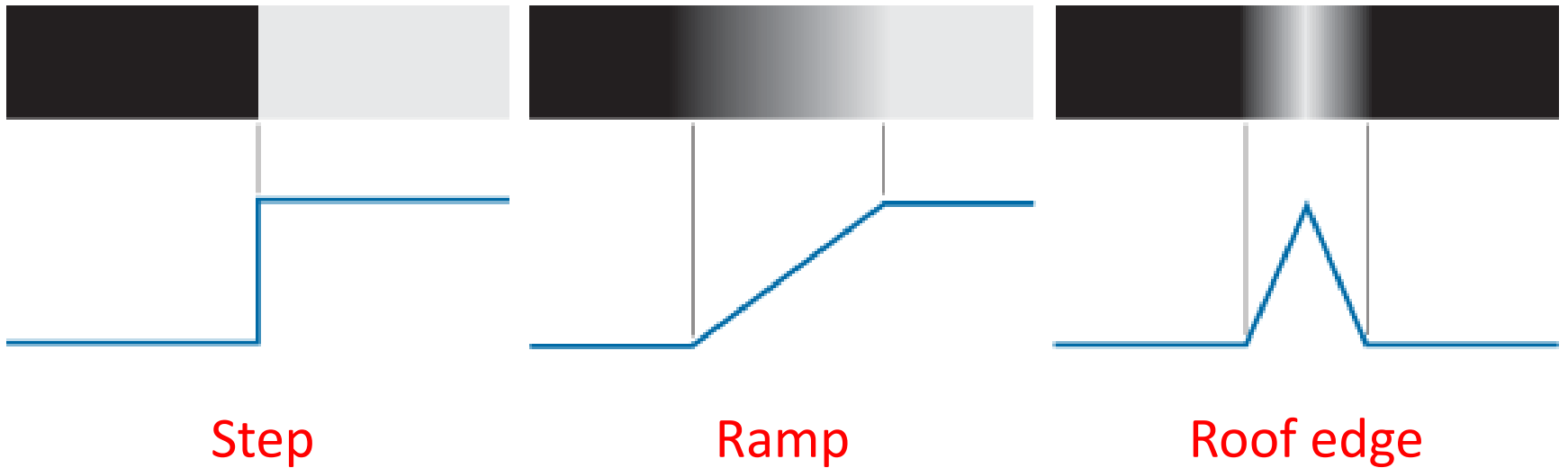
+45°



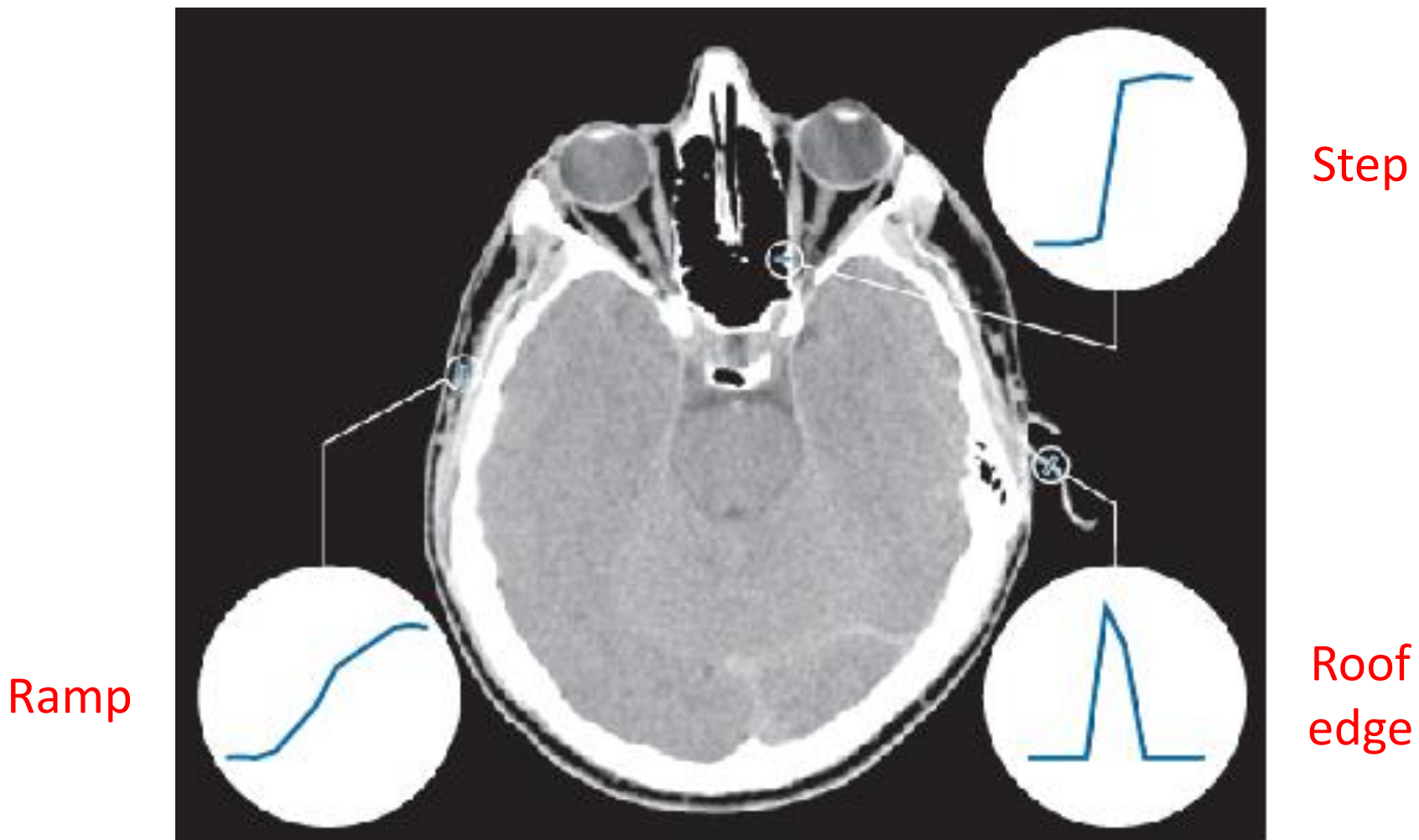
Negative  
values set  
to zero

Threshold

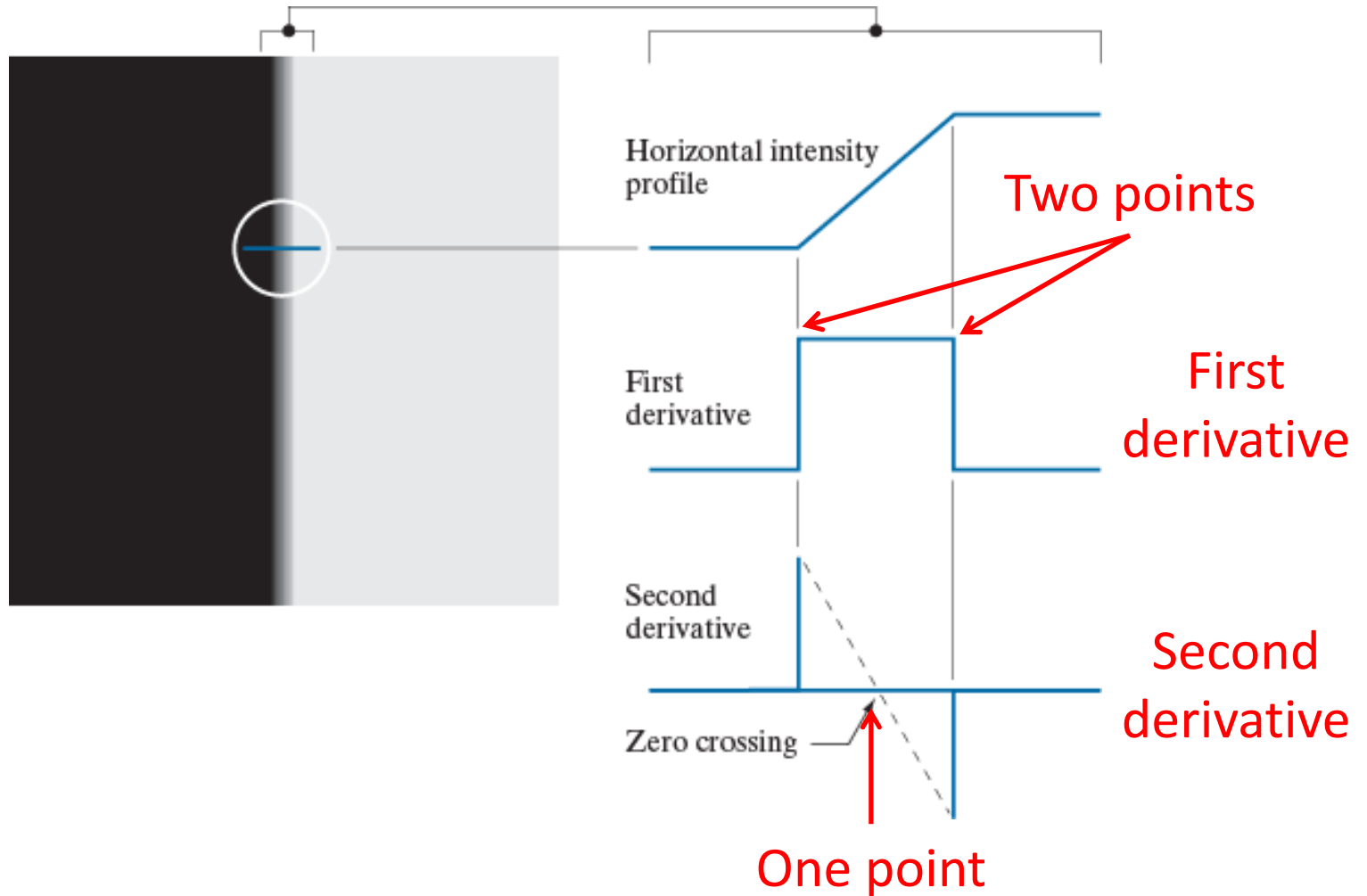
# Edge models



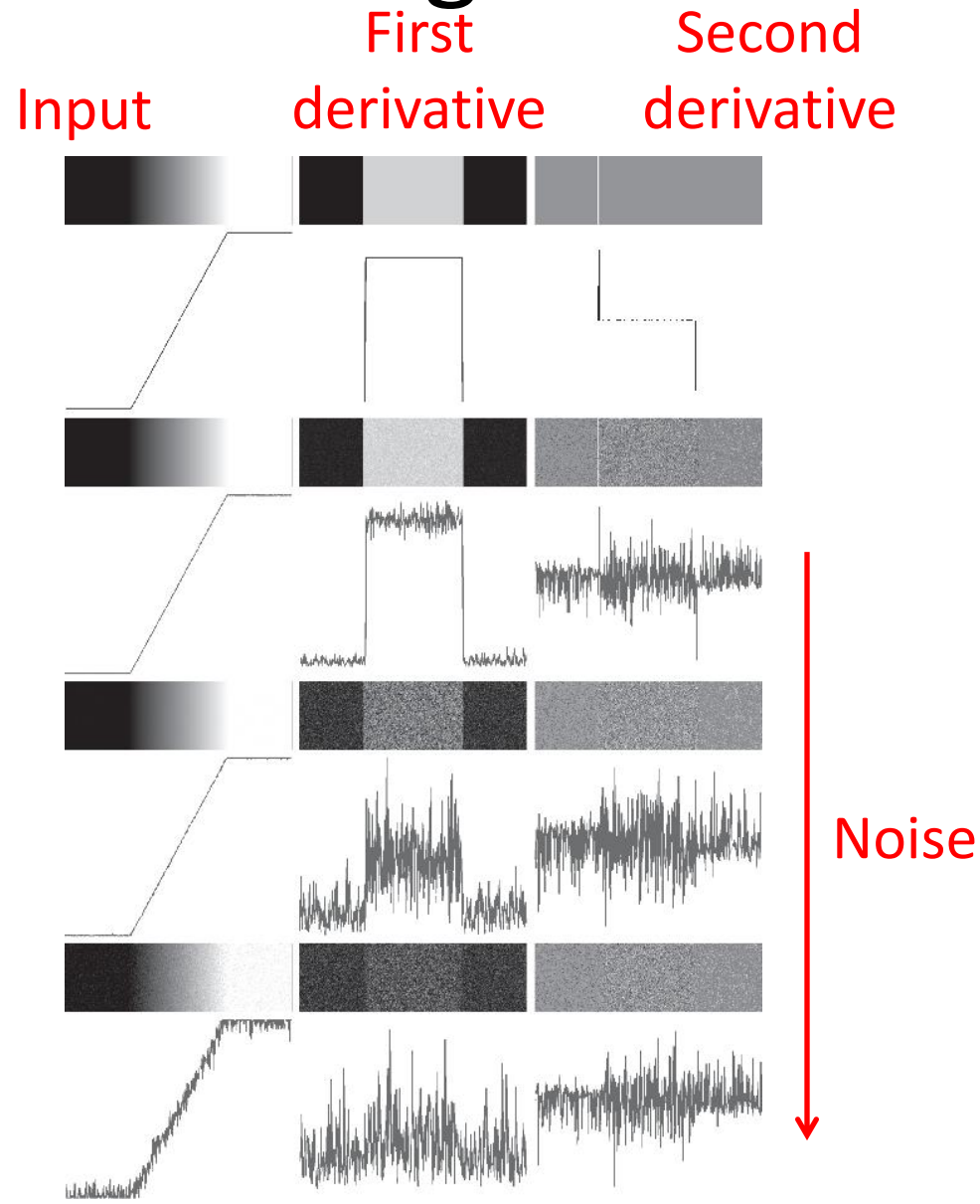
# Edge models



# Ramp edge



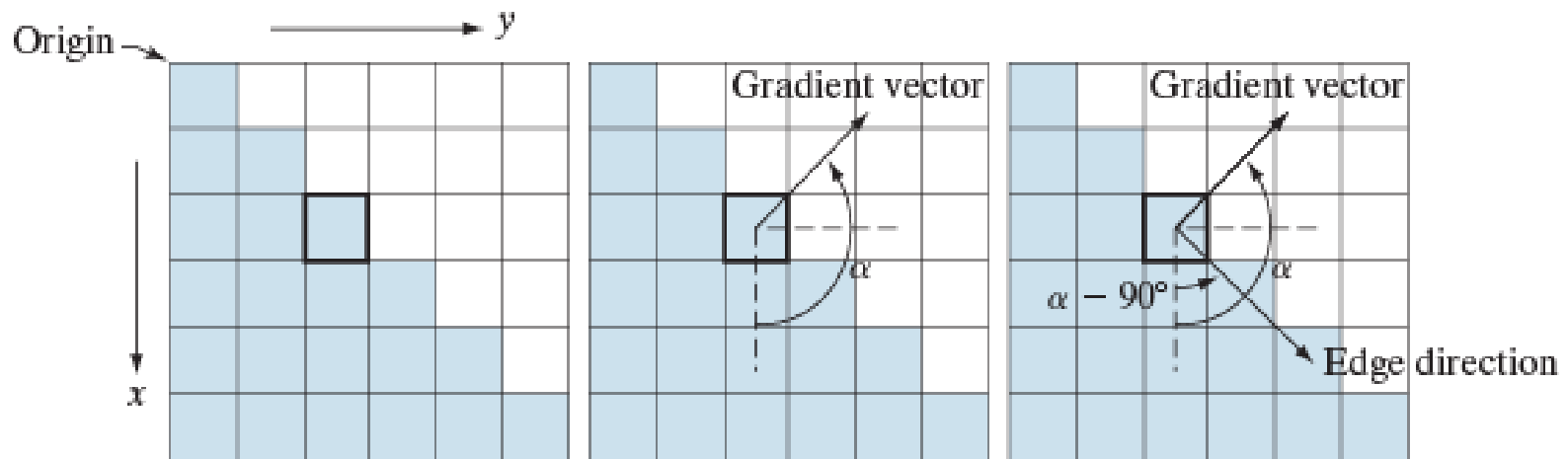
# Noise and image derivatives



# Edge detection

1. Image smoothing for noise reduction
2. Detection of image points (edge point candidates)
3. Edge localization (select from candidates, set of edge points)

# Gradient and edge direction



Gradient direction is orthogonal to edge direction



# Gradient operators

-1
1

-1	1
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Forward difference

-1	0	0	-1
0	1	1	0

Roberts

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

Prewitt

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

Sobel

# Gradients

Input



Magnitude  
of  
vertical  
gradient



Magnitude  
of  
horizontal  
gradient



Magnitude  
of  
gradient  
vector



# Gradients

Smooth image prior to computing gradients.  
Results in more selective edges

Input



Magnitude  
of  
vertical  
gradient



Magnitude  
of  
horizontal  
gradient



Magnitude  
of  
gradient  
vector



# Edge detection

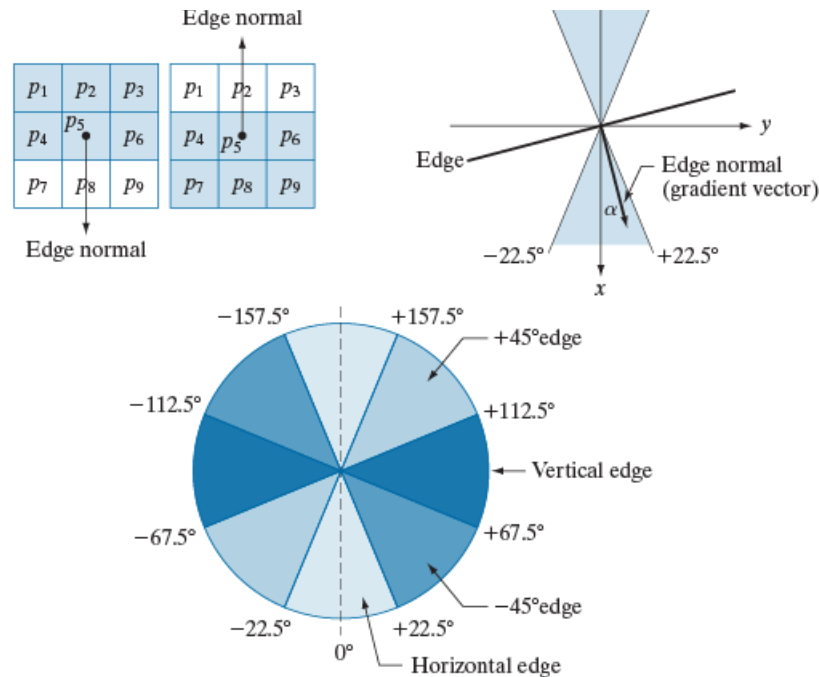
1. Smooth the input image
2. Compute the gradient magnitude image
3. Apply nonmaximal suppression to the gradient magnitude image
4. Threshold the resulting image

# Nonmaxima suppression

Specify a number of discrete orientations  $d_1, d_2, \dots$

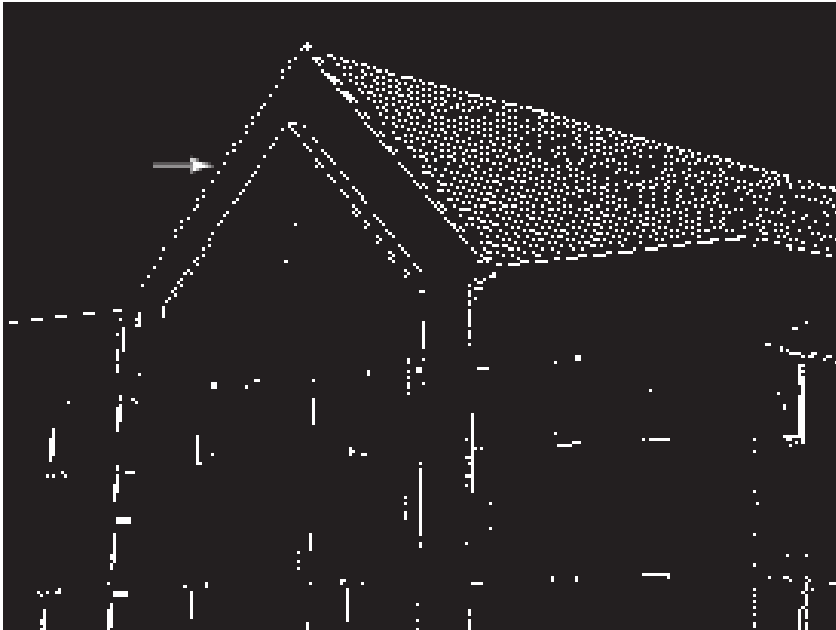
1. Determine the direction  $d_k$  closest to  $\alpha(x, y)$
2. Let  $K$  denote the value of  $\|\nabla f\|$  at  $(x, y)$ . If  $K$  is less than the value of  $\|\nabla f\|$  at one or both of the neighbors of point  $(x, y)$  along  $d_k$ , let  $g_N(x, y) = 0$  (suppression); otherwise, let  $g_N(x, y) = K$ .

Every edge has two possible orientations

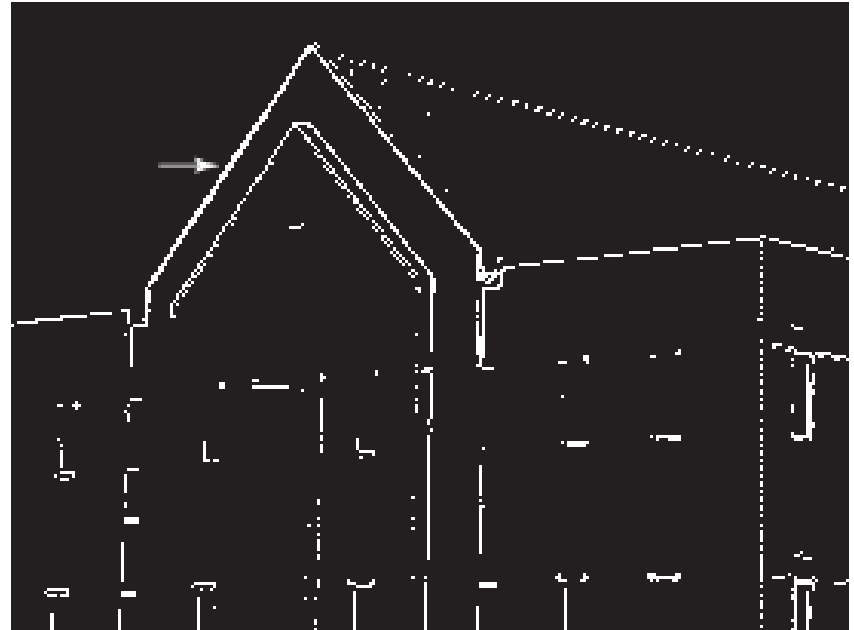


# Edge detection

Threshold magnitude of gradient vector



Without smoothing



With smoothing

# Advanced edge detection

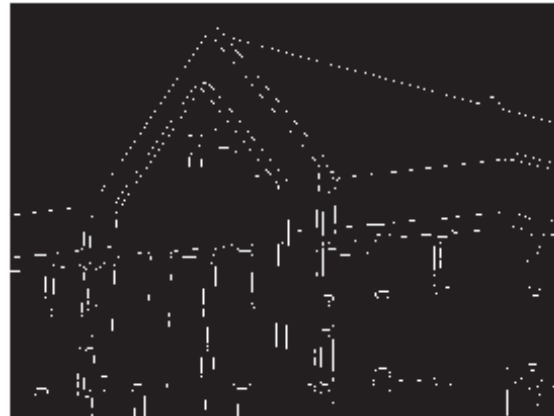
Input



Magnitude of  
gradient vector  
(with smoothing)



Marr-Hildreth



Canny

Figure 10.25 in textbook looks better

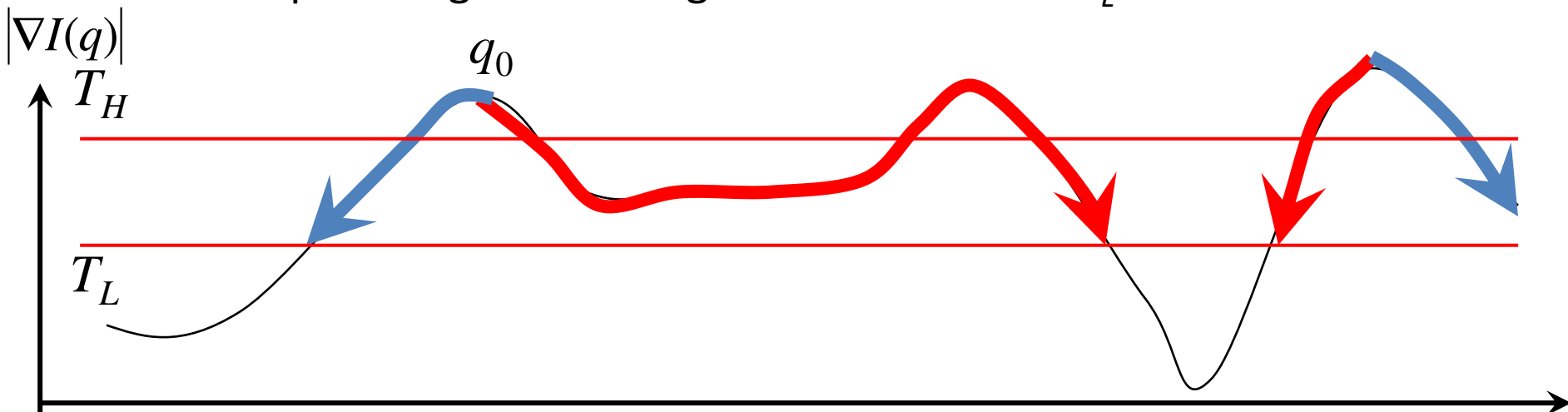
# Canny edge detector

1. Smooth the input image with a Gaussian filter
2. Compute the gradient magnitude and angle images
3. Apply nonmaximal suppression to the gradient magnitude image
4. Use double thresholding and connectivity analysis to detect and link edges



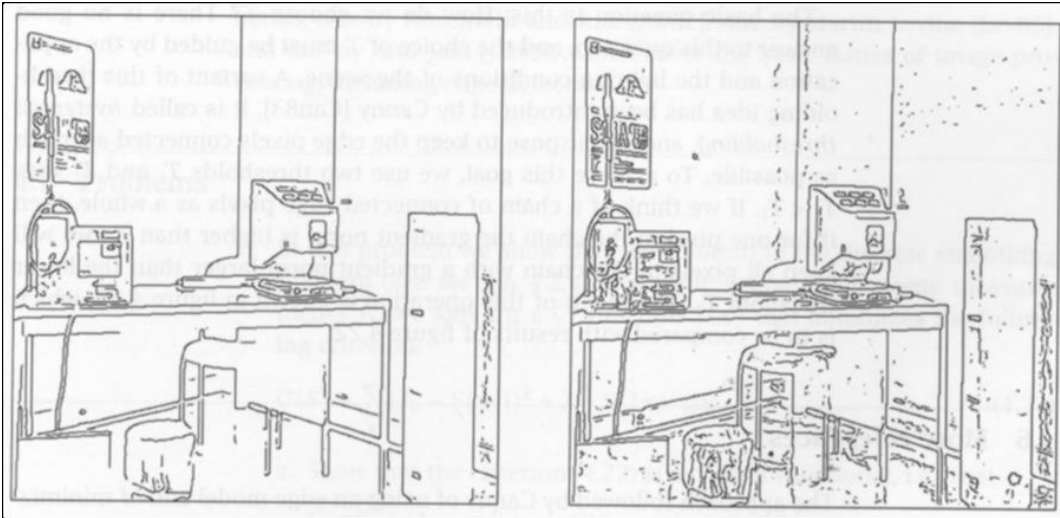
# Double thresholding

- Use a high threshold to start edge curves and a low threshold to continue them
  - Define two thresholds  $T_H$  and  $T_L$
  - Starting with output of nonmaximal suppression, find a point  $q_0$ , which is a local maximum greater than  $T_H$
  - Start tracking an edge chain at pixel location  $q_0$  in one of the two directions
  - Stop when gradient magnitude is less than  $T_L$



# Double thresholding

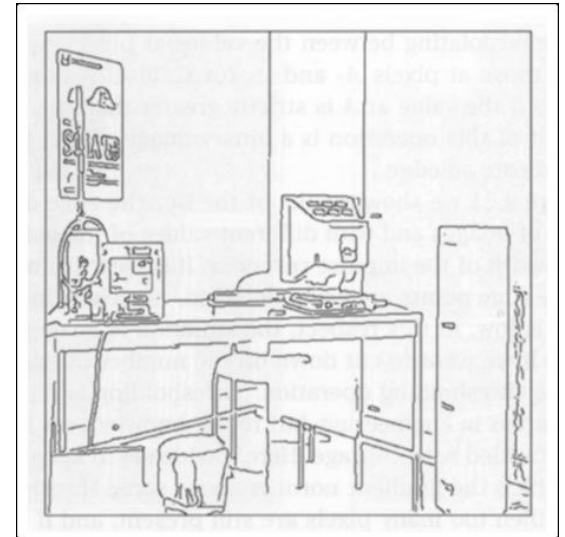
Single threshold



$T = 15$

$T = 5$

Double threshold



$T_H = 15$  and  $T_L = 5$

# Canny edge detector



# Canny edge detector



# Next Lecture

- Image segmentation
- Reading
  - Chapter 10: Image segmentation I: edge detection, thresholding, and region detection
    - Sections 10.3, 10.4, 10.5, and 10.6