Edge:
Canny

Dr. Tushar Sandhan

Introduction

- Directions with operators

Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

Introduction

- Directions with operators

Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+45 degrees

2	−1	−1
−1	2	−1
−1	−1	2

Introduction

- Directions with operators

Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+45 degrees

2	−1	−1
−1	2	−1
−1	−1	2

Vertical

−1	2	−1
−1	2	−1
−1	2	−1

Introduction

- Directions with operators

Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+45 degrees

2	−1	−1
−1	2	−1
−1	−1	2

Vertical

−1	2	−1
−1	2	−1
−1	2	−1

-45 degrees

−1	−1	2
−1	2	−1
2	−1	−1

Introduction

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Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+45 degrees

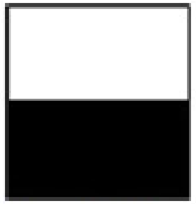
2	−1	−1
−1	2	−1
−1	−1	2

Vertical

−1	2	−1
−1	2	−1
−1	2	−1

-45 degrees

−1	−1	2
−1	2	−1
2	−1	−1



Introduction

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Horizontal

−1	−1	−1
2	2	2
−1	−1	−1

+45 degrees

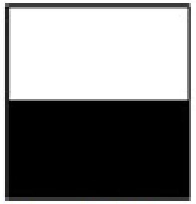
2	−1	−1
−1	2	−1
−1	−1	2

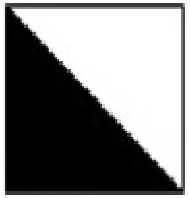
Vertical

−1	2	−1
−1	2	−1
−1	2	−1

-45 degrees

−1	−1	2
−1	2	−1
2	−1	−1





Introduction

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+45 degrees

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−1	2	−1
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−1	2	−1
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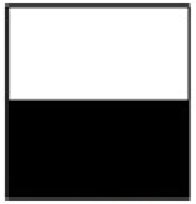
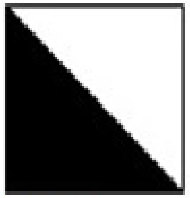
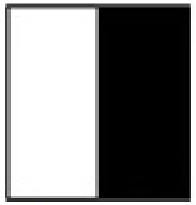
−1	−1	2
−1	2	−1
2	−1	−1







Introduction

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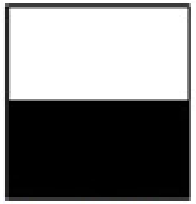
Horizontal

−1	−1	−1
2	2	2
−1	−1	−1



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2	−1	−1
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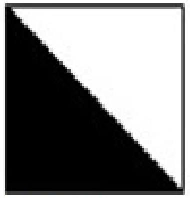
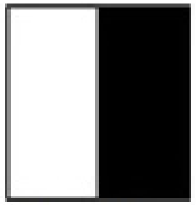
−1	−1	2



Vertical

−1	2	−1
−1	2	−1
−1	2	−1



-45 degrees

−1	−1	2
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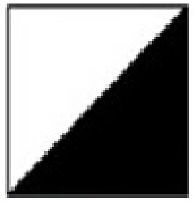

Kirsch operator (compass)

- Directions with Kirsch
  - direction is defined by the mask that produces max edge magnitude

$$h_{n,m} = \max_{z=1,...,8} \sum_{i=-1}^{1} \sum_{j=-1}^{1} g_{ij}^{(z)} \cdot f_{n+i,m+j}$$

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$\mathbf{g}^{(2)}$ 

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$\mathbf{g}^{(1)}$

$\mathbf{g}^{(2)}$

$\mathbf{g}^{(3)}$

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$h_{n,m}$

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$\mathbf{g}^{(1)}$

$\mathbf{g}^{(2)}$

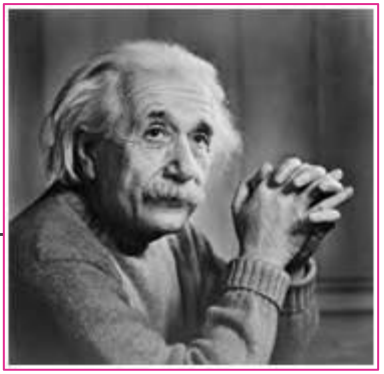
$\mathbf{g}^{(3)}$

$\mathbf{g}^{(4)}$

$h_{n,m}$

Ref: wikipedia

Kirsch operator (compass)



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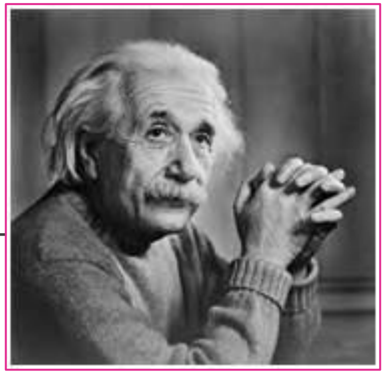

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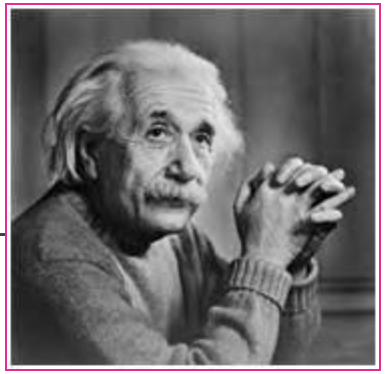
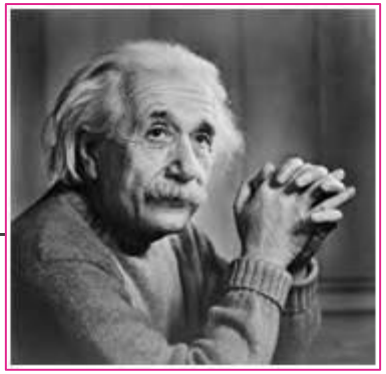


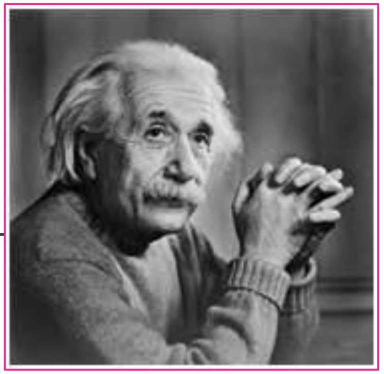
North

Kirsch operator (compass)



North

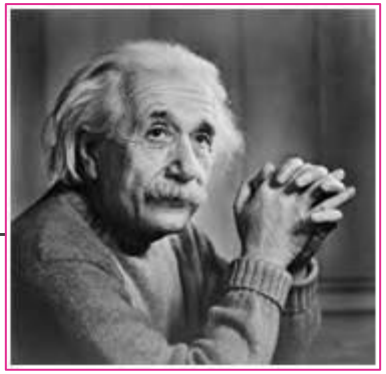
Kirsch operator (compass)



North

North West

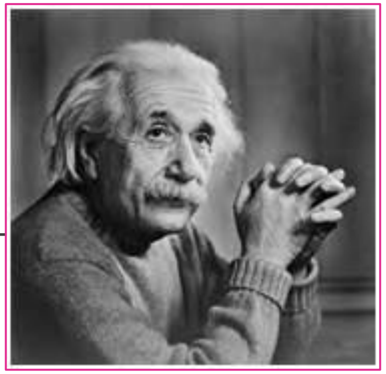
Kirsch operator (compass)



North

North West

Kirsch operator (compass)

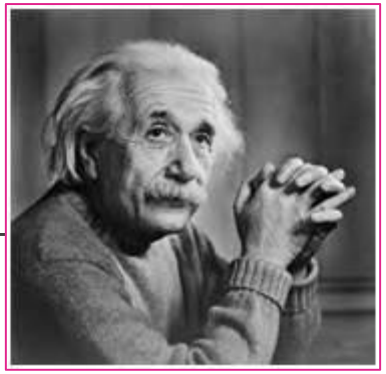


North

North West

West

Kirsch operator (compass)

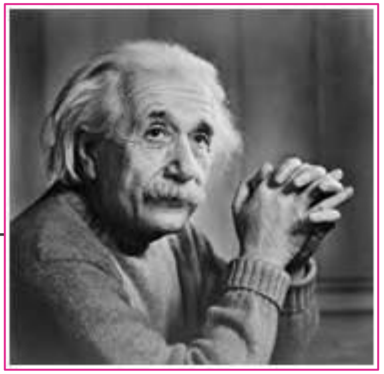


North

North West

West

Kirsch operator (compass)



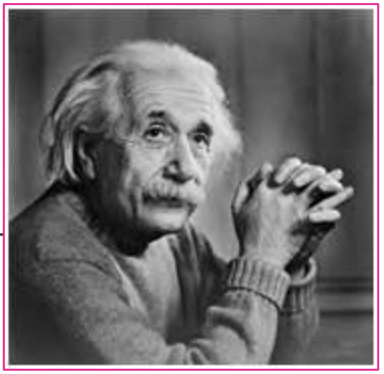
North

North West

West

South West

Kirsch operator (compass)



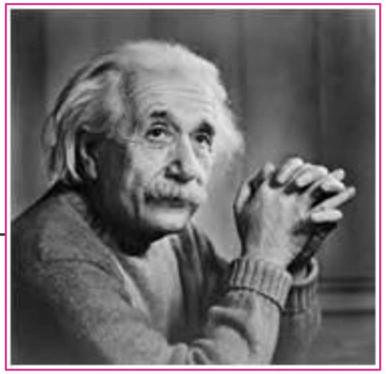
North

North West

West

South West

Kirsch operator (compass)



North

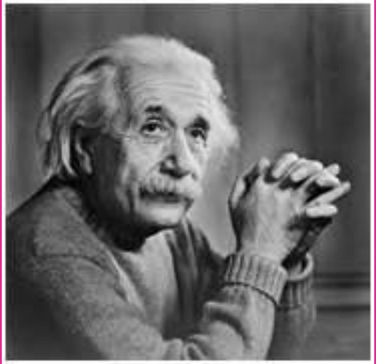
North West

West

South West

South

Kirsch operator (compass)



North

North West

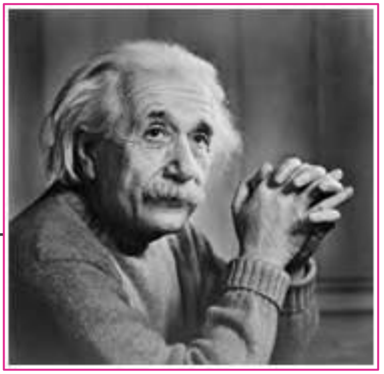
West

South West

South

South East

Kirsch operator (compass)



North

North West

West

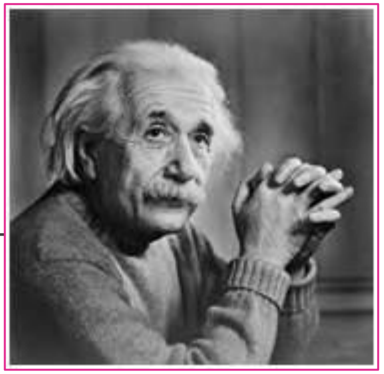
South West

South

South East

East

Kirsch operator (compass)



North

North West

West

South West

South

South East

East

North East

Introduction

- Single point thick edges

input

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input

Canny edges

Introduction

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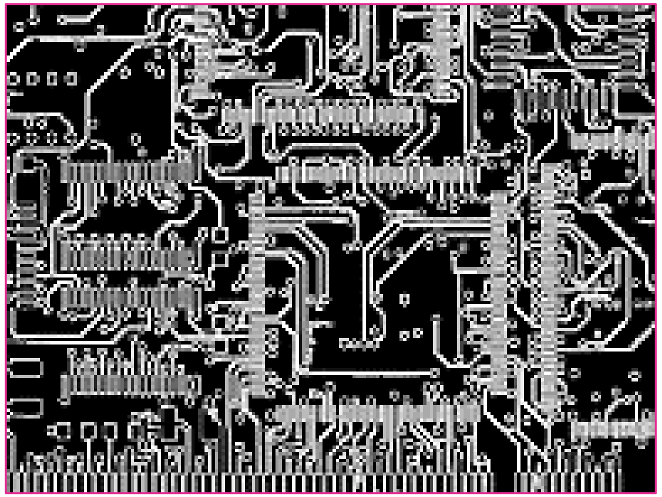
input

Canny edges



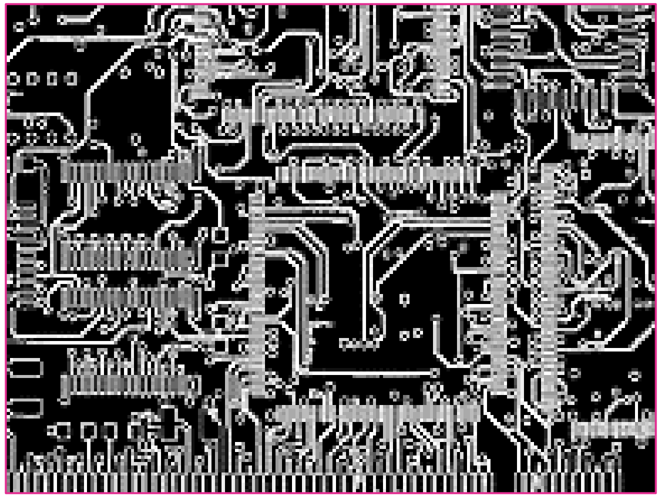
Introduction

- Single point thick edges

input

Canny edges

Canny PCB edges



Edge

- What would be important steps in edge det.

Edge

- What would be important steps in edge det.
    - Smooth derivatives

Edge

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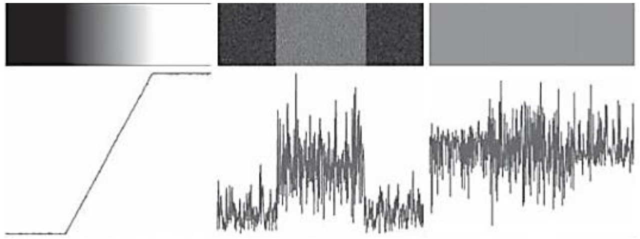
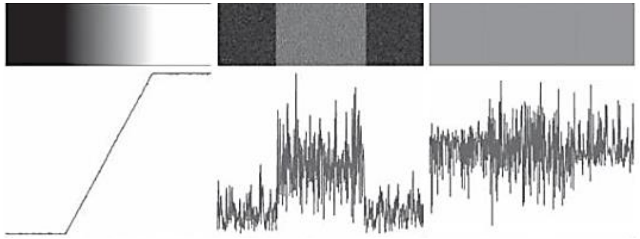


Edge

- What would be important steps in edge det.
  - Smooth derivatives
  - Thresholding



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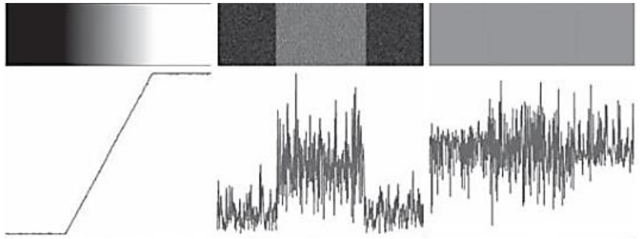

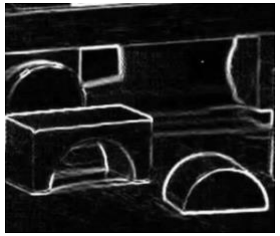

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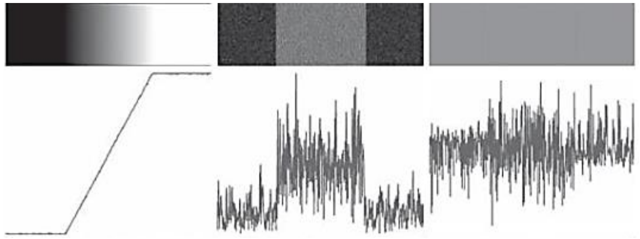
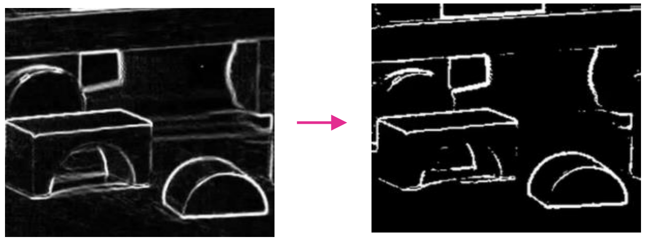
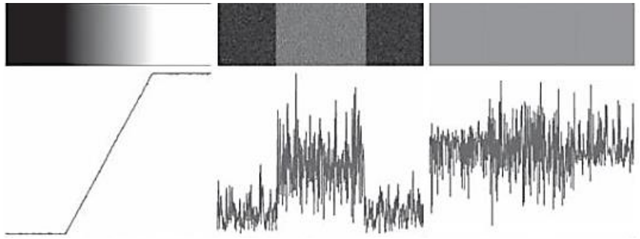
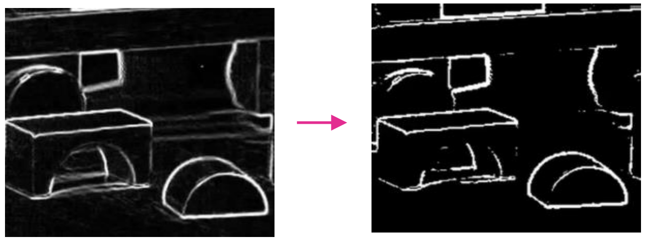




Edge

- What would be important steps in edge det.
  - Smooth derivatives
  - Thresholding
  - Thinning





Edge

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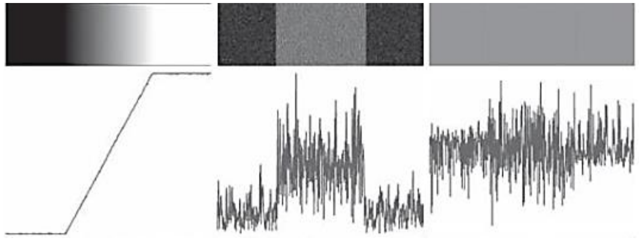
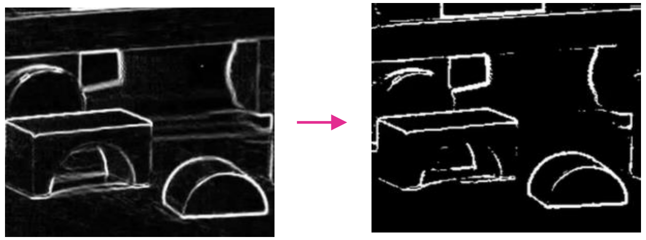
    - Smooth derivatives
    - Thresholding
    - Thinning
    - Linking





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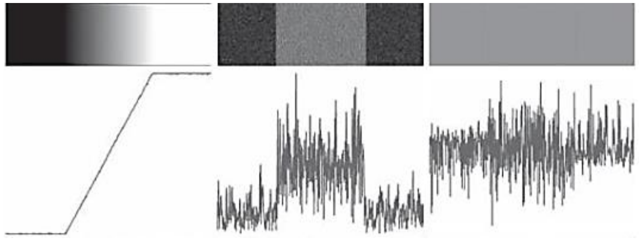

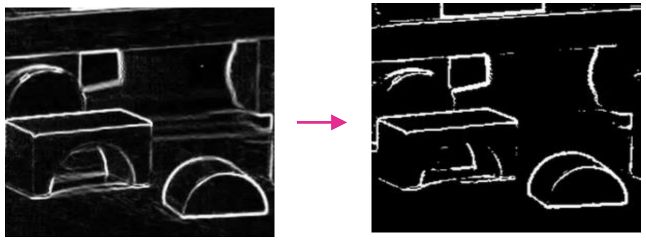

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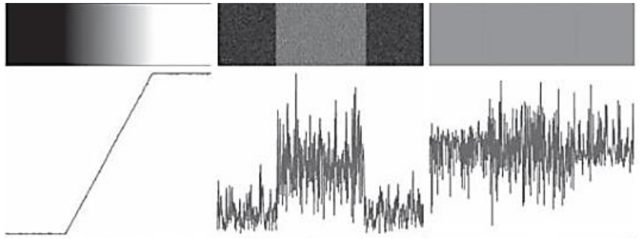

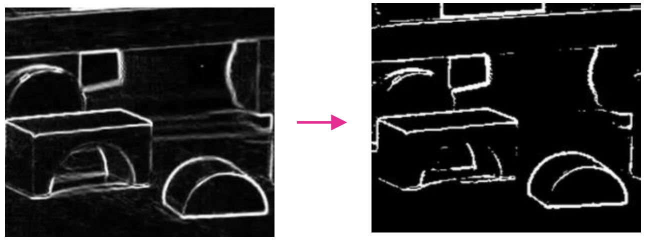

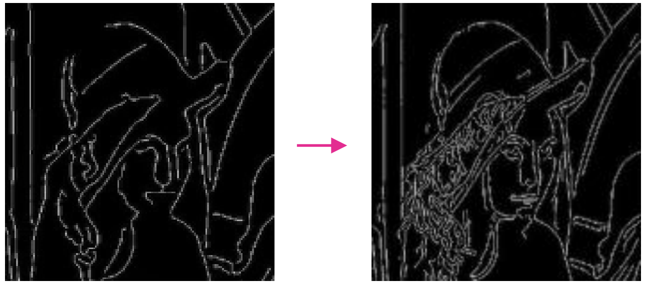

Canny edge detector

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  - single point edge response
    - 1 point for each true edge point

Canny edge detector

- Image derivatives
  - input image $f(x, y)$
  - smoothed $f_s(x, y)$
  - any operator can be used to get $g_x(x, y)$, $g_y(x, y)$

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Canny edge detector

- Thinning
  - $M_s(x, y)$ wide ridges around local maxima
  - ridges thinning is needed
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    - suppress where?

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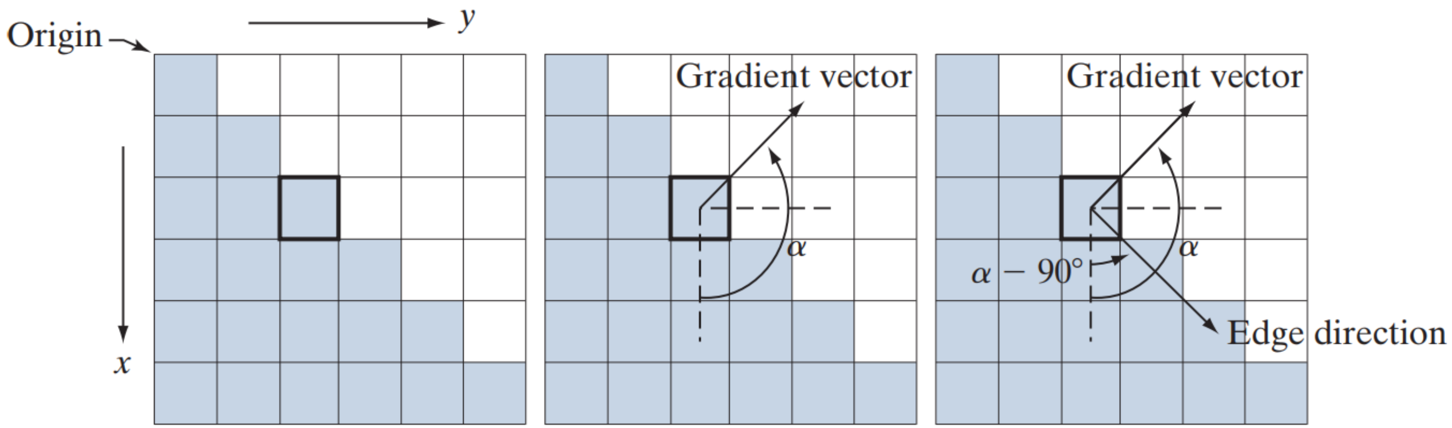

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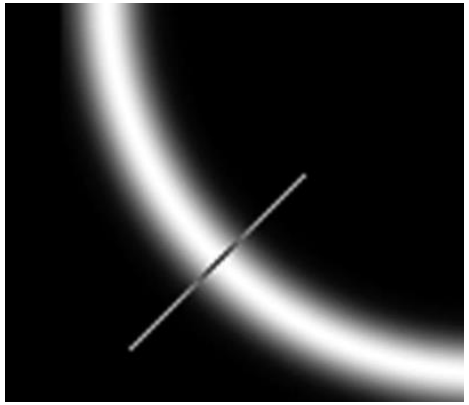

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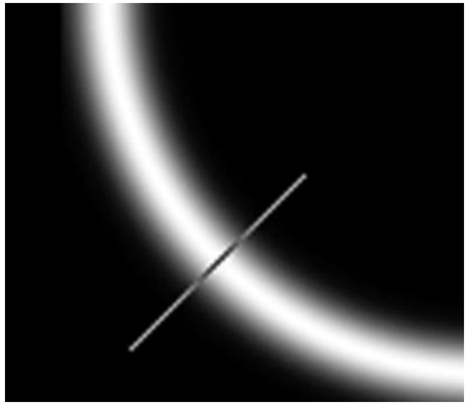

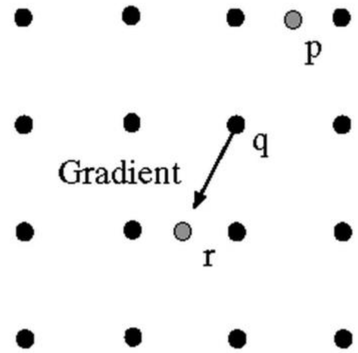

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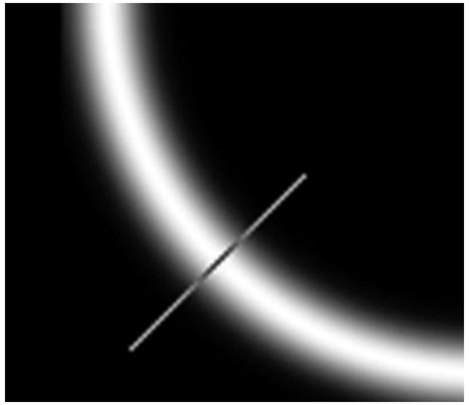

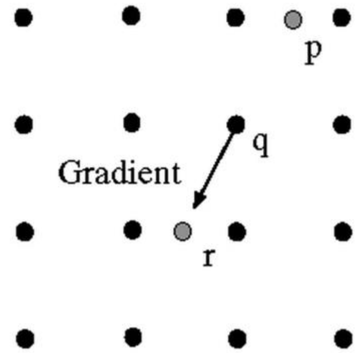

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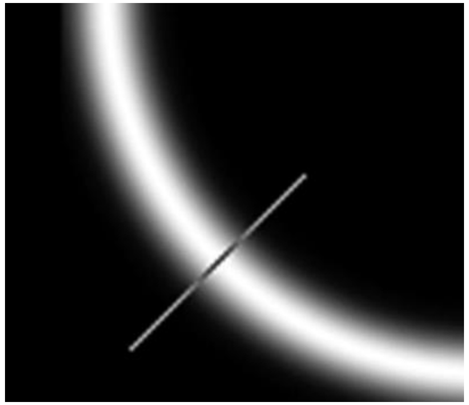

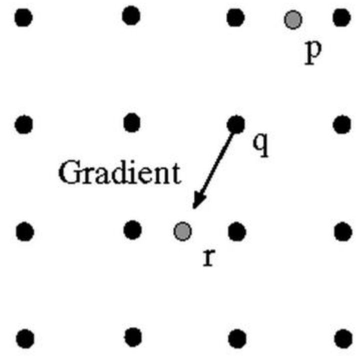

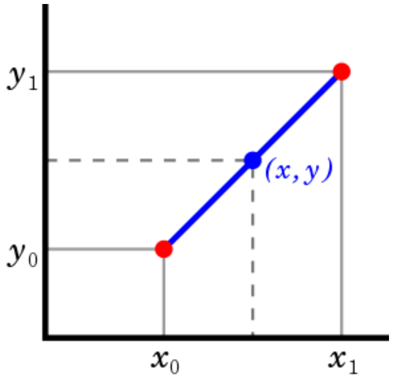

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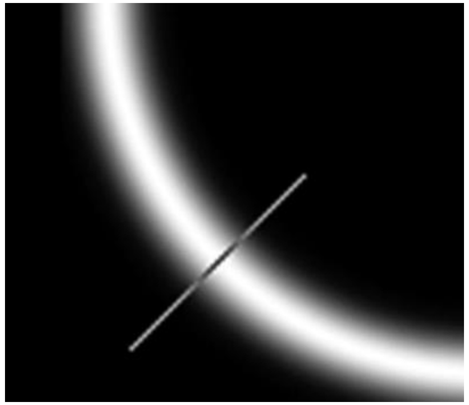
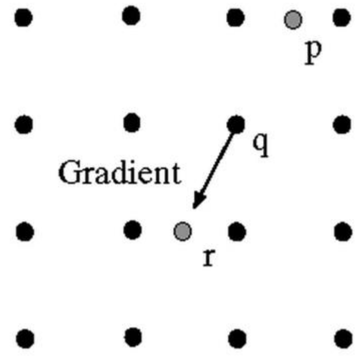
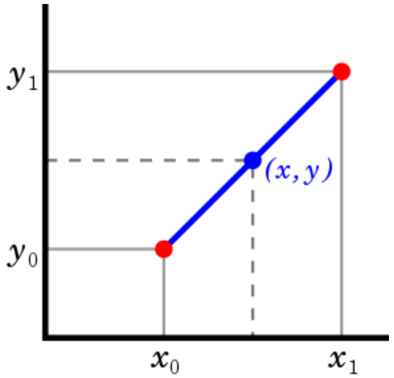




$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$$



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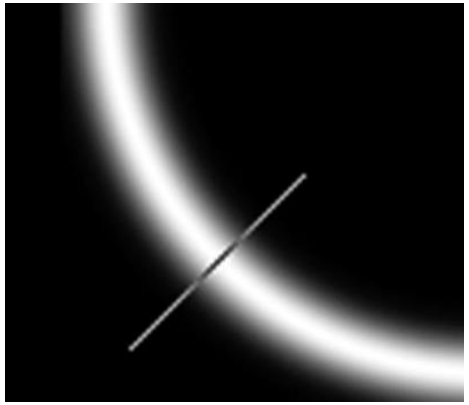

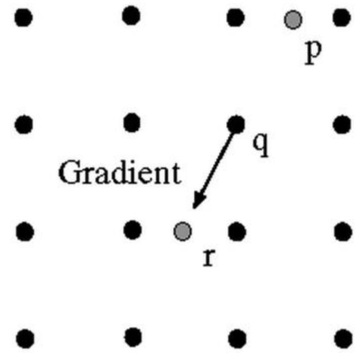

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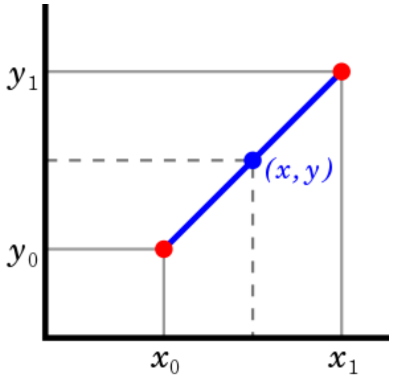

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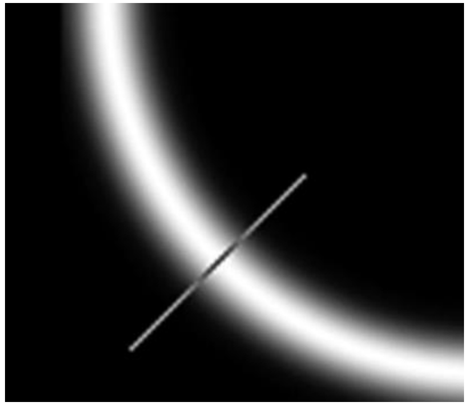

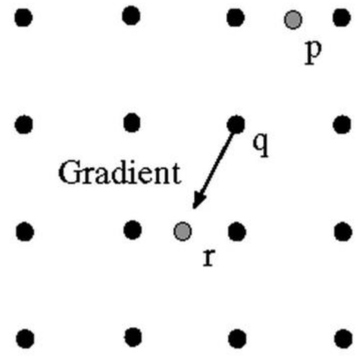

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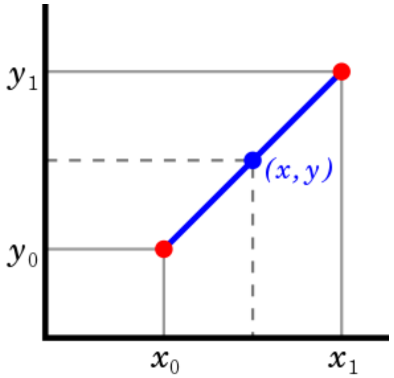

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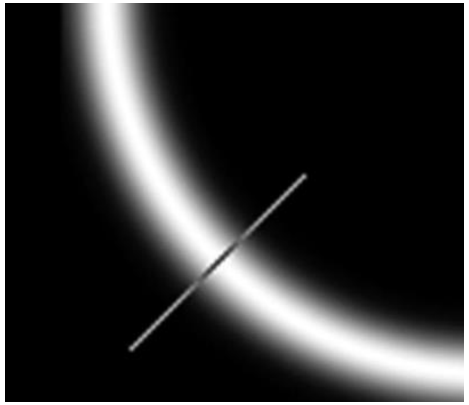

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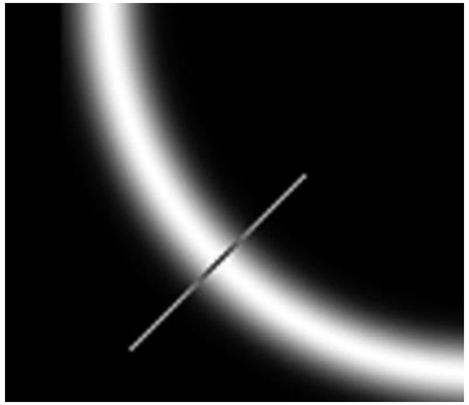

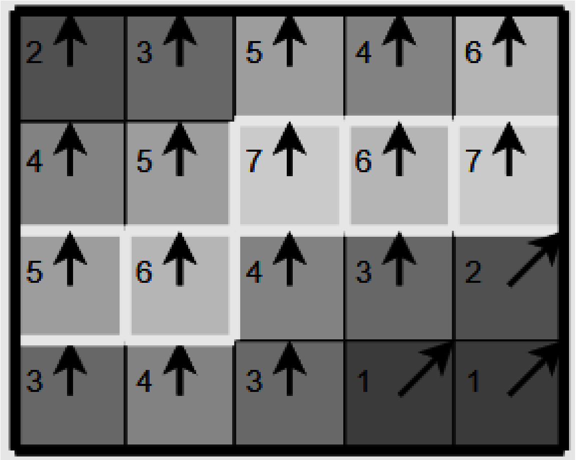

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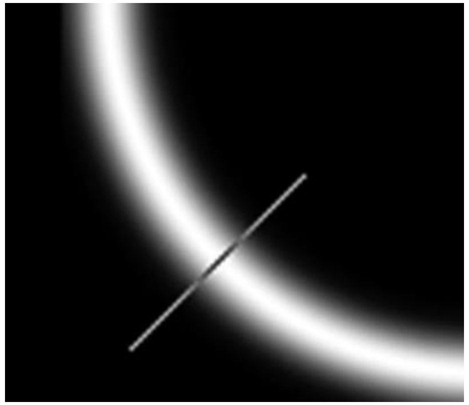

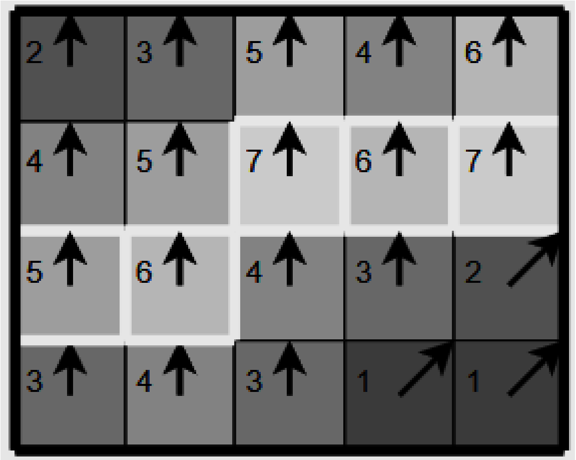

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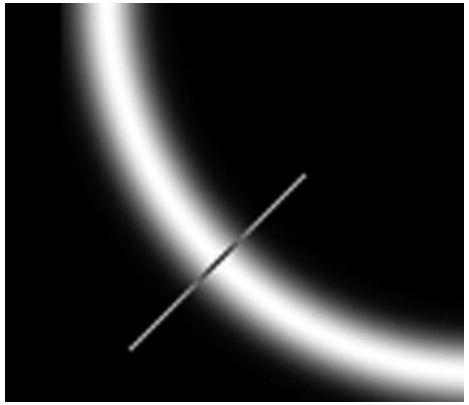

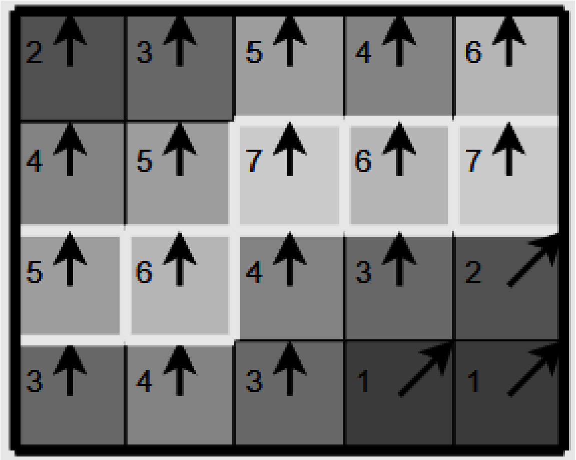

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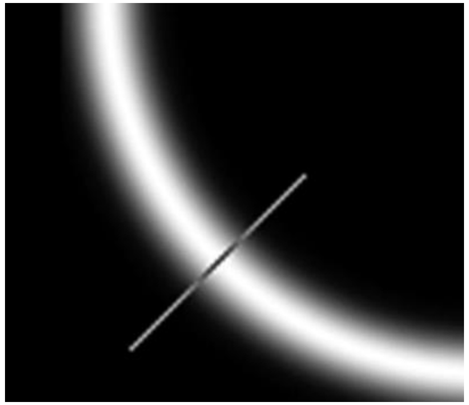

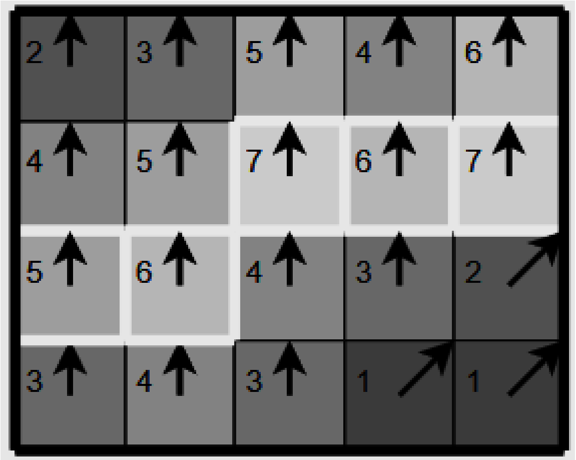

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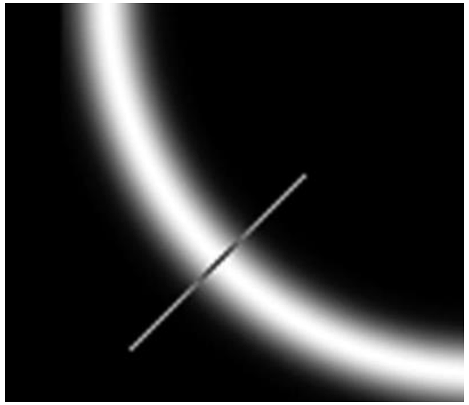

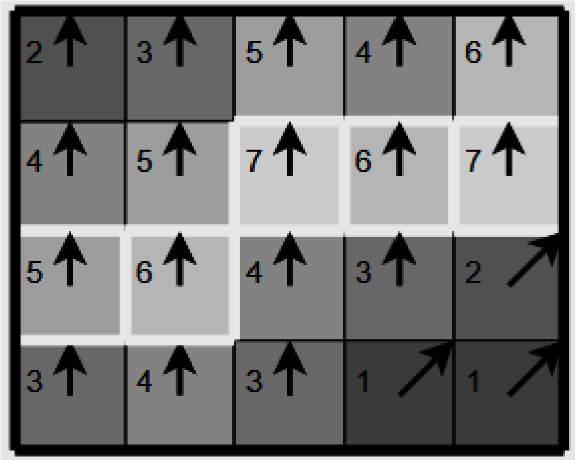

after non-max supp

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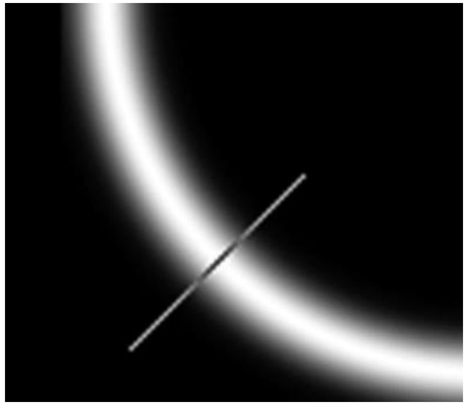

Canny edge detector

- LINKINg Points
  - Canny edge detector
    - It starts with one thing: gradients
    - In the end, it doesn't even matter: which operators have been used
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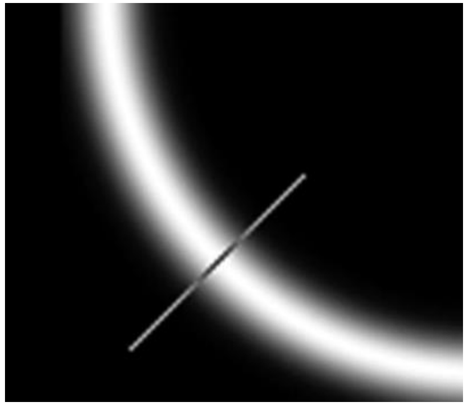

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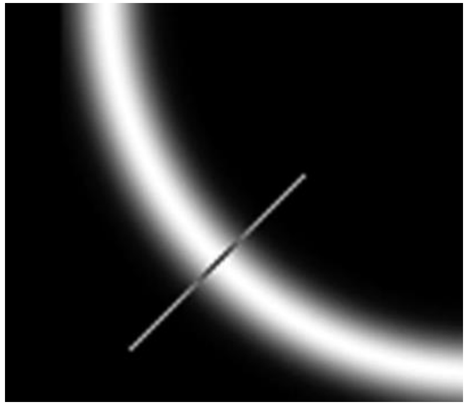

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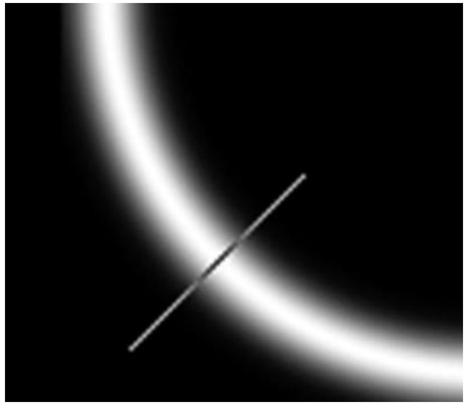

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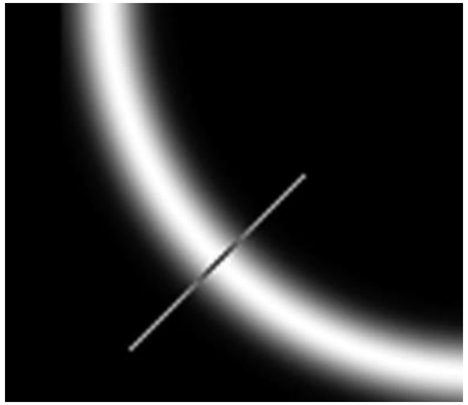

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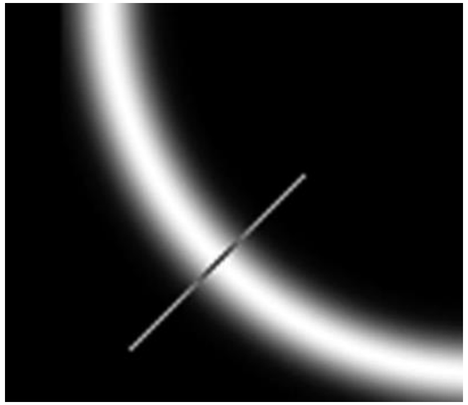

  - two instruments of thresholds: Hysteresis

    a. find all edge points using TH^{high}
    b. from each strong point follow the both side direction ⊥ to the edge normal
    c. in that directions, construct the contours of connected edge points
    d. mark all points greater than TH_{low}

Canny edge detector

- Hysteresis

Canny edge detector

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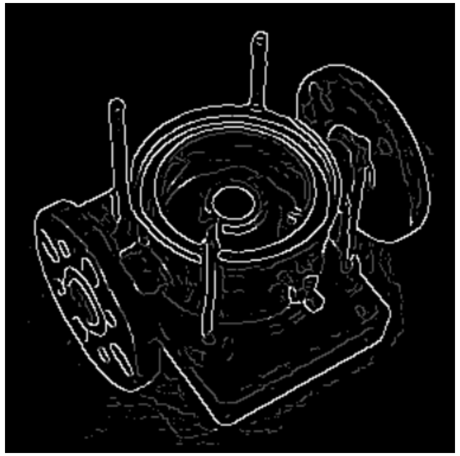
double thresh



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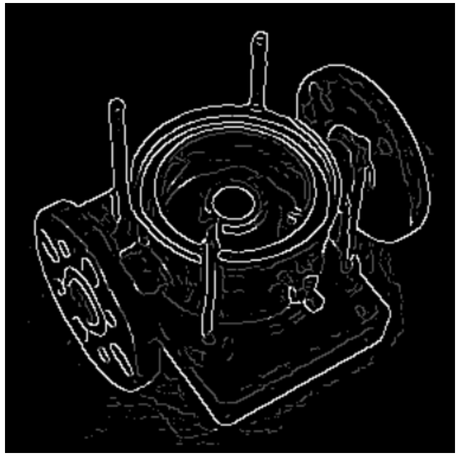
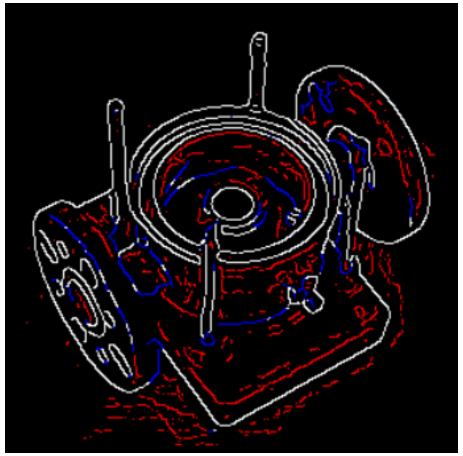


hysteresis



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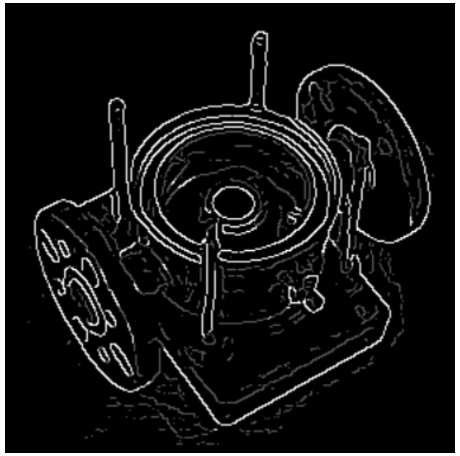
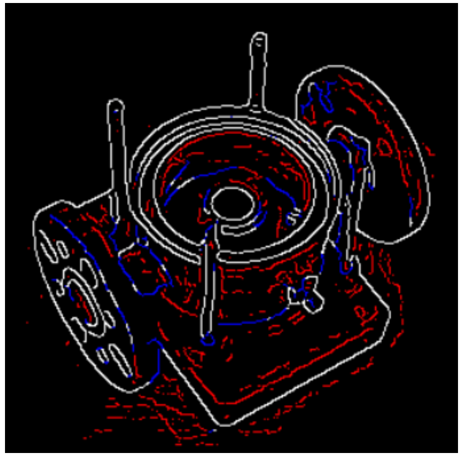
after non-max supp

double thresh



hysteresis



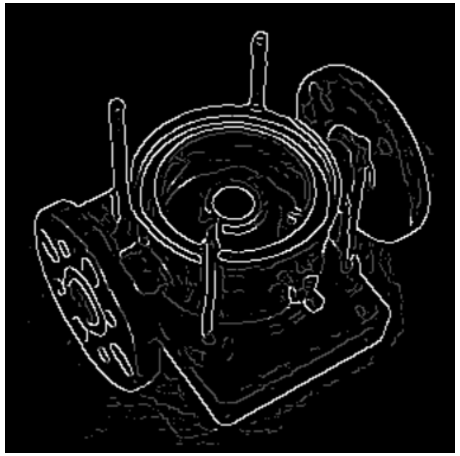
White – strong edges
Blue – weak connect
Red – remaining weak edges (non-edge)

Canny edge detector

- Hysteresis
  - two instruments of thresholds: Hysteresis
    a. find all edge points using TH^{high}
    b. from each strong point follow the both side direction ⊥ to the edge normal
    c. in that directions, construct the contours of connected edge points
    d. mark all points greater than TH_{low}

after non-max supp

double thresh



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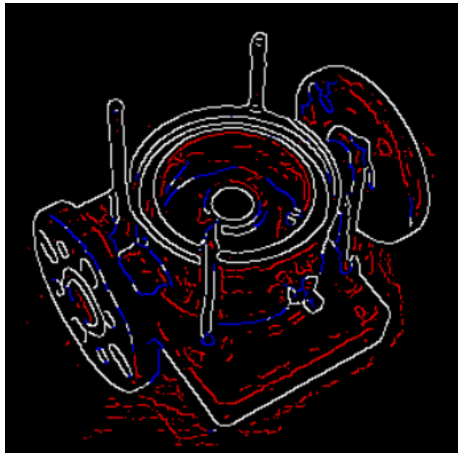

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Ref: P. Kalra

Canny edge detector

- Entire algorithm composition:

Canny edge detector

- Entire algorithm composition:

1. Filter image with derivatives of Gaussian
2. Get M, α
3. Non-max suppression
    - thin multi-pixel wide edges to a single pixel widths
4. Linking: the hysteresis
    - 2 thresholds: TH_{low} , TH^{high}
    - TH^{high}: to start an edge
    - TH_{low} : continue started edge

Canny edge detector

Canny edge detector

- Speeding up the beats of operations
  - binning the α (angles)
  - 4 directions

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    Horizontal

    +45 degrees

    Vertical

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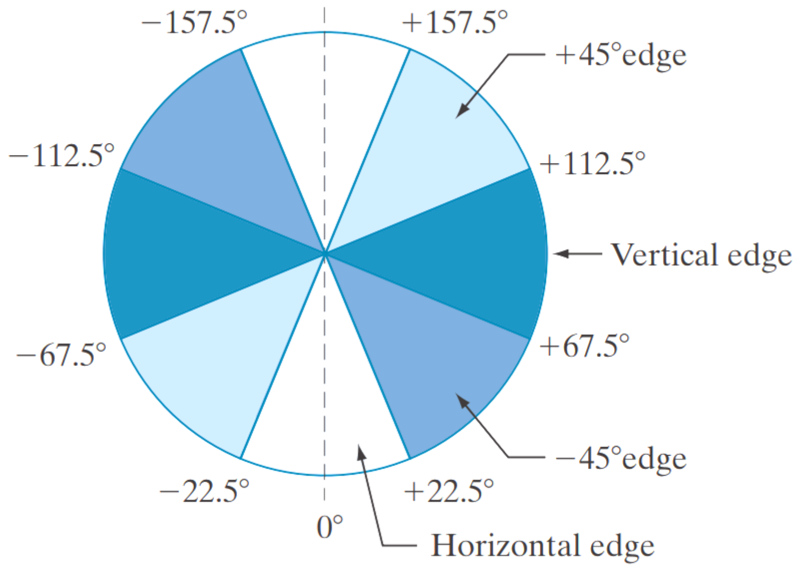

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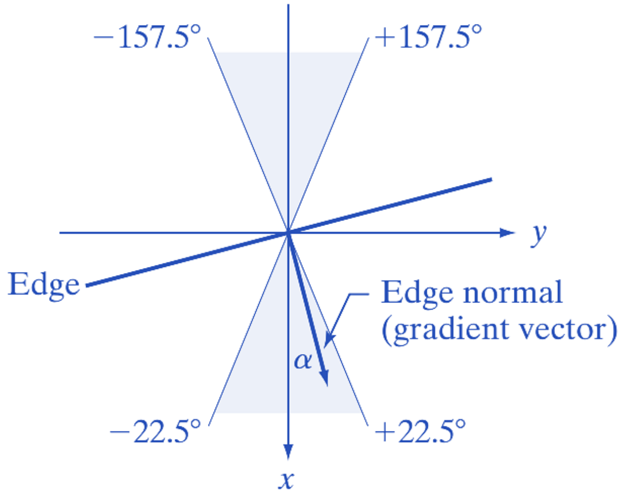
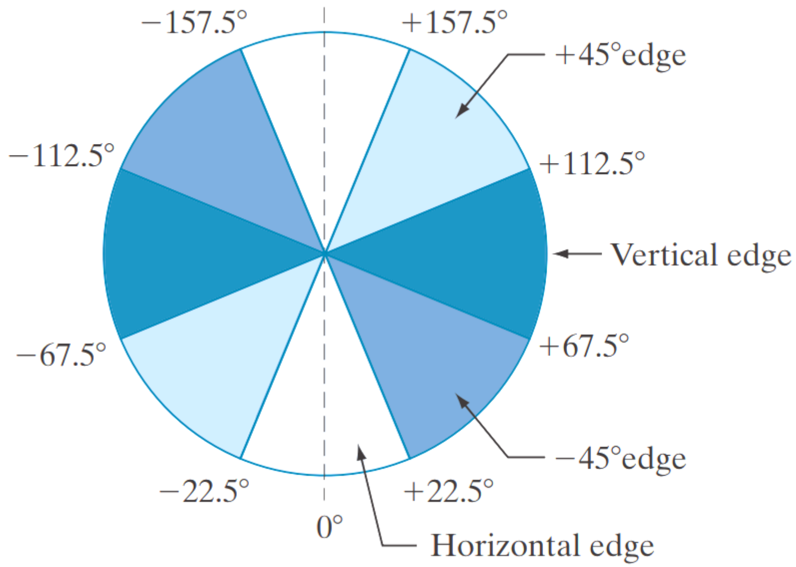
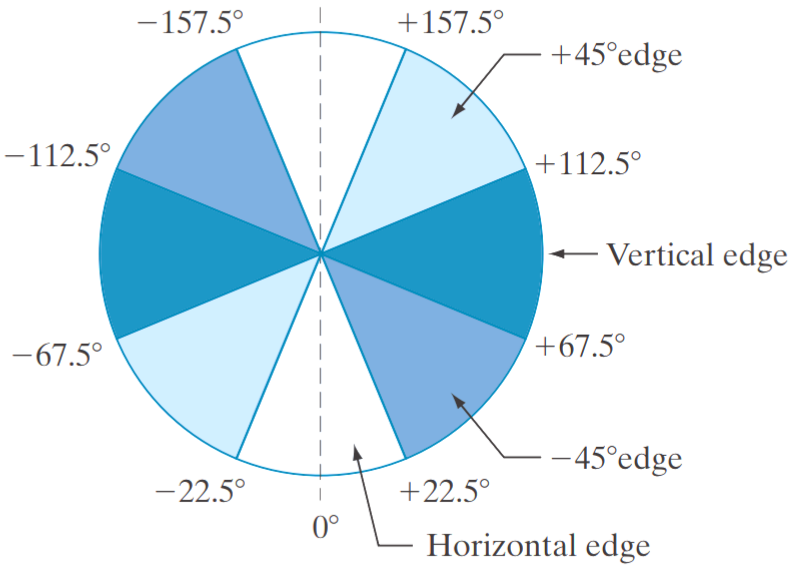




Canny edge detector

- Speeding up the beats of operations
  - binning the α (angles)
    - get the directional bin $Bin()$ closest to α
    - from previous operations edge: $M(x, y)$
    - suppression
      - If $M(x', y') > M(x, y)$ then

        $M(x, y) \rightarrow 0$
      - where neighbors $x', y' \leftarrow Bin(x, y)$



Canny edge detector

1. **Smoothing:** Blurring of the image to remove noise.
2. **Finding gradients:** The edges should be marked where the gradients of the image has large magnitudes.
3. **Non-maximum suppression:** Only local maxima should be marked as edges.
4. **Double thresholding:** Potential edges are determined by thresholding.
5. **Edge tracking by hysteresis:** Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

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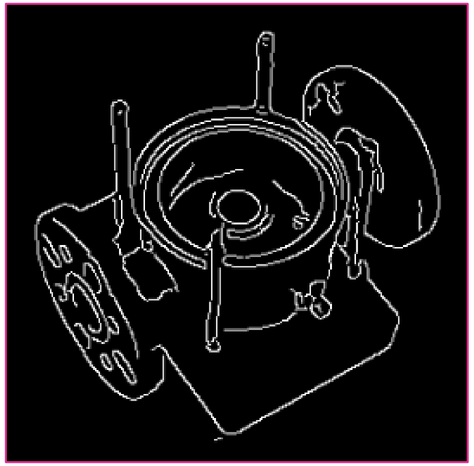

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Canny edge detector

- Varying σ

input

Canny edge detector

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Canny edge detector

- Varying σ

input

σ small

Canny edge detector

- Varying σ

input

σ small

σ large

Canny edge detector

- Comparing other edge detectors

input

Canny edge detector

- Comparing other edge detectors

input

Sobel with TH

Canny edge detector

- Comparing other edge detectors

input

Sobel with TH

LoG zero crossings

Canny edge detector

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input

Sobel with TH

LoG zero crossings

Canny

Canny edge detector

- Comparing other edge detectors

input

Canny edge detector

- Comparing other edge detectors

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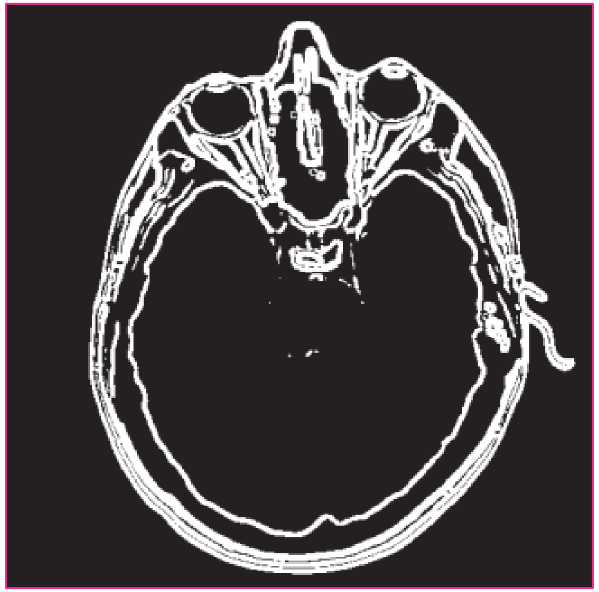
Sobel with TH

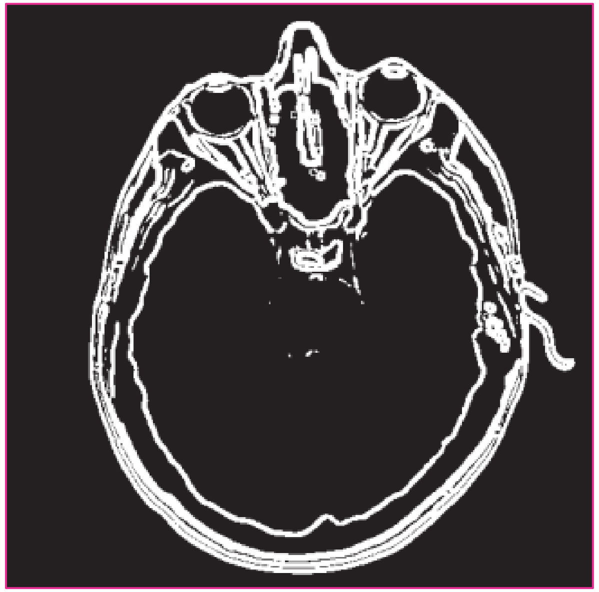


Canny edge detector

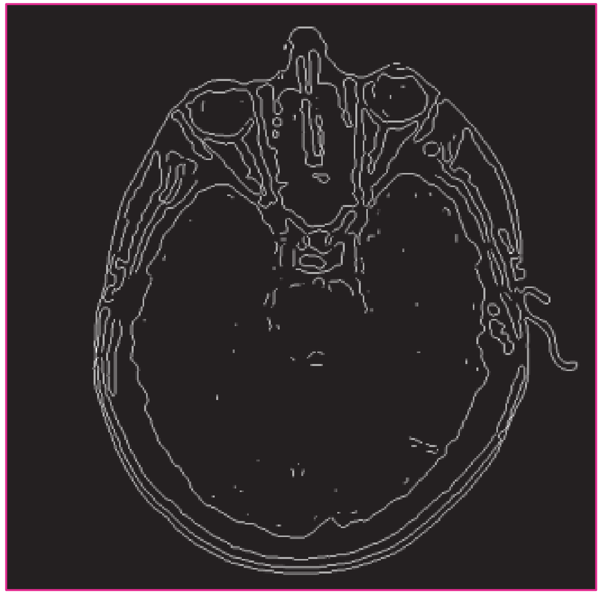
- Comparing other edge detectors

input

Sobel with TH



LoG zero crossings

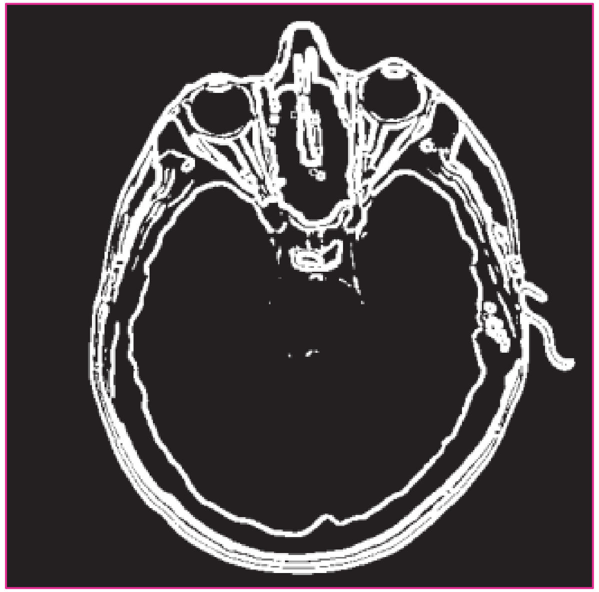


Canny edge detector

- Comparing other edge detectors

input

Sobel with TH



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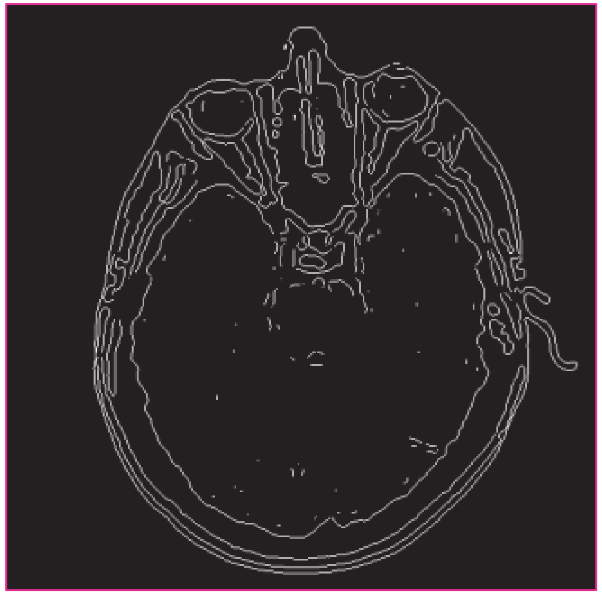
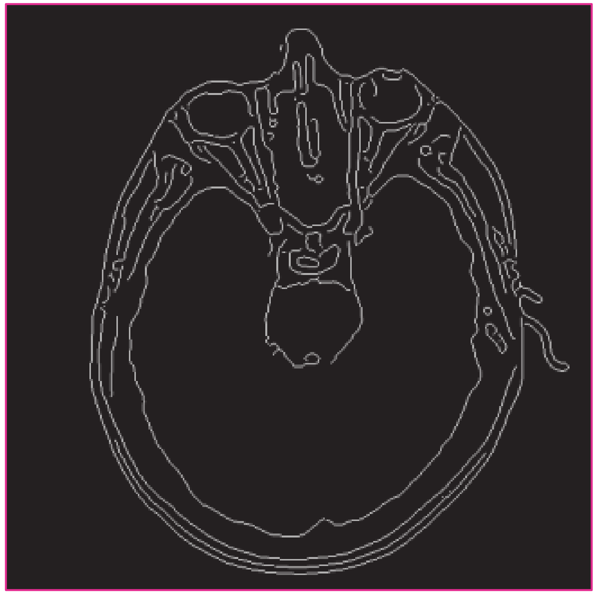


Canny



A canny player with a Canny edge!

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Messi

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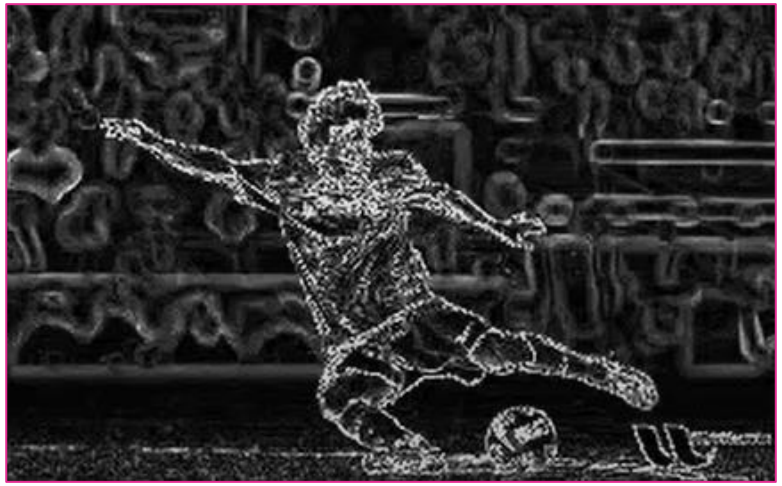

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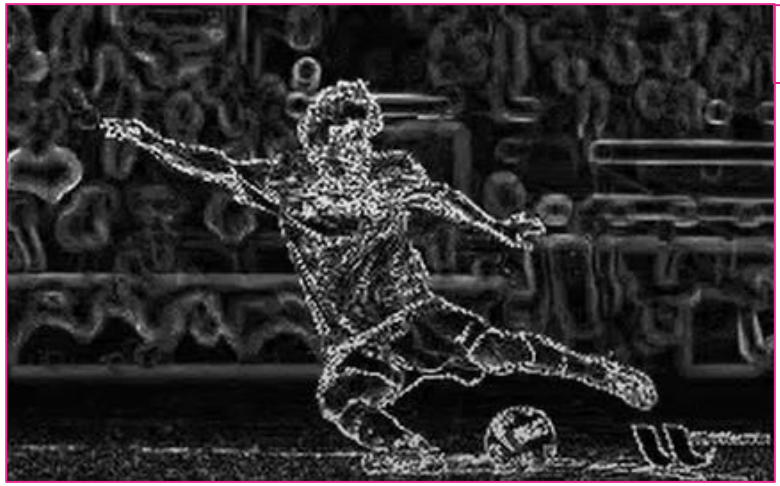

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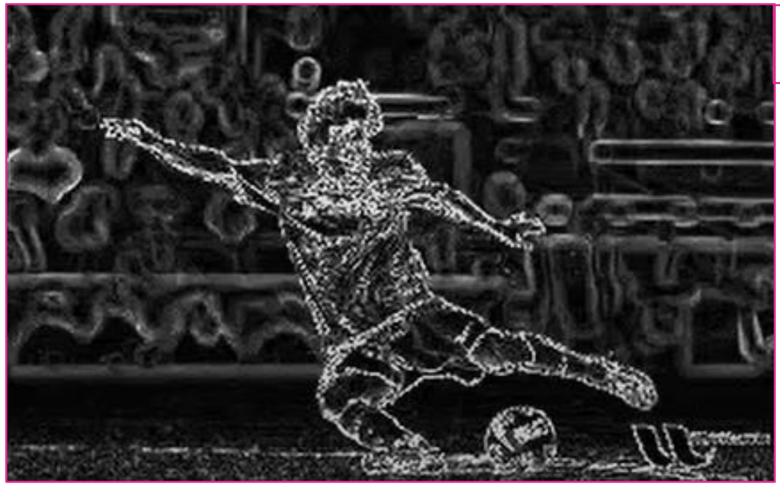

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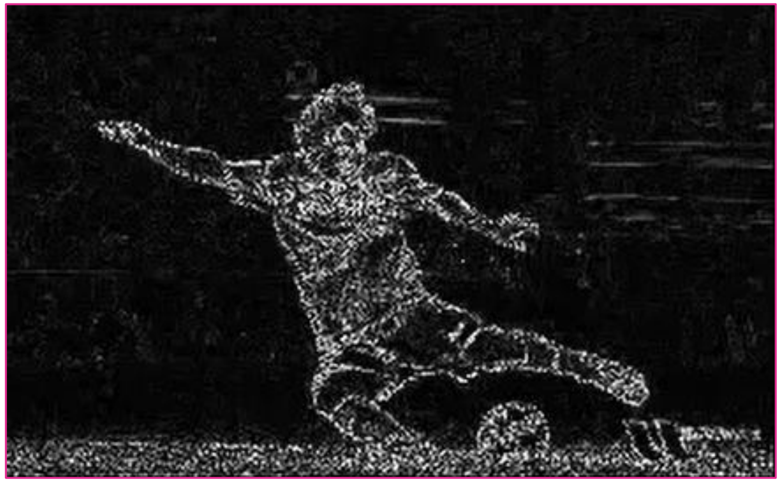

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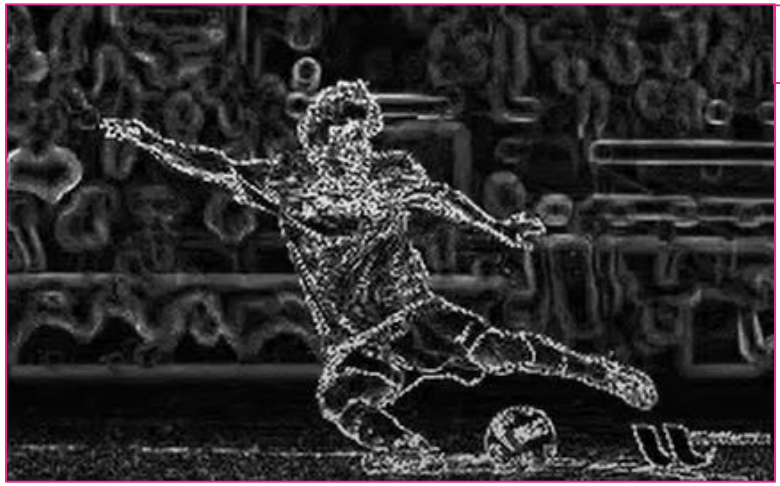

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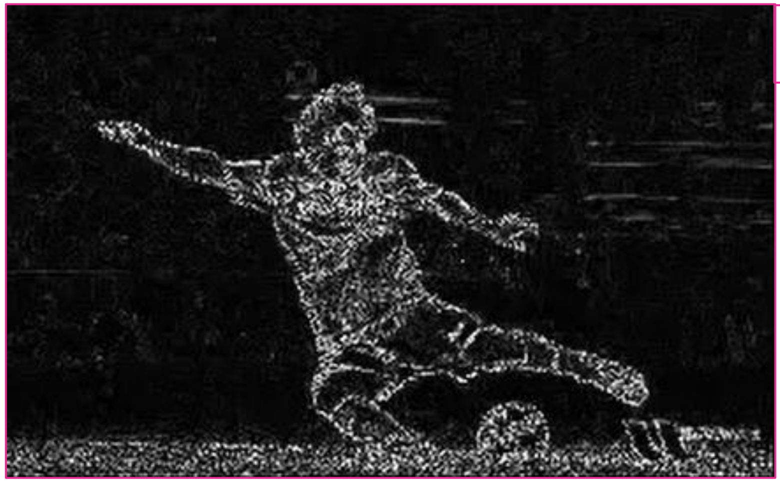
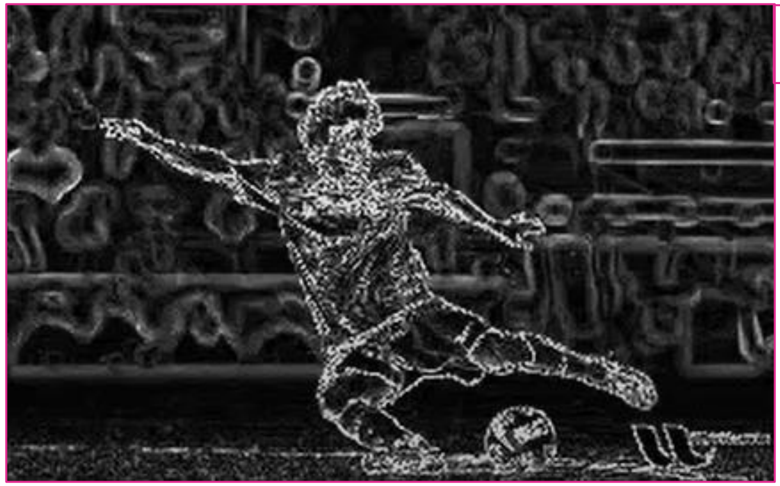


Laplacian

A canny player with a Canny edge!

Messi



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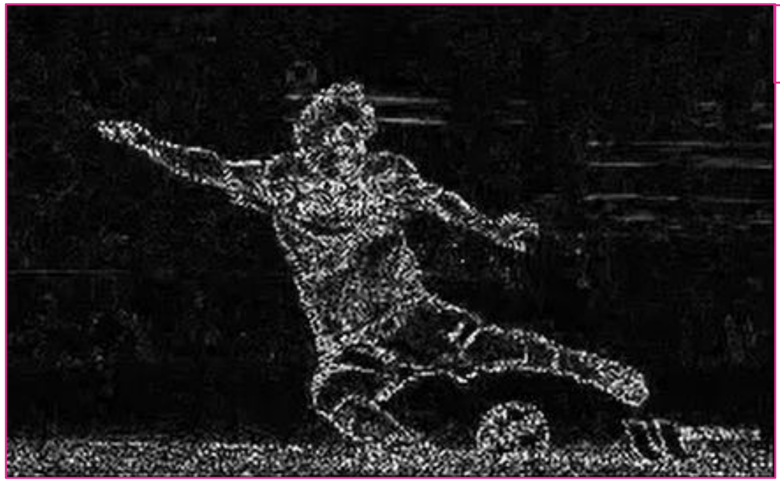

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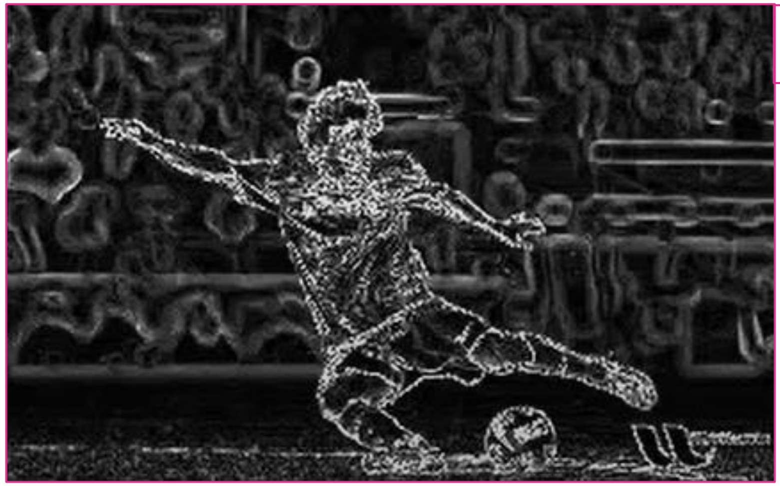

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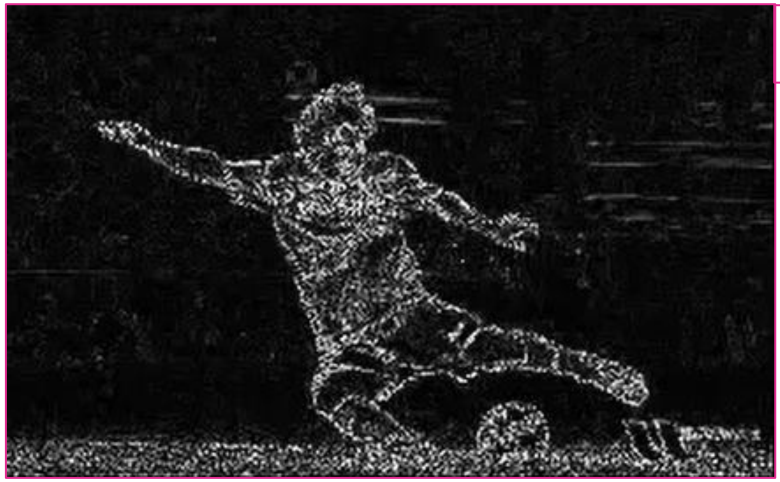


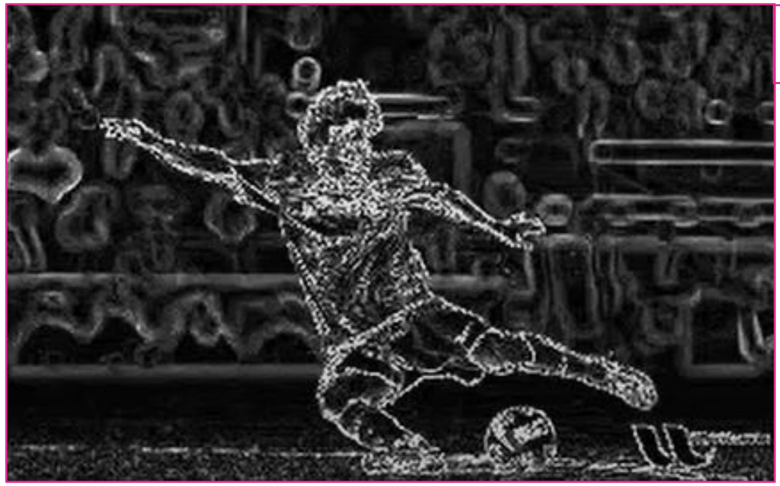
Laplacian

Canny

A canny player with a Canny edge!

Messi

who will you go with?



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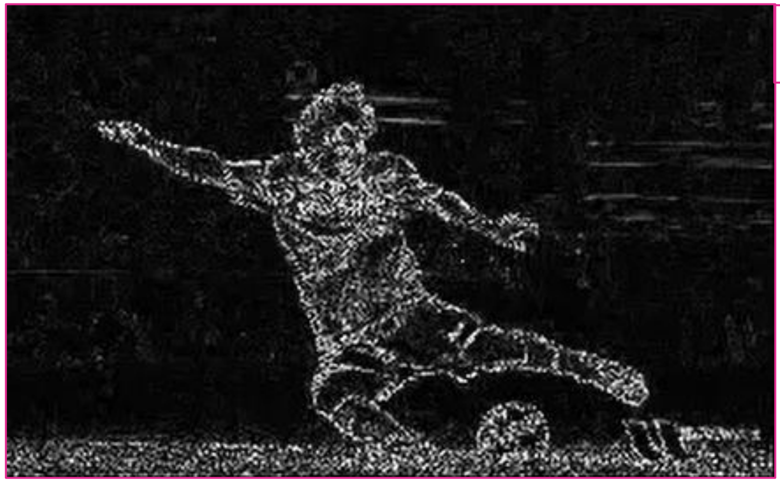

Laplacian

Canny

Conclusion

- Canny edge detector

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- Single point thick edges

- Canny operations
  - Thinning: non-max suppression
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Go with a ‘canny’ player, for accuracy

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And with uSΘin BΘLt, for speed!

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