Computer Vision (CSE3010)

Dr. Susant Kumar Panigrahi
Assistant Professor
School of Electrical & Electronics Engineering

VIT BHOPAL

Module-1 Syllabus

Digital Image Formation And Low Level Processing:

- Overview and State-of-the-art, Fundamentals of Image Formation, Transformation: Orthogonal, Euclidean, Affine, Projective, Fourier Transform,
- Convolution and Filtering, Image Enhancement, Restoration, Histogram Processing.

Module-2 Syllabus

Depth Estimation And Multi-Camera Views:

Depth Estimation and Multi-Camera Views: Perspective, Binocular Stereopsis: Camera and Epipolar Geometry; Homography, Rectification, DLT, RANSAC, 3-D reconstruction framework; Auto-calibration. apparel.

Module-3 Syllabus

Feature Extraction And Image Segmentation:

- **Feature Extraction**: Edges - Canny, LOG, DOG; Line detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram, SIFT, SURF, HOG, GLOH, Scale-Space Analysis- Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT.
- **Image Segmentation:** Region Growing, Edge Based approaches to segmentation, Graph-Cut, Mean-Shift, MRFs, Texture Segmentation; Object detection.

Module-4 Syllabus

Pattern Analysis And Motion Analysis:

- **Pattern Analysis**: Clustering: K-Means, K-Medoids, Mixture of Gaussians, Classification: Discriminant Function, Supervised, Un-supervised, Semi-supervised; Classifiers: Bayes, KNN, ANN models;
- **Dimensionality Reduction**: PCA, LDA, ICA; Non-parametric methods. Motion Analysis: Background Subtraction and Modelling, Optical Flow, KLT, Spatio-Temporal Analysis, Dynamic Stereo; Motion parameter estimation.

Module-5 Syllabus

Shape From X:

Light at Surfaces; Phong Model; Reflectance Map;

Albedo estimation; Photometric Stereo; Use of Surface Smoothness

Constraint; Shape from Texture, color, motion and edges.

Guest Lecture on Contemporary Topics

Text Books

1. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer-Verlag London Limited 2011.
2. Computer Vision: A Modern Approach, D. A. Forsyth, J. Ponce, Pearson Education, 2003.

Reference Book(s):

1. R.C. Gonzalez and R.E. Woods, Digital Image Processing, Addison- Wesley, 1992.
2. Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, March 2004.
3. K. Fukunaga; Introduction to Statistical Pattern Recognition, Second Edition, Academic Press, Morgan Kaufmann, 1990.

Required Tools/Software/IDLE:

1. Python/jupyter-notebook/google-colab
2. OpenCV
3. MATLAB

Indicative List of Experiments:

1. Implement image preprocessing and Edge
2. Implement camera calibration methods
3. Implement Projection
4. Determine depth map from Stereo pair
5. Construct 3D model from Stereo pair
6. Implement Segmentation methods
7. Construct 3D model from defocus image
8. Construct 3D model from Images
9. Implement optical flow method
10. Implement object detection and tracking from video
11. Face detection and Recognition
12. Object detection from dynamic Background for Surveillance
13. Content based video retrieval
14. Construct 3D model from single image

Computer Vision
Unit – 03
Hough Transform and Region Growing

Standing on the shoulder of Giants: Ref: Few Slides borrowed from:

1. Prof. Shree Nayar, *First Principles of Computer Vision is a lecture series*.
2. Prof. Mubarak Shah, *Computer Vision Video Lectures.*

Hough Transform

- ✓ The Hough transform is a feature extraction technique used in image analysis, computer vision, and digital image processing.

- ✓ The purpose of the technique is to find imperfect instances of objects within a certain class of shapes by a voting procedure.

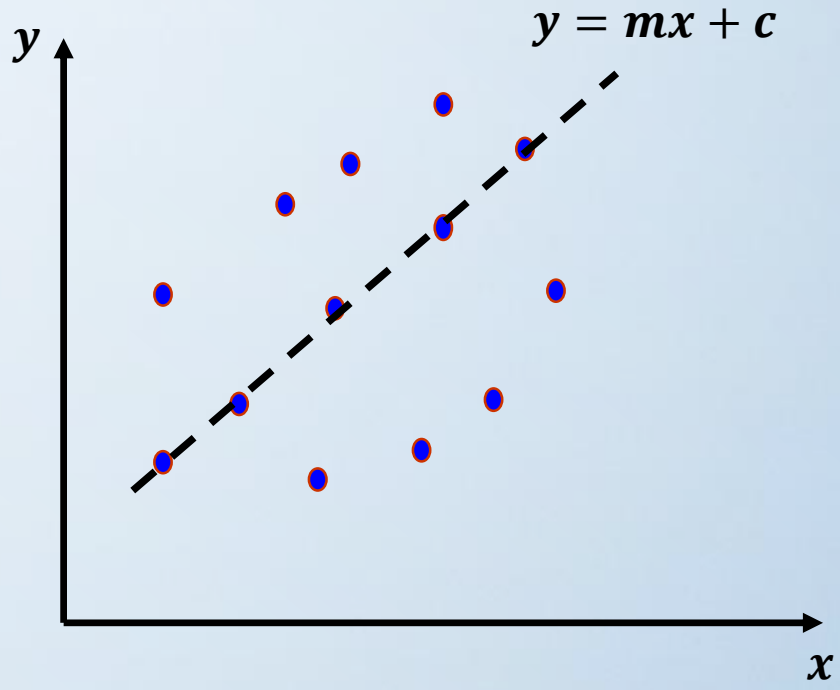
- ✓ This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough transform.

- ✓ The classical Hough transform was concerned with the identification of lines in the image, but later the Hough transform has been extended to identifying positions of arbitrary shapes, most commonly circles or ellipses.

Difficulty for Fitting Approach: Why Hough Transform?

- ✓ Extraneous Data: Which point to fit to?
- ✓ Incomplete Data: Only part of the model is visible.
- ✓ Noise

Hough Transform: Line Detection



Given: Edge points (x_i, y_i)

Task: Detect Lines

$$y = mx + c$$

Consider any edge points (x_i, y_i)

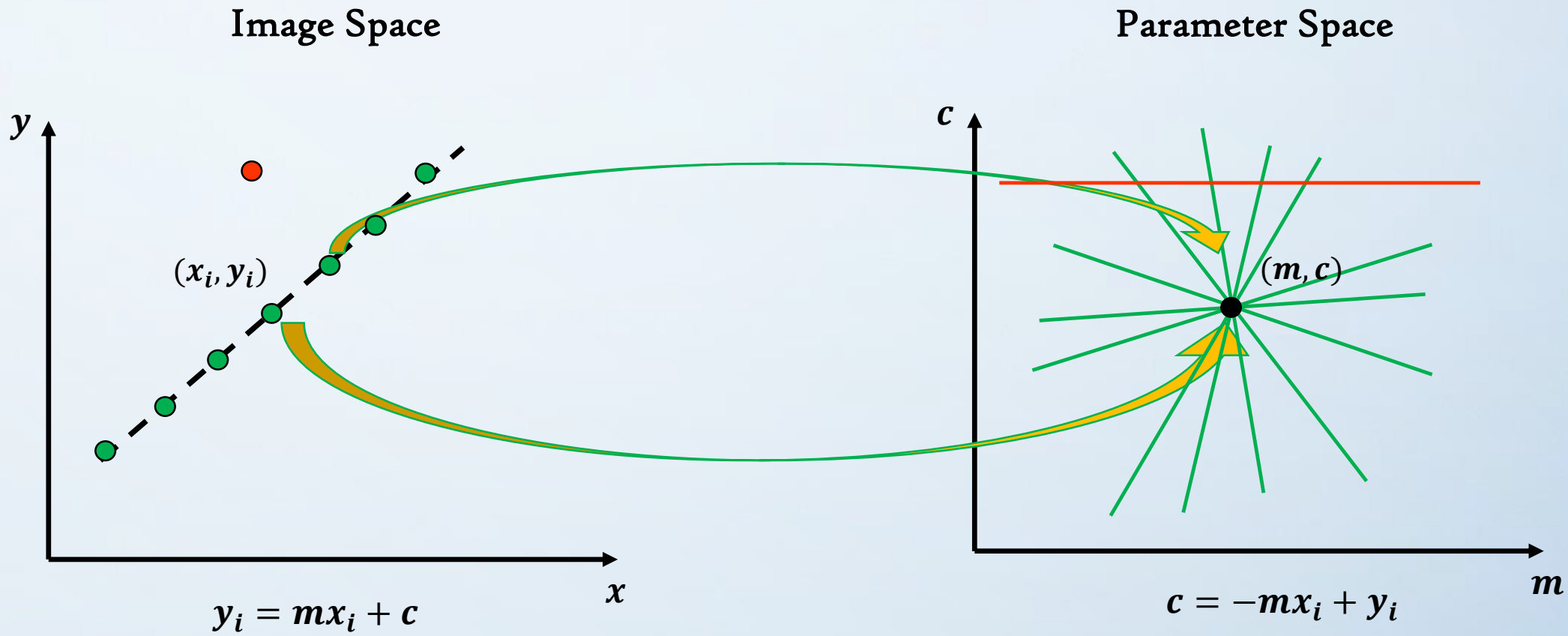
Line passing through the given point

$$y_i = mx_i + c$$

Parameter Space:

$$c = -mx_i + y_i$$

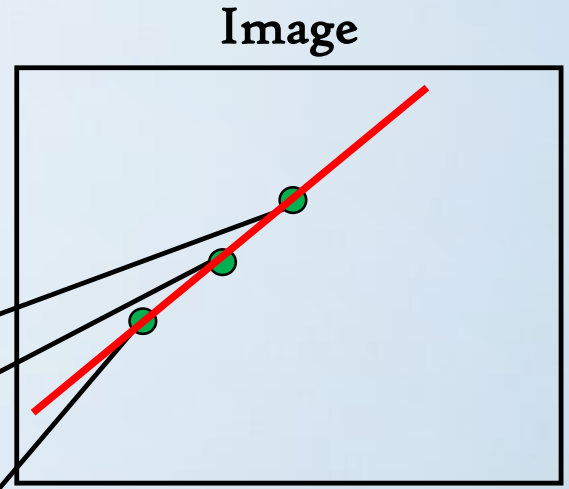
Hough Transform: Concepts



Point ⟷ Line

Line ⟷ Point

Line Detection Algorithm



Step - 1: Quantize parameter space (m, c)

Step - 2: Create Accumulator array $A(m, c)$

Step - 3: Set $A(m, c) = 0$ for all (m, c)

Step - 4: For each edge point (x_i, y_i),

$$A(m, c) = A(m, c) + 1$$

If (m, c) lies on the line: $c = -mx_i + y_i$

$A(c, m)$

c \ m					
	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

$A(c, m)$

c \ m					
	1	0	0	0	1
	0	1	0	1	0
	1	1	3	1	1
	0	1	0	1	0
	1	0	0	0	1

$A(c, m)$

c \ m					
	1	0	0	0	1
	0	1	0	1	0
	0	0	2	0	0
	0	1	0	1	0
	1	0	0	0	1

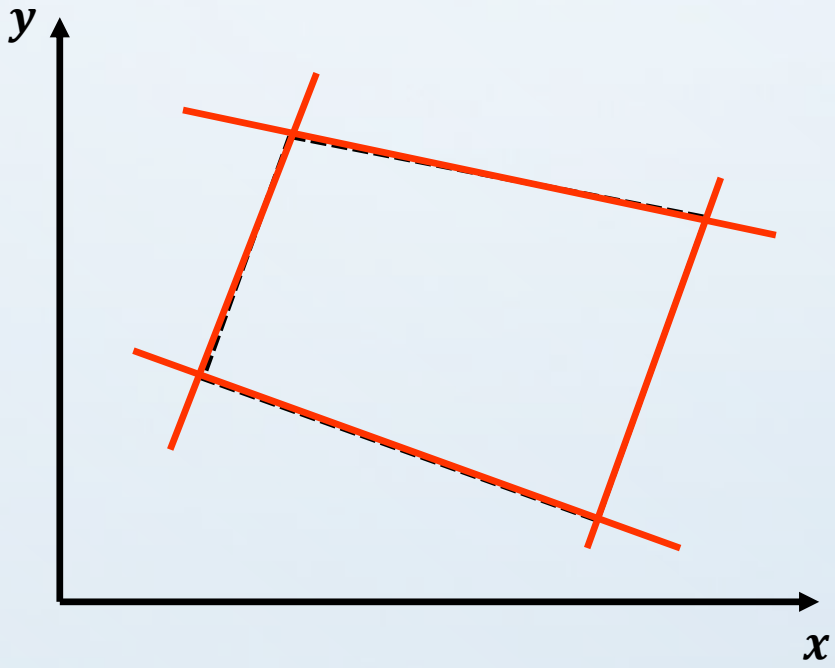
$A(c, m)$

c \ m					
	1	0	0	0	0
	0	1	0	0	0
	0	0	1	0	0
	0	0	0	1	0
	0	0	0	0	1

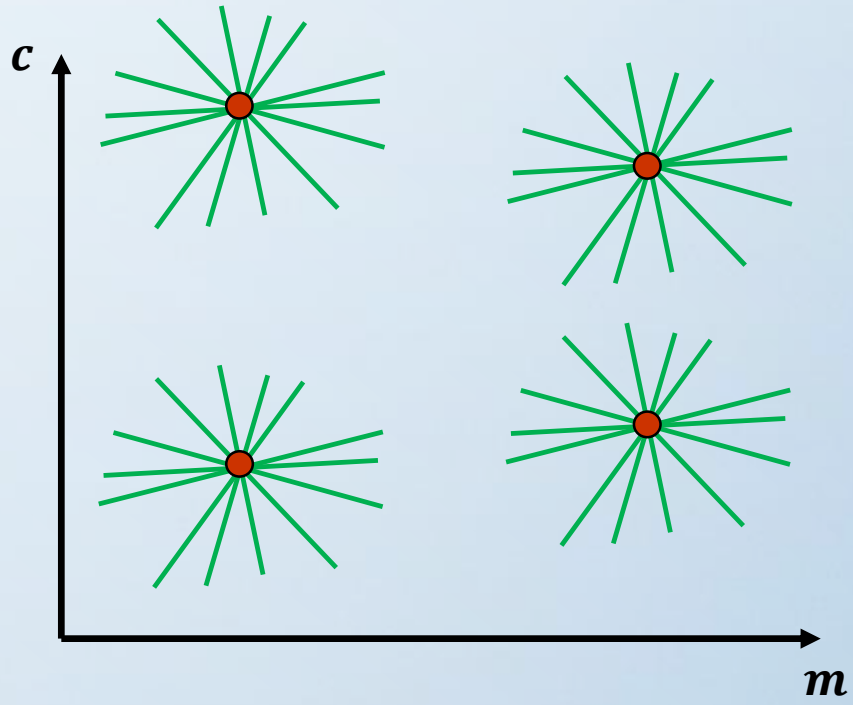
Step - 5: Find local maxima in $A(m, c) = 0$.

Multiple Line Detection Algorithm

Image Space



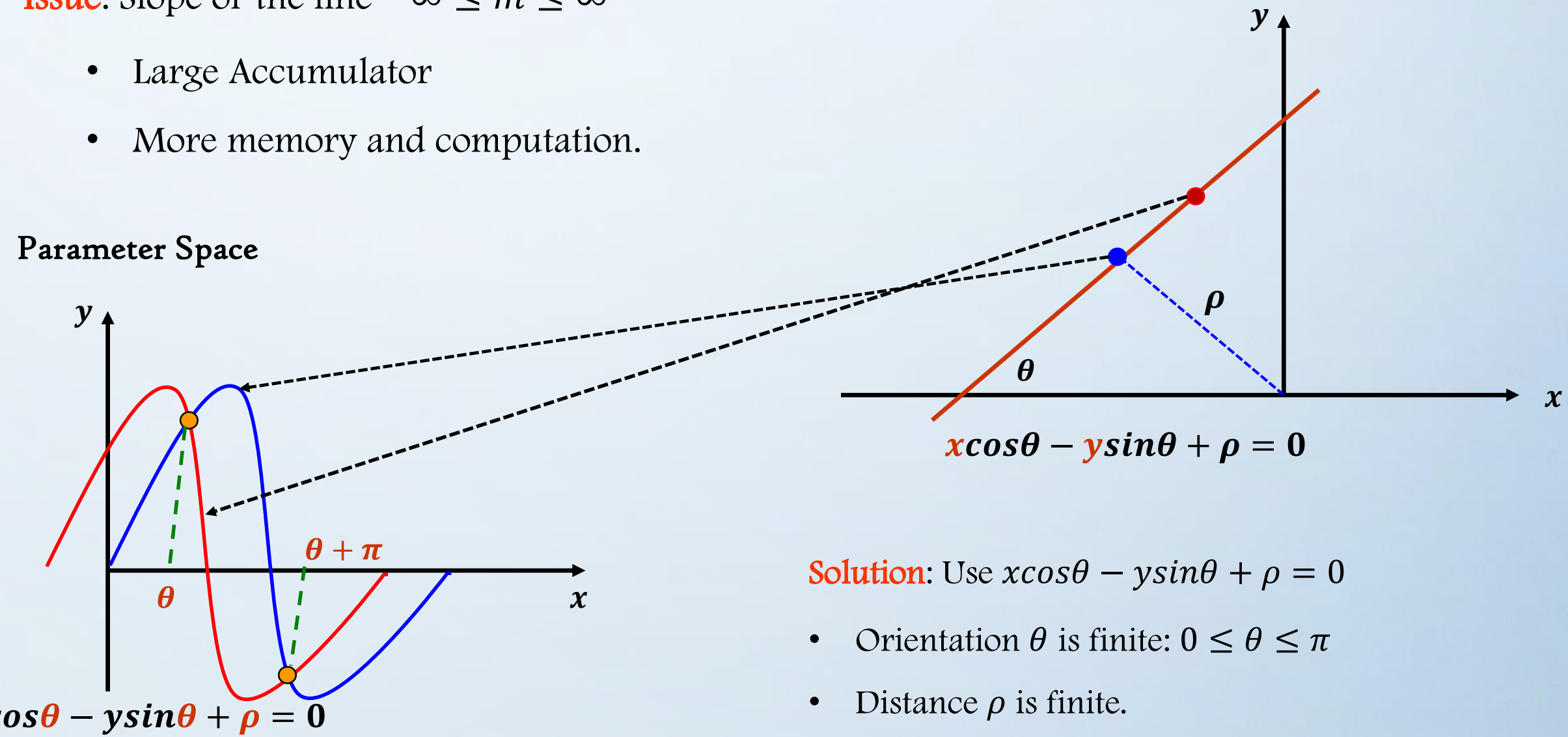
Parameter Space



Better Parameterization

Issue: Slope of the line $-\infty \leq m \leq \infty$

- Large Accumulator
- More memory and computation.



Solution: Use $xcos\theta - ysin\theta + \rho = 0$

- Orientation θ is finite: $0 \leq \theta \leq \pi$
- Distance ρ is finite.

Hough Transform Mechanism

How big the accumulator cells be?

- Too big and different lines may be merged.
- Too small and noise causes lines to be missed.

How Many Lines?

- Count the peaks in the accumulator array.

Handling inaccurate edge locations.

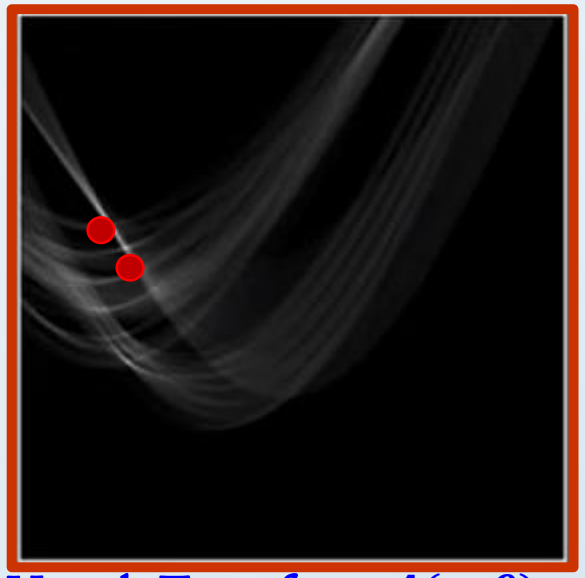
- Increment patch in accumulator rather than single point.

Line Detection Results Hough Transform

Original Image

Gradient

Edge (Threshold)

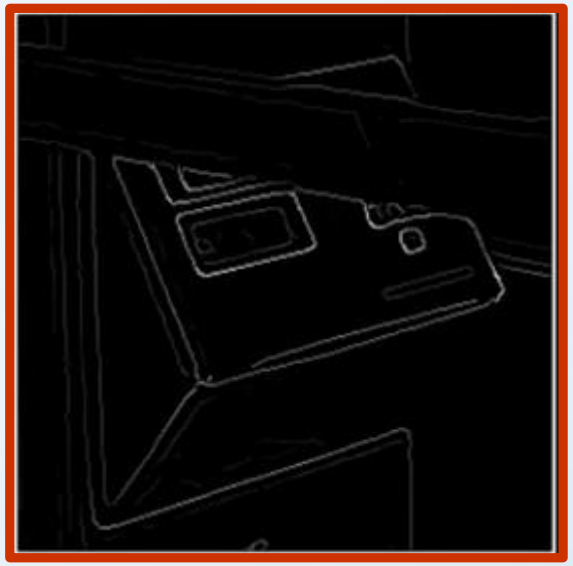


Hough Transform $A(\rho, \theta)$

Detected Line

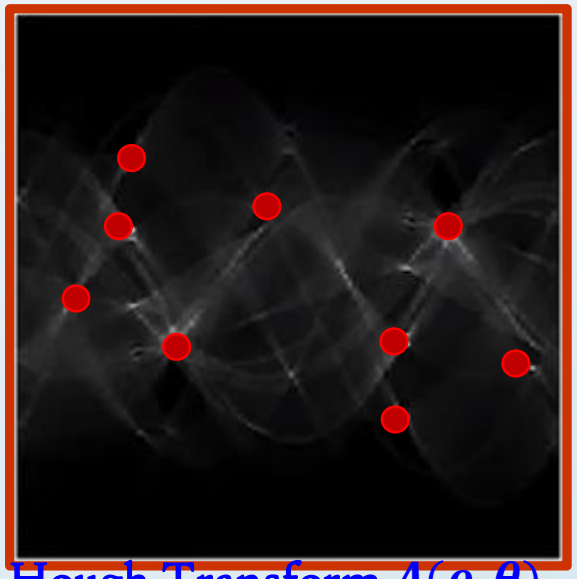
Line Detection Results Hough Transform

Original Image

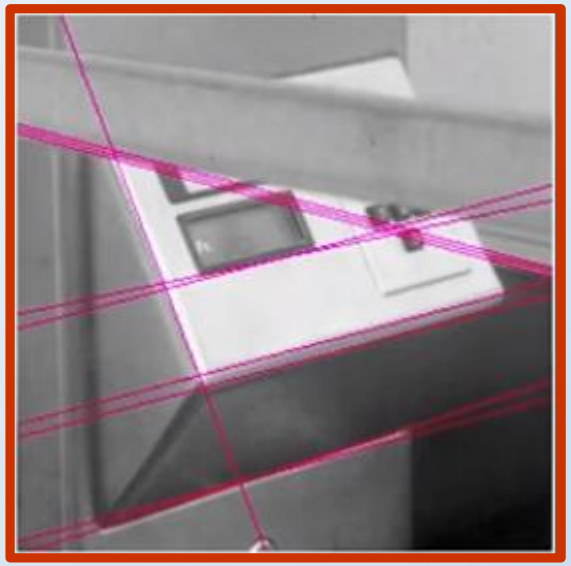


Gradient

Edge (Threshold)

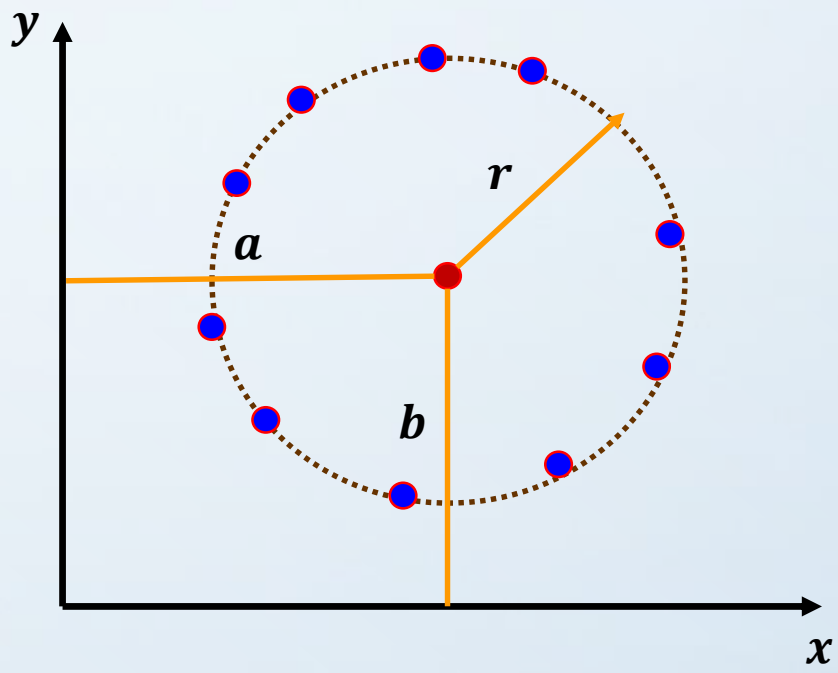


Hough Transform $A(\rho, \theta)$



Detected Line

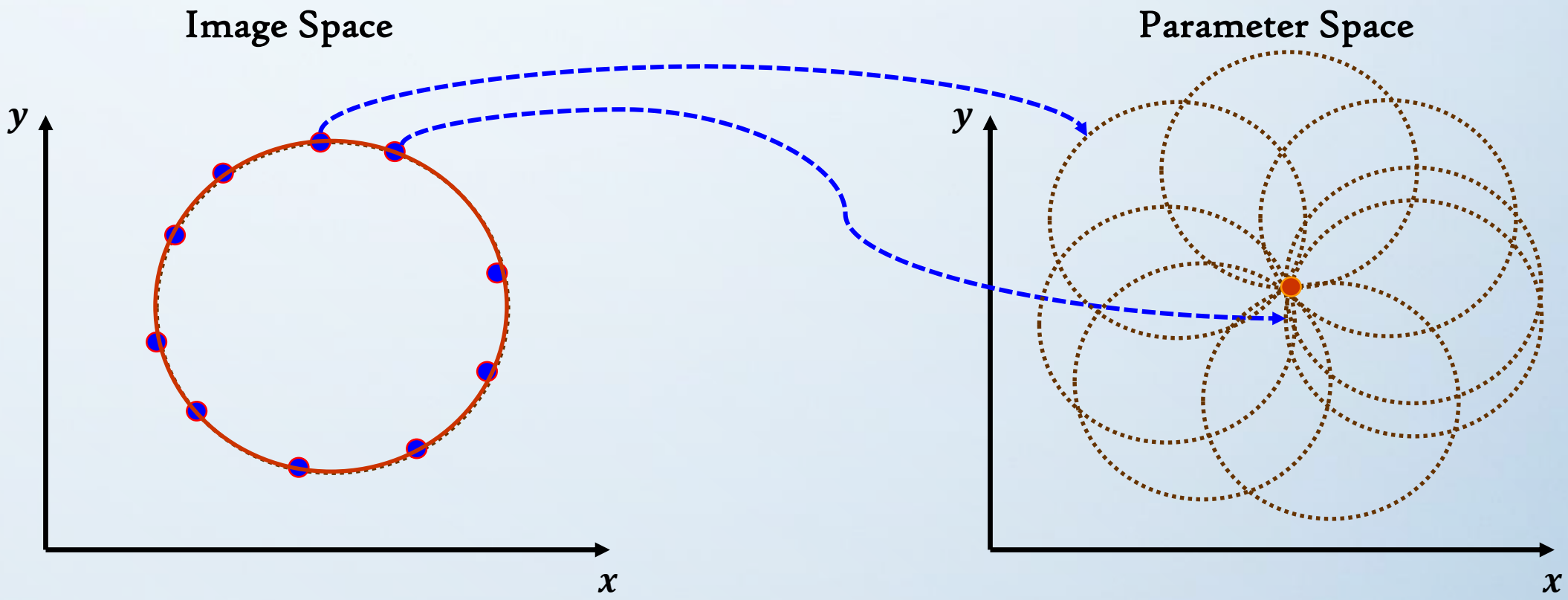
Hough Transform Circle Detection



Equation of Circle: $(x_i - a)^2 + (y_i - b)^2 = r^2$

Hough Transform Circle Detection

If radius r is known: Accumulator array $A(a, b)$



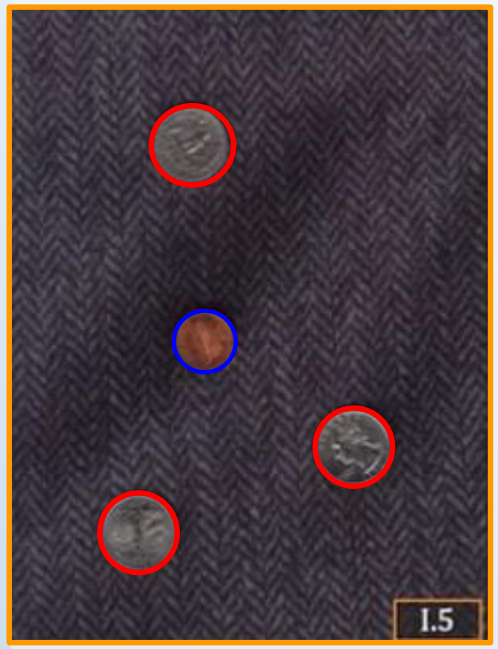
$$(x_i - a)^2 + (y_i - b)^2 = r^2$$

$$(x_i - a)^2 + (y_i - b)^2 = r^2$$

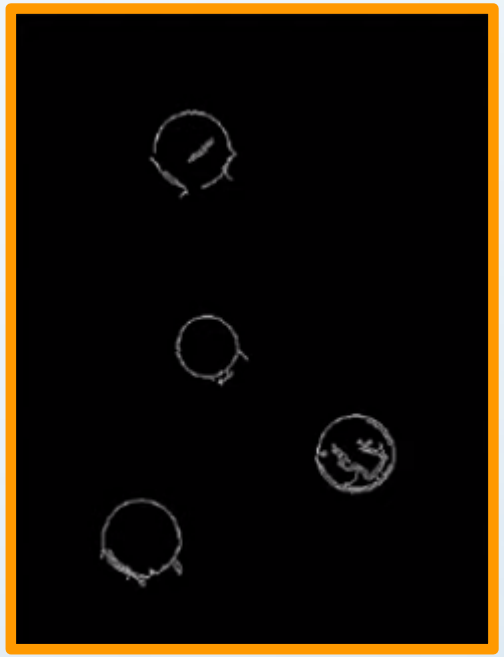
Hough Transform Circle Detection: Results

Penny ($r = r_1$)

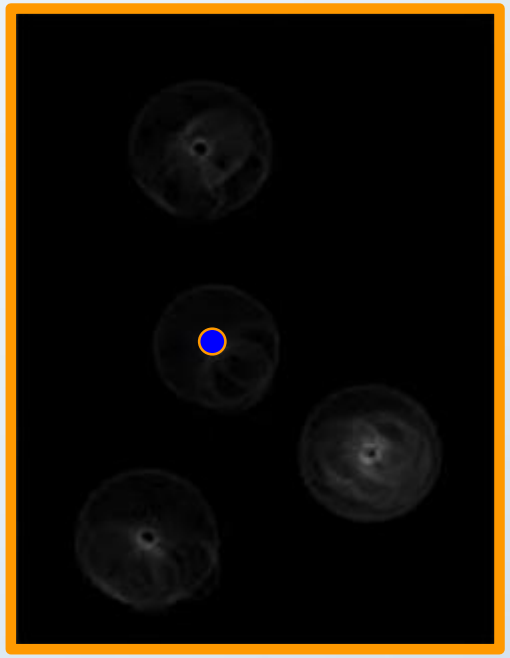
Quarter ($r = r_2$)



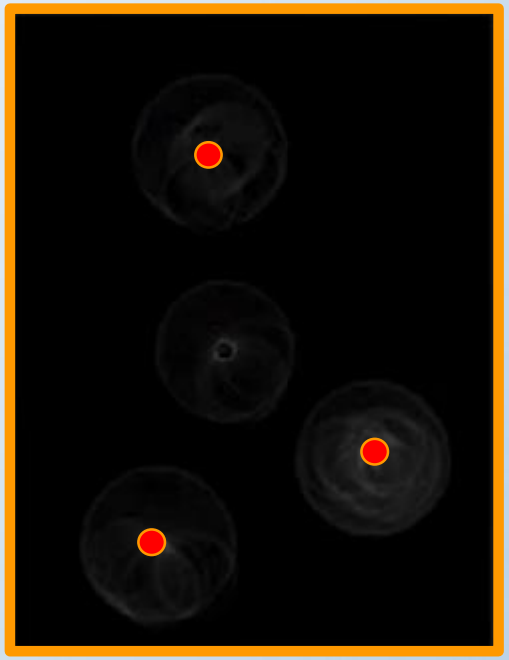
Original Image



Edge (Thresholded)



Hough Transform
$A_1(a, b)$



Hough Transform
$A_2(a, b)$