HMI
HUMAN MACHINE INTERACTION LABORATORY

COMPUTER VISION

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Hough Transform

- The Hough transform is a technique which can be used to isolate features of a particular shape: line, circle, eclipse

- It uses a voting machenism in parameter space for detecting these shapes.

Parameter function

- Object in image can be defined by a function of parameter (parameter function):

$$f(x, y, a_1, \cdots, a_n) = 0$$

In which (x,y) is pixel position and $\{a_1, \cdots, a_n\}$ is a set of n parameters specifying the shape.

Hough transform

- Transform to parameter space:
  - Every pixel (x,y) in a 2D image is transformed into a surface of n-dimension space.

- Transform back to image spatial space:
  - Every point $(a_1, \cdots, a_n)$ in the n-dimension space is transformed to a shape in the 2D image.

Line detection

- Parameter function to be used:

  $y = ax + b$

  - It is a line in Image

  - But, it is only a point (a,b) in parameter space.

Line Detection

- A point $(x_0,y_0) \in I$ corresponds to the line $a = y_0/x_0 - b/x_0$ in the parameter space P.

- And, a point $(a_0,b_0) \in P$ corresponds to the line $y = a_0x+b_0$ in image space I.

Line detection

- Construct the line function of following image by hough transform:

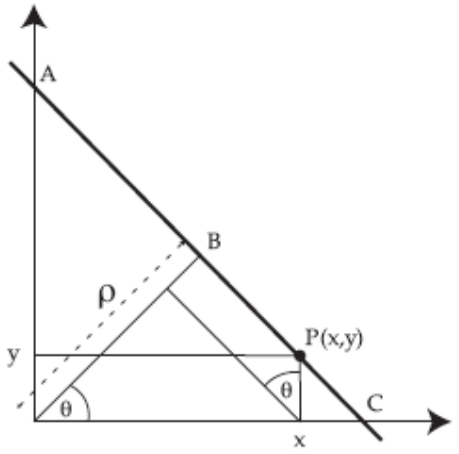
0	0	1	0
0	1	0	0
1	0	0	0
0	0	0	0

Line detection

- Another line function can be used:

$$f(x, y, \rho_0, \theta_0) = x\ cos\ \theta_0 + y\ sin\ \theta_0 - \rho_0 = 0$$

in which ρ_0 là is the distance between line and the origin, and θ_0 là is the angle between the distance vector and Ox axis.



Line detection algorithm

- Create a 2D matrix H(ρ, θ) for the parameter space. Initialize the matrix with 0 values.
- Find gradient G(x,y) of I(x,y)
- For pixel (x,y) satisfies |G(x,y)| > T_s, increase H(ρ, θ) such that:

$$\forall \theta \quad | \quad \rho = x\ cos\ \theta + y\ sin\ \theta$$

$$H(\rho, \theta) = H(\rho, \theta) + 1;$$

Line detection algorithm

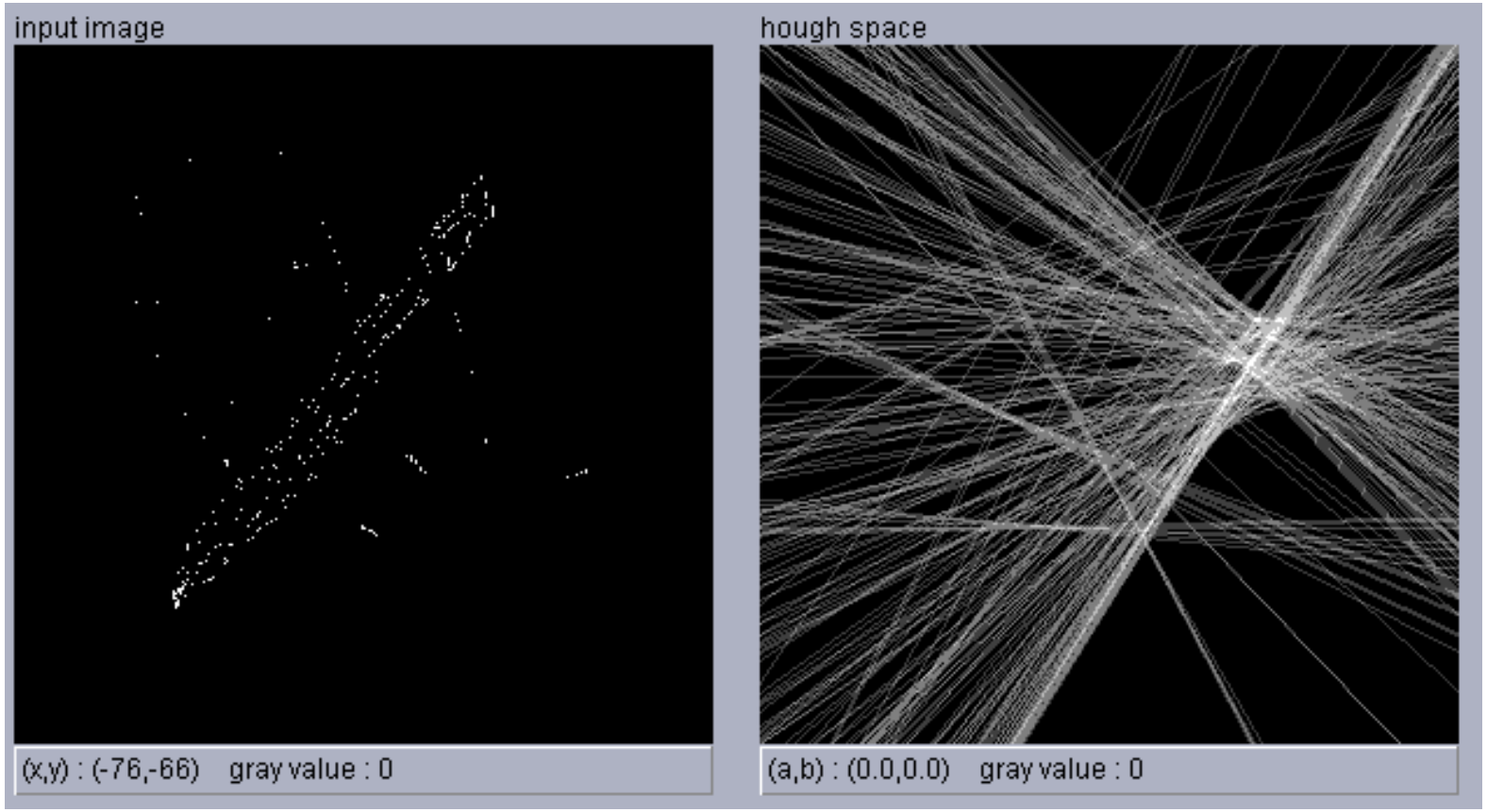
- This algorithm can be improved by using the gradient angle ∠G(x,y)

$$\forall \theta \quad | \quad \angle G(x,y) - \Delta\theta \leq \theta \leq \angle G(x,y) + \Delta\theta$$

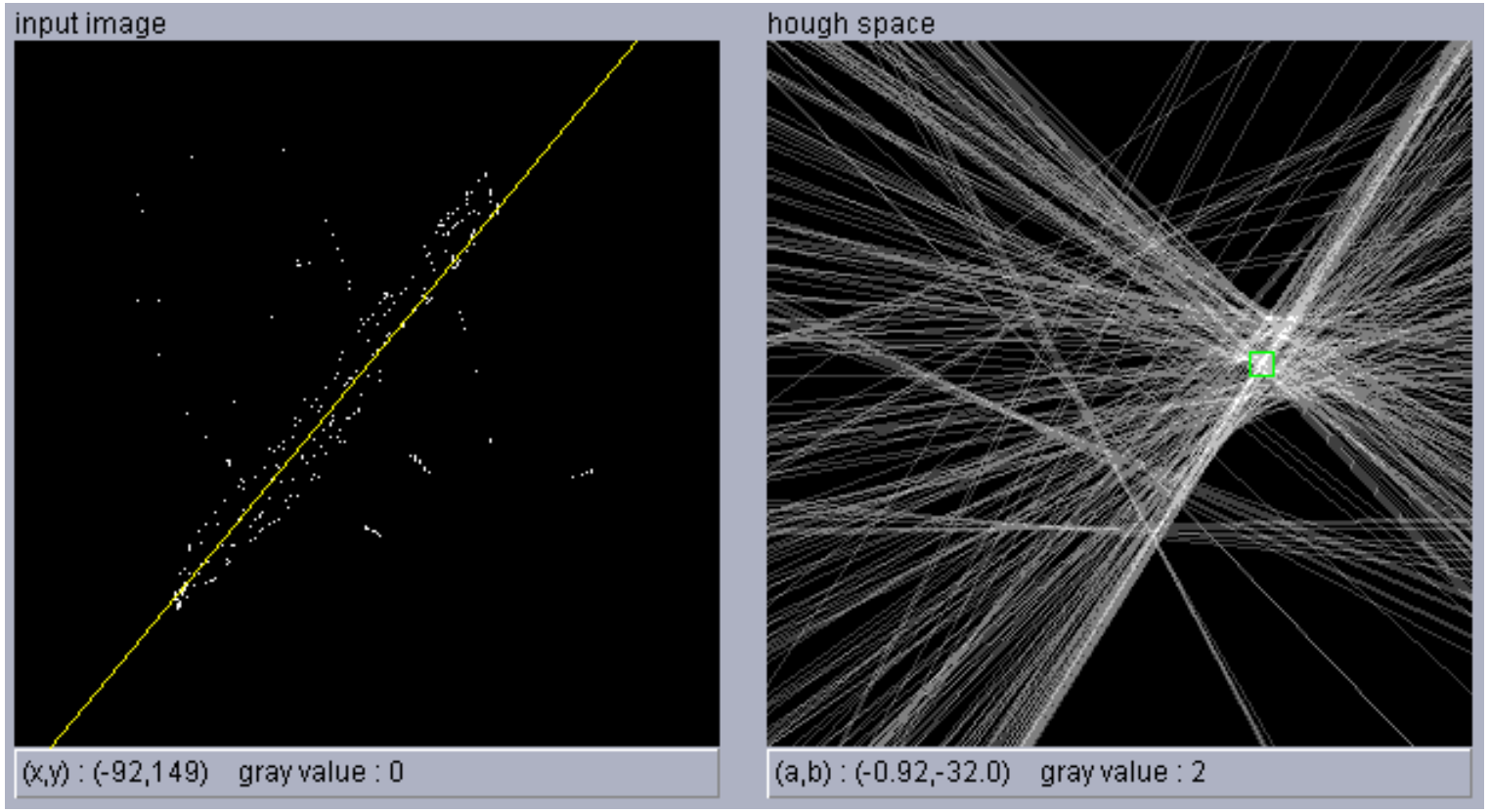
$$\rho = x\ cos\ \theta + y\ sin\ \theta$$

$$H(\rho,\theta) = H(\rho,\theta) + 1;$$

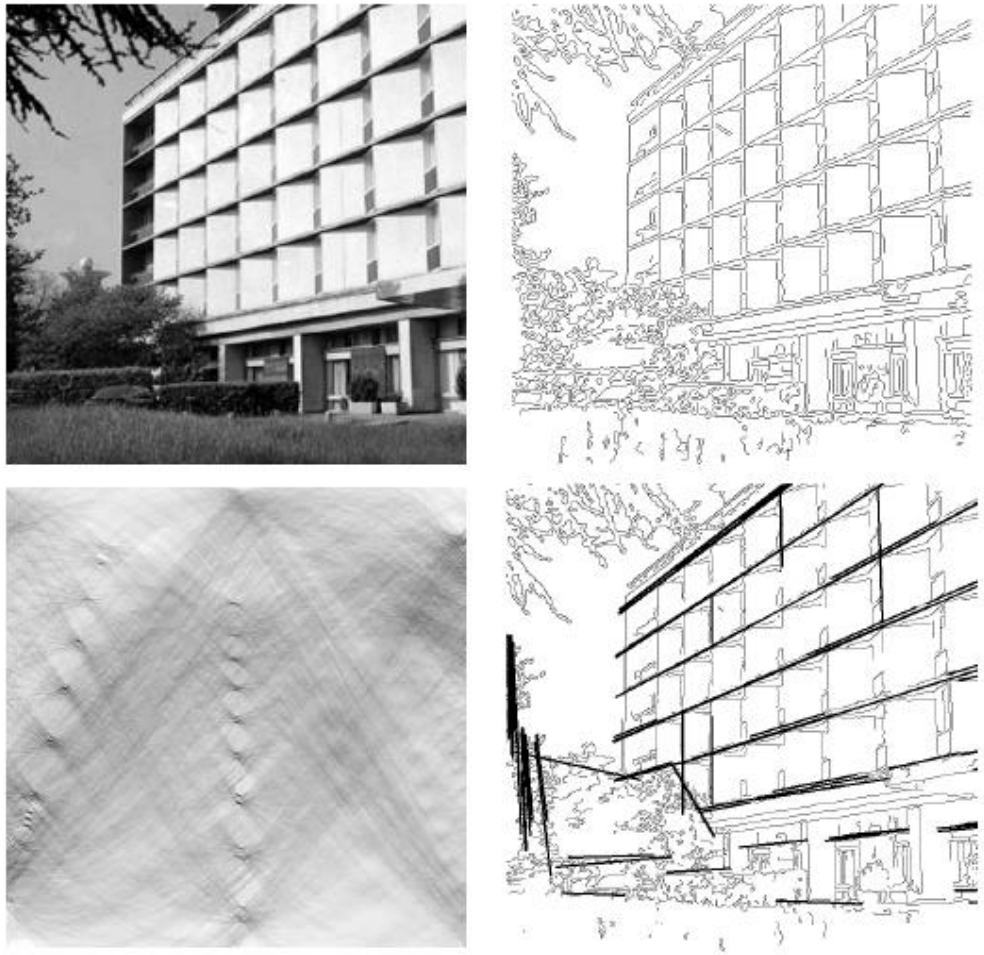
Line detection



Line detection



Line detection



Circle detection

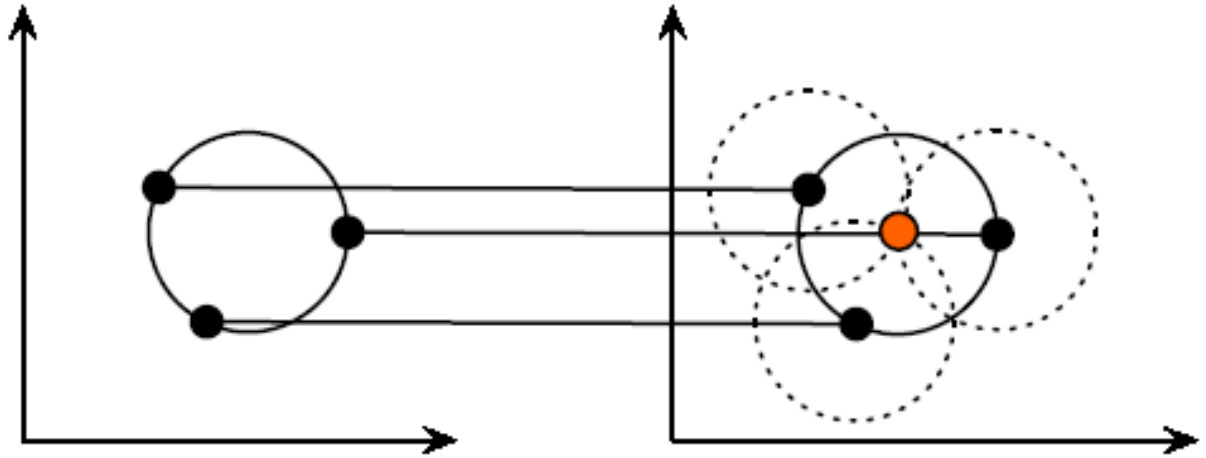
- A circle with radius R at position (a,b) can be specified by a function:

$$x = a + R\cos(\theta)$$
$$y = b + R\sin(\theta)$$

  - θ scans from 0 to 360 degree
  - A pixel belonging to a circle corresponds to a set of (a,b,θ)

Circle detection

- With a fixed radius R, (a,b) has a circle orbit centered at (x,y) and radius R.
- The coordinate of the real cirle can be found by a cummulative table



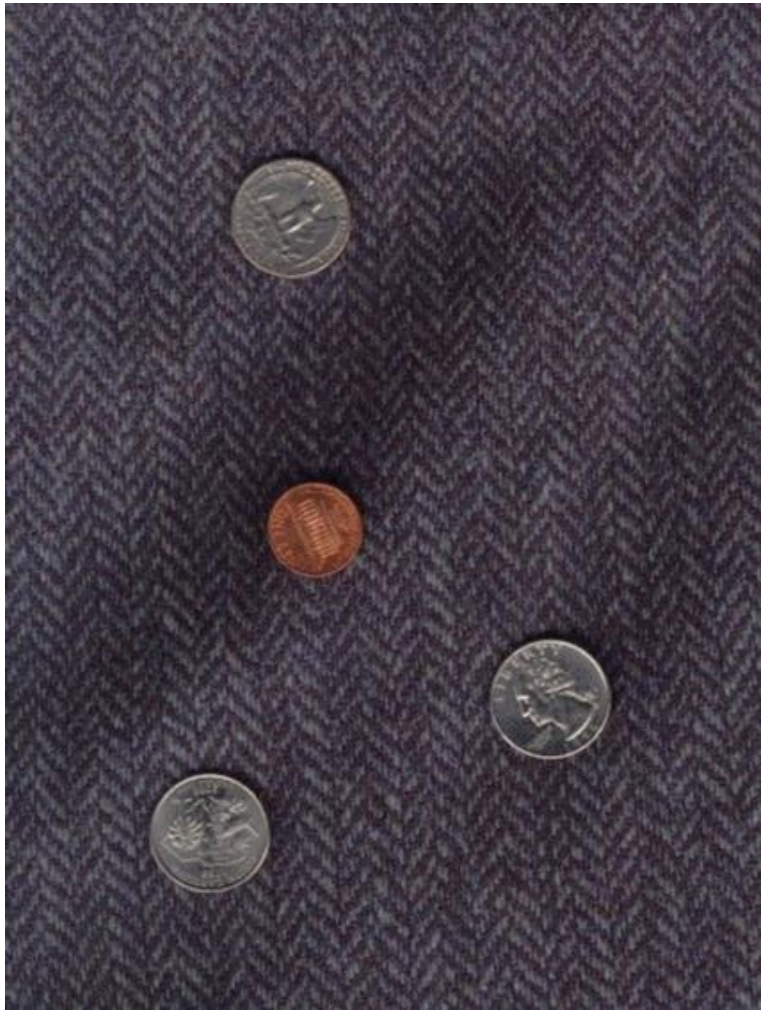
Circle Detection

- For pixel (x,y) satisfies $|G(x,y)| > T_s$, increase the cummulative table in in parameter space such that:

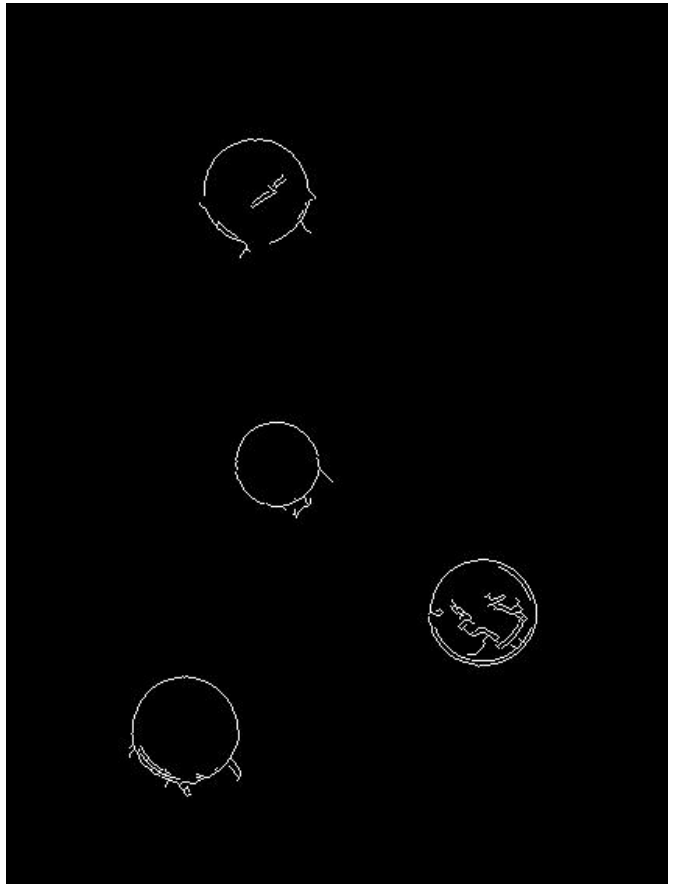
$$\forall R, \quad \begin{cases} a = x \pm R\cos\angle G \\ b = y \pm R\sin\angle G \end{cases}$$

$$H(a,b,R) = H(a,b,R) + 1$$

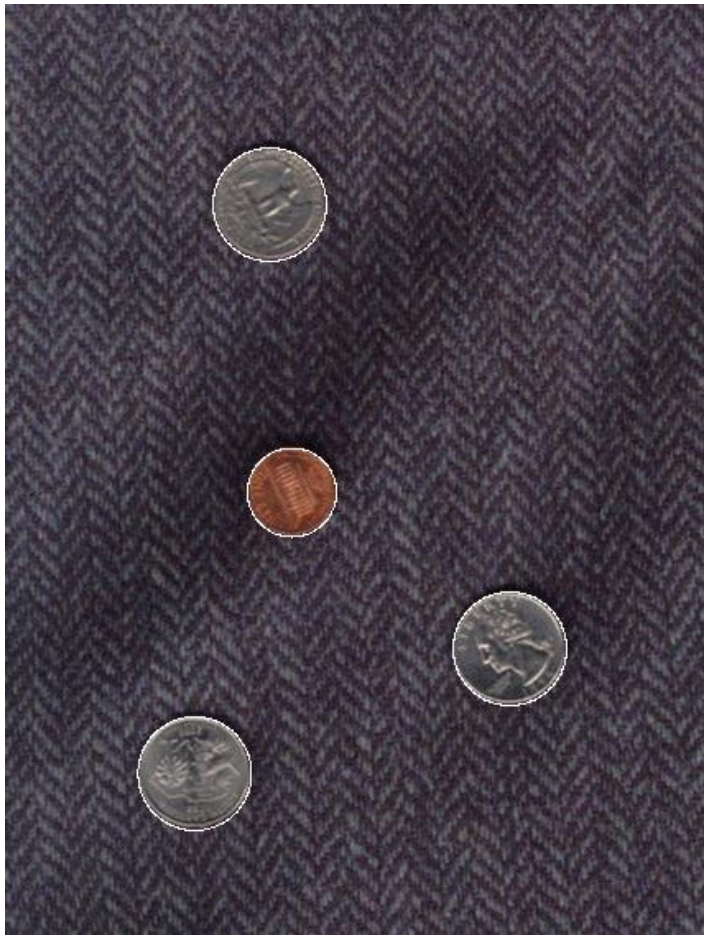
Circle Detection



Circle Detection



Circle Detection



Summary

- Hough transform
- It can be used to detect some image features having a paticular shape properties: line, circle, …