Introduction to Computer Vision

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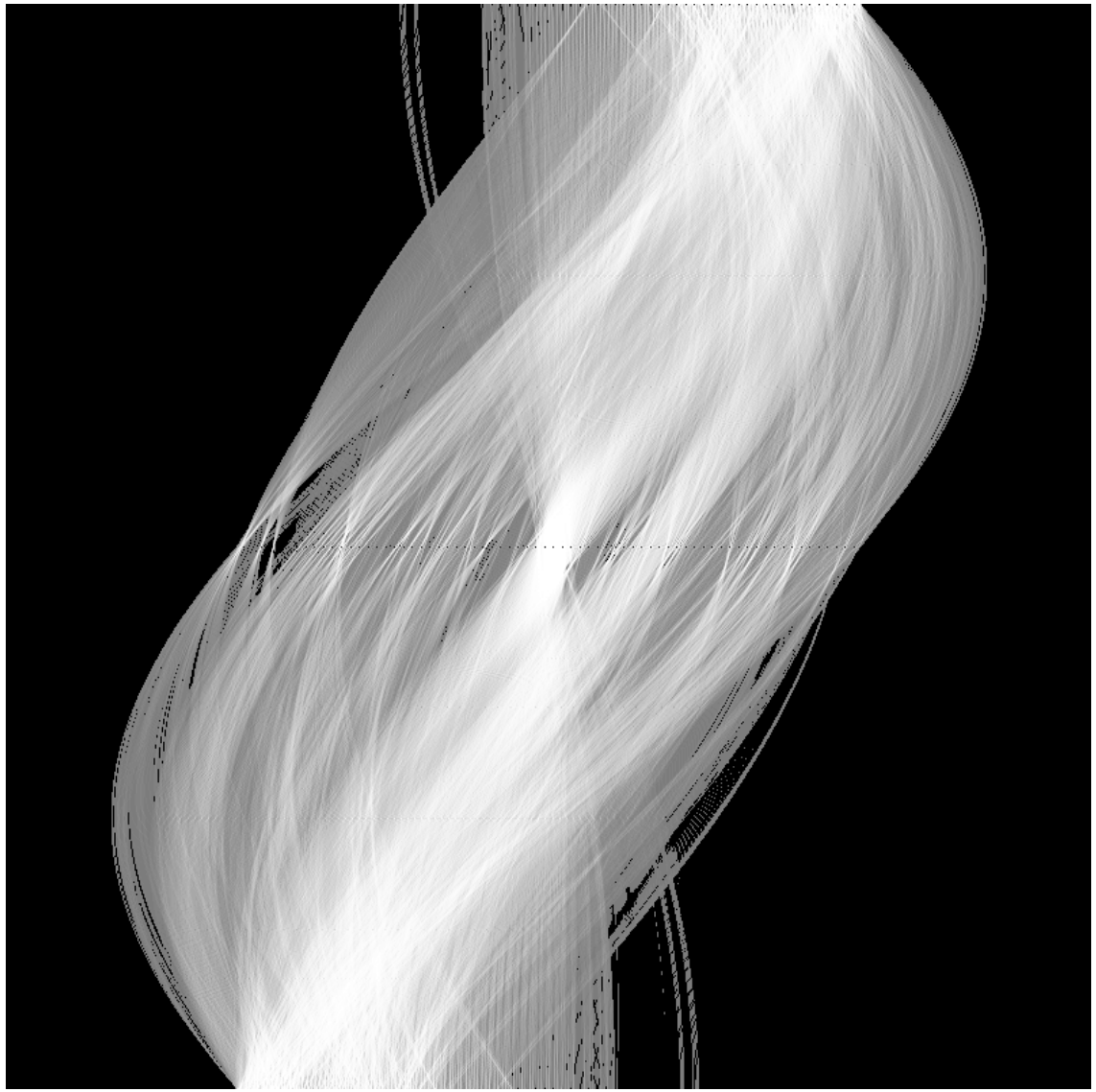
Lecture 7

Learning Outcomes

- Hough Transform
- Line Detection



Hough transform

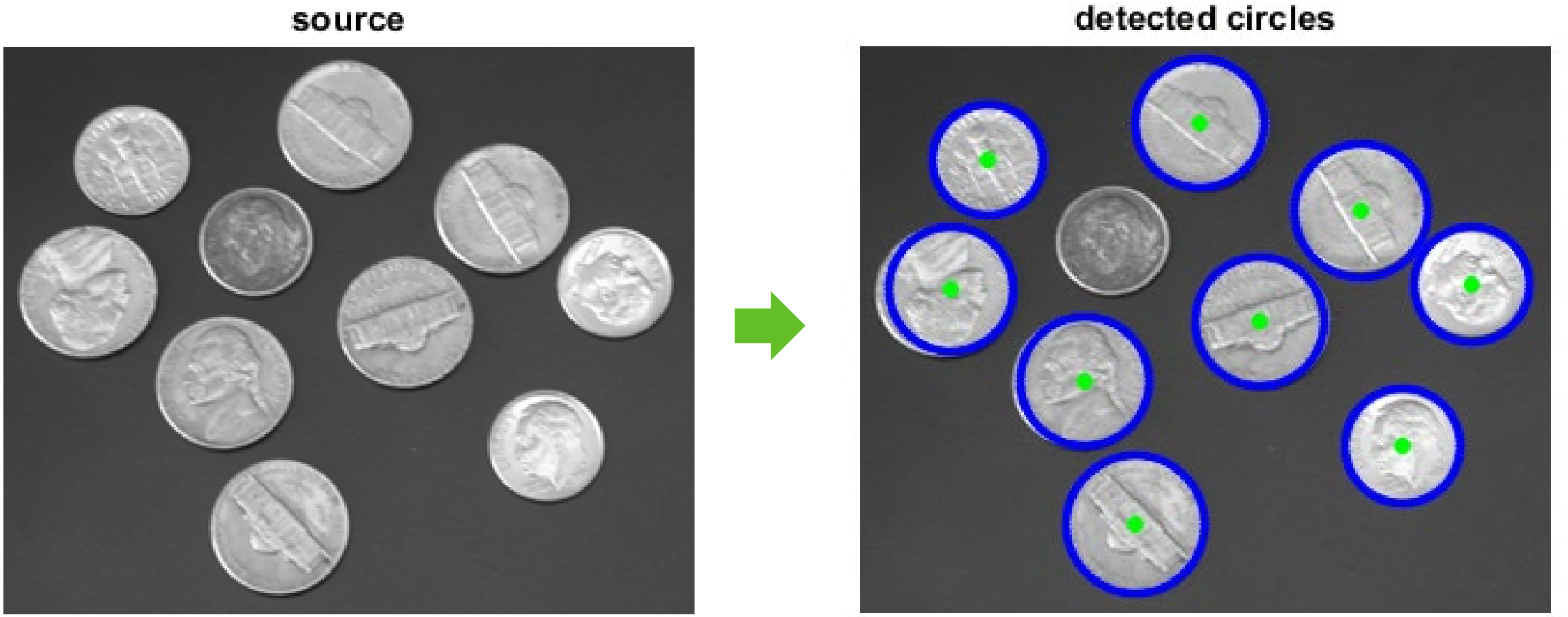
Hough transform is a **generic framework** for detecting a parametric model

Example: Hough transform can detect lines

Why Hough transform? E.g., vs. Canny edge detection?

- Edges don't have to be connected
- Lines can be occluded
- Key idea: edges **vote** for the possible models

Circles



Example: Hough transform for circle detection
What is its application?

Image and parameter space

variables

$$y = mx + b$$

parameters

variables

$$y - mx = b$$

parameters

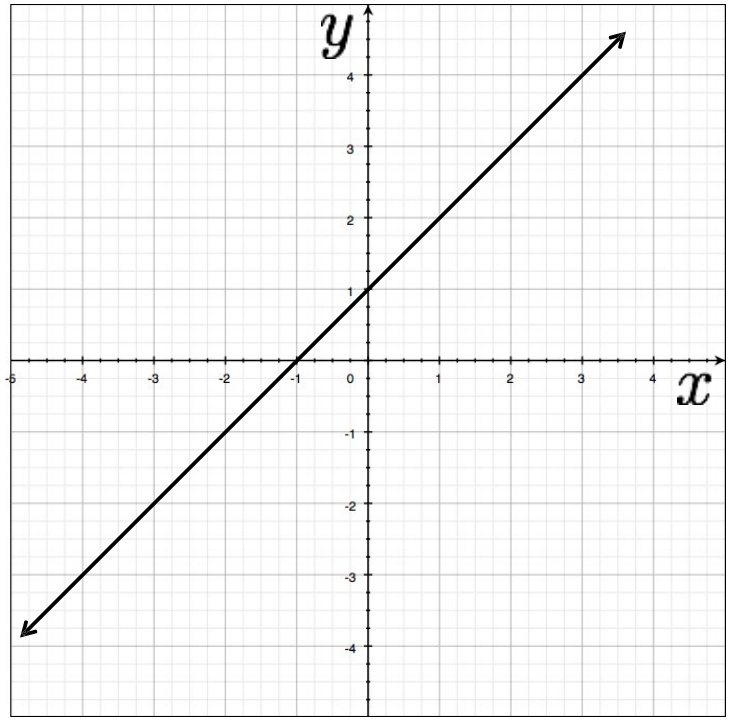
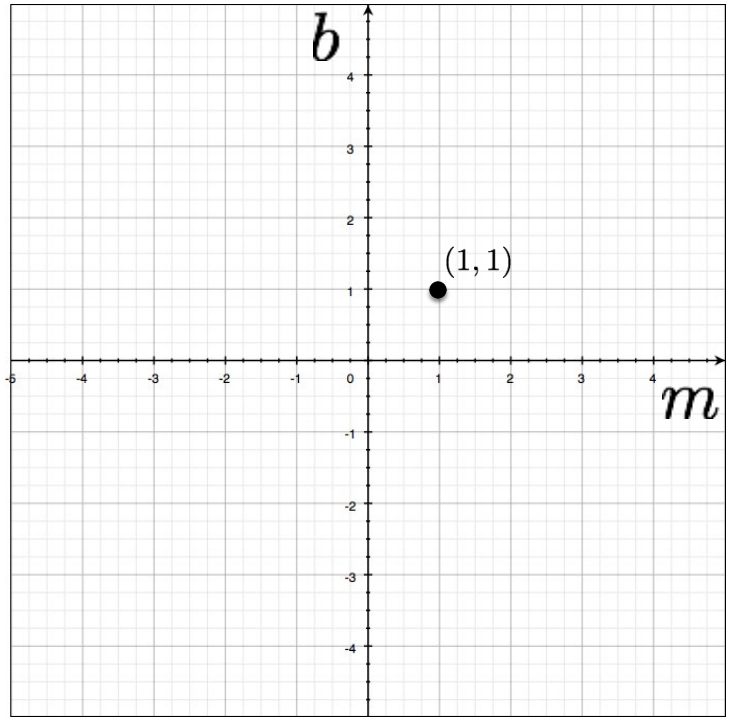


Image space

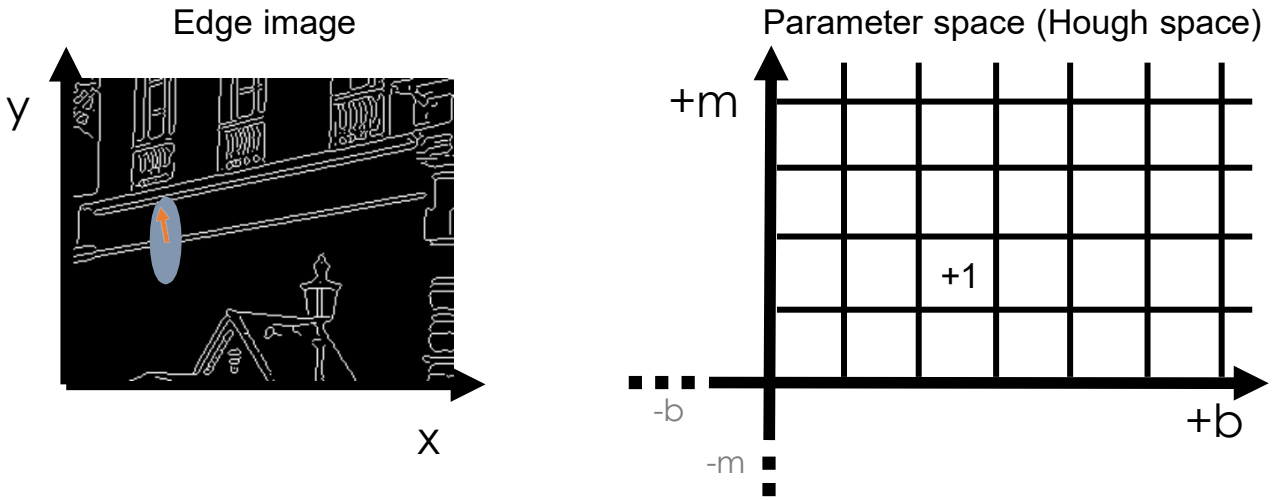
a line becomes a point



Parameter space

Hough Transform: Outline

- Create a *grid* of candidate m,b parameter values: **accumulator**
  - Why a grid?
  - m,b are continuous; grid discretizes into hypotheses.
- Each edge pixel votes for a set of parameters, which increments those values in grid



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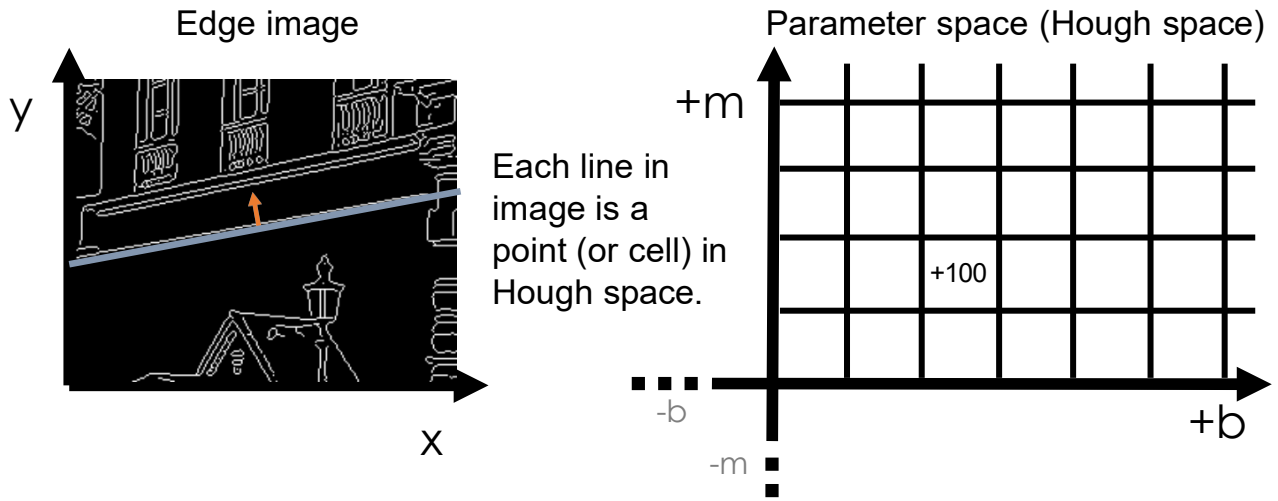

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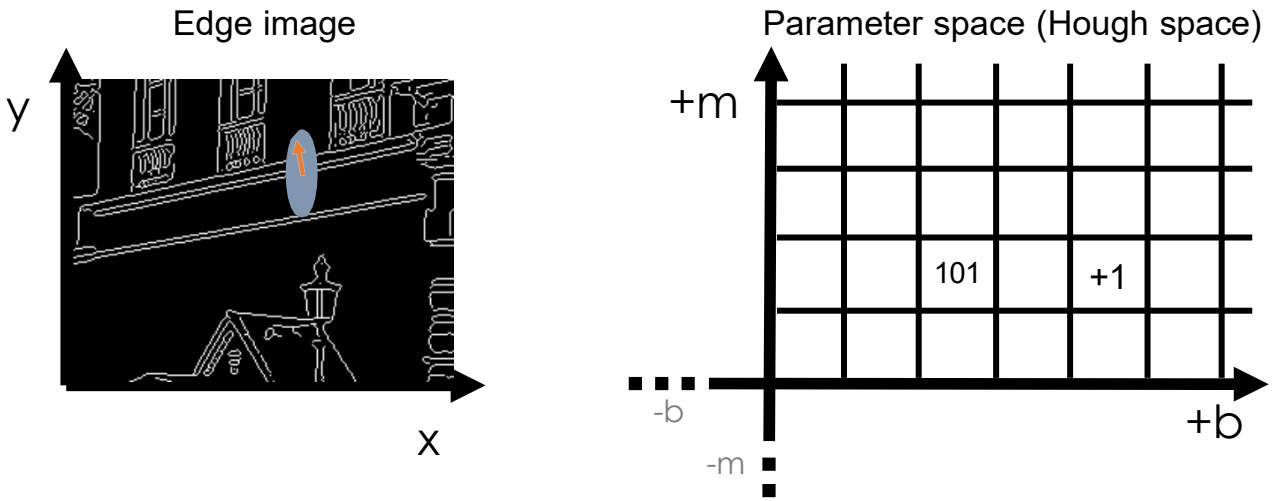

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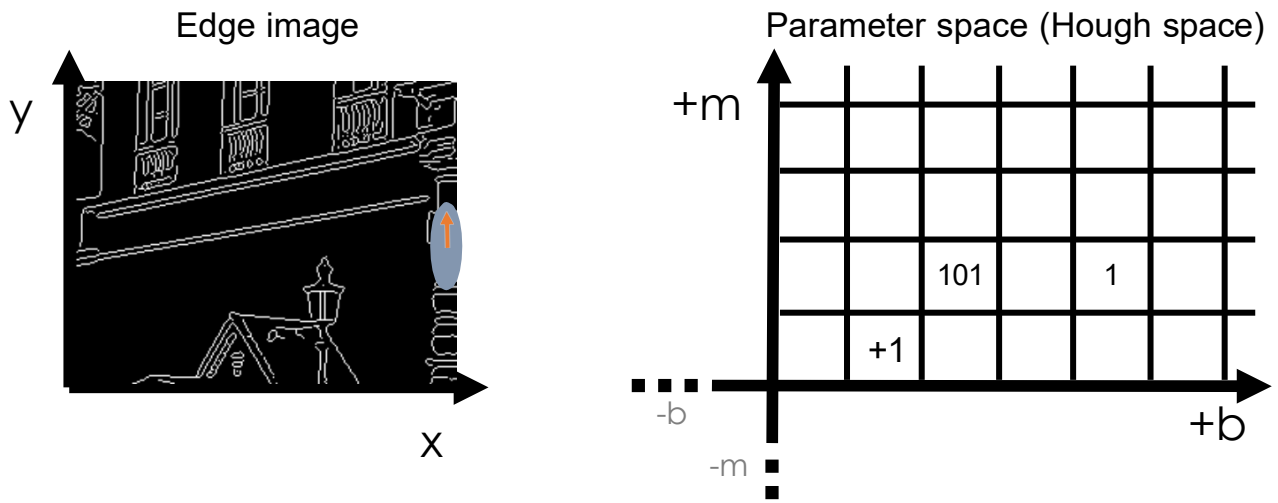

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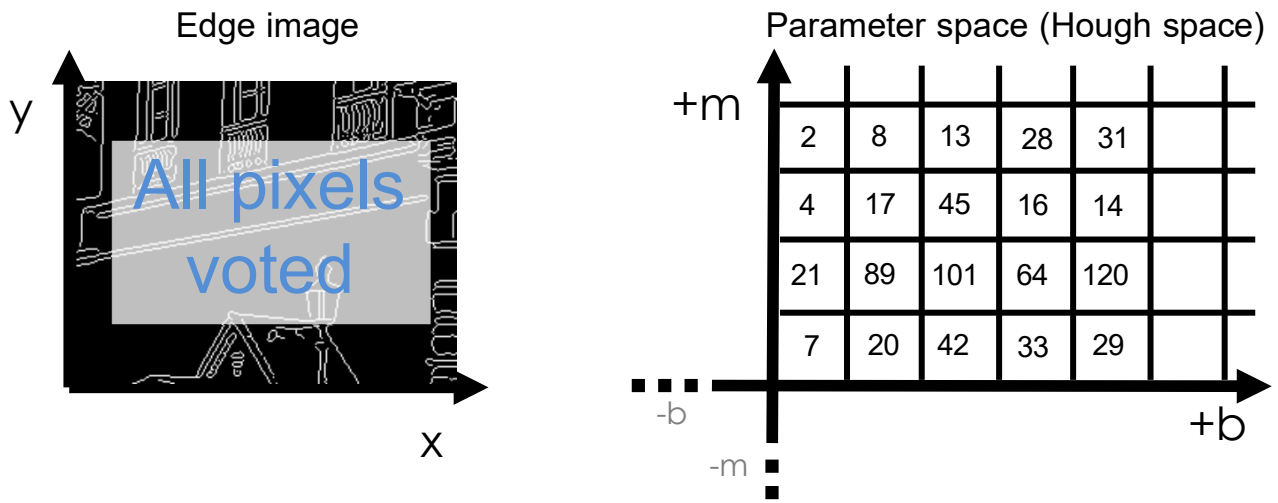

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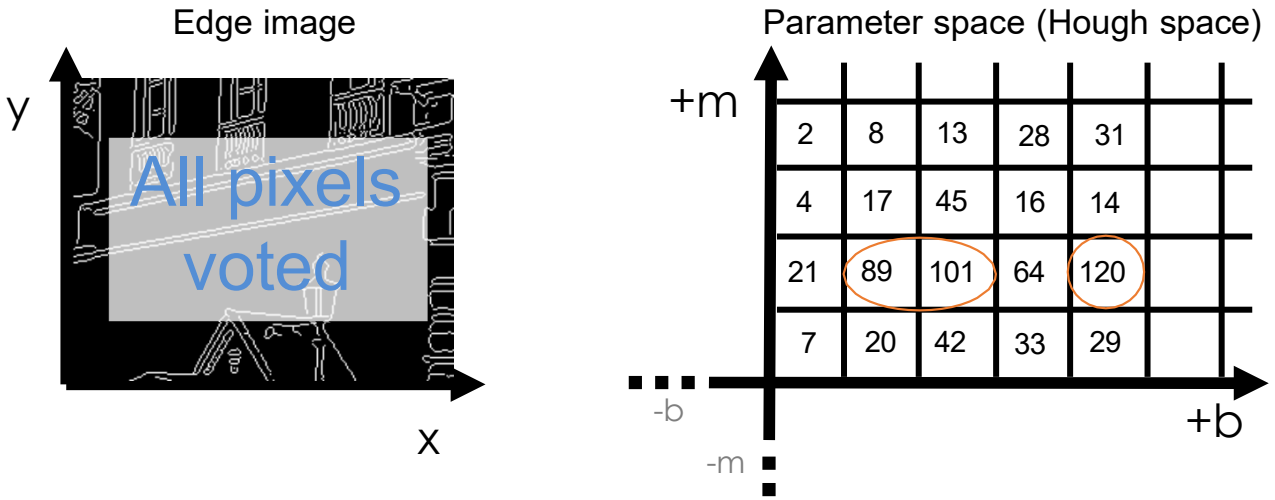
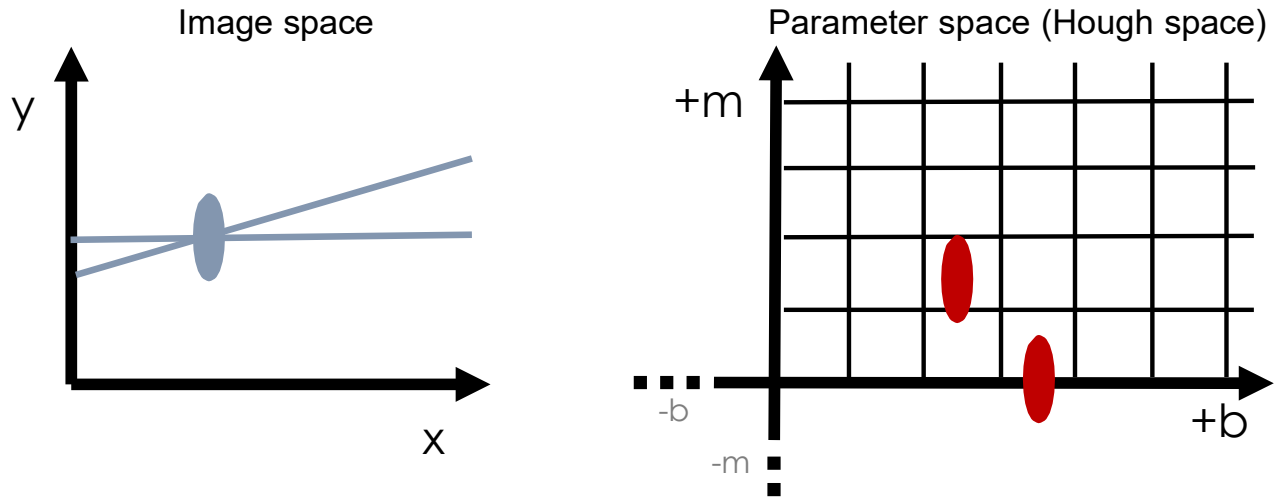
- Find maxima – our line candidates.



Hough Transform: Step back

- Hough space represents all possible lines.
- With gradient information constraint:
  - Edge is single point in Hough space.
- Without gradient orientation information?



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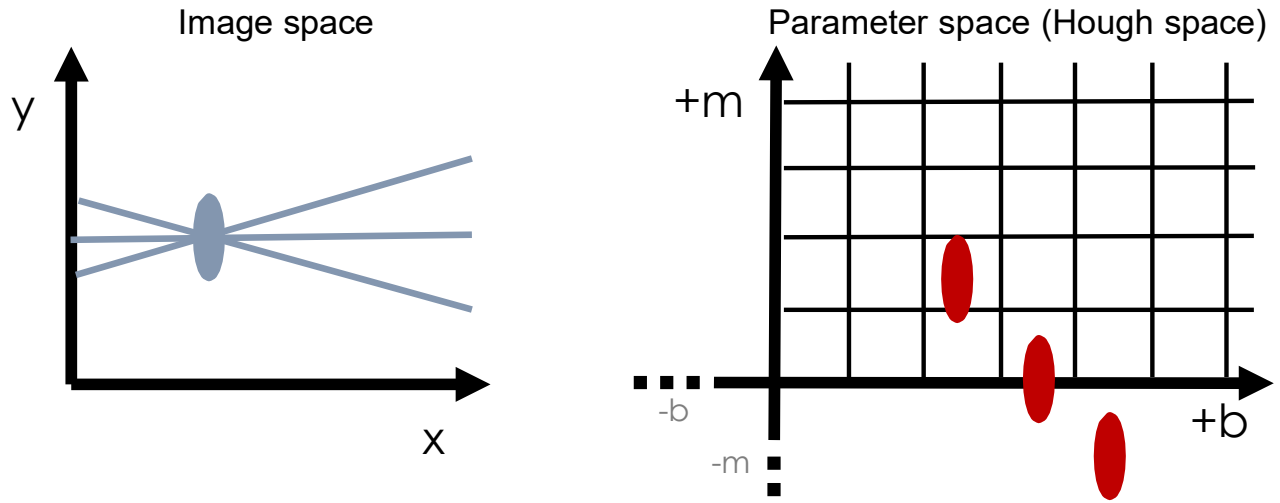

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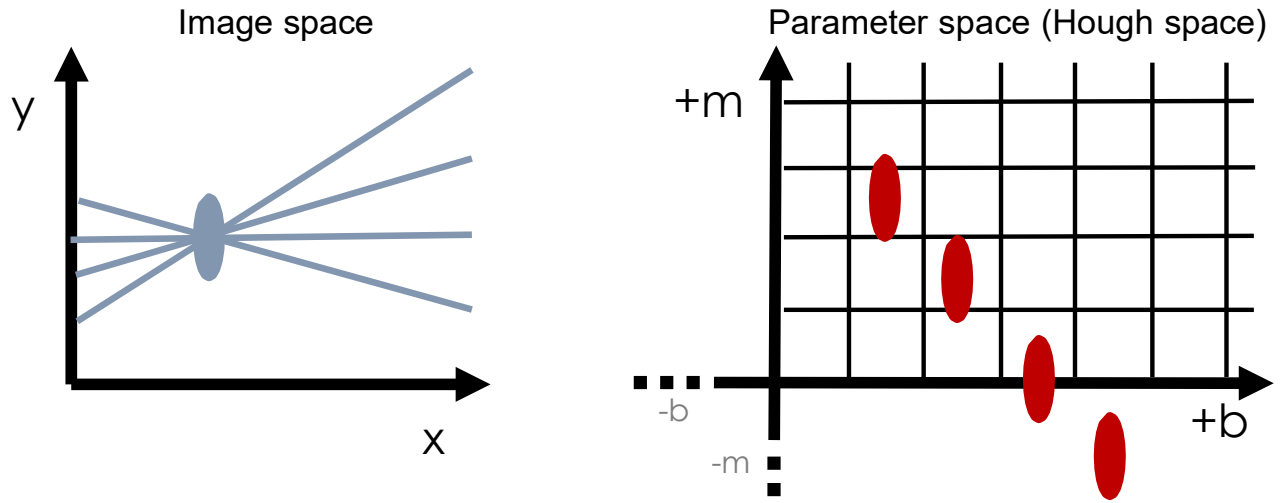

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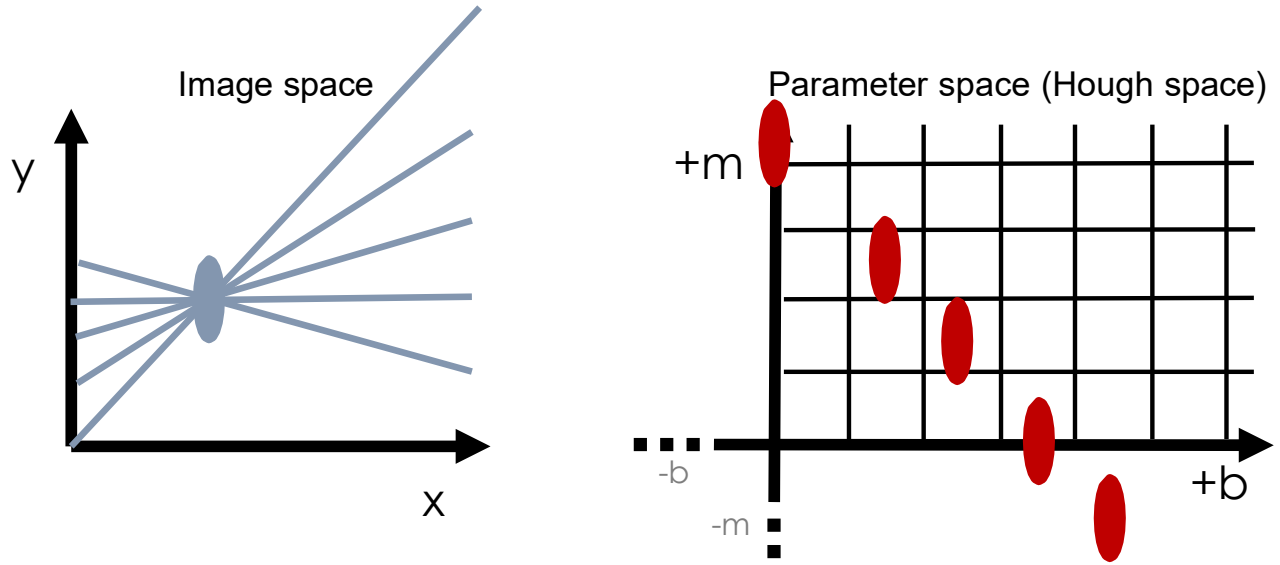


Hough Transform: Step back

- Hough space represents all possible lines.
- With gradient information constraint:
  - Edge is single point in Hough space.
- Without gradient orientation information?
  - Point is line in Hough space

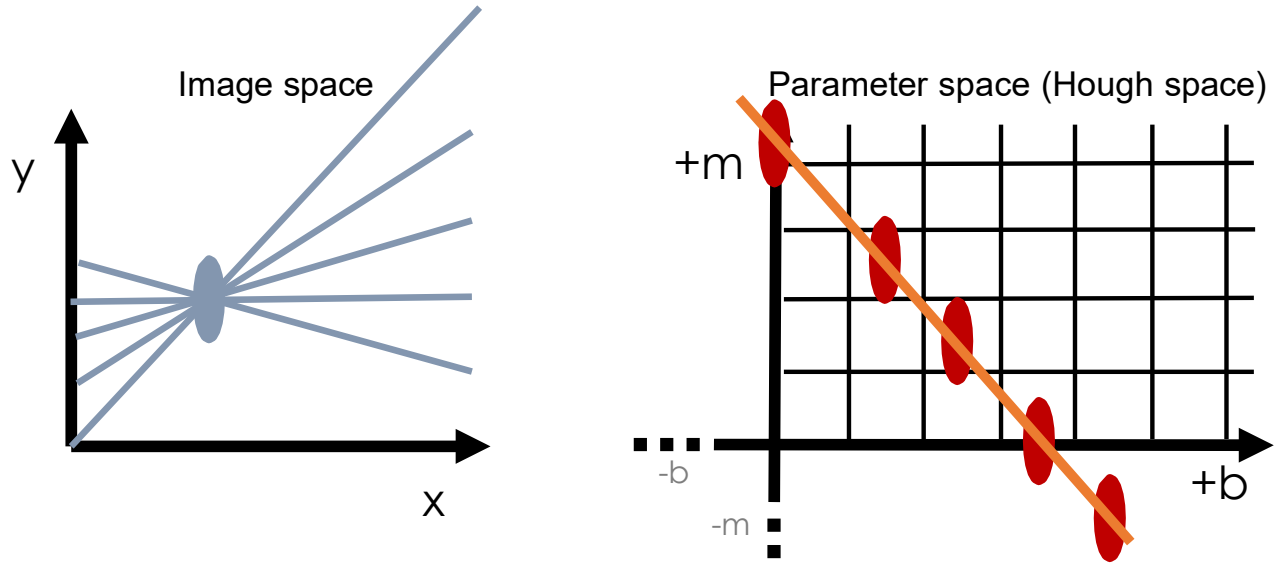


Image and parameter space

variables

$$y = mx + b$$

parameters

variables

$$y - mx = b$$

parameters

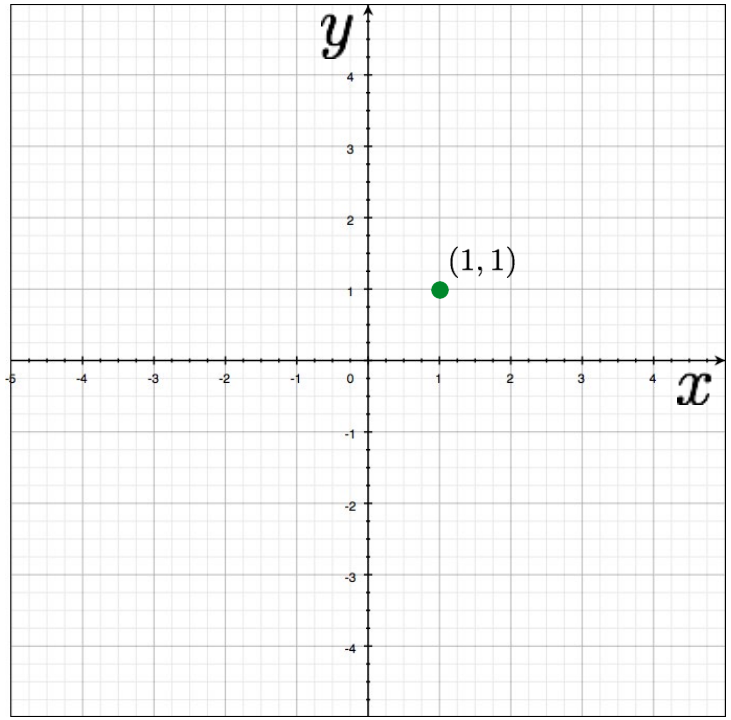
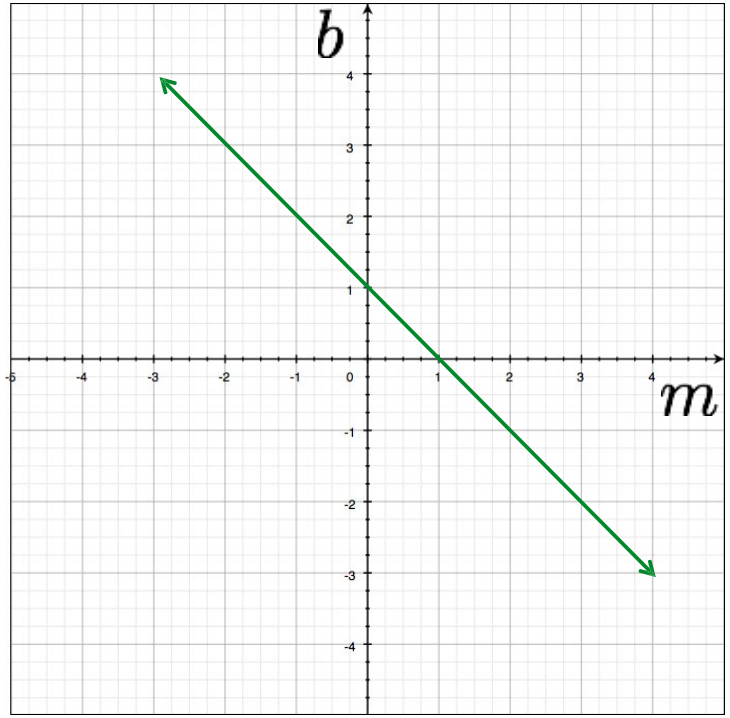


Image space

a point becomes a line



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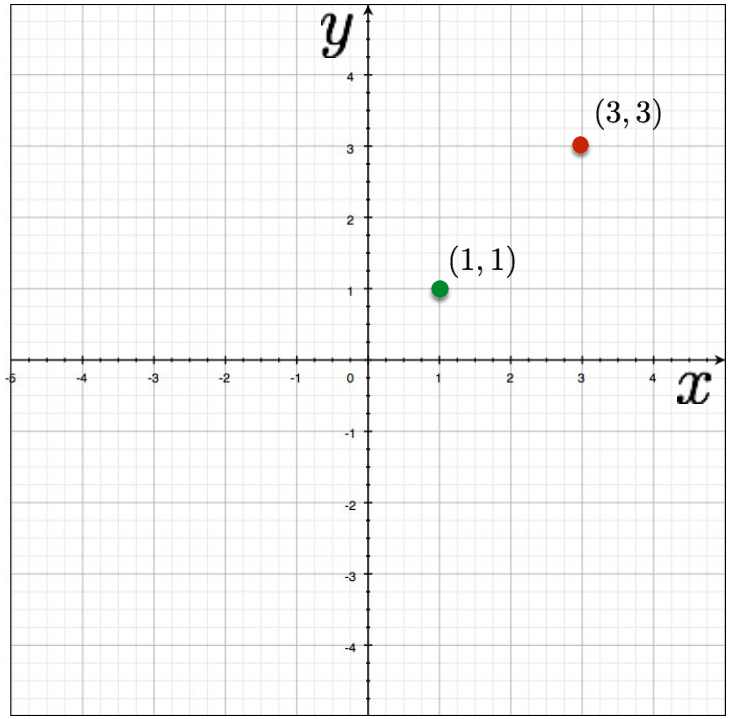
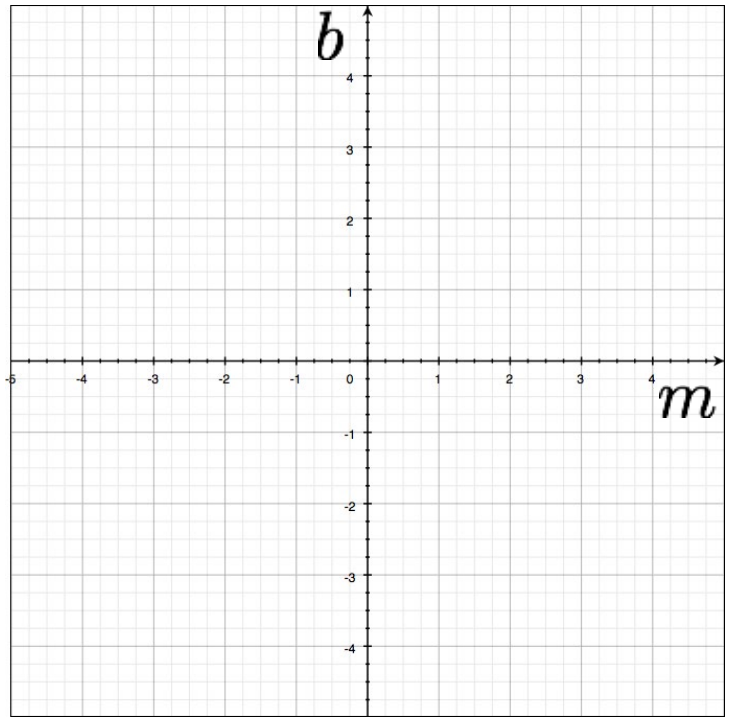


Image space

two points become ?



Parameter space

Image and parameter space

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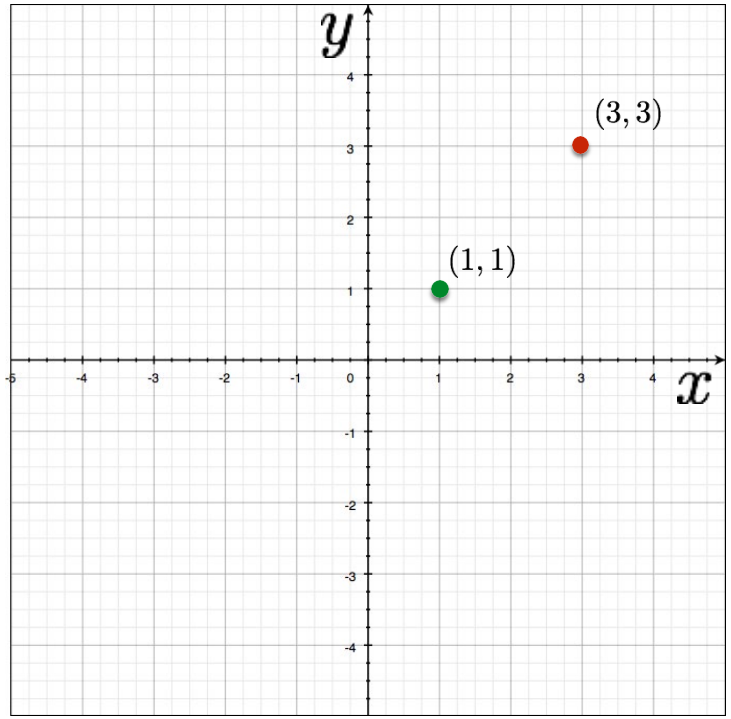

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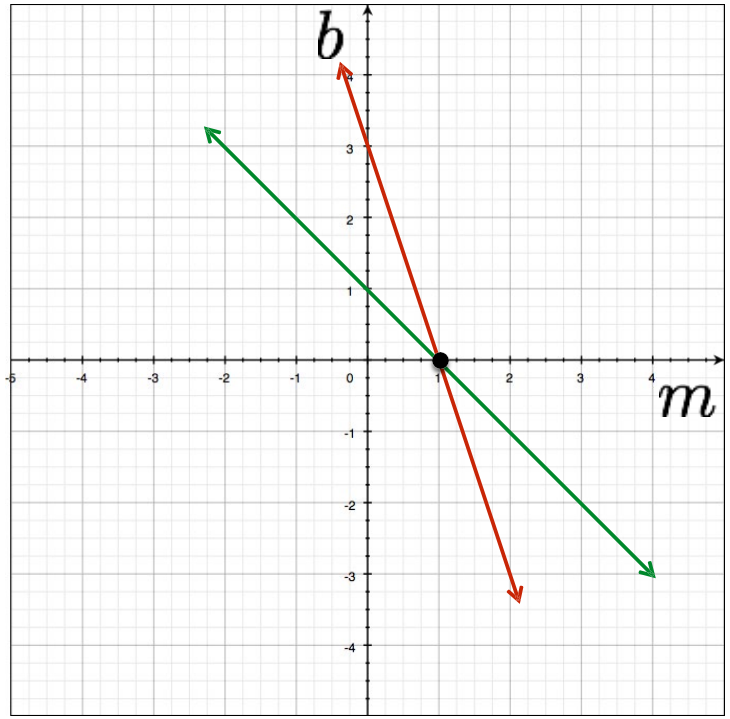

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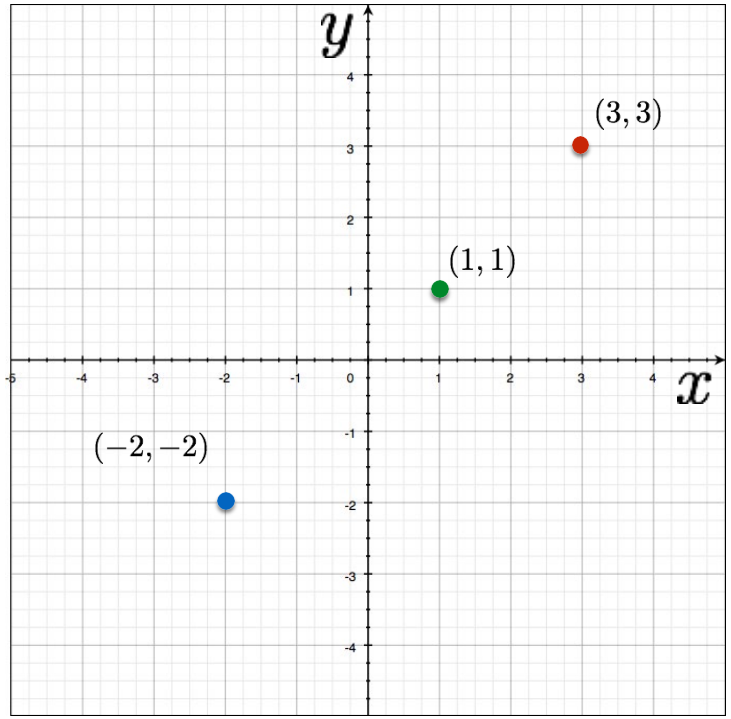
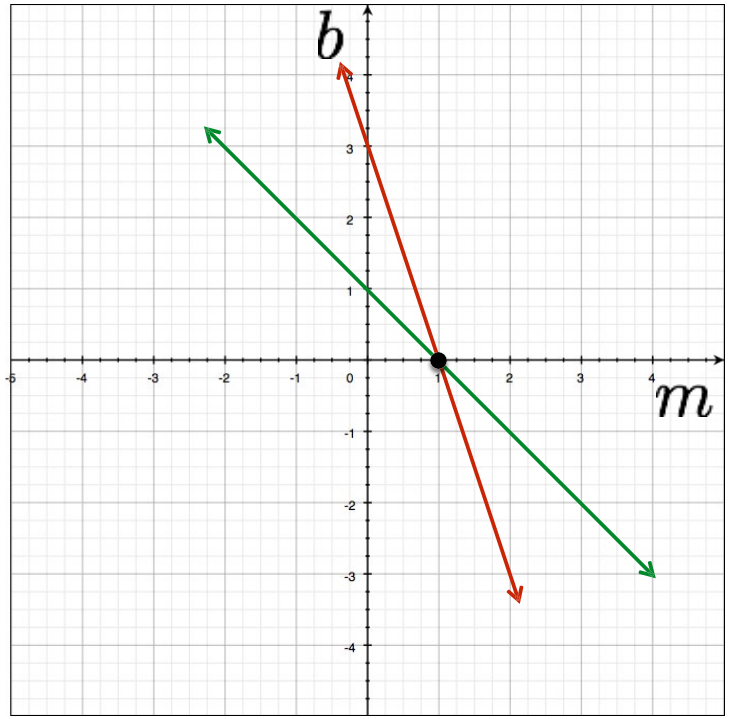


Image space

three points become ?



Parameter space

Image and parameter space

variables

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parameters

variables

$$y - mx = b$$

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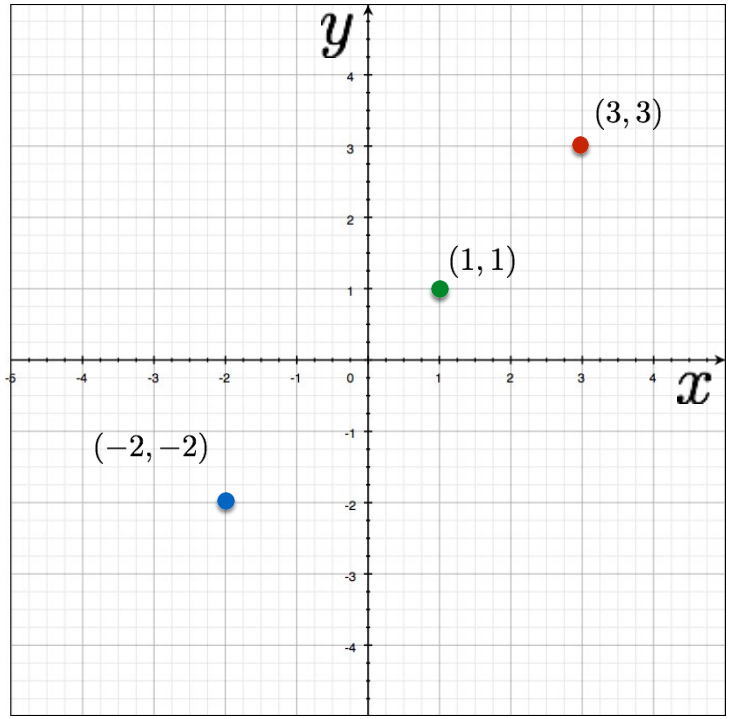

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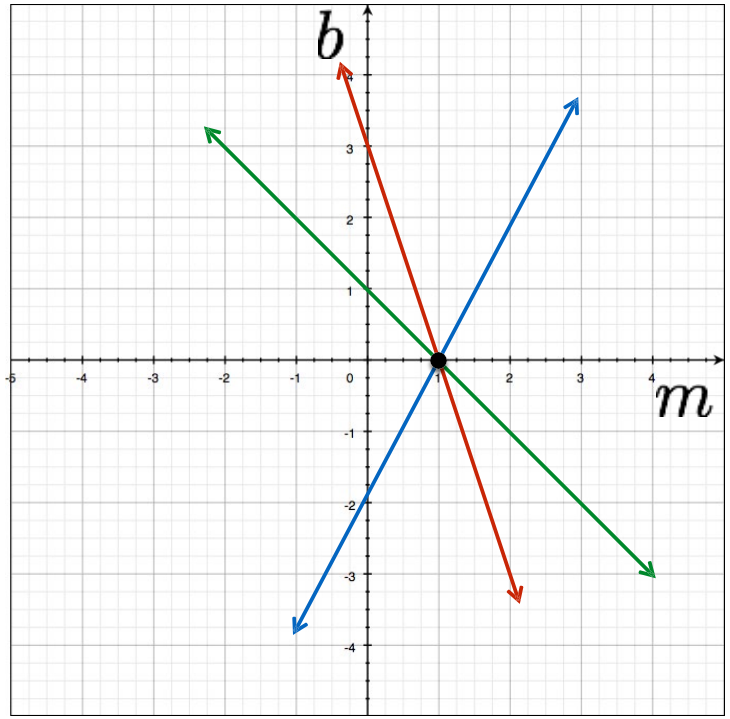

Parameter space

Image and parameter space

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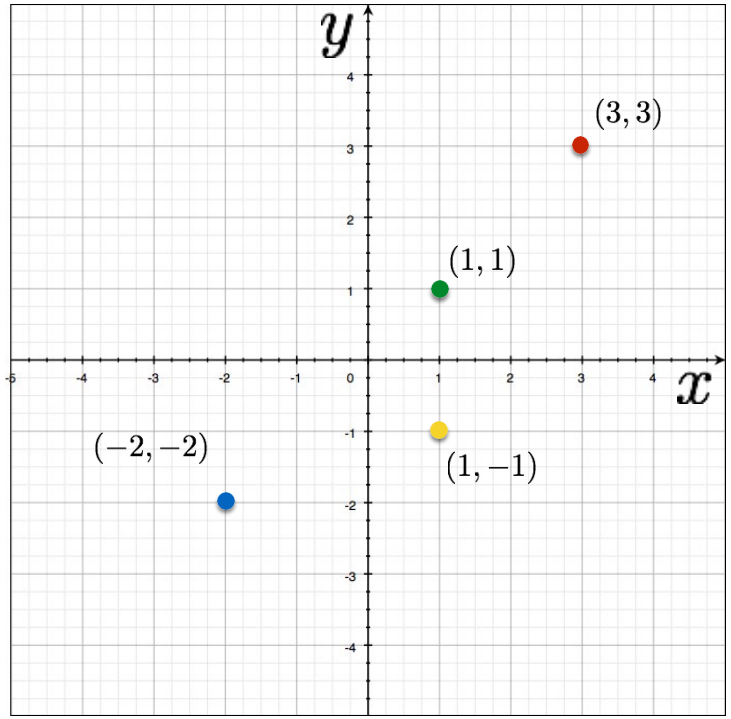
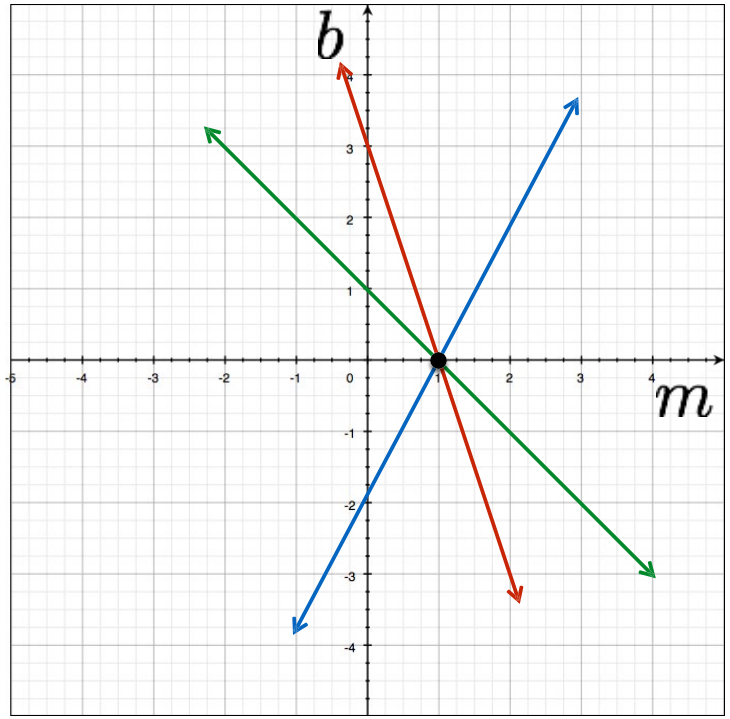


Image space

four points become ?



Parameter space

Image and parameter space

variables

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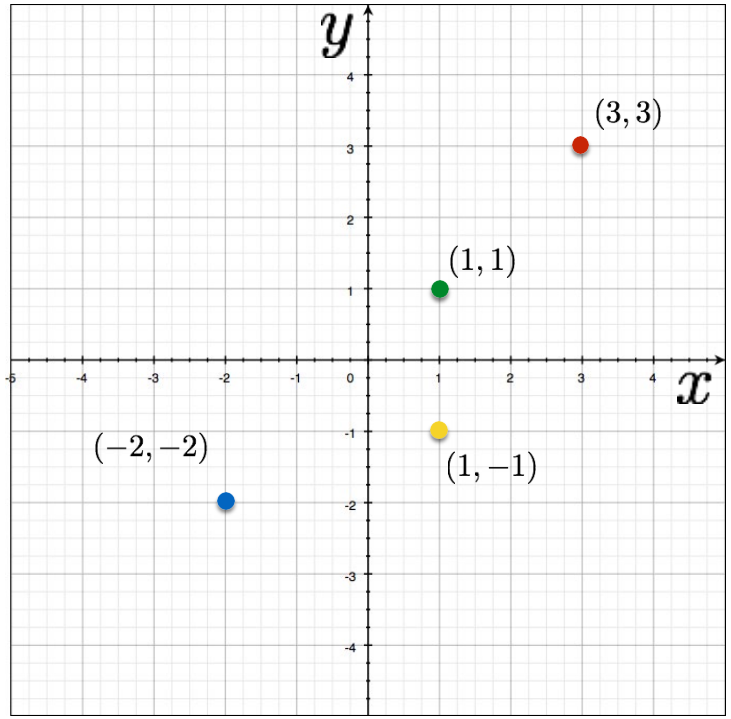

Image space

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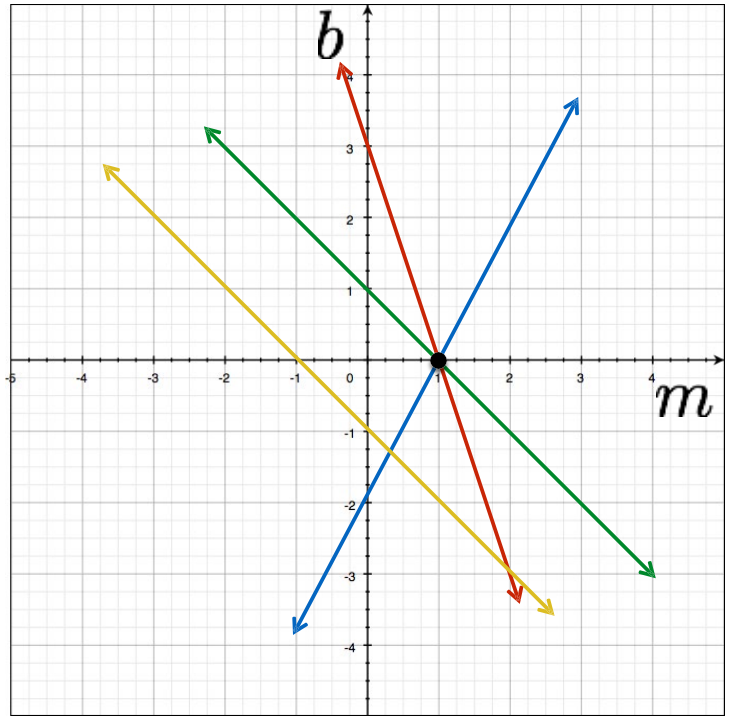
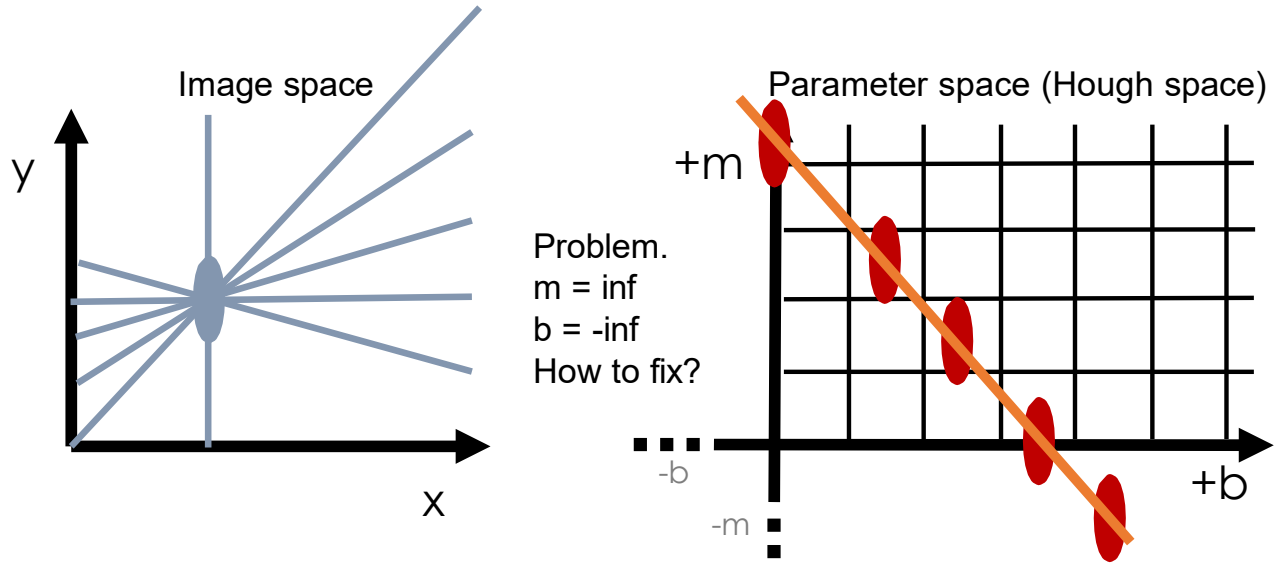


Parameter space

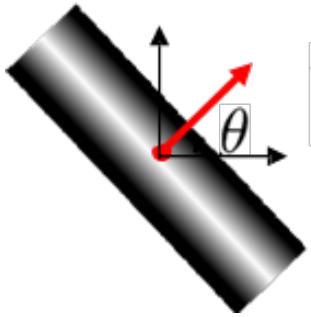
Hough Transform: Step back

- Hough space represents all possible lines
- With gradient information constraint:
  - Edge is single point in Hough space
- Without gradient orientation information?
  - How big is Hough space?

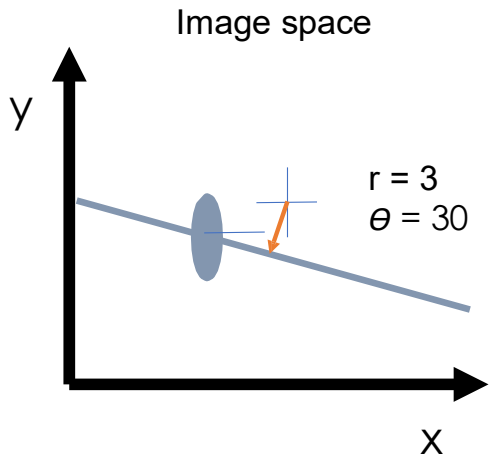


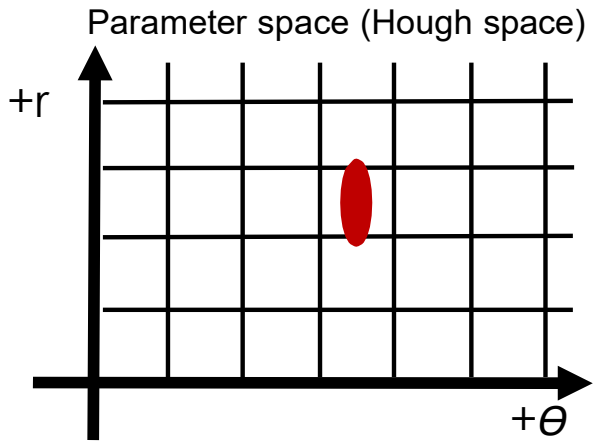
Hough Transform: Line Normal Form

- Use $\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$
  - Space is 0 to 360
- Use r = distance to line from some origin
  - $r_i = x_i \cos\theta_i + y_i \sin\theta_i$
  - Space is $\pm\sqrt{\max\_x^2 + \max\_y^2}$



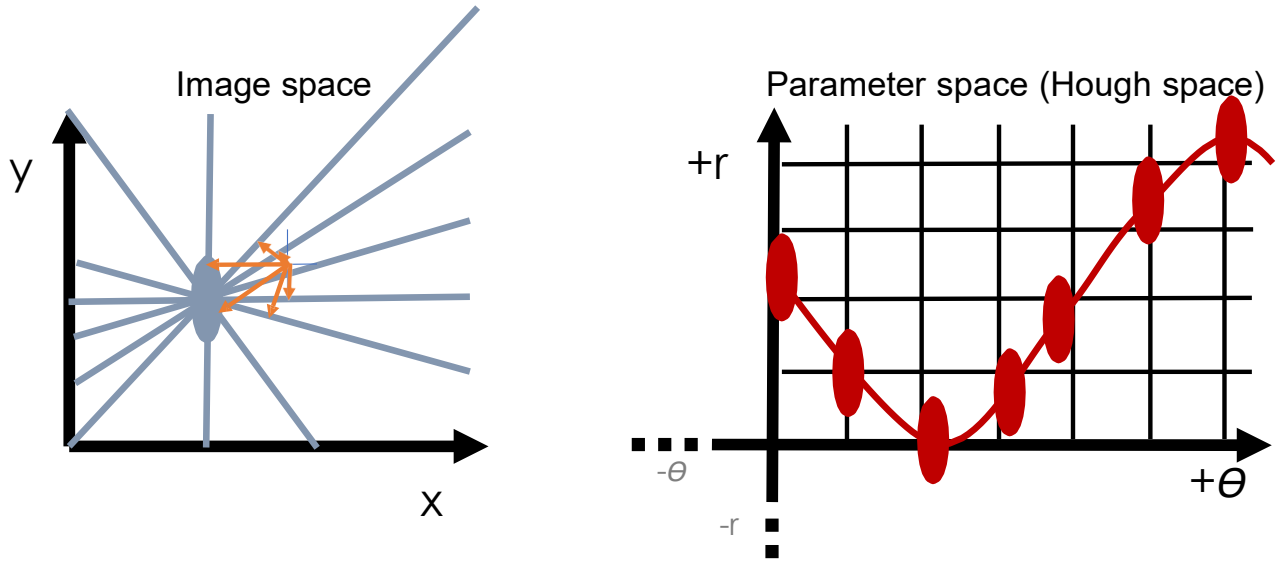
$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$





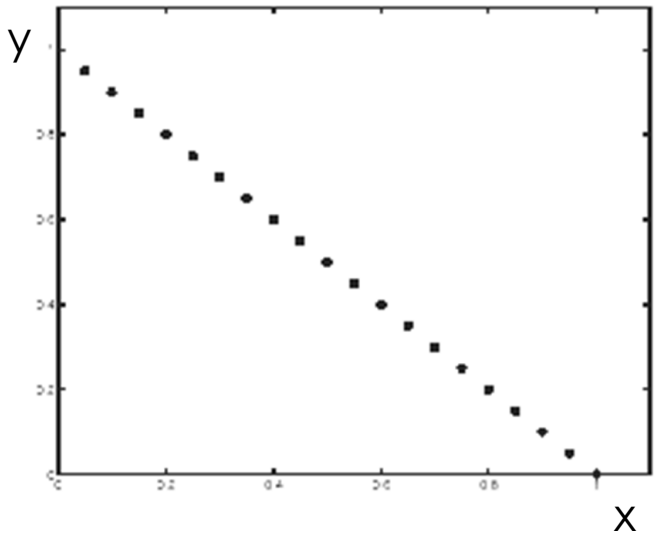
Hough Transform: Line Normal Form

- In this line form, unoriented edge draws a sinusoid in Hough space:

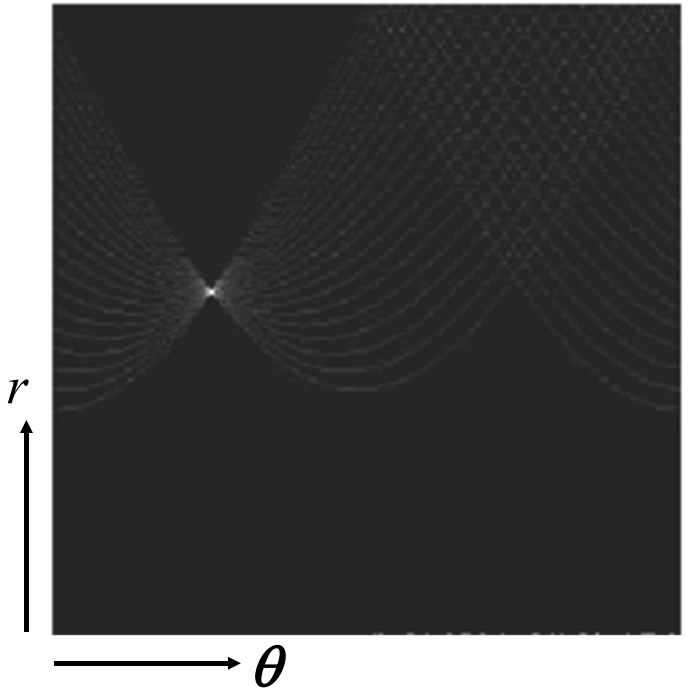


Hough transform - experiment

Next few images *ignore* edge orientation.
Each point is one sinusoid.

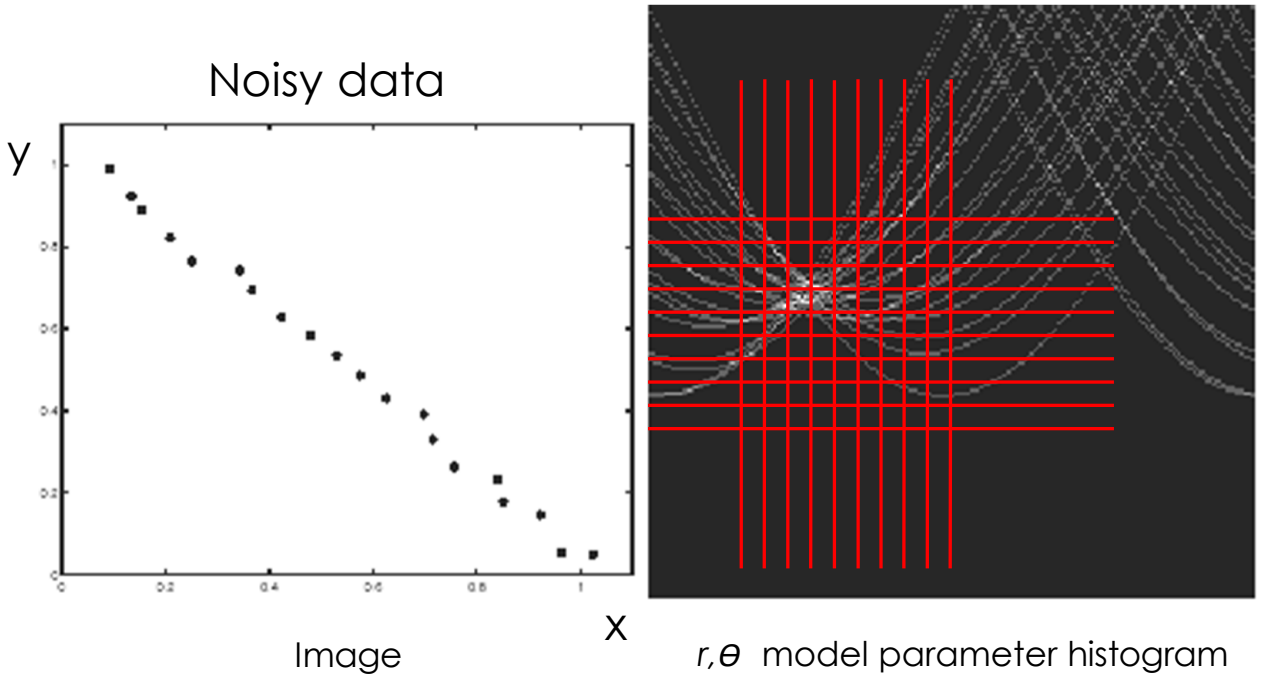


Image



r,*θ* model parameter histogram

Hough transform - experiment



Need to adjust grid size or smooth

- Practical considerations
  - Bin size
  - Smoothing
  - Finding multiple lines
  - Finding line segments

Hough transform example

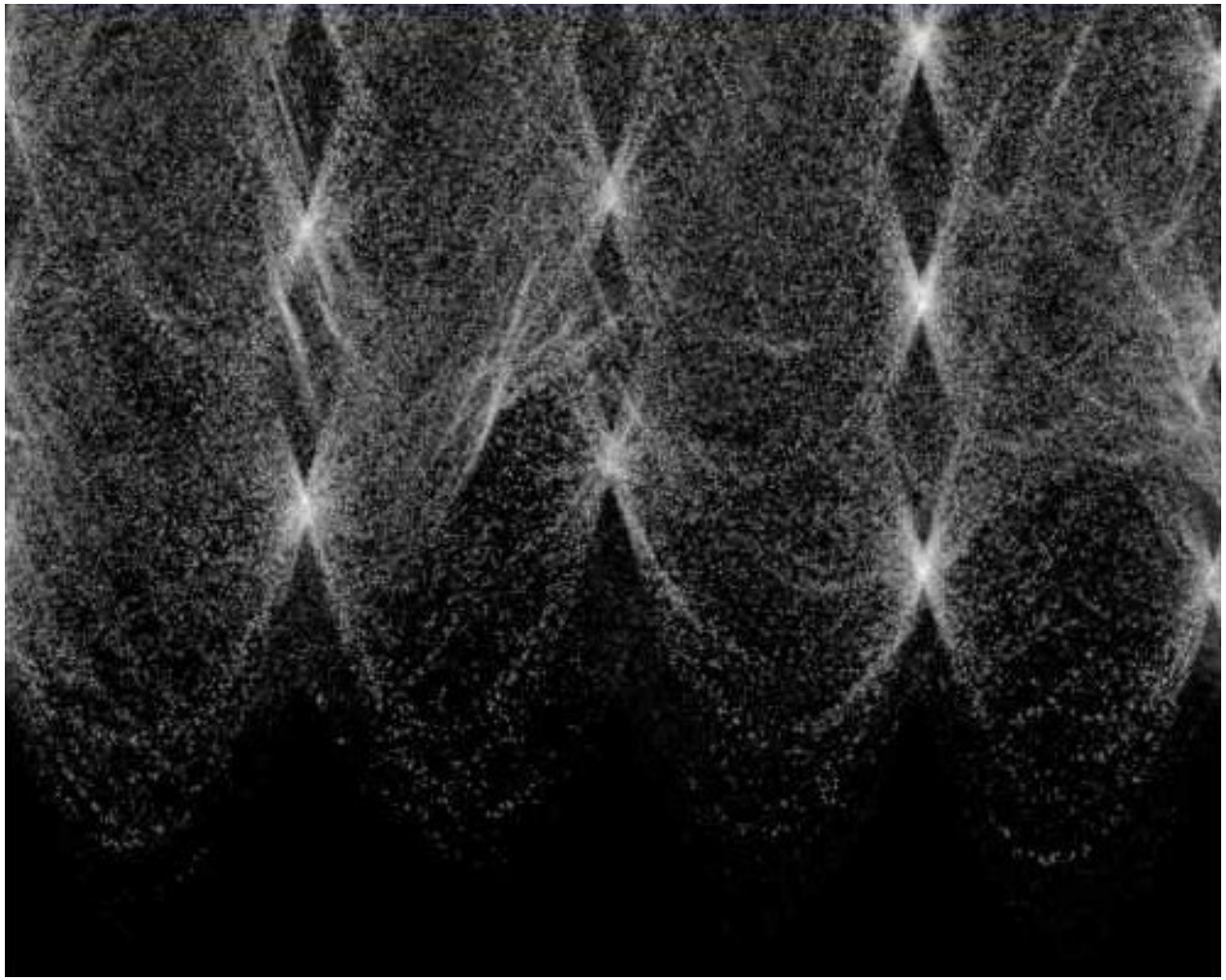
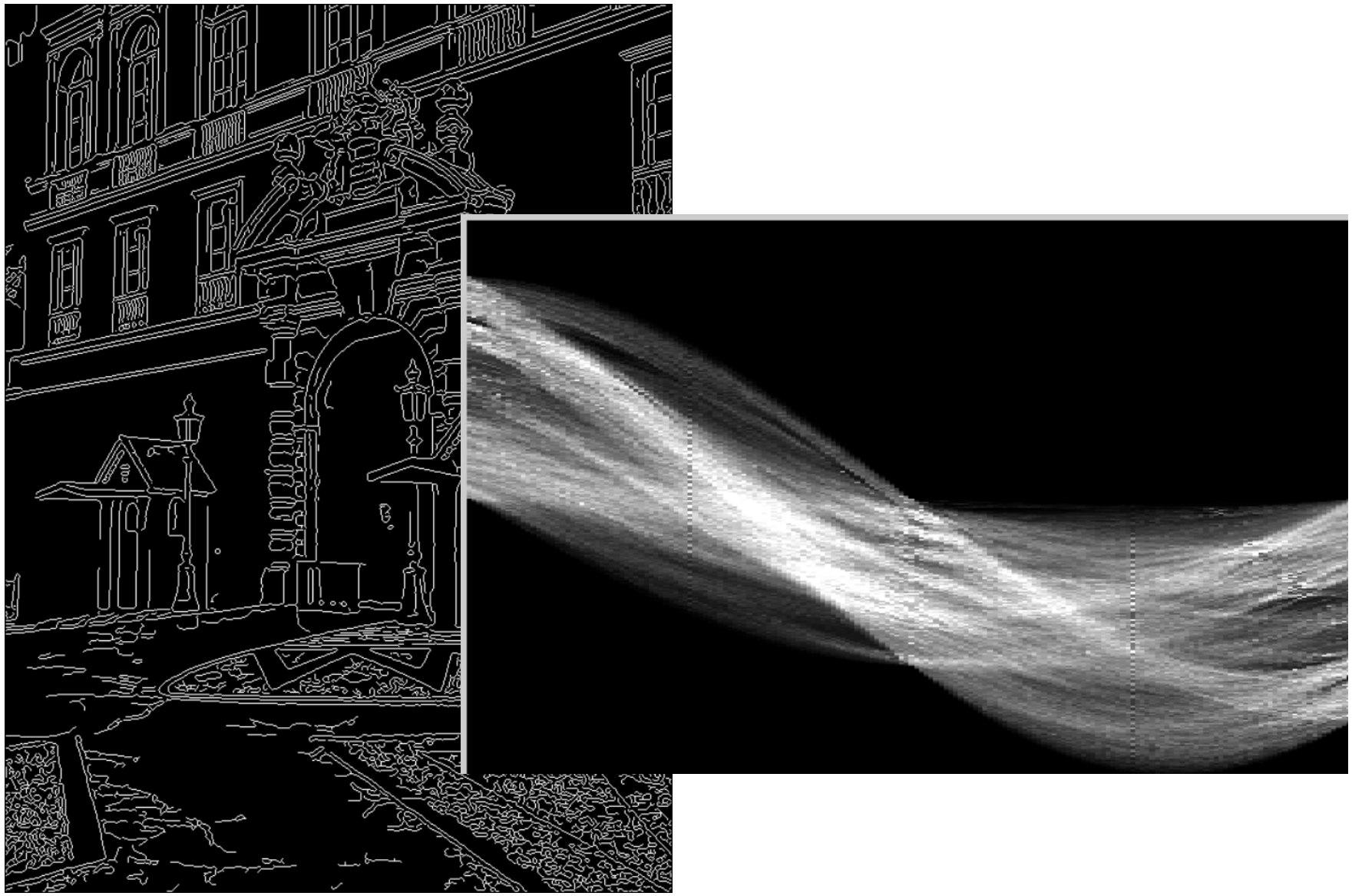


Image → Canny

Canny → Hough votes



Hough votes → Edges

Find peaks and post-process.