CANNY EDGE DETECTOR

Canny (Characteristics)

- Good Detection : Robustness to noise
  - The optimum detector must minimize the probability of false positive as well as false negative
- Good Localization:
  - The edge must be as close as possible to the true edges
- Strong Response Constraint:
  - Not too many or too few responses : The detector must return one point only for each point

Canny (Steps)

- Smoothing with Gaussian Filter
- Compute Derivative of filter image
- Find magnitude & orientation of gradient
- Apply Non Maxima Suppression
- Apply Hysteresis Threshold

Canny (Steps – Gaussian filter)

- Smoothing with Gaussian filter on Image I(r,c)

$$\textit{Smoothing Gaussian Filter} \quad G(r,c)=\frac{1}{2\pi\sigma^2}e^{-\frac{r^2+c^2}{2\sigma^2}}$$

$$\textit{Smoothened Image } SM(r,c)=I(r,c)*G(r,c)$$

$$\frac{1}{16}\begin{bmatrix}1&2&1\\2&4&2\\1&2&1\end{bmatrix} \qquad \frac{1}{273}\begin{bmatrix}1&4&7&4&1\\4&16&26&16&4\\7&26&41&26&7\\4&16&26&16&4\\1&4&7&4&1\end{bmatrix}$$

$$\frac{1}{1003}\begin{bmatrix}0&0&1&2&1&0&0\\0&3&13&22&13&3&0\\1&13&59&97&59&13&1\\2&22&97&150&87&22&2\\1&13&59&97&59&13&1\\0&3&13&22&13&3&0\\0&0&1&2&1&0&0\end{bmatrix}$$

Canny (Steps - Derivative)

2	2	2	2	2	2	2
1	2	2	2	2	2	2
1	1	2	2	2	2	2
1	1	1	2	2	2	2
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1

I

	-3	-1	0	0	0	
	-3	-1	-1	0	0	
	-1	-3	-4	-4	-4	
	0	-1	-3	-4	-4	
	0	0	0	0	0	

$I \circ S_H$

	3	1	0	0	0	
	3	3	1	0	0	
	1	3	2	0	0	
	0	1	1	0	0	
	0	0	0	0	0	

$I \circ S_V$

-1	-2	-1
0	0	0
1	2	1

S_H

-1	0	1
-2	0	2
-1	0	1

S_V

Canny (Steps - Magnitude and Orientation)

	-3	-1	0	0	0	
	-3	-1	-1	0	0	
	-1	-3	-4	-4	-4	
	0	-1	-3	-4	-4	
	0	0	0	0	0	

$I \circ S_H$

	3	1	0	0	0	
	3	3	1	0	0	
	1	3	2	0	0	
	0	1	1	0	0	
	0	0	0	0	0	

$I \circ S_V$

$$\sqrt{I \circ S_H{}^2 + I \circ S_V{}^2}$$

	-45°	-45°	D	D	D	
	-45°	-45°	-45°	D	D	
	-45°	-45°	-27°	0°	0°	
	D	-45°	-18°	0°	0°	
	D	D	D	D	D	

$$tan^{-1}\left[\frac{I \circ S_V}{I \circ S_H}\right]$$

	4.2	1.4	0	0	0	
	4.2	3.2	1.4	0	0	
	1.4	4.2	4.5	4	4	
	0	1.4	3.2	4	4	
	0	0	0	0	0	

Canny (Steps - Apply Non Maxima Suppression)

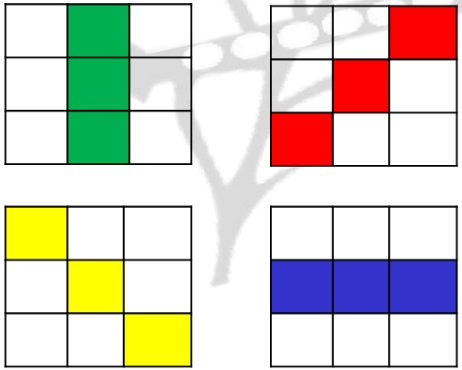
$67.5° < \theta \leq 90°$

$22.5° < \theta \leq 67.5°$

$-22.5° < \theta \leq 22.5°$

$-67.5° < \theta \leq -22.5°$

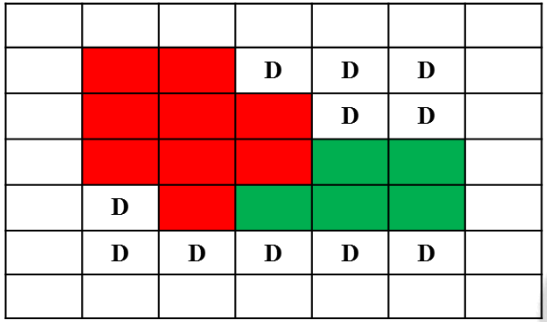
$-90° < \theta \leq -67.5°$



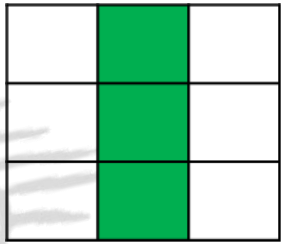
	-45°	-45°	D	D	D	
	-45°	-45°	-45°	D	D	
	-45°	-45°	-27°	0°	0°	
	D	-45°	-18°	0°	0°	
	D	D	D	D	D	

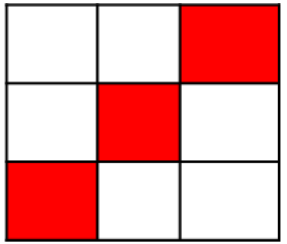
			D	D	D	
				D	D	
	D					
	D	D	D	D	D	

Canny (Steps - Apply Non Maxima Suppression)



Colour Coded Orientation





Exploring Pixels for NonMaxima Suppression

	4.2	1.4	0	0	0	
	4.2	3.2	1.4	0	0	
	1.4	4.2	4.5	4	4	
	0	1.4	3.2	4	4	
	0	0	0	0	0	

Gradient Magnitude

	4.3	1.4	0	0	0	
	4.1	3.3	1.5	0	0	
	1.3	4.3	4.4	4.1	4.0	
	0	1.5	3.3	4.0	3.9	
	0	0	0	0	0	

Additive Noise: Dithering

	4.3	0	0	0	0	
	4.1	3.3	0	0	0	
	0	4.3	4.4	4.1	4.0	
	0	0	0	0	0	
	0	0	0	0	0	

Gradient Magnitude after NonMaxima Suppression

Canny (Steps – Apply Hysteresis Thresholding)

40	50	60				
	60		80	70	60	
10			55		90	
		80			100	70
	40					70
80			40			60
60		20		40		50

0.4	0.5	0.6				
	0.6		0.8	0.7	0.6	
0.1			0.5		0.9	
		0.8			1.0	0.7
	0.4					0.7
0.8			0.4			0.6
0.6		0.2		0.4		0.5

Strong Weak No Edges

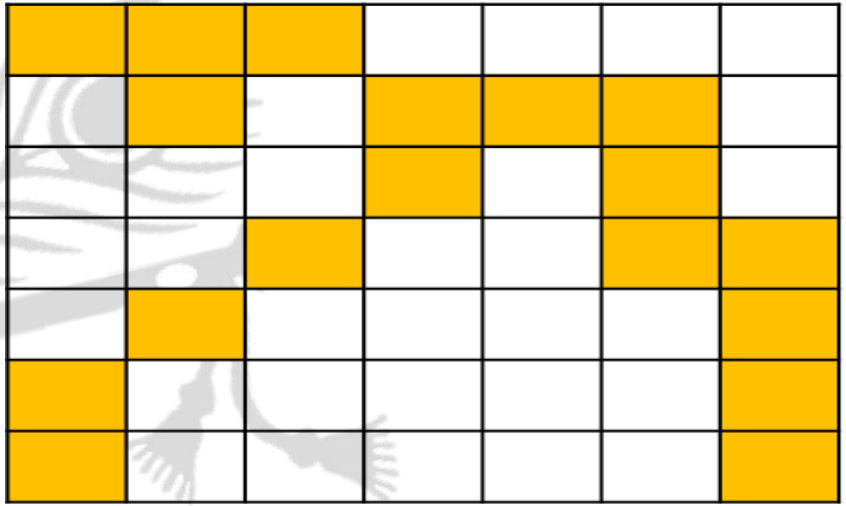
0.4	0.5	0.6				
	0.6		0.8	0.7	0.6	
0.1			0.5		0.9	
		0.8			1.0	0.7
	0.4					0.7
0.8			0.4			0.6
0.6		0.2		0.4		0.5

0.4	0.5	0.6				
	0.6		0.8	0.7	0.6	
			0.5		0.9	
		0.8			1.0	0.7
	0.4					0.7
0.8			0.4			0.6
0.6				0.4		0.5

0.4	0.5	0.6				
	0.6		0.8	0.7	0.6	
			0.5		0.9	
		0.8			1.0	0.7
	0.4					0.7
0.8			0.4			0.6
0.6				0.4		0.5

Canny (Steps – Apply Hysteresis Thresholding)

40	50	60				
	60		80	70	60	
10			55		90	
		80			100	70
	40					70
80			40			60
60		20		40		50



Canny

- Eg:
  - Compute derivative

2	2	2	2	2	2	2
1	2	2	2	2	2	2
1	1	1	2	2	2	2
1	1	1	1	2	2	2
1	1	1	1	1	1	2
1	1	1	1	1	1	1
1	1	1	1	1	1	1

I

Canny

- Eg:
  - Compute magnitude and orientation

	-4	-3	-1	0	0	
	-3	-4	-3	-1	0	
	0	-1	-3	-4	-3	
	0	0	-1	-3	-4	
	0	0	0	0	-1	

	2	1	1	0	0	
	1	2	3	1	0	
	0	1	3	2	1	
	0	0	1	1	2	
	0	0	0	0	1	

Canny

- Eg:
  - Apply Non-maxima suppression

	4.5	3.2	1.4	0	0	
	3.2	4.5	4.2	1.4	0	
	0	1.4	4.2	4.5	3.2	
	0	0	1.4	3.2	4.5	
	0	0	0	0	1.4	

	-27	-18	-45	D	D	
	-18	-27	-45	-45	D	
	D	-45	-45	-27	-18	
	D	D	-45	-18	-27	
	D	D	D	D	-45	

Canny

- Eg:
  - Apply Hysteresis Threshold

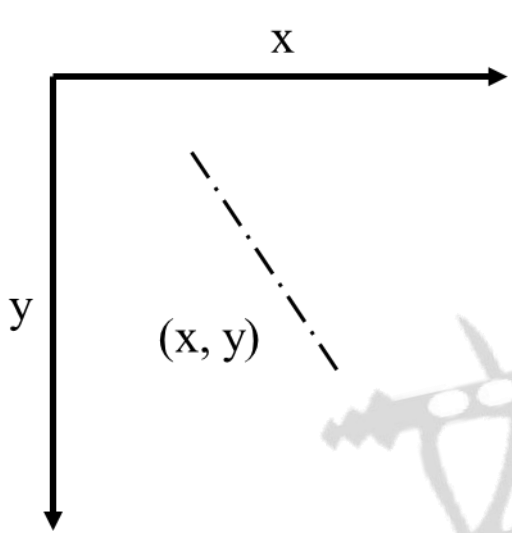
	-27	-18	-45	D	D	
	-18	-27	-45	-45	D	
	D	-45	-45	-27	-18	
	D	D	-45	-18	-27	
	D	D	D	D	-45	

	4.5	0	0	0	0	
	0	4.5	4.2	0	0	
	0	0	4.2	4.5	0	
	0	0	0	0	4.5	
	0	0	0	0	1.4	

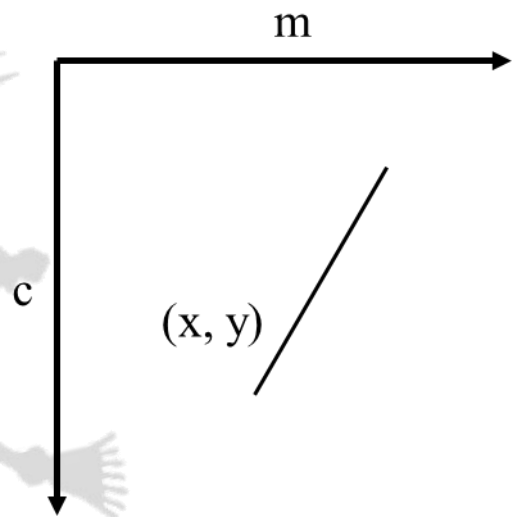
HOUGH TRANSFORM

Hough Transform

- Image and Parameter space



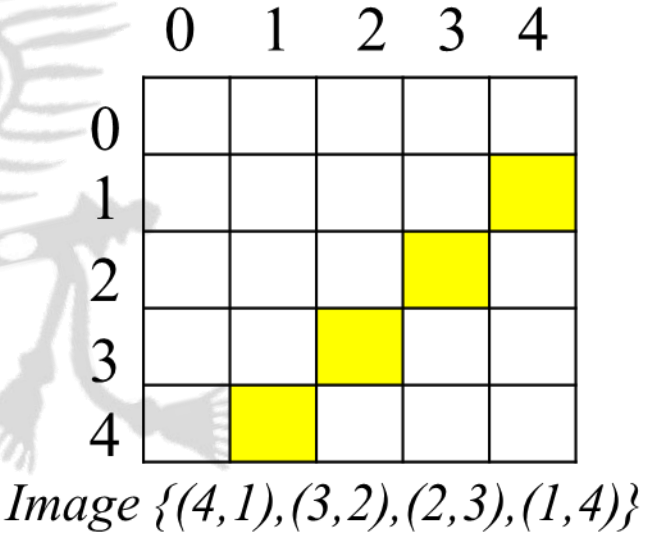
y = mx+c
variable: x, y
parameter: m, c



c = -mx+y
variable: m, c
parameter: x, y

Hough Transform

- Eg:



Hough Transform

- Step 1:
  - Known
    - -1.2<=m<=-0.8
    - step_m = 0.1
    - m = -0.8, -0.9, -1.0, -1.1, -1.2
    - c = -mx+y

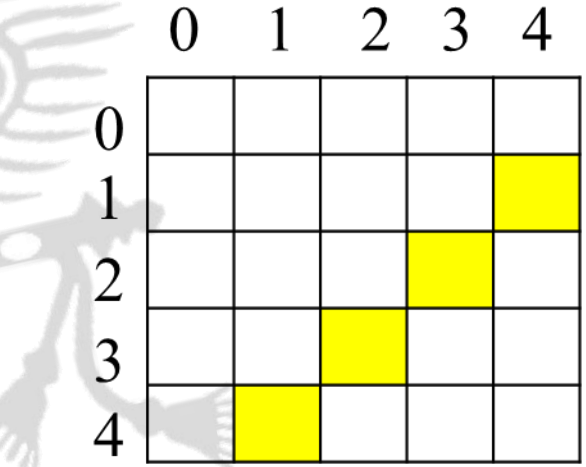


Image {(4,1),(3,2),(2,3),(1,4)}

Hough Transform

- Step 2:
  - Compute c

(x,y) = (4,1)
c = -4m+1

m	c
-0.8	4.2
-0.9	4.6
-1.0	5.0
-1.1	5.4
-1.2	5.8

(x,y) = (3,2)
c = -3m+2

m	c
-0.8	4.4
-0.9	4.7
-1.0	5.0
-1.1	5.3
-1.2	5.6

(x,y) = (2,3)
c = -2m+3

m	c
-0.8	4.6
-0.9	4.8
-1.0	5.0
-1.1	5.2
-1.2	5.4

(x,y) = (1,4)
c = -m+4

m	c
-0.8	4.8
-0.9	4.9
-1.0	5.0
-1.1	5.1
-1.2	5.2

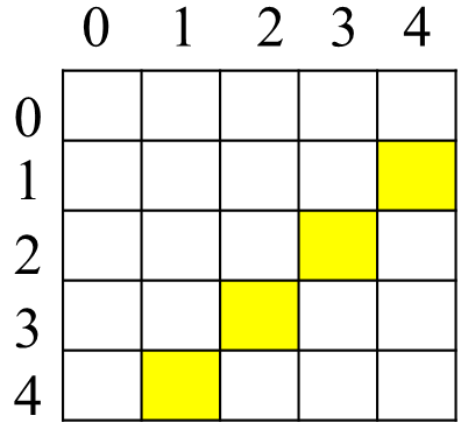


Image {(4,1),(3,2),(2,3),(1,4)}

Hough Transform

- Step 3:
  - Find min and max of c

- Range: 4.2 to 5.8
- Interval: 0.1

(x,y) = (4,1)
c = -4m+1

m	c
-0.8	4.2
-0.9	4.6
-1.0	5.0
-1.1	5.4
-1.2	5.8

(x,y) = (3,2)
c = -3m+2

m	c
-0.8	4.4
-0.9	4.7
-1.0	5.0
-1.1	5.3
-1.2	5.6

(x,y) = (2,3)
c = -2m+3

m	c
-0.8	4.6
-0.9	4.8
-1.0	5.0
-1.1	5.2
-1.2	5.4

(x,y) = (1,4)
c = -m+4

m	c
-0.8	4.8
-0.9	4.9
-1.0	5.0
-1.1	5.1
-1.2	5.2

Hough Transform

- Step 4:
  - Voting

(x,y) = (4,1)
c = -4m+1

m	c
-0.8	4.2
-0.9	4.6
-1.0	5.0
-1.1	5.4
-1.2	5.8

(x,y) = (3,2)
c = -3m+2

m	c
-0.8	4.4
-0.9	4.7
-1.0	5.0
-1.1	5.3
-1.2	5.6

(x,y) = (2,3)
c = -2m+3

m	c
-0.8	4.6
-0.9	4.8
-1.0	5.0
-1.1	5.2
-1.2	5.4

(x,y) = (1,4)
c = -m+4

m	c
-0.8	4.8
-0.9	4.9
-1.0	5.0
-1.1	5.1
-1.2	5.2

	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
-0.8	1		1		1		1										
-0.9					1	1	1	1									
-1.0									4								
-1.1										1	1	1	1				
-1.2											1		1		1		1

Hough Transform

- Step 5:
  - Find equation

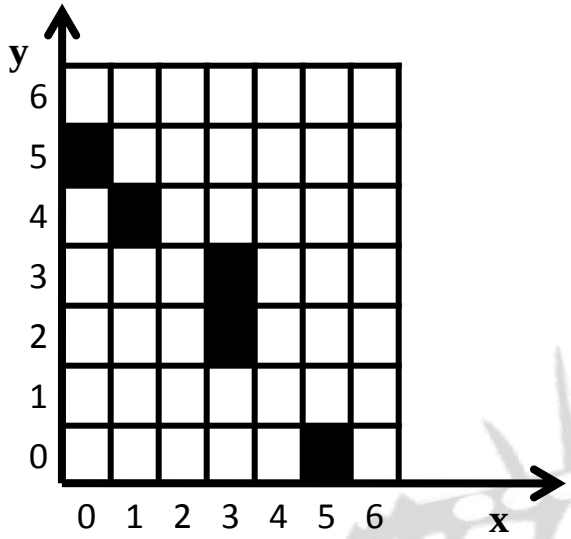
	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
-0.8	1		1		1		1										
-0.9					1	1	1	1									
-1.0									4								
-1.1										1	1	1	1				
-1.2											1		1		1		1

- m =-1.0
- c = 5.0
- y = -x+5

Hough Transform

- Problem
  - The slope of line parallel to y – axis is infinity, the computer can not handle it.
  - So, we follow another parameterization of a line
  - $p = x \cos \theta + y \sin \theta$

Hough Transform



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

Edgels: (0,5), (1,4), (3,2), (3,3), (5,0)

Hough Transform

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

$p = 0 \cos\theta + 5 \sin\theta$ (0,5)

$p = 1 \cos\theta + 4 \sin\theta$ (1,4)

$p = 3 \cos\theta + 2 \sin\theta$ (3,2)

$p = 3 \cos\theta + 3 \sin\theta$ (3,3)

$p = 5 \cos\theta + 0 \sin\theta$ (5,0)

Hough Transform

	0 cos θ + 5 sin θ	1 cos θ + 4 sin θ	3 cos θ + 2 sin θ	3 cos θ + 3 sin θ	5 cos θ + 0 sin θ
0	0	1	3	3	5
30	2.5	2.9	3.9	4	4.3
45	3.5	3.5	3.5	4.2	3.5
60	4.3	3.9	3.2	4	2.5
90	5	4	2	3	0

Hough Transform

- The equation for the edge will be:

$$3.5 = x \cos 45 + y \sin 45$$