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# VC 11/12 – T8

## Segmentation

Mestrado em Ciência de Computadores  
Mestrado Integrado em Engenharia de Redes e  
Sistemas Informáticos

*Miguel Tavares Coimbra*

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# Outline

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- Thresholding
- Geometric structures
- Hough Transform

**Acknowledgements: Most of this course is based on the excellent courses offered by Prof. Shree Nayar at Columbia University, USA and by Prof. Srinivasa Narasimhan at CMU, USA. Please acknowledge the original source when reusing these slides for academic purposes.**

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# Topic: Thresholding

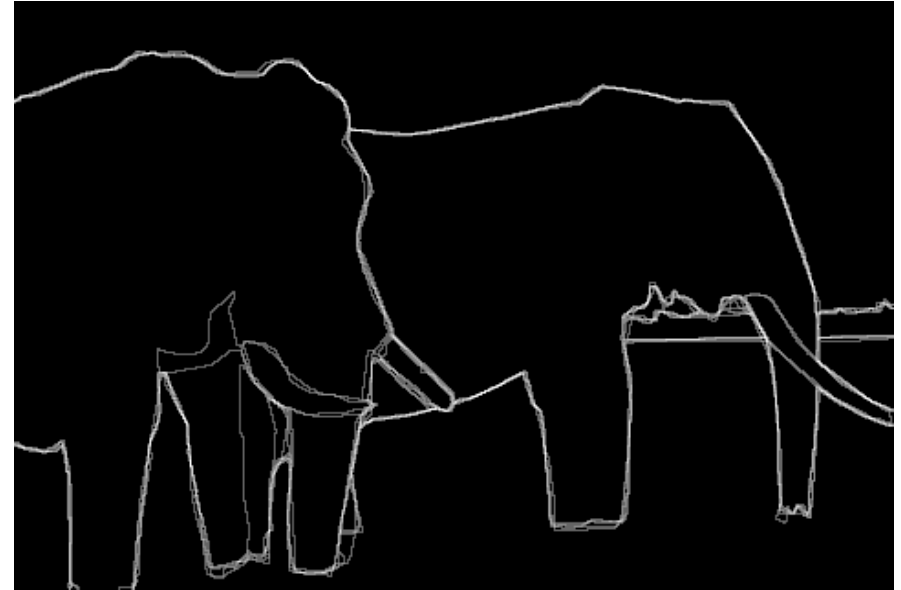
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- Thresholding
- Geometric structures
- Hough Transform

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# Boundaries of Objects

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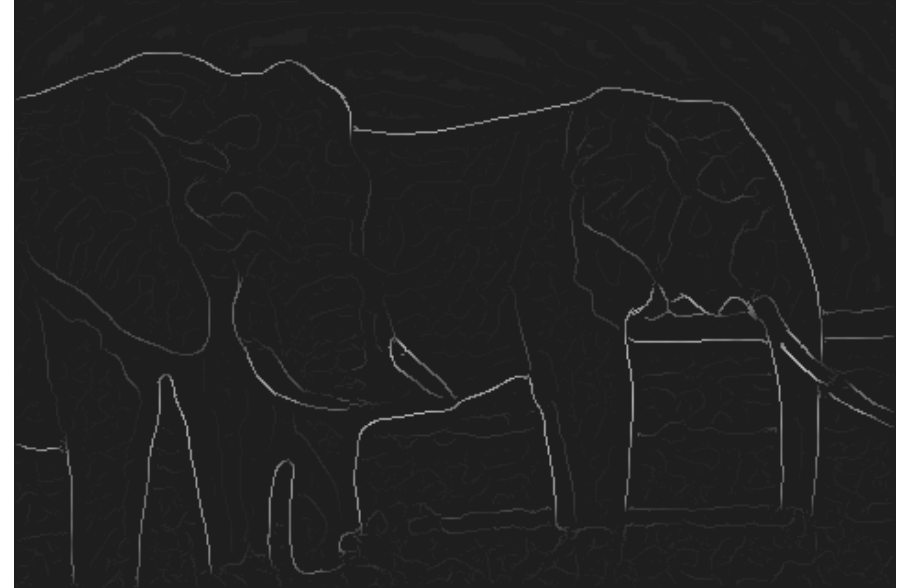
Marked by many users

<http://www.eecs.berkeley.edu/Research/Projects/CS/vision/grouping/segbench/bench/html/images.html>

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# Boundaries of Objects from Edges

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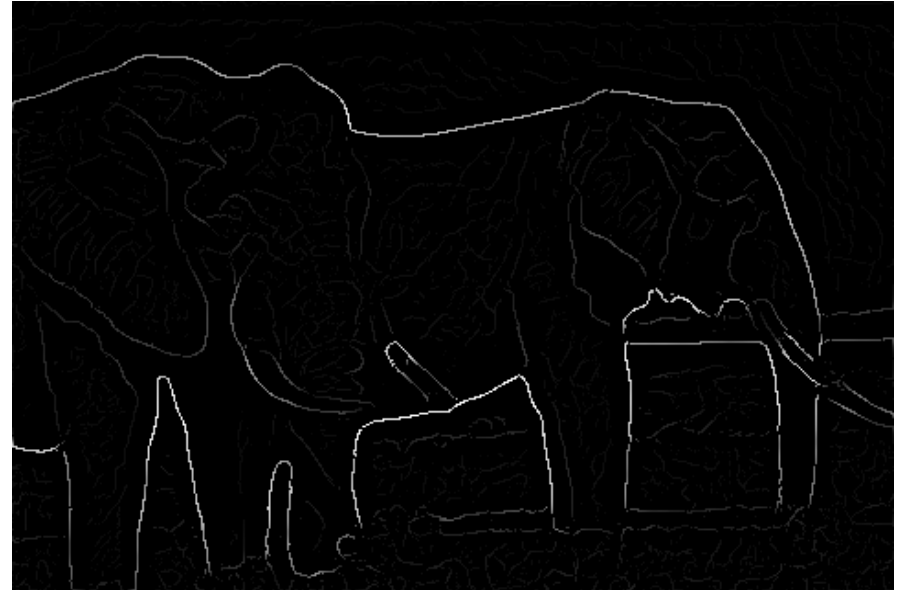
Brightness Gradient (Edge detection)

- Missing edge continuity, many spurious edges

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# Boundaries of Objects from Edges

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Multi-scale Brightness Gradient

- But, low strength edges may be very important

## Machine Edge Detection



Image



Human Boundary Marking

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# Boundaries in Medical Imaging

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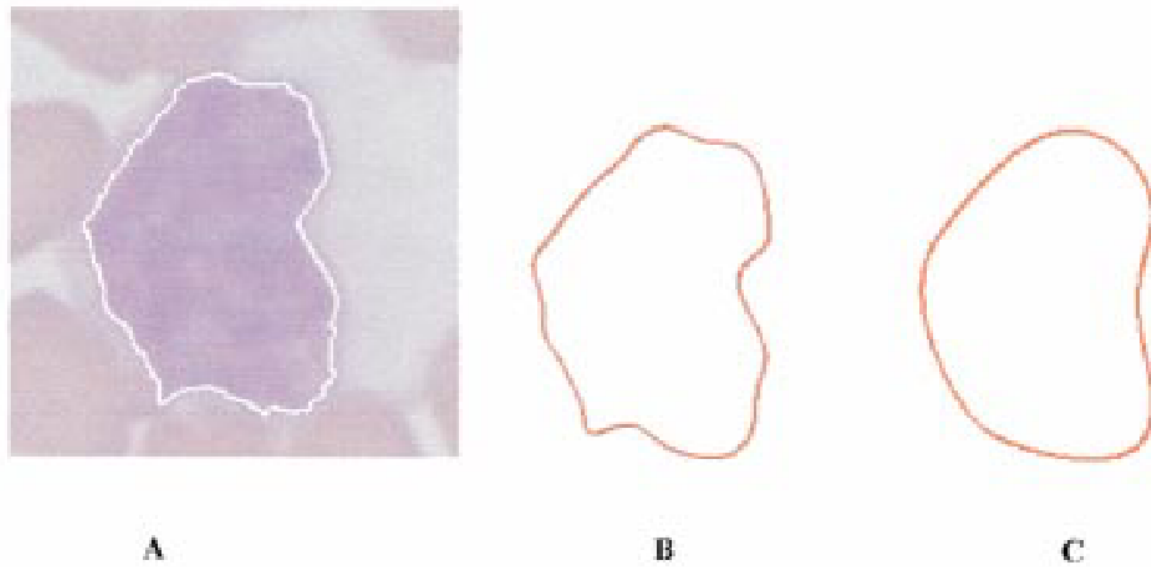
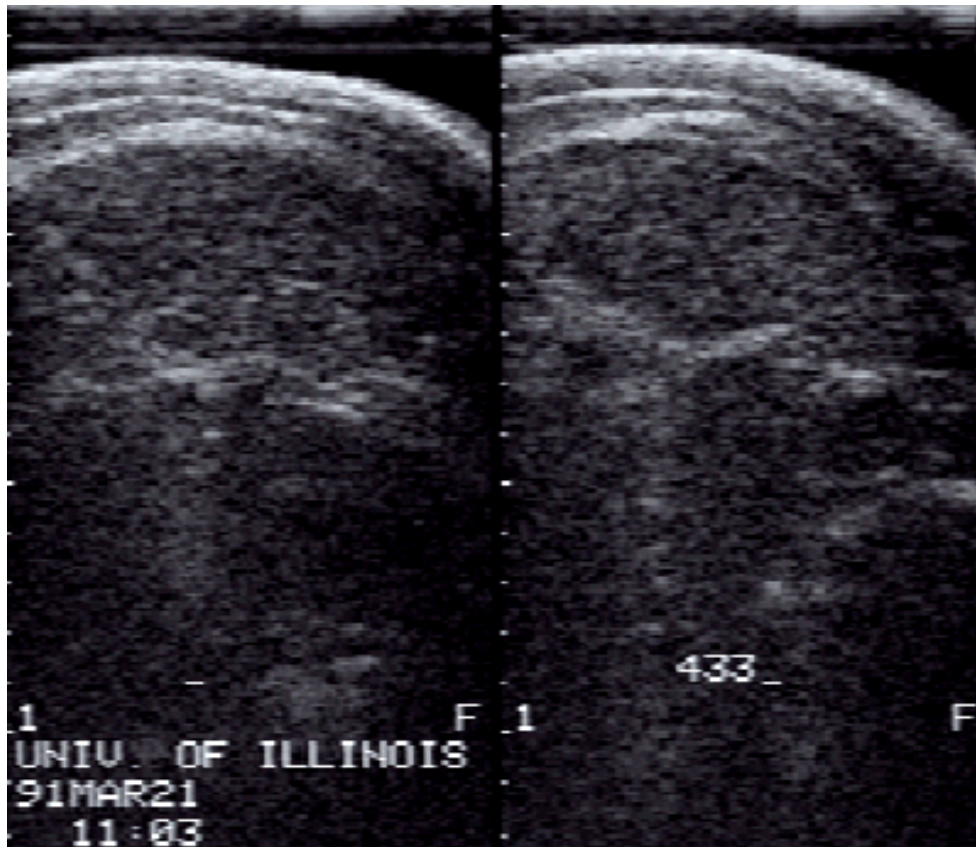


Fig. 2. Representation of a closed contour by elliptic Fourier descriptors. (a) Input. (b) Series truncated at 16 harmonics. (c) Series truncated to four harmonics.

Detection of cancerous regions.



# Boundaries in Ultrasound Images



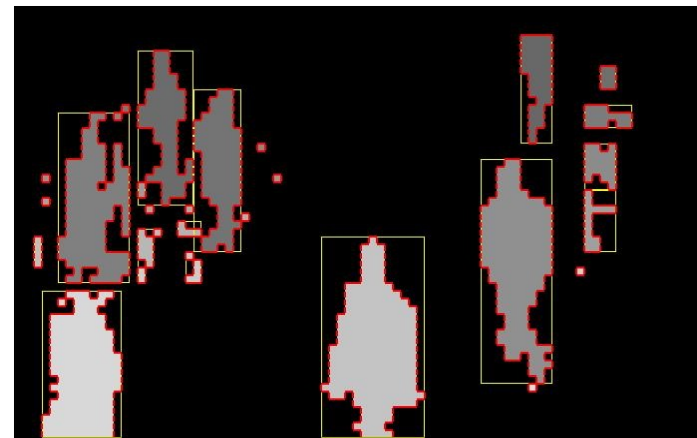
Hard to detect in the presence of large amount of speckle noise



Sometimes hard even for humans!

# What is 'Segmentation'?

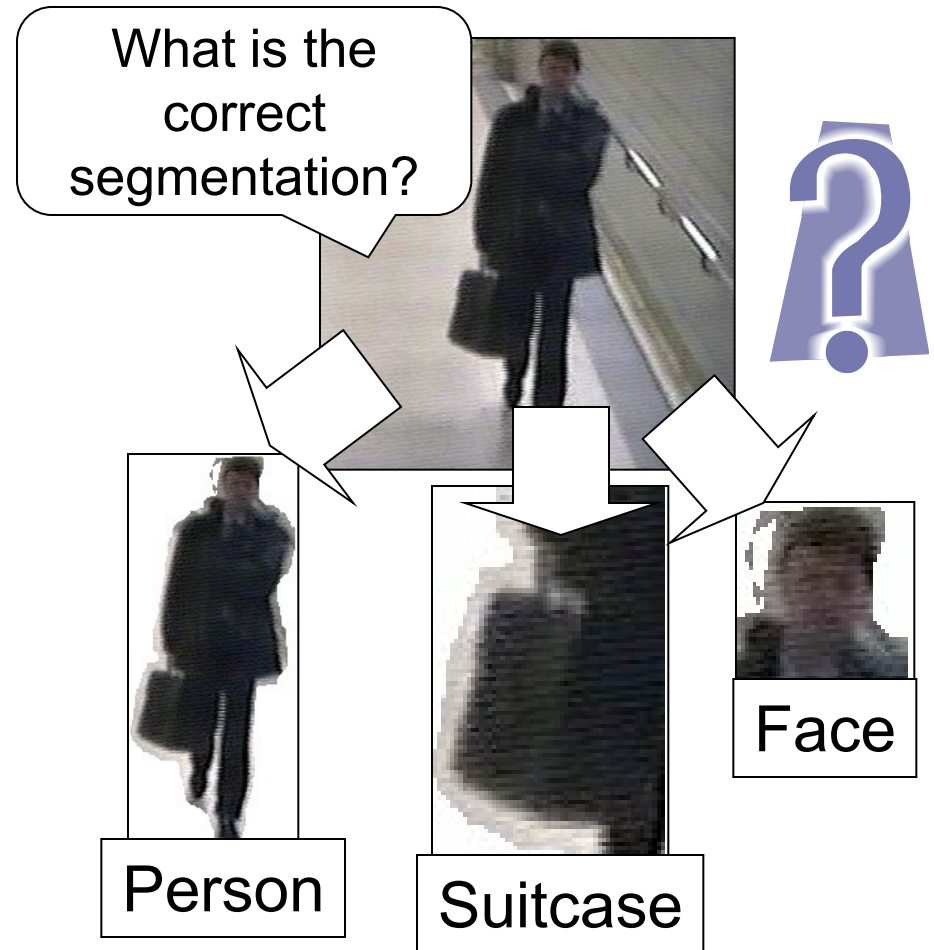
- Separation of the image in different areas.
  - Objects.
  - Areas with similar visual or semantic characteristics.



Not trivial! It is the holy grail of most computer vision problems!

# Subjectivity

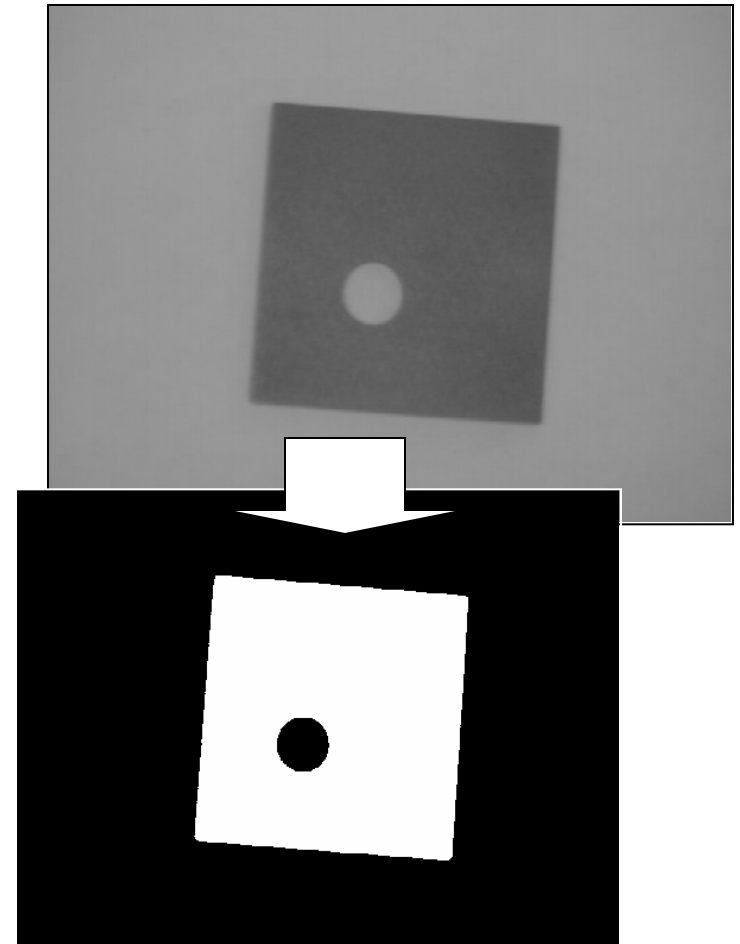
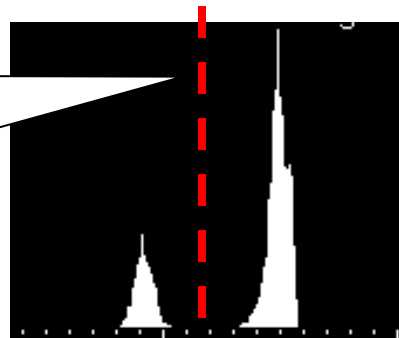
- A 'correct' segmentation result is only valid for a specific context.
  - Subjectivity!
  - Hard to implement.
  - Hard to evaluate.



# Core Technique: *Thresholding*

- Divide the image into two areas:
  - 1, if  $f(x,y) > K$
  - 0, if  $f(x,y) \leq K$
- Not easy to find the ideal *k* magic number.
- Core segmentation technique
  - Simple
  - Reasonably effective

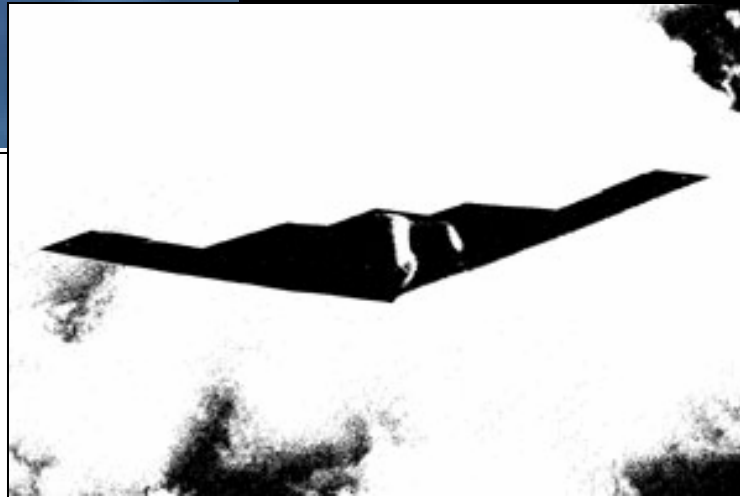
Adequate  
*threshold*



# Finding the 'magic number'



Correct  
( $k = 74$ )



Wrong!  
( $k = 128$ )

## Sonnet for Lena

O dear Lena, your beauty is so vast  
It is hard sometimes to describe it fast.  
I thought the entire world I would impress  
If only your portrait I could compress.  
Alas! First when I tried to use VQ  
I found that your cheeks belong to only you.  
Your silky hair contains a thousand lines  
Hard to match with sums of discrete cosines.  
And for your lips, sensual and tactual  
Thirteen Crays found not the proper fractal.  
And while these setbacks are all quite severe  
I might have fixed them with hacks here or there  
But when filters took sparkle from your eyes  
I said, 'Damn all this. I'll just digitize.'

*Thomas Colthurst*

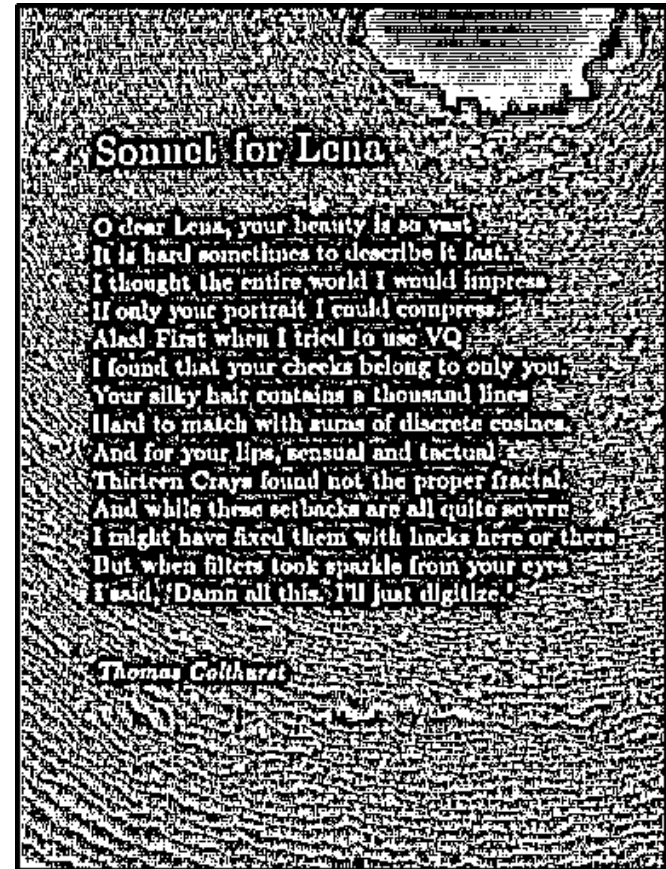
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Global thresholds are not  
always adequate...

# Adaptive Thresholding

- Adapt the threshold value for each pixel.
- Use characteristics of nearby pixels.
- How?
  - Mean
  - Median
  - Mean + K
  - ...



Mean of 7x7 neighborhood



## Sonnet for Lena

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7x7 window;  $K = 7$

75x75 window;  $K = 10$

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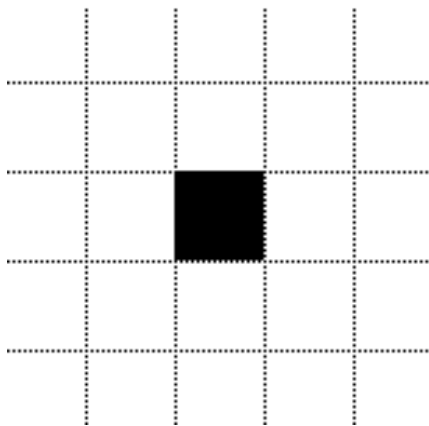
# Topic: Geometric structures

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- Thresholding
- **Geometric structures**
- Hough Transform

# Points

- What is a point?
  - Pixel with a significant illumination difference to its neighbors.
  - Group of pixels?



- Spatial Mask!
- Need to define a threshold  $K$ .

-1	-1	-1
-1	8	-1
-1	-1	-1

$$R = \sum_{i=1}^9 w_i z_i$$

$$|R| > K \Leftrightarrow \text{point!}$$

# Lines

- **Spatial filter**
  - One per line direction
  - Sensitive to line width

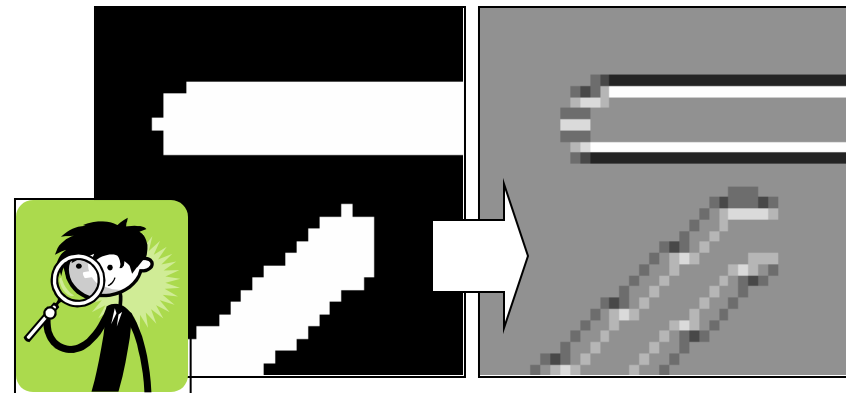
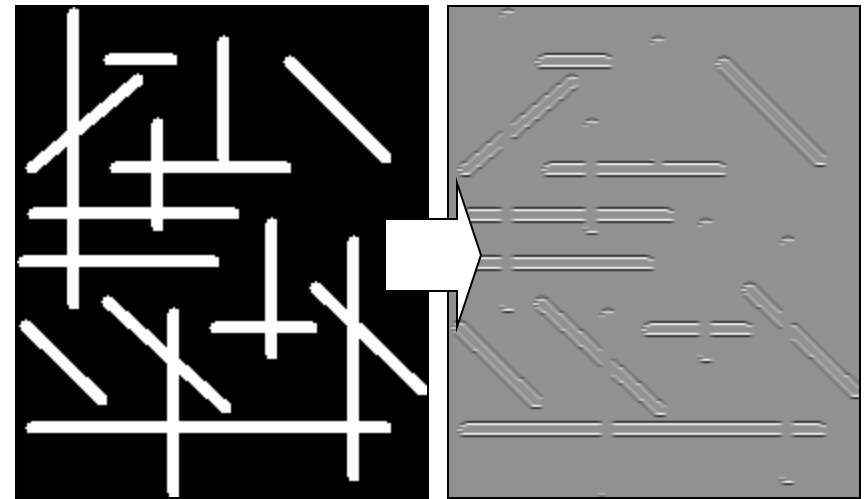
-1	-1	-1
2	2	2
-1	-1	-1

Horizontal

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

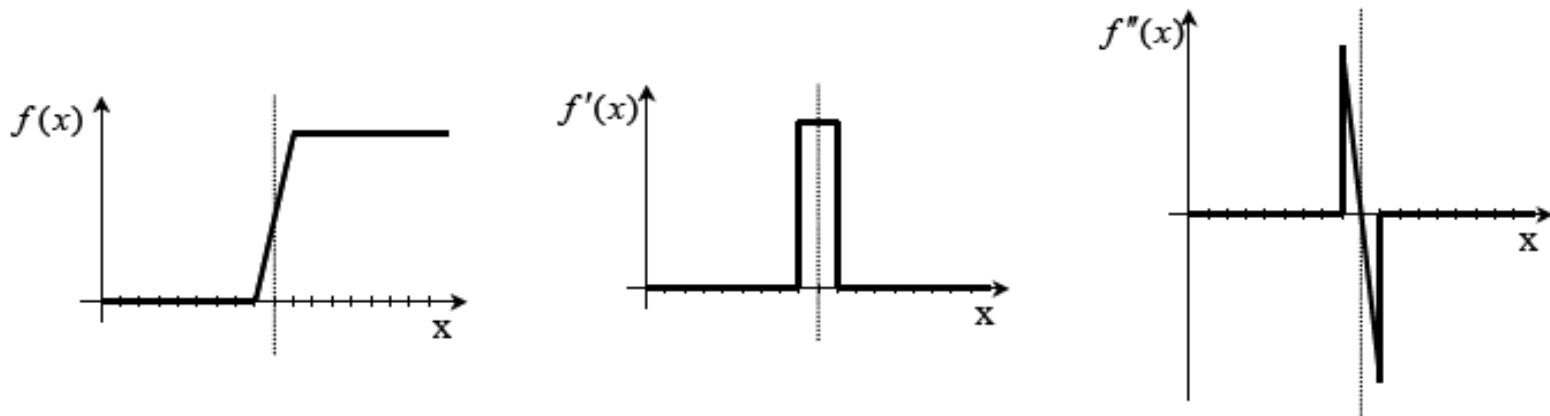
Vertical

Diagonal?



# Edges

- **Edge:**
  - Spatial discontinuity of pixel amplitude.
  - High spatial gradient
    - First derivative (*peak*)
    - Second derivative (*zero crossing*)



# Popular operators

- **Edge detection**

- Great utility for several problems.

$$G_x \rightarrow \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G_y \rightarrow \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

a) Sobel edge detector

- Well studied problem.

$$G_x \rightarrow \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G_y \rightarrow \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

b) Prewitt edge detector

- **A variety of solutions exists.**

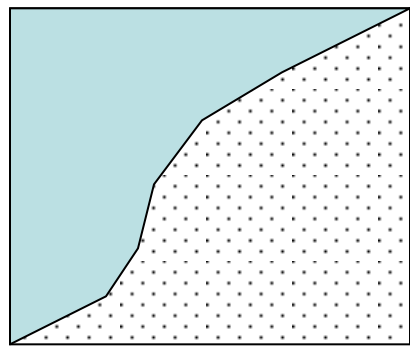
$$G_x \rightarrow \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$G_y \rightarrow \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

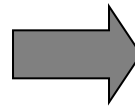
c) Roberts edge detector



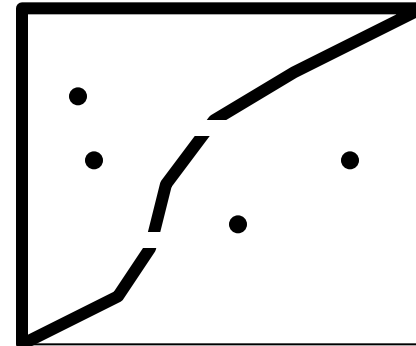
# Processing Edge Images



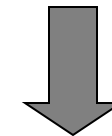
Image



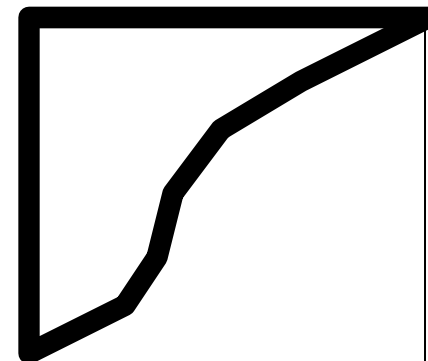
Edge detection  
and Thresholding



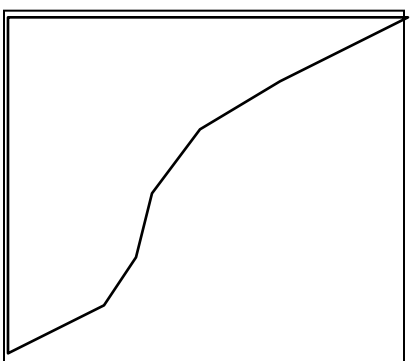
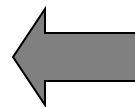
Noisy edge image  
Incomplete boundaries



Edge Tracking



Thinning





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# Edge Tracking Methods

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- **Adjusting a priori Boundaries**

**Given:** Approximate Location of Boundary

**Task:** Find Accurate Location of Boundary

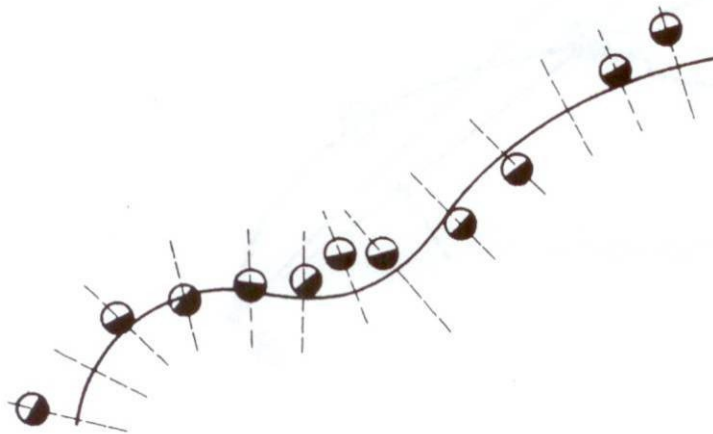


Fig. 4.2 Search orientations from an approximate boundary location.

- Search for **STRONG EDGES** along normals to approximate boundary.
- Fit curve (eg., polynomials) to strong edges.

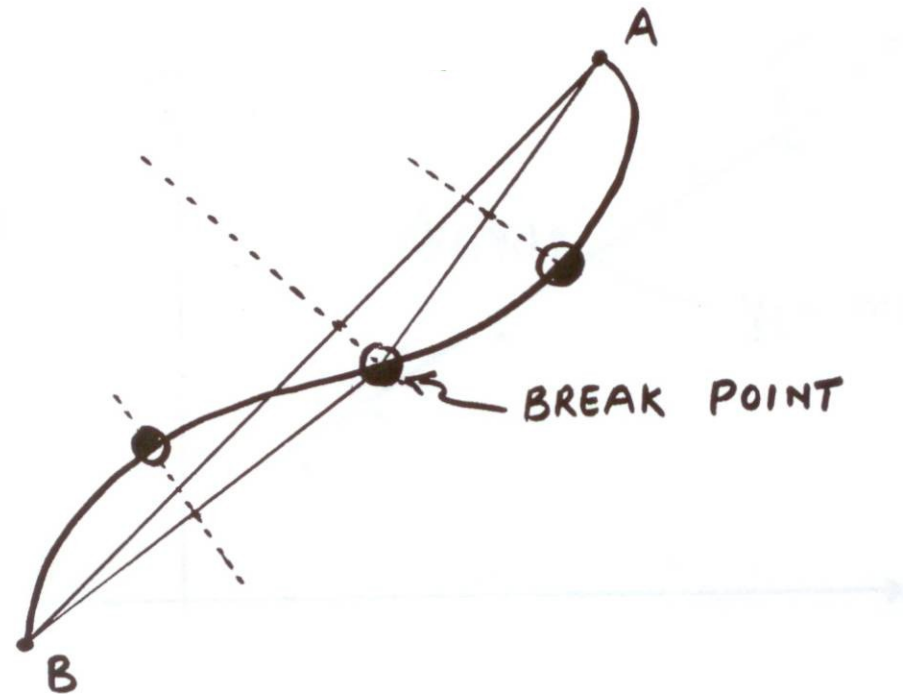
# Edge Tracking Methods

- **Divide and Conquer**

**Given:** Boundary lies between points A and B

**Task:** Find Boundary

- Connect A and B with Line
- Find strongest edge along line bisector
- Use edge point as break point
- Repeat



# Fitting Lines to Edges (Least Squares)

**Given:** Many  $(x_i, y_i)$  pairs  
**Find:** Parameters  $(m, c)$

**Minimize:** Average square distance:

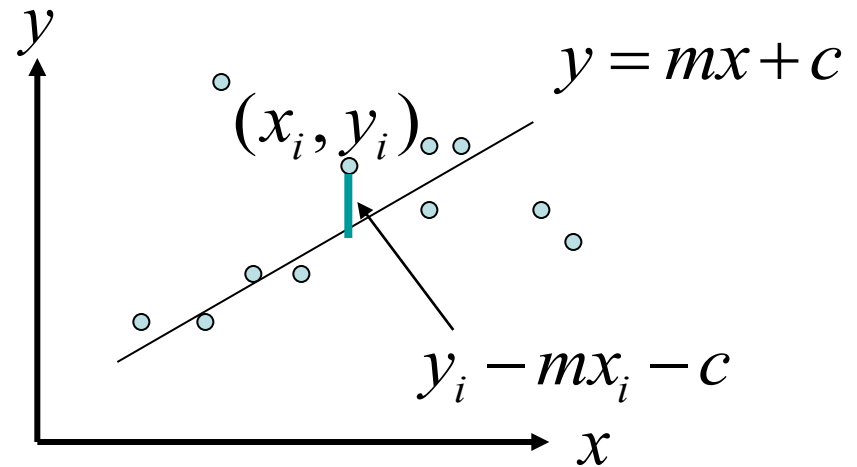
$$E = \sum_i \frac{(y_i - mx_i - c)^2}{N}$$

**Using:**

$$\frac{\partial E}{\partial m} = 0 \quad \& \quad \frac{\partial E}{\partial c} = 0$$

**Note:**

$$\bar{y} = \frac{\sum y_i}{N} \quad \bar{x} = \frac{\sum x_i}{N}$$



$$c = \bar{y} - m \bar{x}$$
$$m = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sum_i (x_i - \bar{x})^2}$$

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# Topic: Hough Transform

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- Thresholding
- Geometric structures
- **Hough Transform**

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# Hough Transform

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- Elegant method for direct object recognition
- Edges need not be connected
- Complete object need not be visible
- Key Idea: Edges **VOTE** for the possible model

# Image and Parameter Spaces

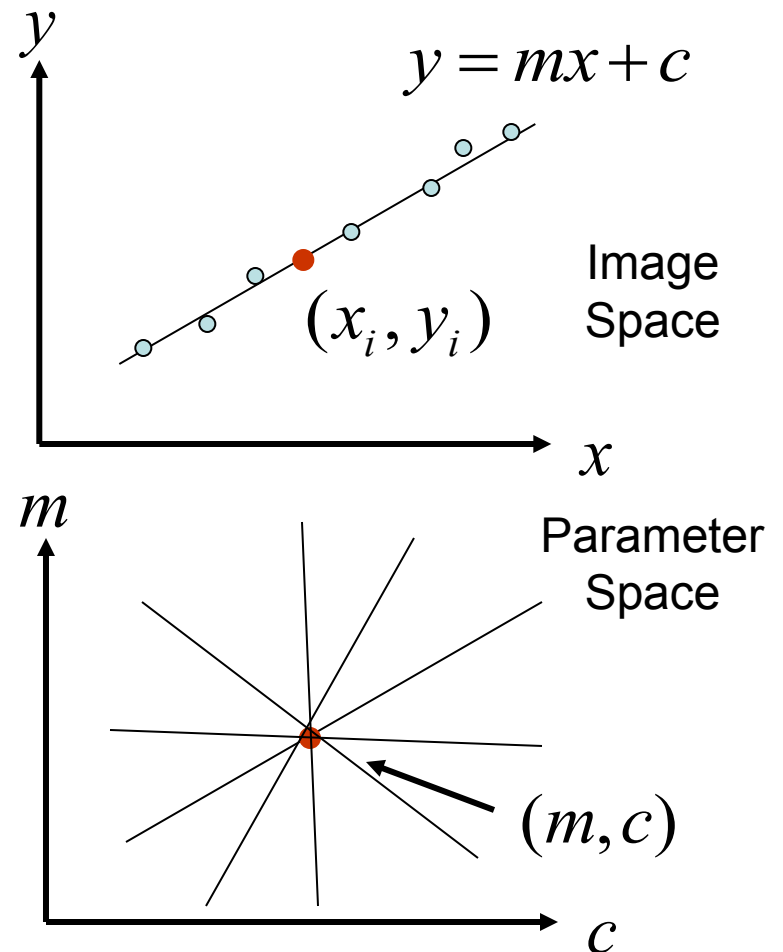
Equation of Line:  $y = mx + c$

Find:  $(m, c)$

Consider point:  $(x_i, y_i)$

$$y_i = mx_i + c \quad \text{or} \quad c = -x_i m + y_i$$

Parameter space also called Hough Space





# Better Parameterization

NOTE:  $-\infty \leq m \leq \infty$   
Large Accumulator

More memory and computations

Improvement: (Finite Accumulator Array Size)

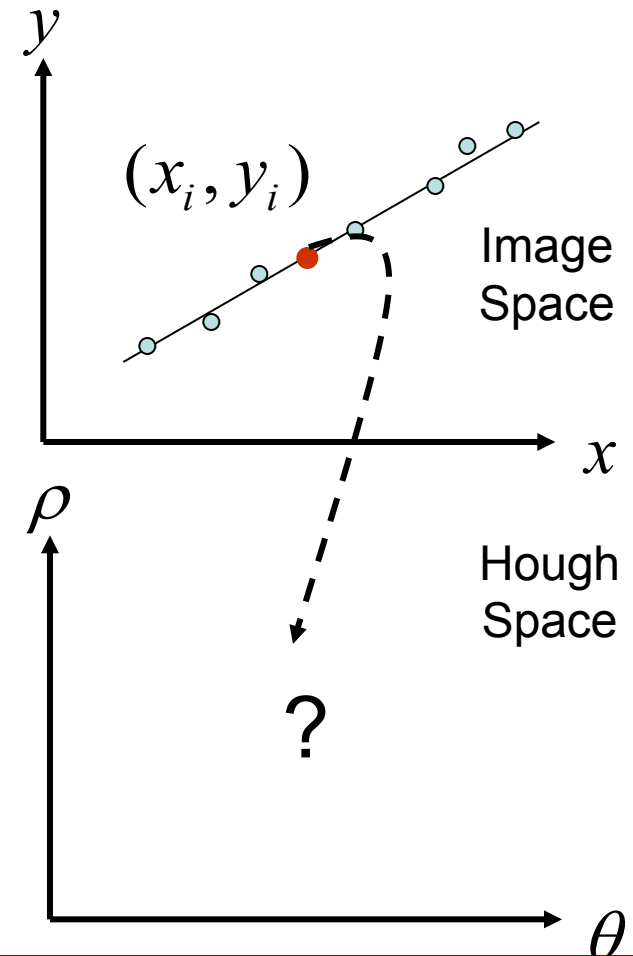
Line equation:  $\rho = -x \cos \theta + y \sin \theta$

Here  $0 \leq \theta \leq 2\pi$

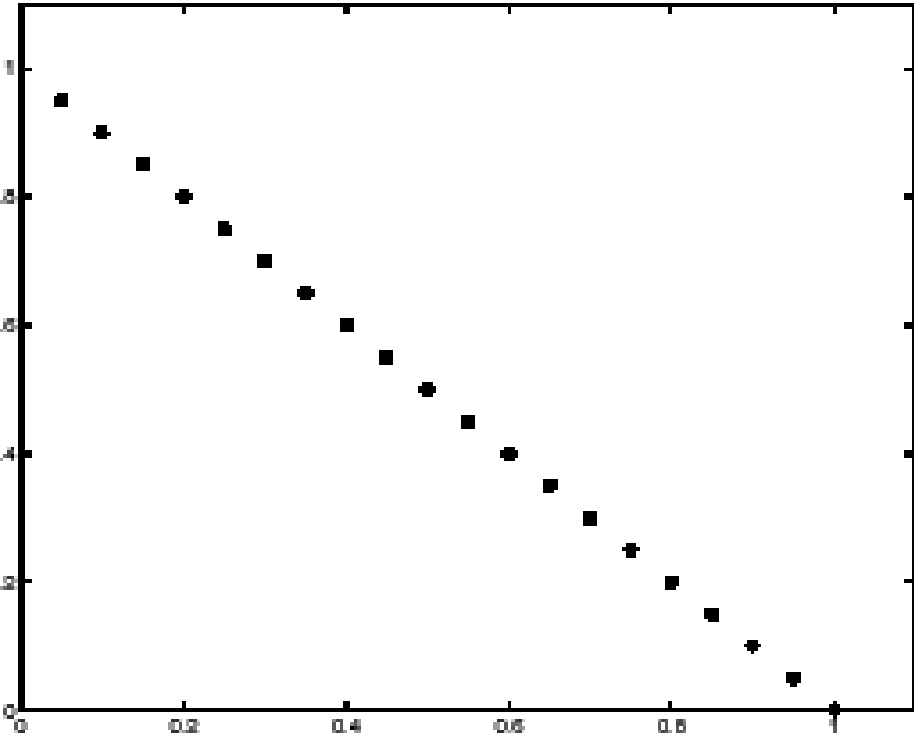
$0 \leq \rho \leq \rho_{\max}$

Given points  $(x_i, y_i)$  find  $(\rho, \theta)$

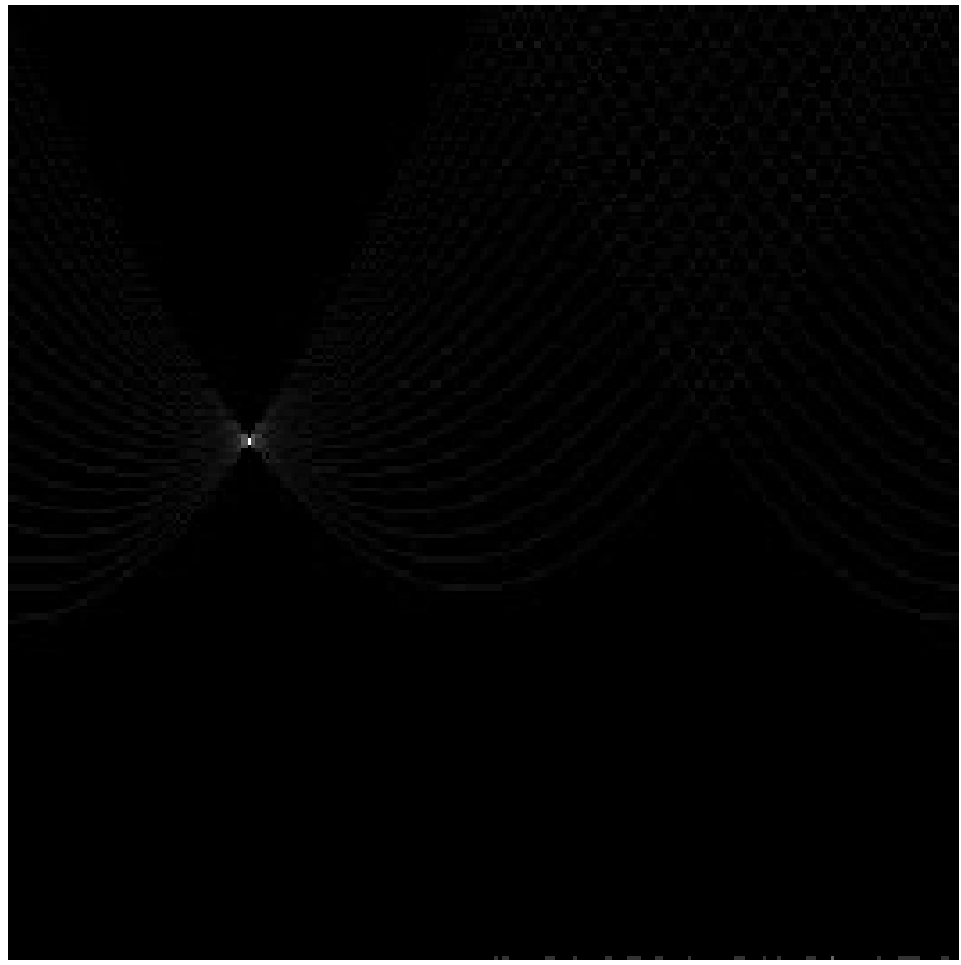
Hough Space Sinusoid





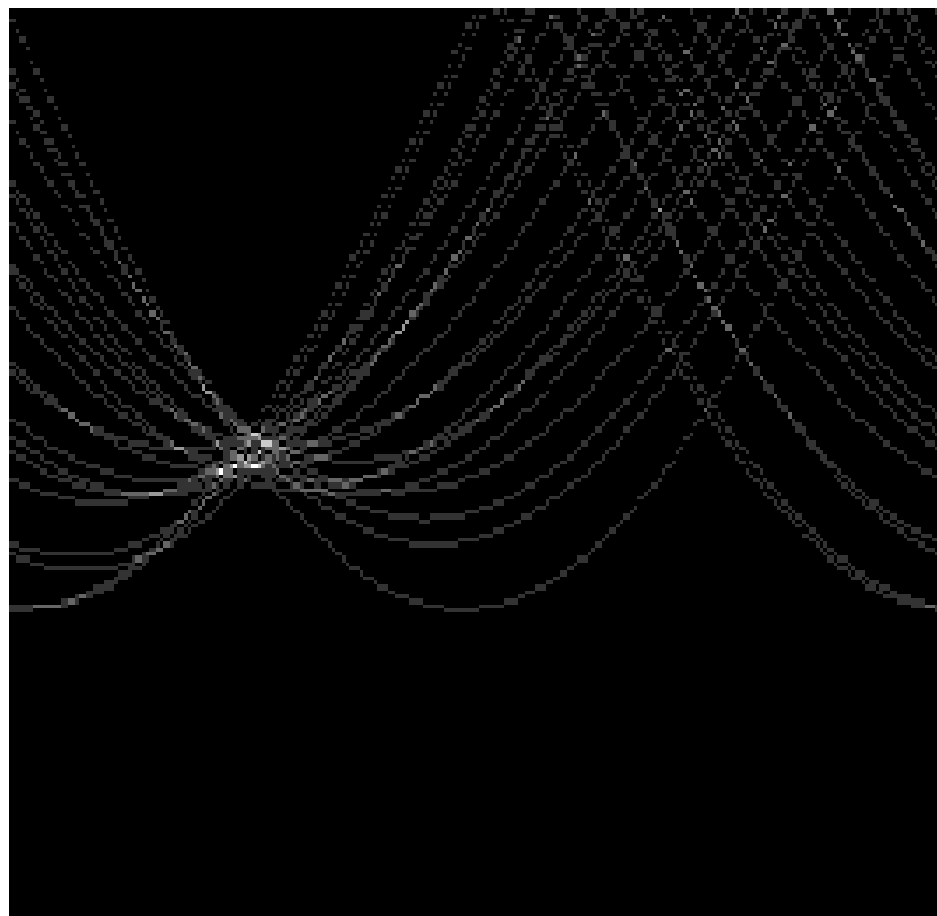
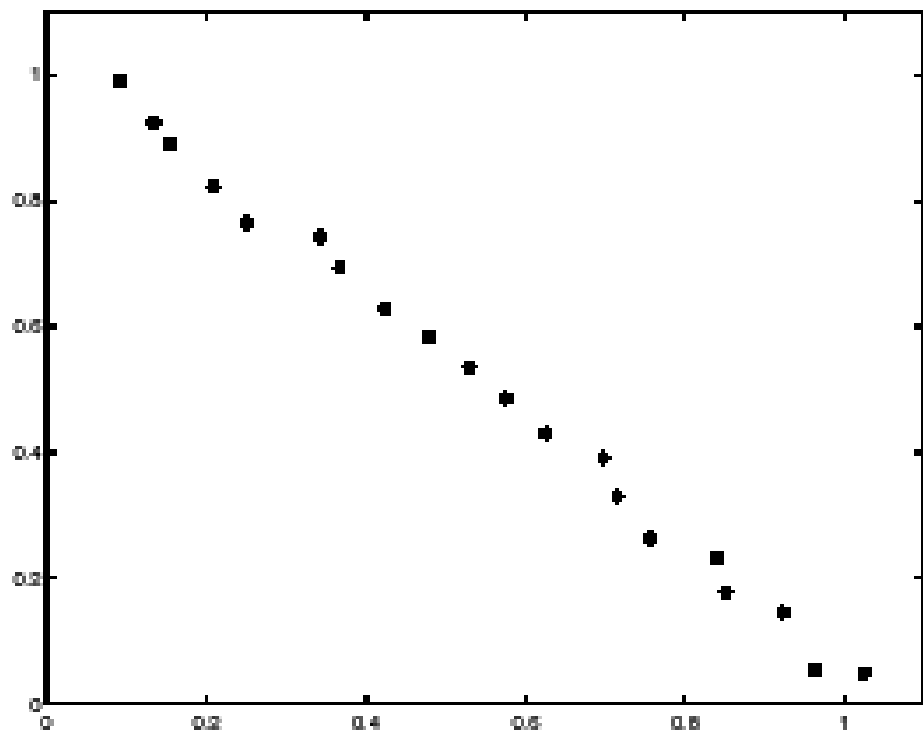


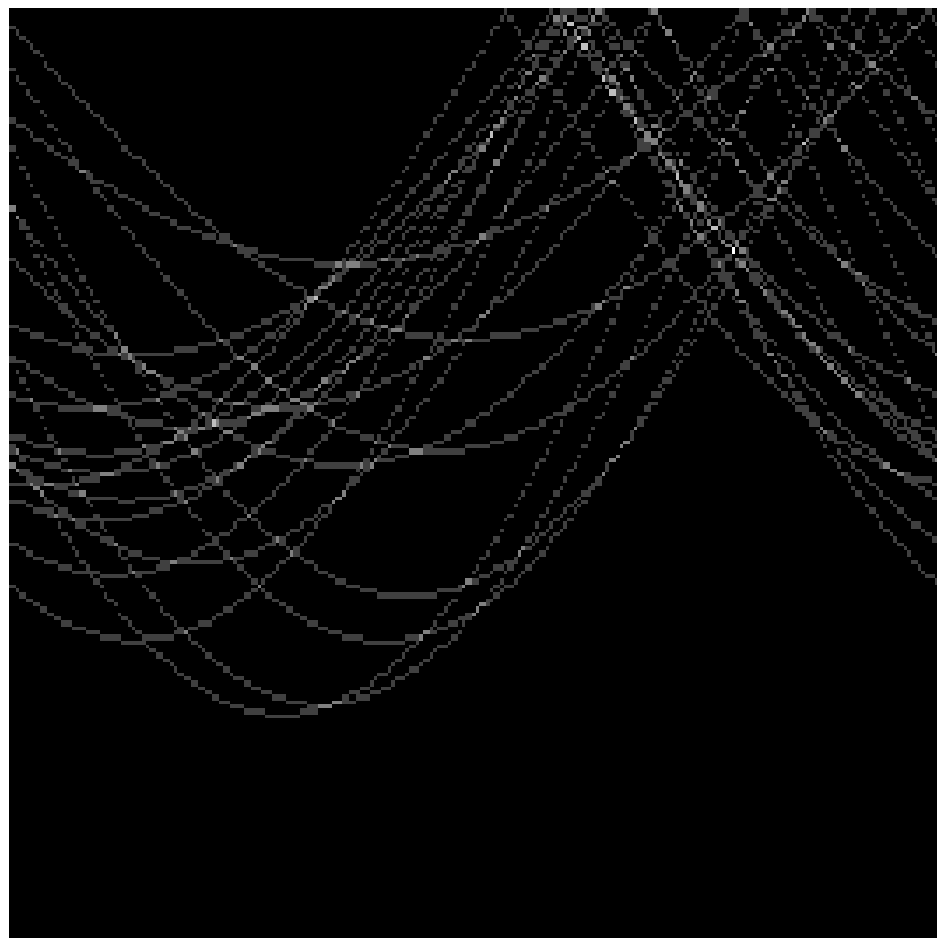
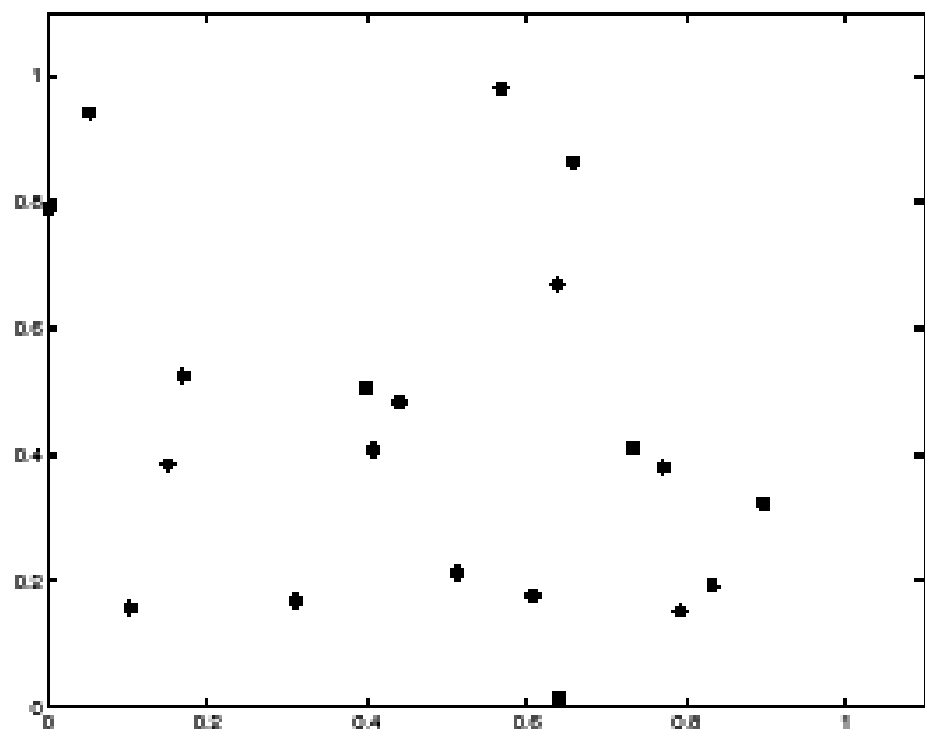
**Image space**



**Votes**

Horizontal axis is  $\theta$ ,  
vertical is  $\rho$ .





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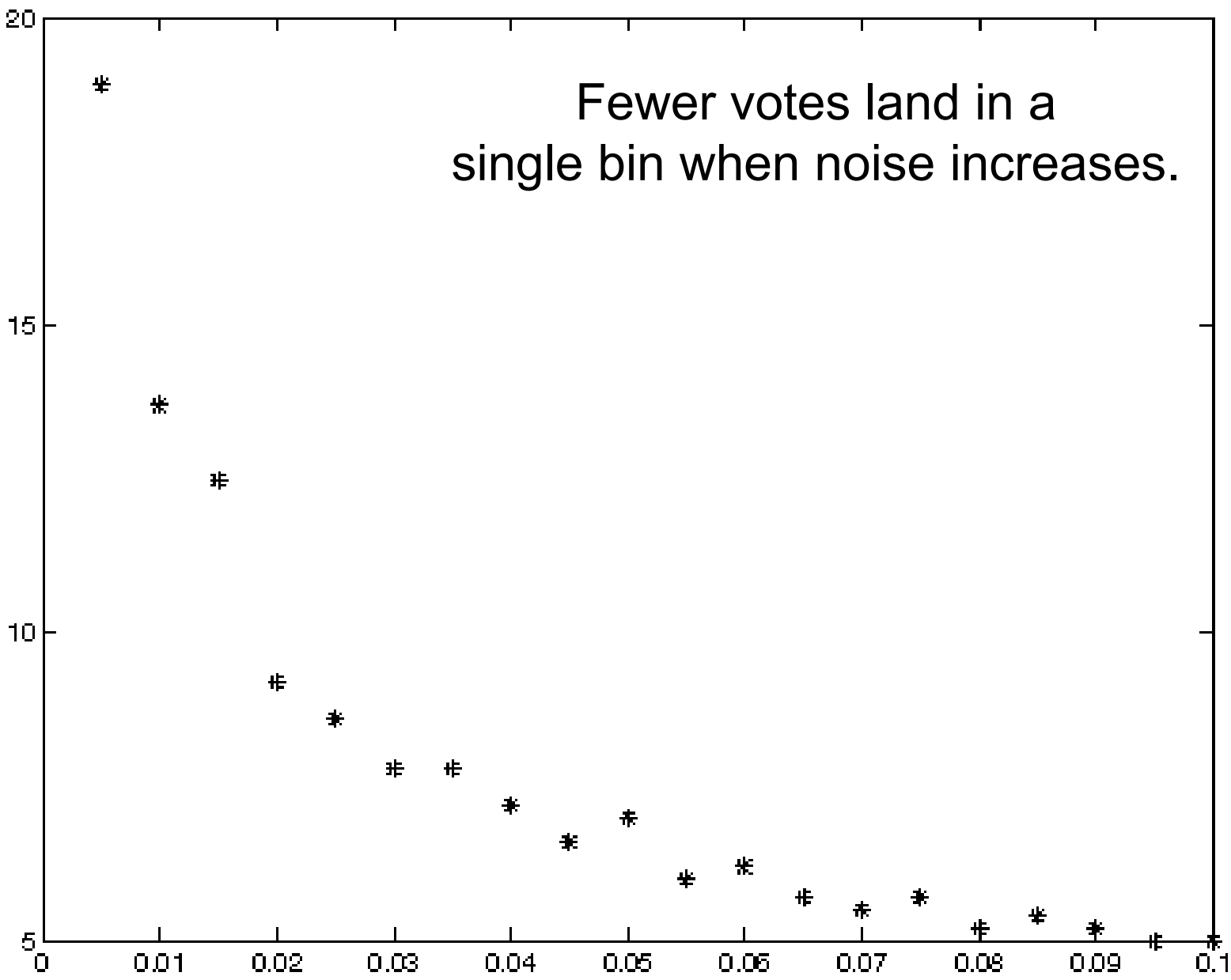
# Mechanics of the Hough Transform

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- **Difficulties**
  - how big should the cells be? (too big, and we merge quite different lines; too small, and noise causes lines to be missed)
- **How many lines?**
  - Count the peaks in the Hough array
  - Treat adjacent peaks as a single peak
- **Which points belong to each line?**
  - Search for points close to the line
  - Solve again for line and iterate

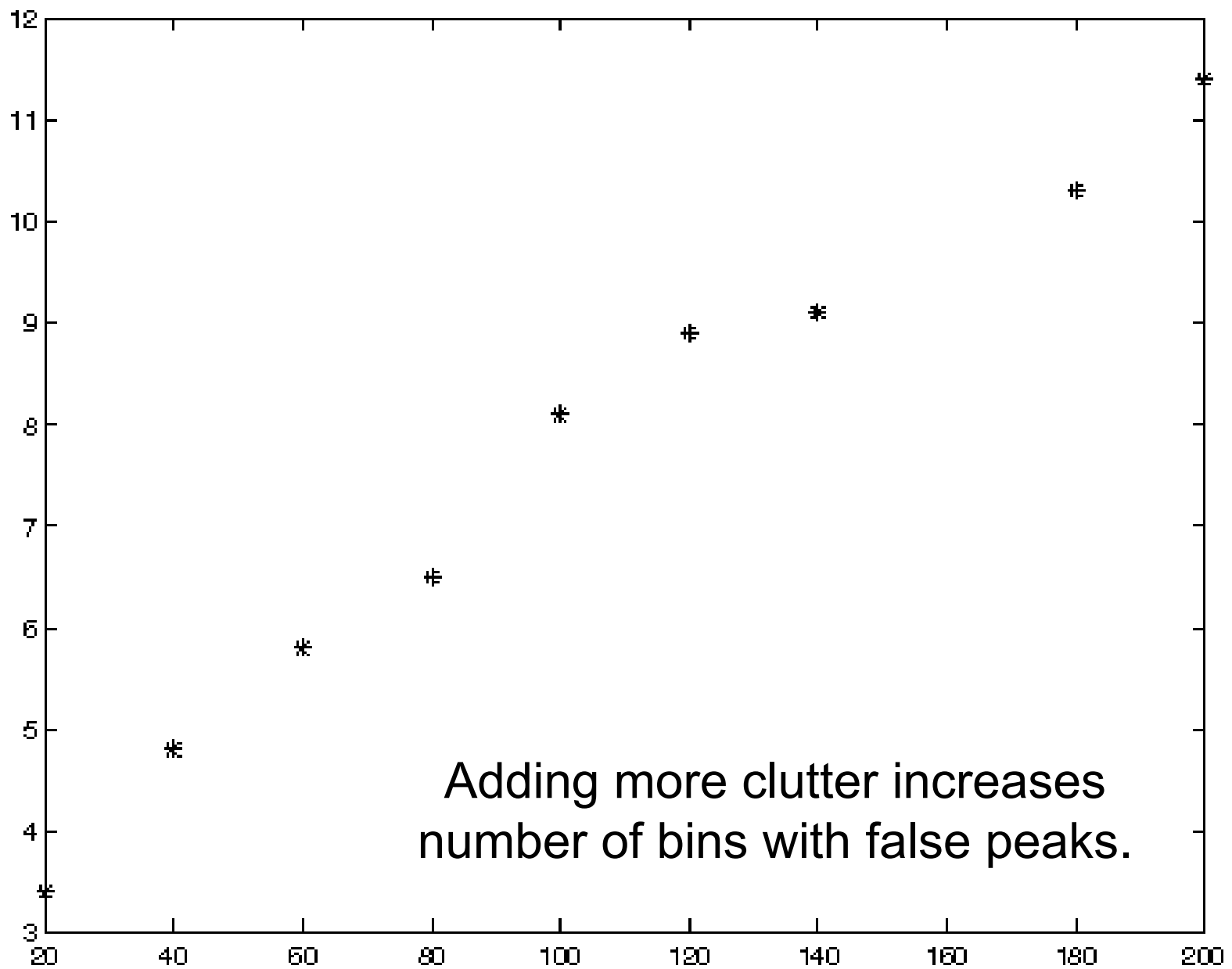
Fewer votes land in a single bin when noise increases.

Maximum number of votes



Noise level

Maximum number of votes



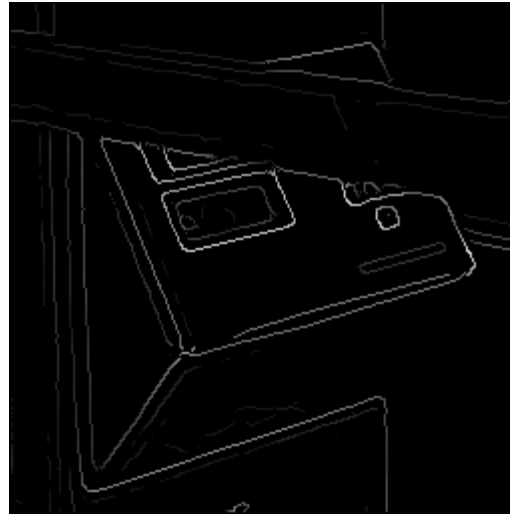
Adding more clutter increases number of bins with false peaks.

Number of noise points

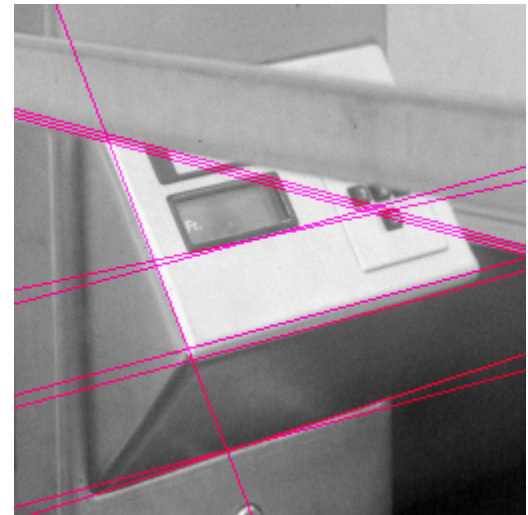
# Real World Example



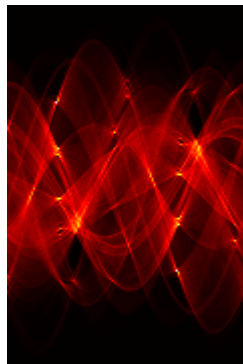
Original



Edge  
Detection



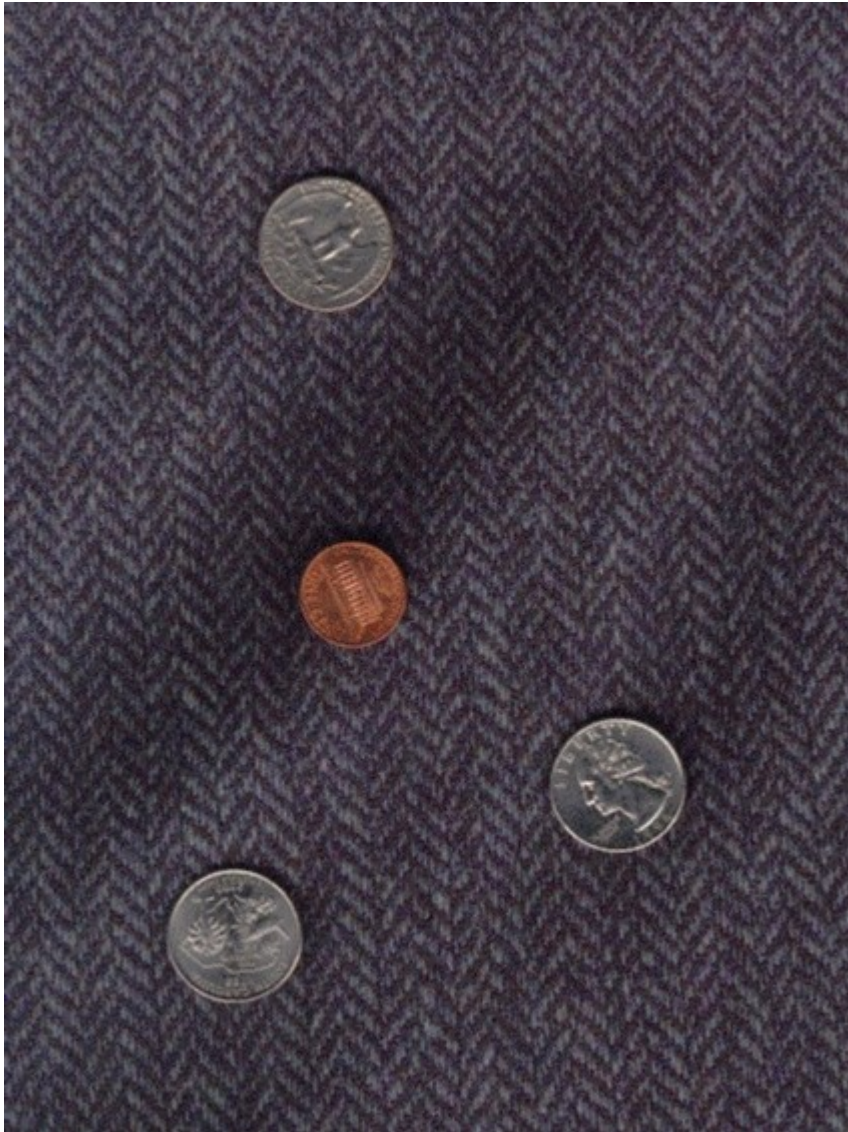
Found Lines



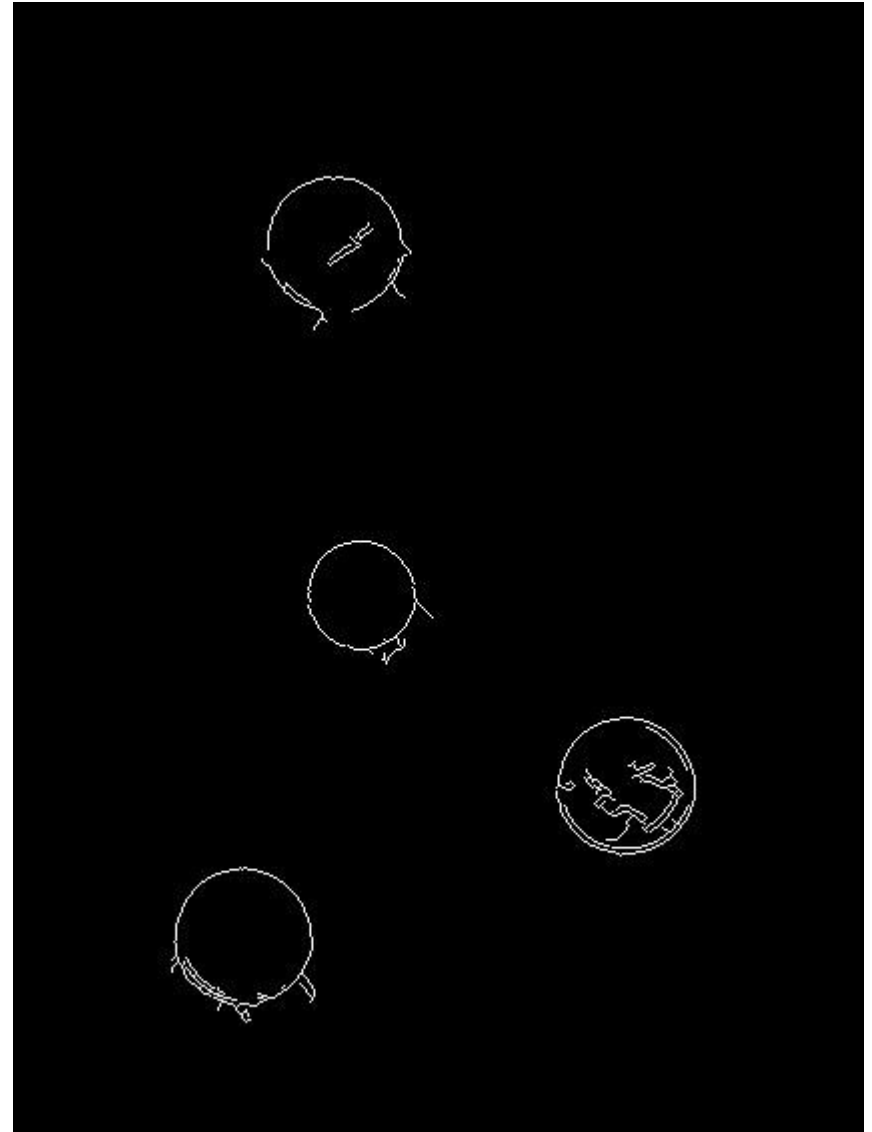
Parameter Space

# Other shapes

Original



Edges when using circle model





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# Resources

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- Gonzalez & Woods – Chapter 7
- Russ – Chapter 7
- N. Otsu, “A threshold selection method from gray-level histograms,” *IEEE Trans. Sys., Man., Cyber.*, vol. 9, pp. 62–66, 1979.