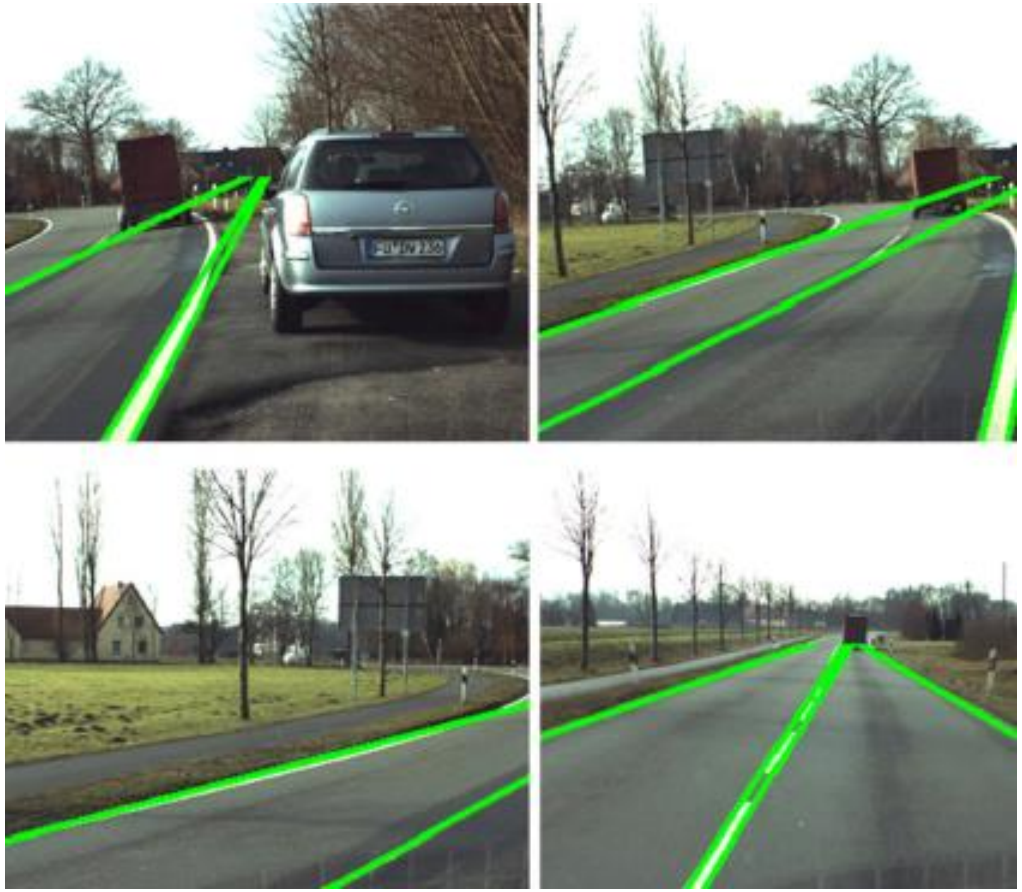
Line Detection using Hough Transform

CSE 5005: CVIP

Detection of Lines



- Real-world images often show straight lines, such as edges of buildings, lane borders, or power poles

Detection of Lines

An edge detector is first used to map a given image into a binary edge map

- How to describe a line?

Hough transform

- An early type of voting scheme
- General outline:
  - Discretize parameter space into bins
  - For each feature point in the image, put a vote in every bin in the parameter space that could have generated this point
  - Find bins that have the most votes

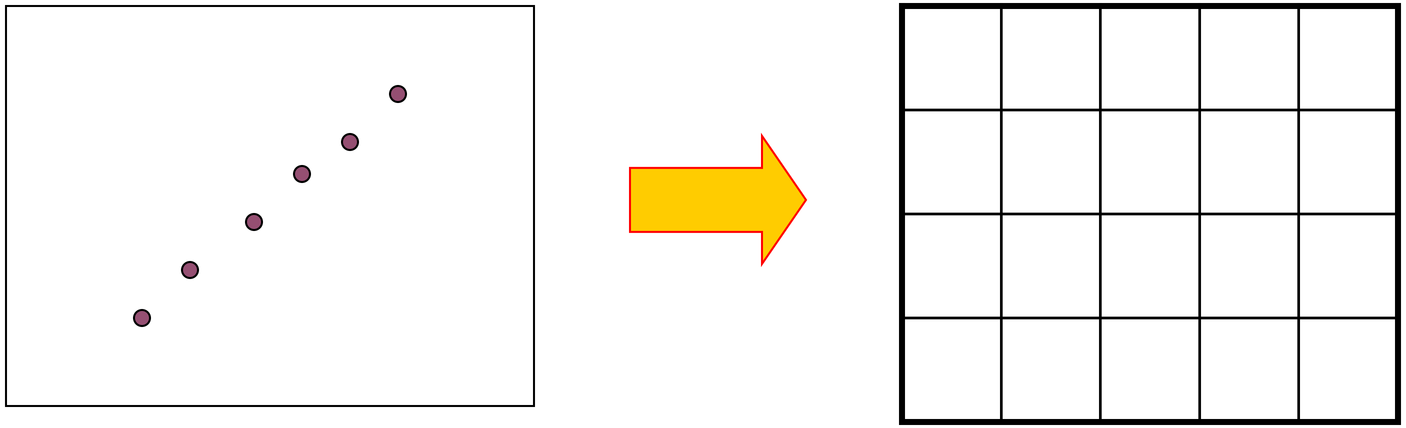


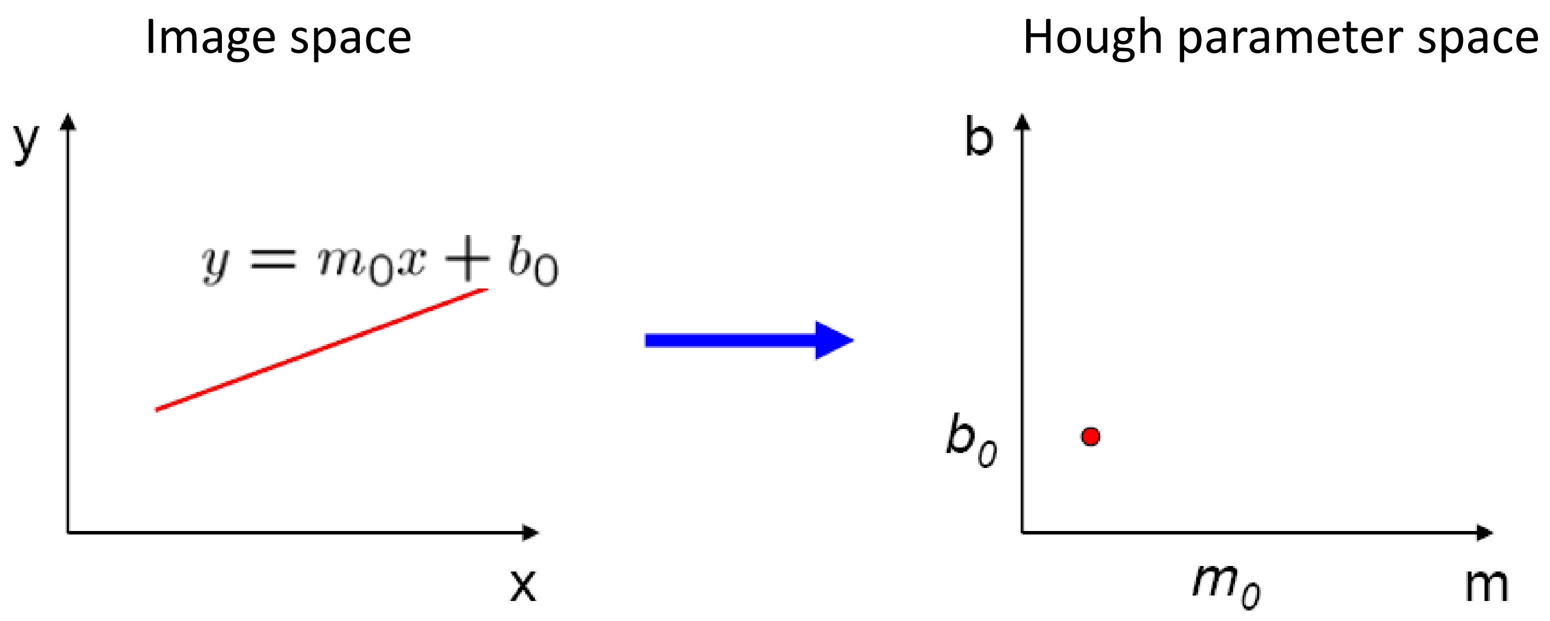
Image space

Hough parameter space

P.V.C. Hough, *Machine Analysis of Bubble Chamber Pictures,* Proc. Int. Conf. High Energy Accelerators and Instrumentation, 1959

Parameter space representation

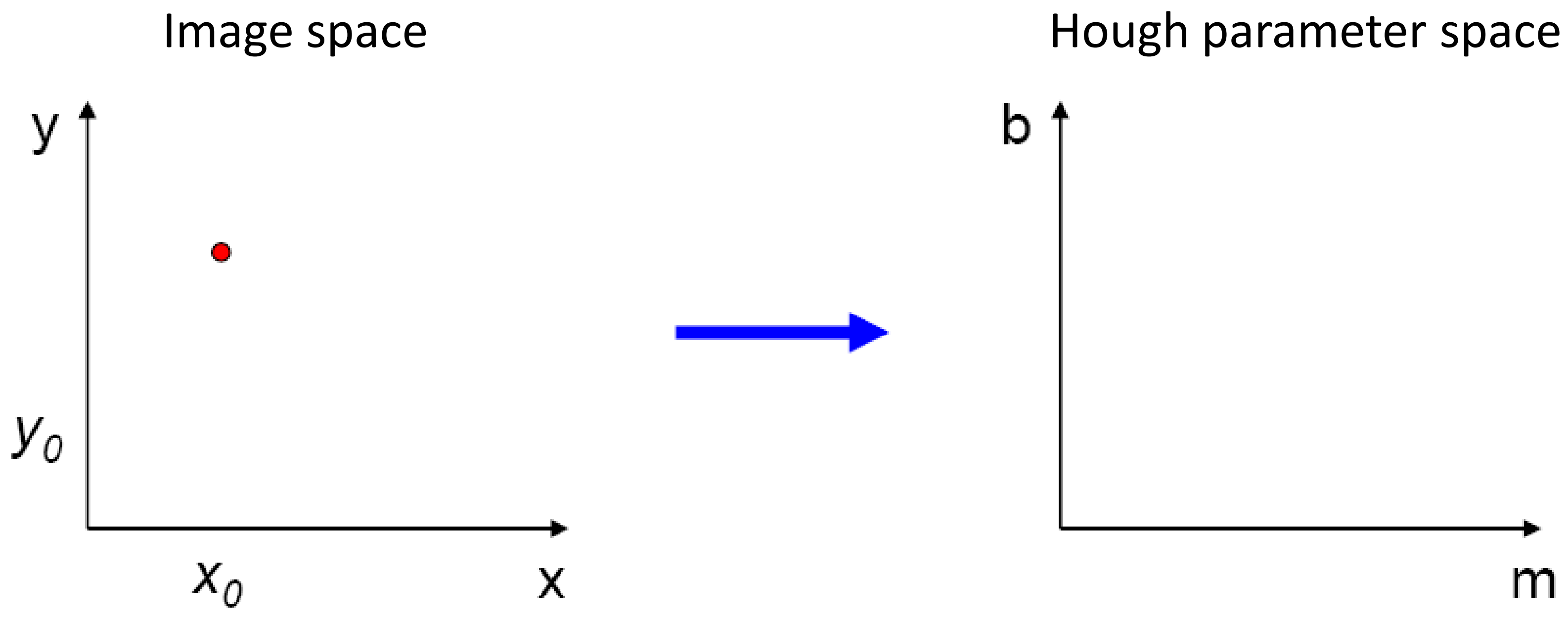
- A line in the image corresponds to a point in Hough space



Source: S. Seitz

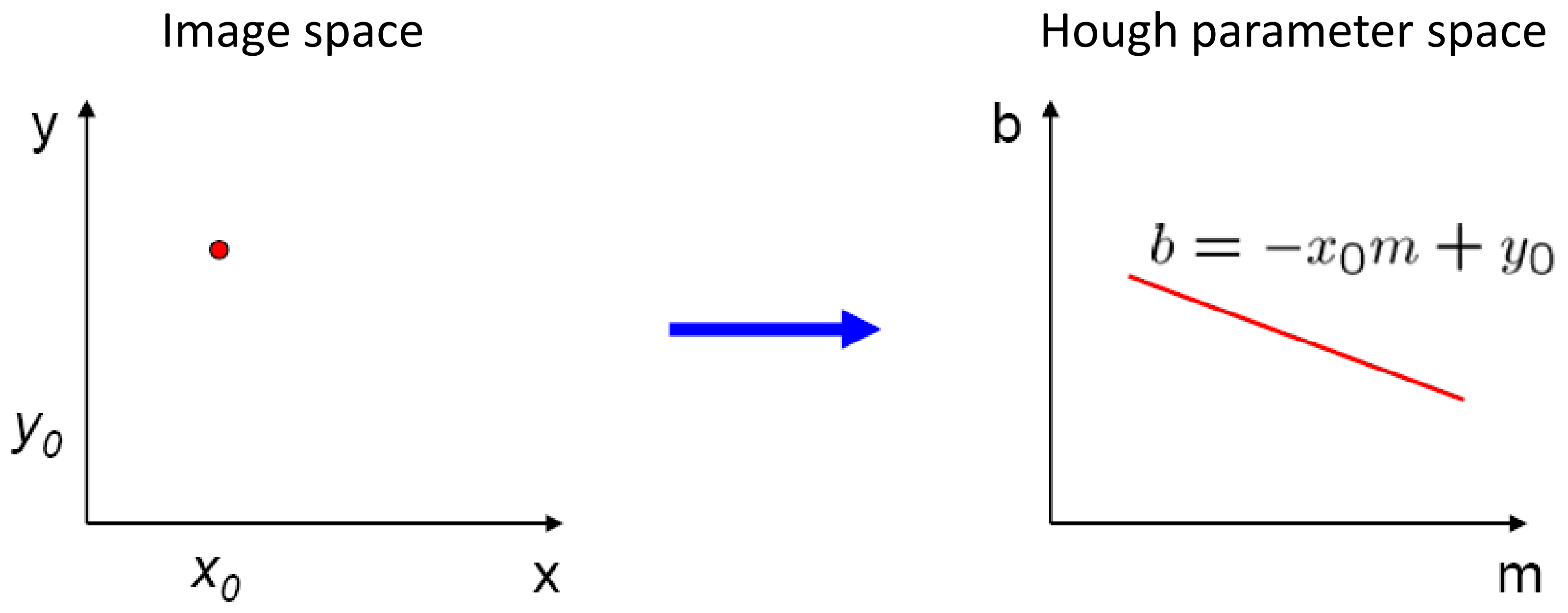
Parameter space representation

- What does a point (x_0, y_0) in the image space map to in the Hough space?



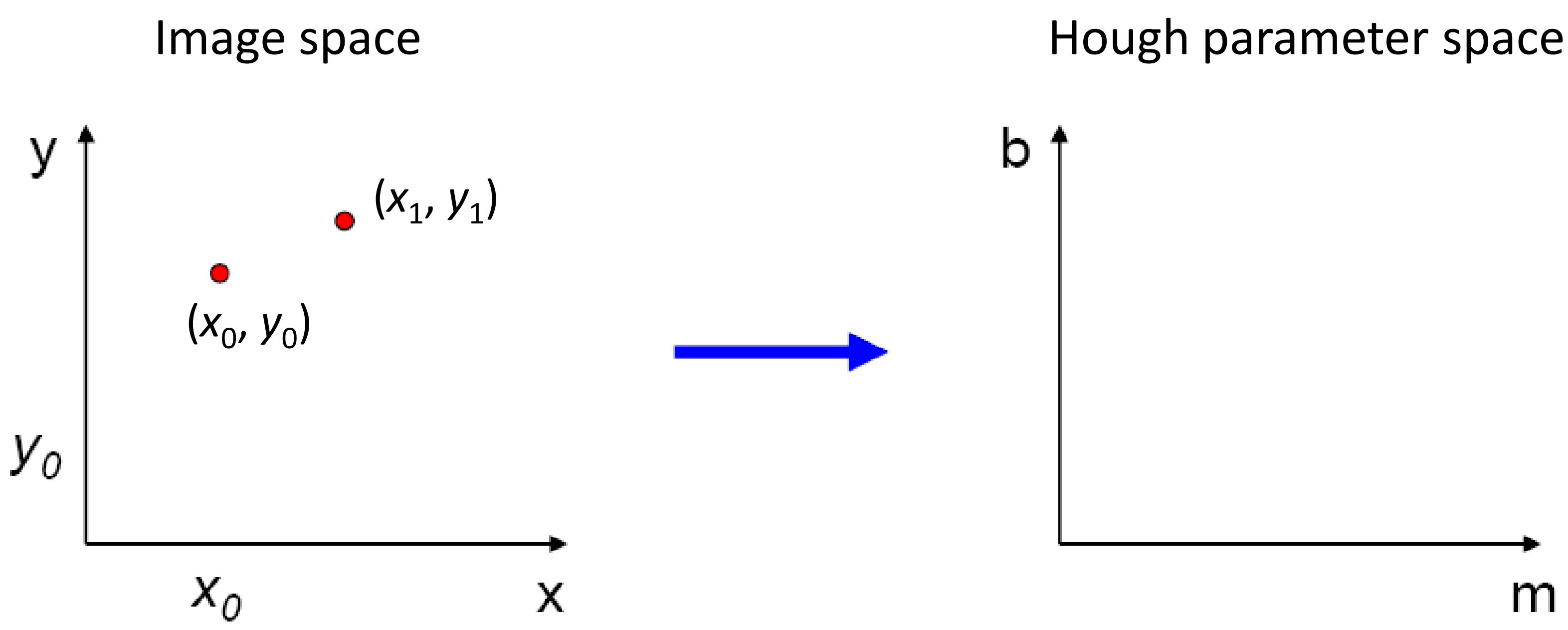
Parameter space representation

- What does a point (x_0, y_0) in the image space map to in the Hough space?
  - Answer: the solutions of $b = -x_0 m + y_0$
  - This is a line in Hough space



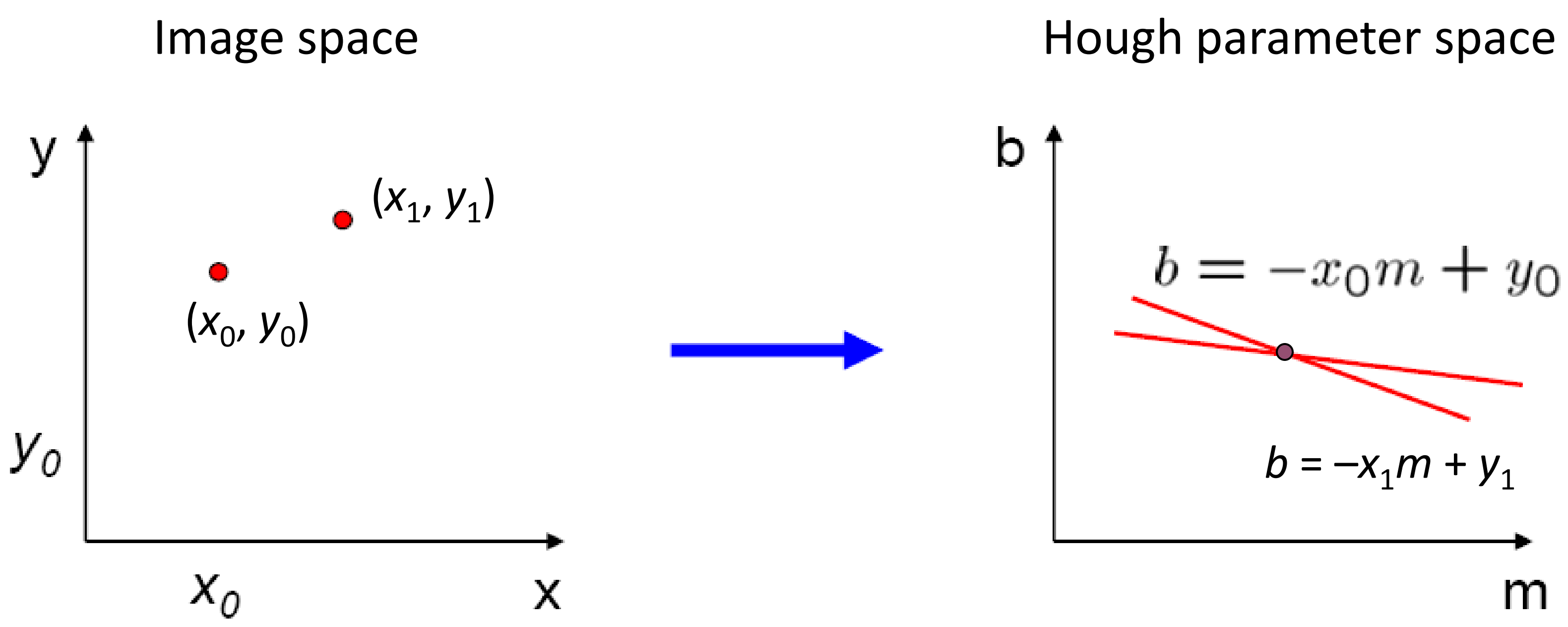
Parameter space representation

- Where is the line that contains both (x_0, y_0) and (x_1, y_1)?



Parameter space representation

- Where is the line that contains both (x_0, y_0) and (x_1, y_1)?
  - It is the intersection of the lines $b = -x_0m + y_0$ and $b = -x_1m + y_1$

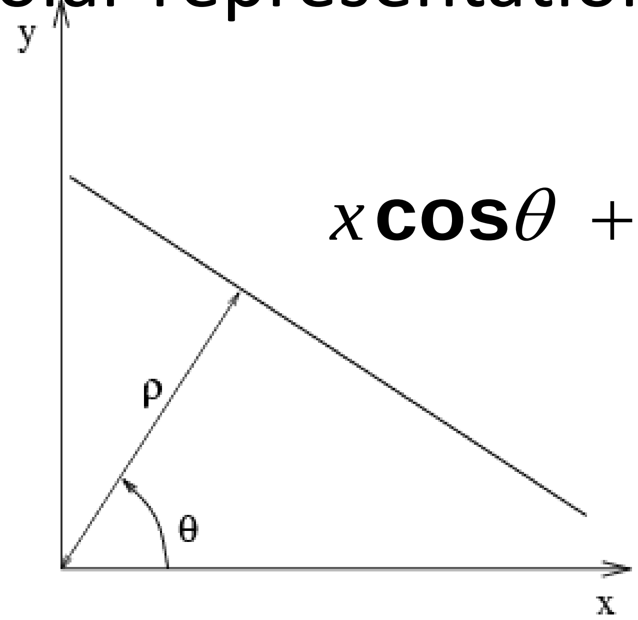


Parameter space representation

- Problems with the (m,b) space:
  - Unbounded parameter domain
  - Vertical lines require infinite m

Parameter space representation

- Problems with the (m,b) space:
  - Unbounded parameter domain
  - Vertical lines require infinite m
- Alternative: polar representation

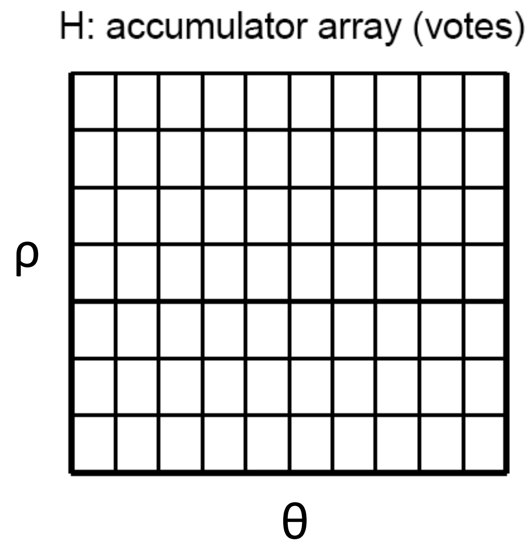


$$x\cos\theta + y\sin\theta = \rho$$

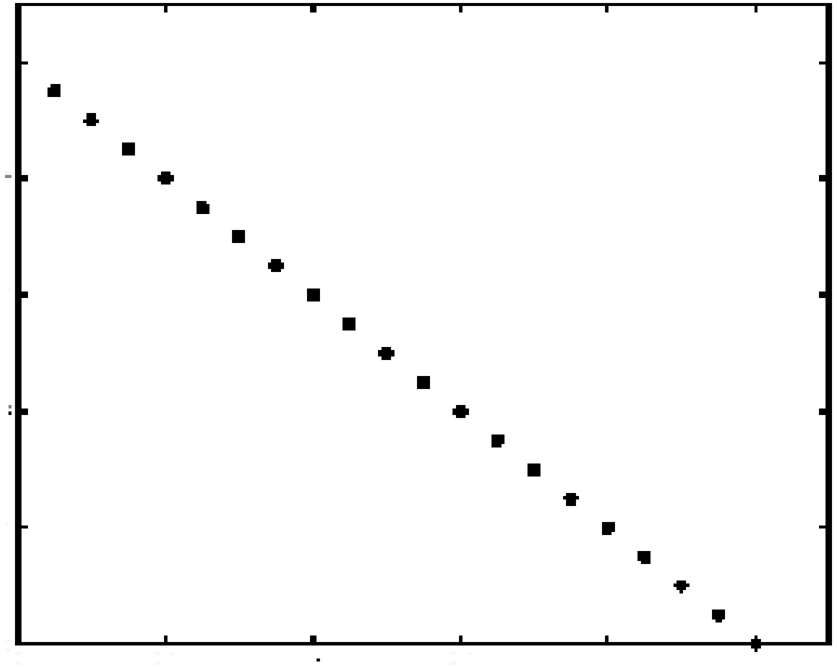
Each point will add a sinusoid in the (θ,ρ) parameter space

Algorithm outline

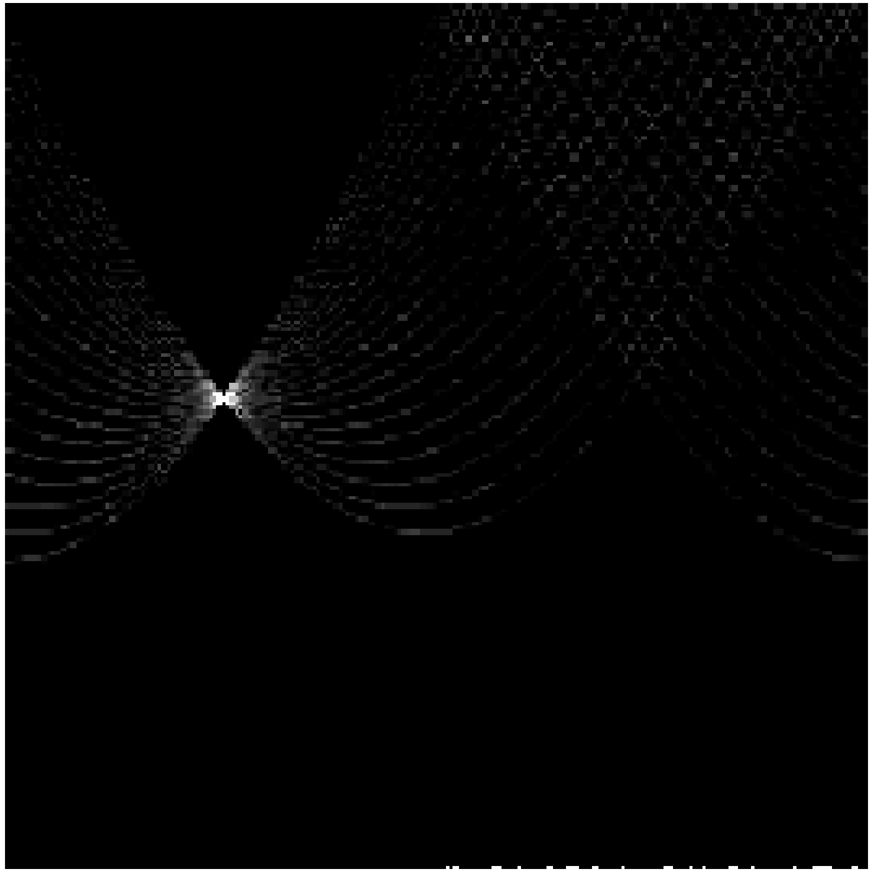
- Initialize accumulator H to all zeros
- For each edge point (x,y) in the image
  For θ = 0 to 180
  $\rho = x \cos\theta + y \sin\theta$
  $H(\theta, \rho) = H(\theta, \rho) + 1$
  end
  end
- Find the value(s) of (θ, ρ) where $H(\theta, \rho)$ is a local maximum
  - The detected line in the image is given by $\rho = x \cos\theta + y \sin\theta$



Basic illustration



features

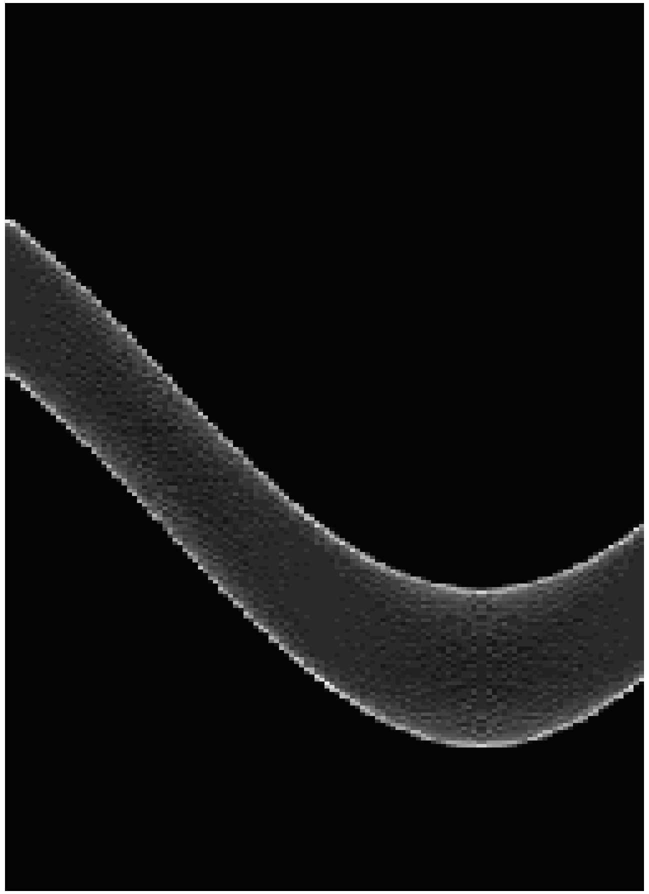


votes

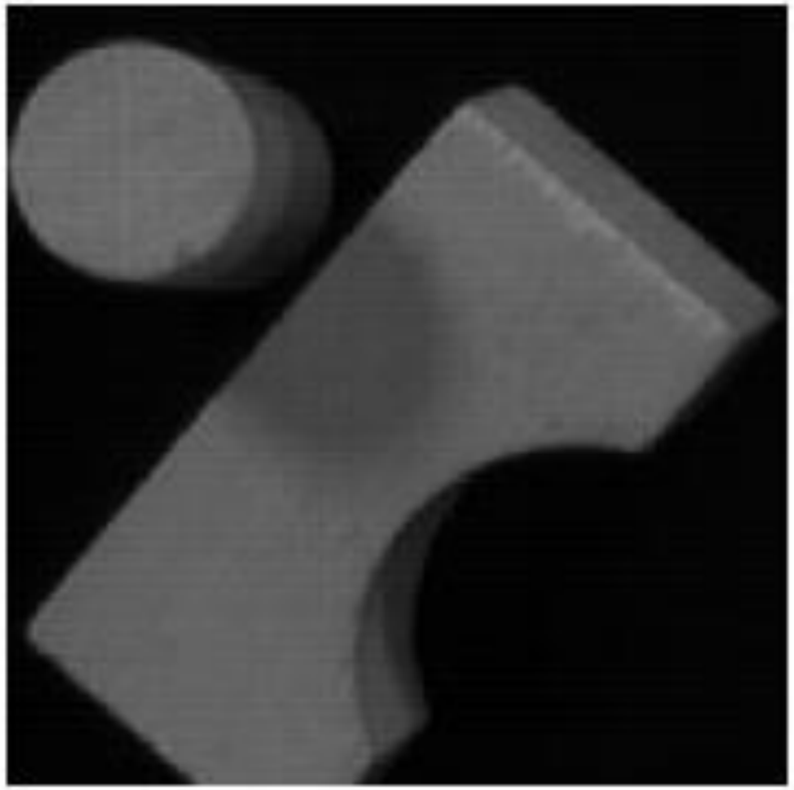
Other shapes

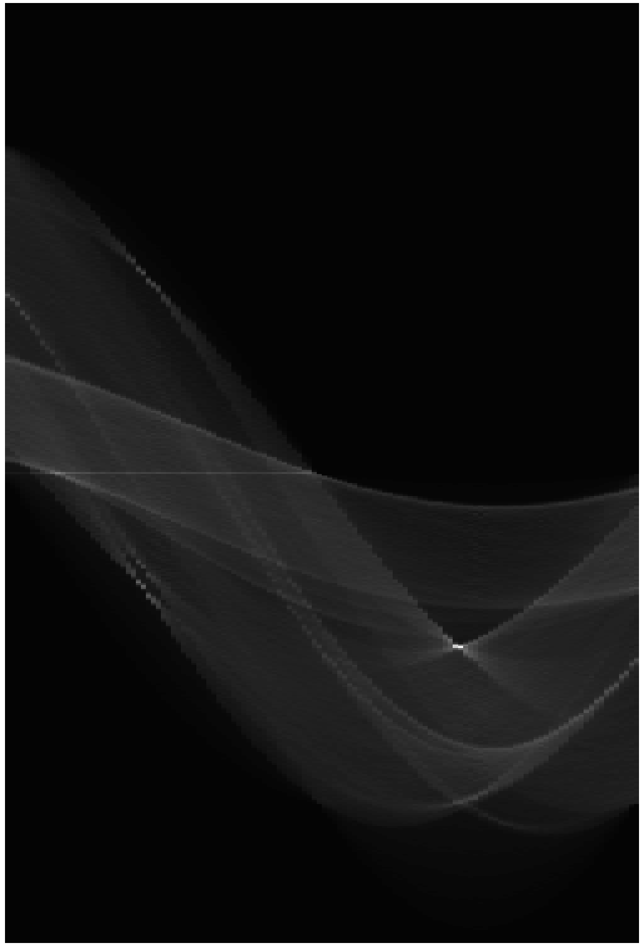
Square

Circle

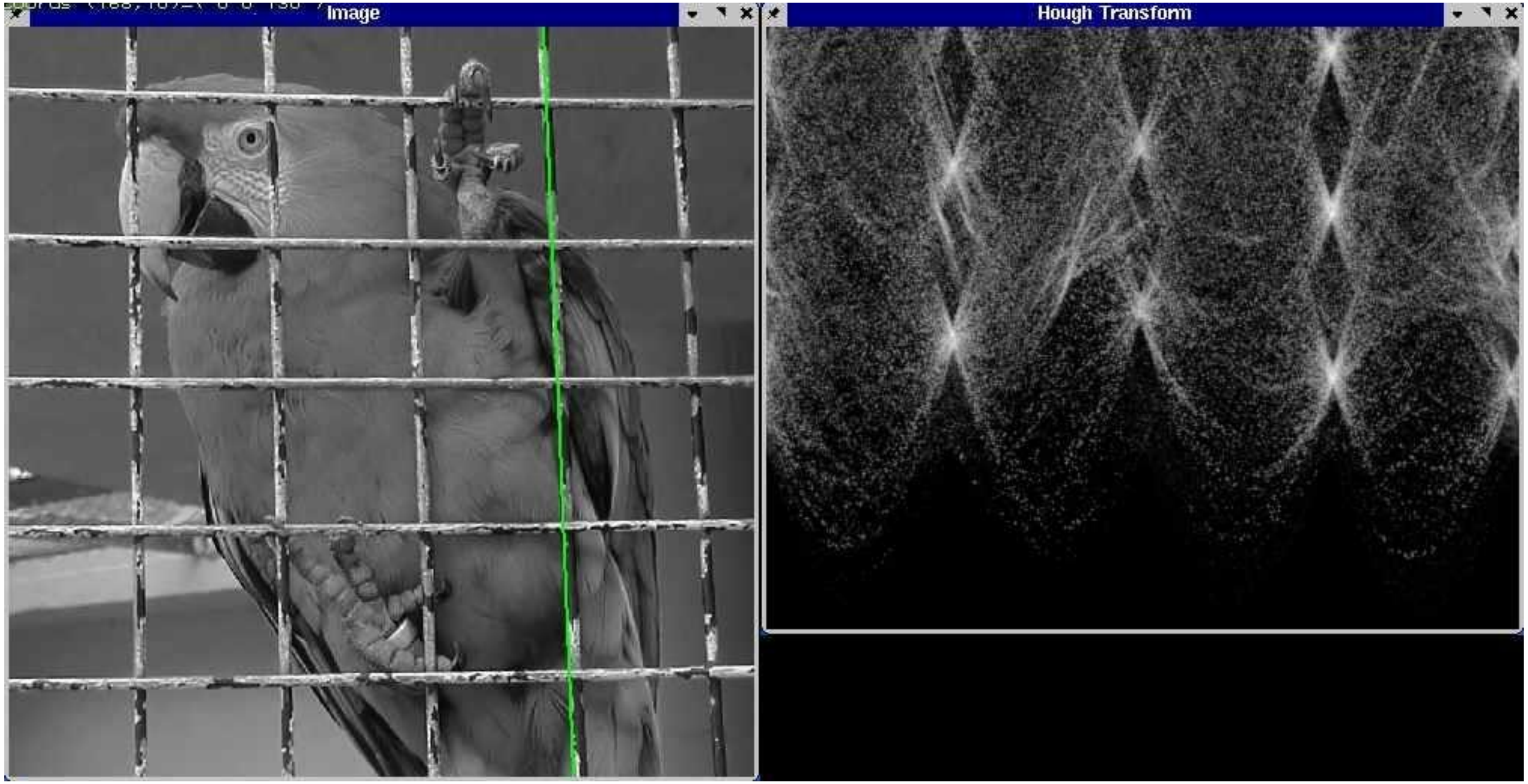


Several lines



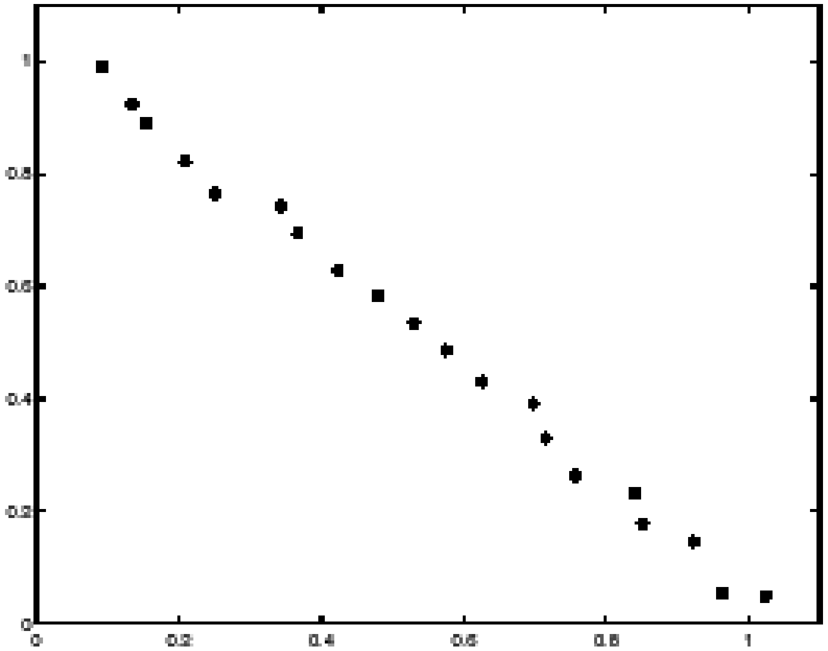


A more complicated image

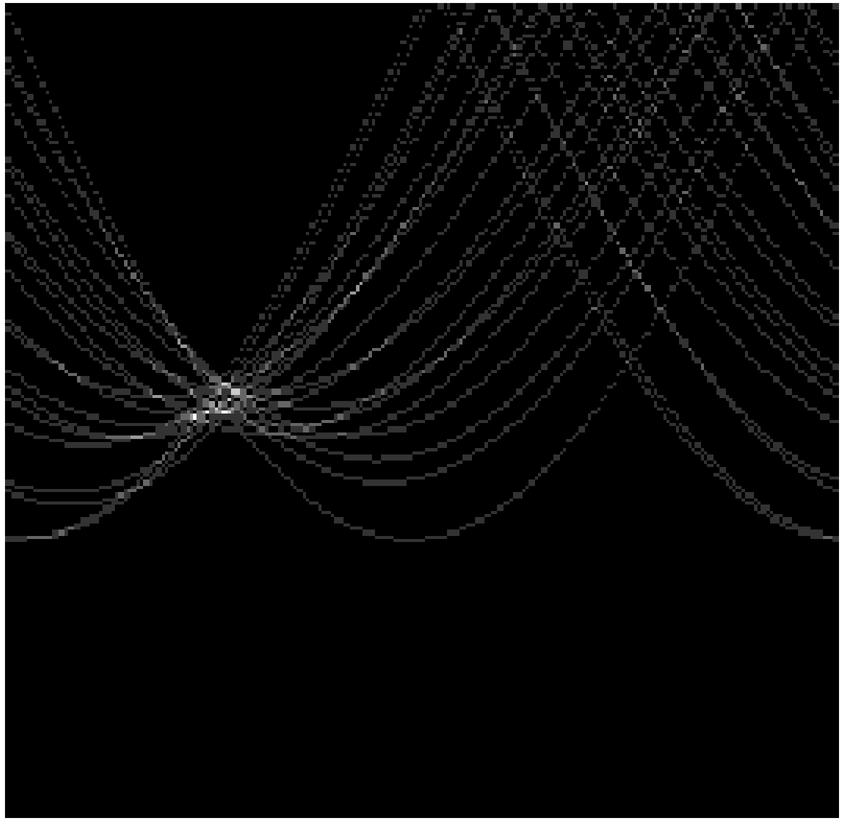


http://ostatic.com/files/images/ss_hough.jpg

Effect of noise



features



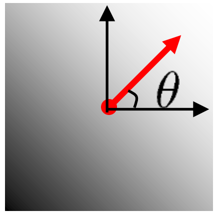
votes

- Peak gets fuzzy and hard to locate

Incorporating image gradients

- To deal with noise, Try to get rid of irrelevant features

  Take only edge points with significant gradient magnitude



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

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

- Recall: when we detect an edge point, we also know its gradient direction
- But this means that the line is uniquely determined!
- Modified Hough transform:
- For each edge point (x,y)

  θ = gradient orientation at (x,y)

  ρ = x cos θ + y sin θ

  H(θ, ρ) = H(θ, ρ) + 1

  end