ETH zürich

IRIS
Institute of Robotics and Intelligent Systems

Computer Vision

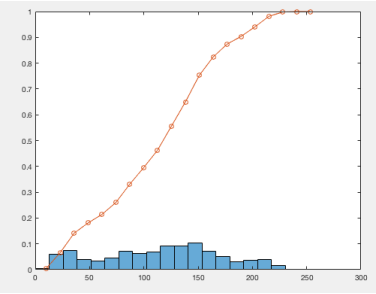
Computer vision algorithms

- Histogram Equalization / Thresholding / Binarization
- Image Filtering (Gaussian, Median, Image Sharpening, …)
- Segmentation (Dilation, Erosion)
- Edge Detection (Canny Edge detector, Hough Transform, Gradient, Laplacian, Non-Maxima Supression, …)

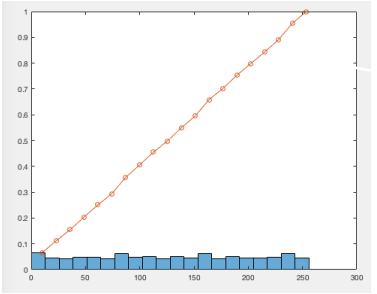
Histogram

- Histogram shows the distribution of intensities in the image.

- Histogram Equalization : increase global contrast, create flat histogram



Histogram Equalization



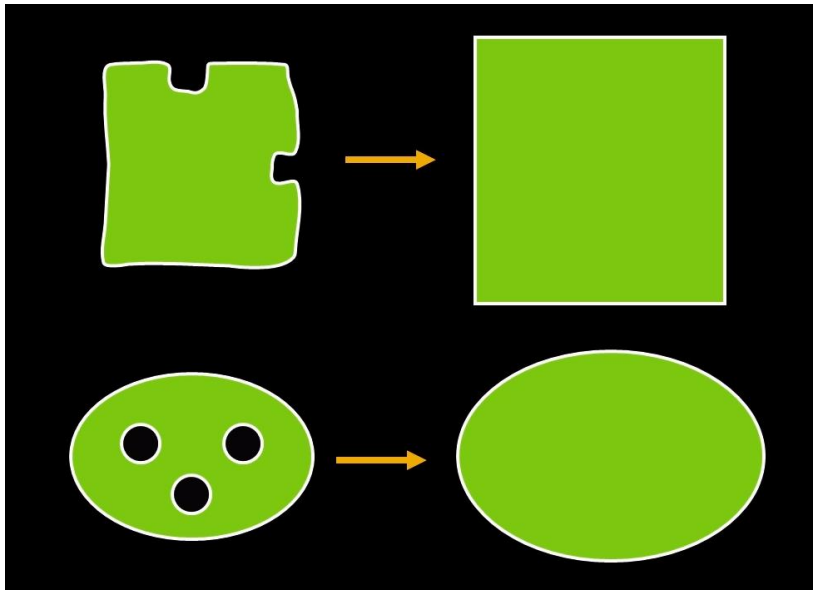
cumulative histogram

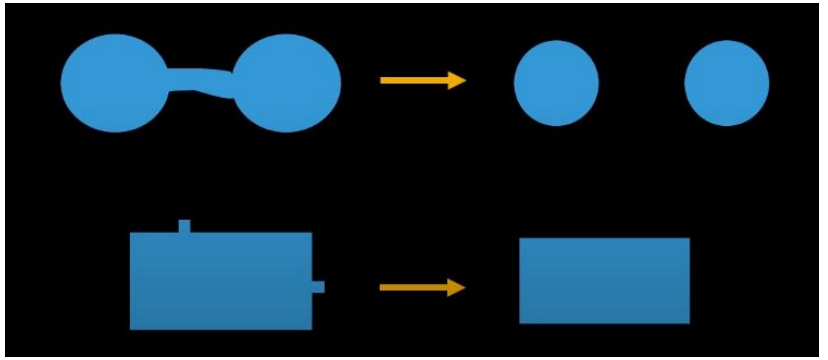
- Thresholding/Binarization: depending on image intensity, either black or white

Dilation/Erosion

- After Thresholding, regions can be distorted by noise and texture

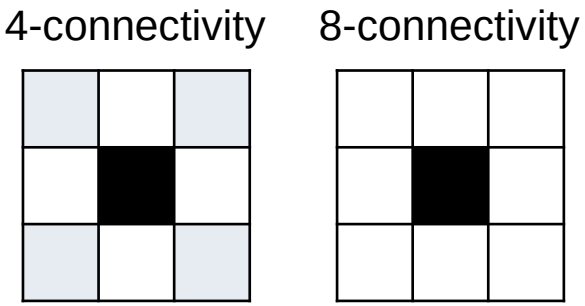
  → Remove small imperfections with Dilation/Erosion





Dilation/Erosion

- Dilation : bright regions in the image to grow
- Erosion : bright regions in the image to shrink/dark regions in the image to grow



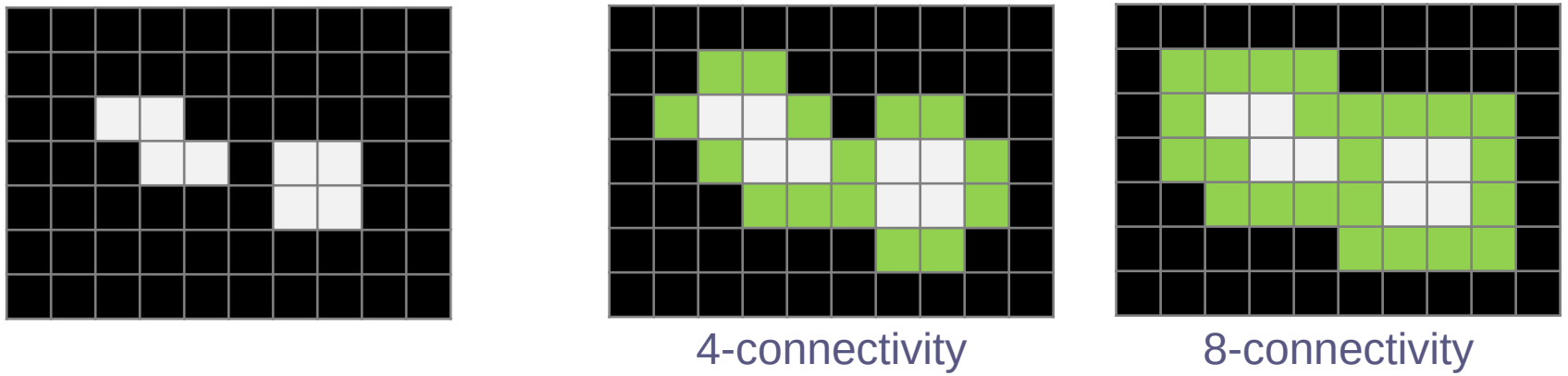
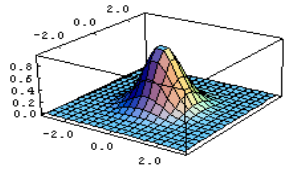


Image Filtering

- Mean Filter : replace pixels with the mean of the neighboring pixels

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$

- Gaussian Smoothing Filter : replace pixels with the weighted mean of the neighboring pixels



$$\frac{1}{16}\begin{bmatrix}1 & 2 & 1\\ 2 & 4 & 2\\ 1 & 2 & 1\end{bmatrix}$$

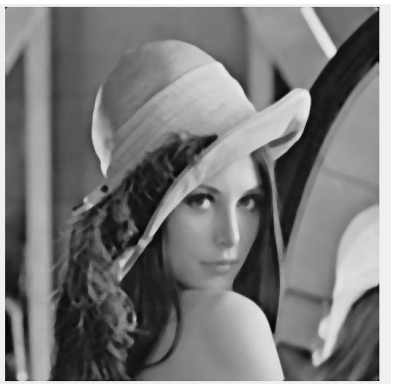
- Median Filter : replace pixels with the median intensity in the window, requiring expensive computation for sorting

$$117, 122, 122, 123, \mathbf{124}, 125, 125, 130, 137$$

123	122	117
125	137	124
125	130	122

mean filter

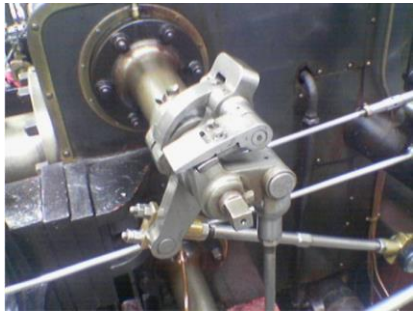
Gaussian filter



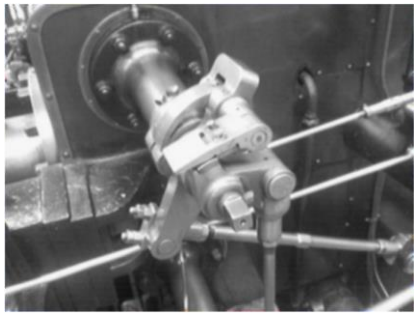
median filter

Canny Edge Detector

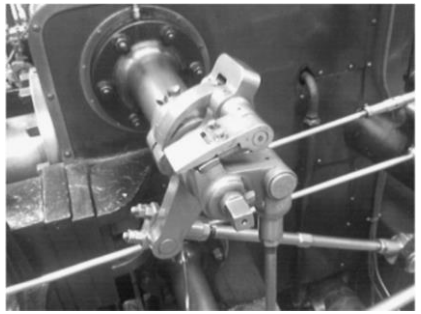
1. Gaussian filter to remove noise (smoothing)
2. Find derivatives along x,y and compute the edge strength and orientation
3. Non-maxima Suppression: select edge strength above some threshold and larger than neighbors along the edge orientation
4. Hysteresis Thresholding : suppress all the other edges that are weak and not connected to strong edges



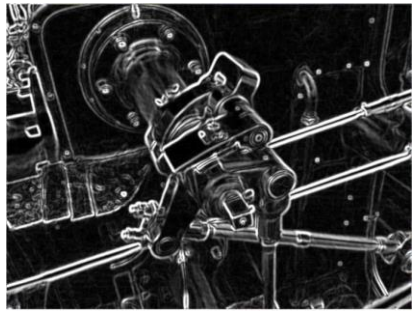
Original Image



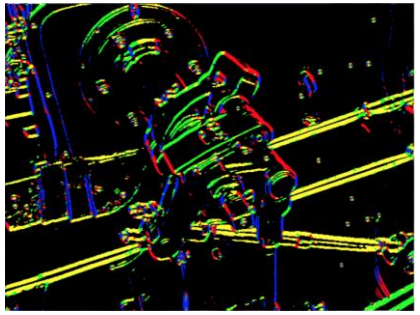
Grey scale



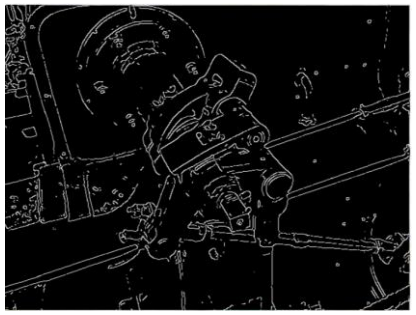
Smoothing



Gradient Magnitude

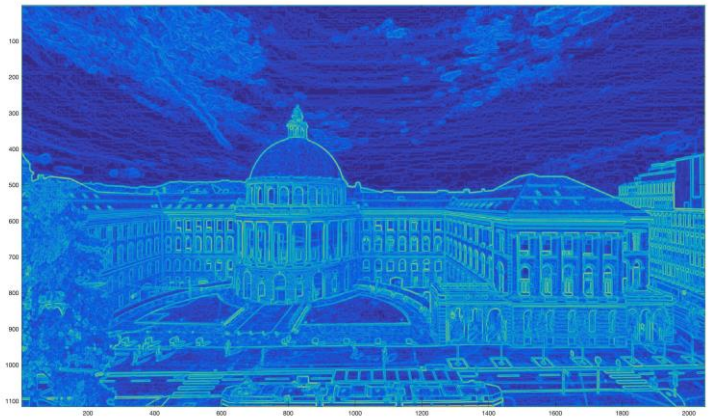


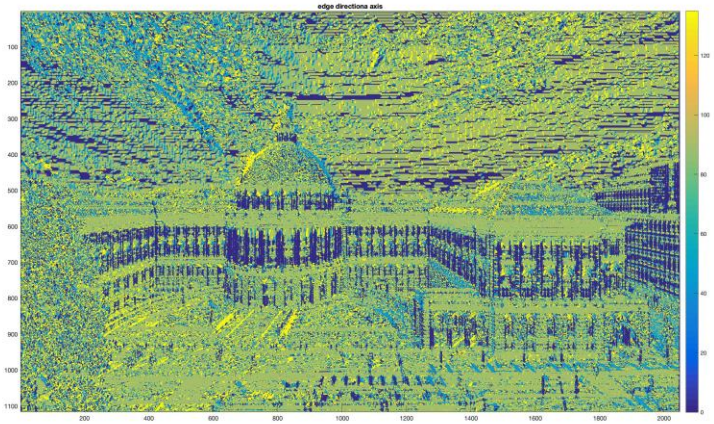
Thresholding and direction



Hysteresis thresholding

Canny Edge Detector Example





Gradient

Compare intensity of vertical (along y) and horizontal (along x) neighbors

Edge orientation

Perpendicular to main gradient direction (according to x,y gradient components)

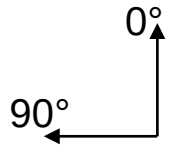
Canny Edge Detector Example – non-maxima suppression

Gradient magnitude map

25	30	35	36	33	30
29	44	58	64	56	40
24	45	55	62	56	32
40	51	21	28	53	40
64	77	65	67	77	62
64	84	94	92	79	55
33	50	63	60	43	0

“Angles” map (Edge orientation)

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135

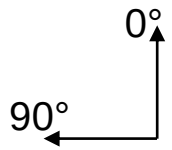


1. Start with Gradient and “angles” map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map

Canny Edge Detector Example – non-maxima suppression

25	30	35	36	33	30
29	44	58	64	56	40
24	45	55	62	56	32
40	51	21	28	53	40
64	77	65	67	77	62
64	84	94	92	79	55
33	50	63	60	43	0

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135

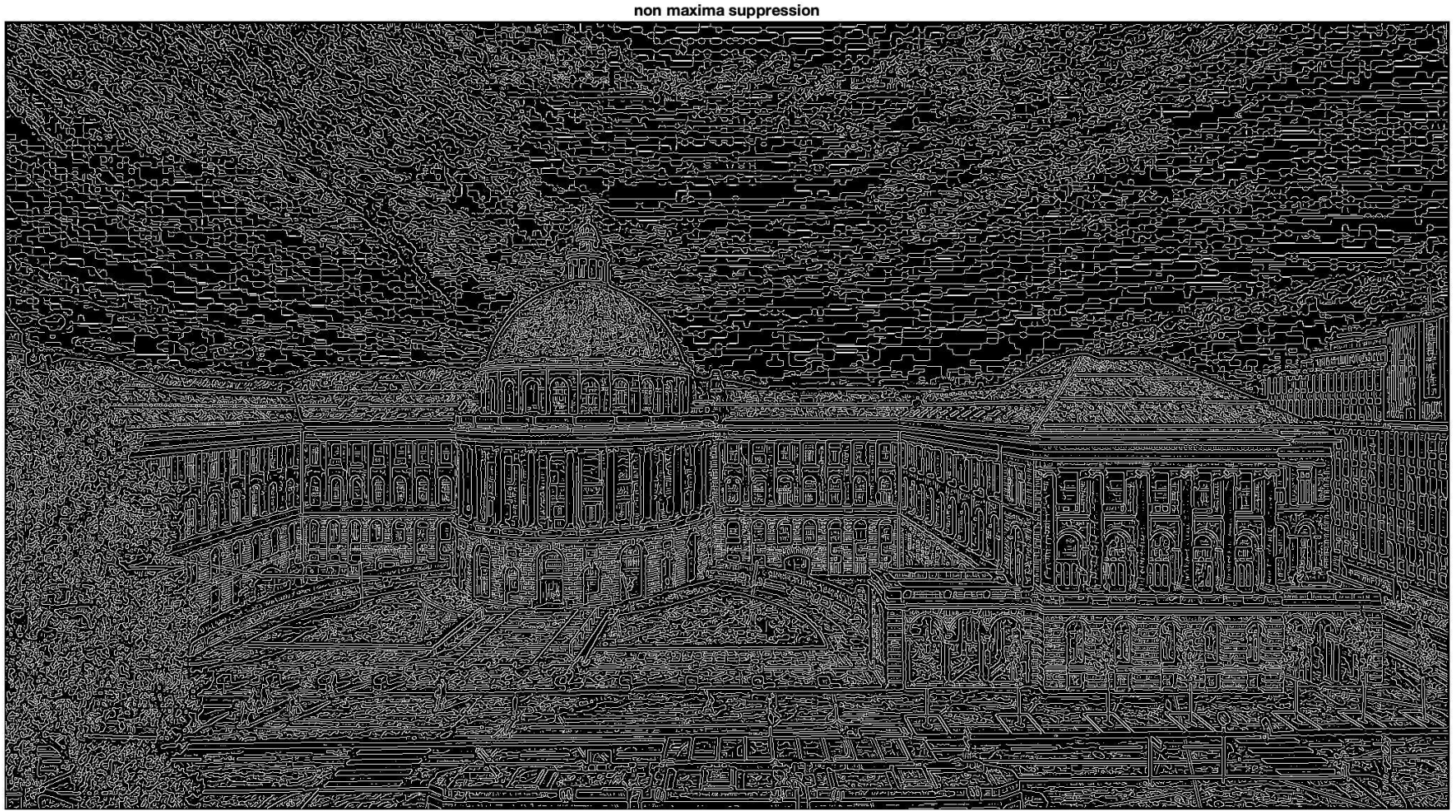


Non-maxima suppression map

0	0	0	0	0	0
29	0	58	64	56	40
0	45	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	84	94	92	79	0
0	0	0	0	0	0

1. Start with Gradient and “angles” map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map

Canny Edge Detector Example – non-maxima suppression



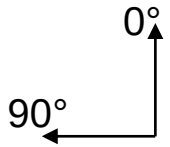
Canny Edge Detector Example – hysteresis thresholding

Non-maxima suppression map

0	0	0	0	0	0
29	0	58	64	56	40
0	45	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	84	94	92	79	0
0	0	0	0	0	0

“Angles” map

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135



T_H = 90

T_L = 50

1. Start with Gradient and “angles” map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map
2. Mark values above T_H (=strong edge), set values below T_L to zero (=weak edge)

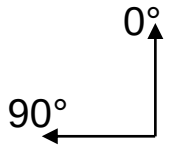
Canny Edge Detector Example – hysteresis thresholding

Non-maxima suppression map

0	0	0	0	0	0
29	0	58	64	56	40
0	45	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	84	94	92	79	0
0	0	0	0	0	0

“Angles” map

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135



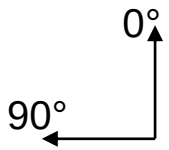
T_H = 90
T_L = 50

1. Start with Gradient and “angles” map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map
2. Mark values above T_H (=strong edge), set values below T_L to zero (=weak edge)
3. Compare neighbors along edge direction; if neighbor to strong edge is above T_L = strong edge

Canny Edge Detector Example – hysteresis thresholding

0	0	0	0	0	0
29	0	58	64	56	40
0	45	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	84	94	92	79	0
0	0	0	0	0	0

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135



T_H = 90
T_L = 50

“strong edge” map

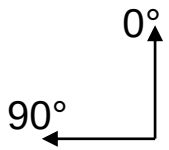
0	0	0	0	0	0
0	0	58	64	56	0
0	0	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	1	1	1	1	0
0	0	0	0	0	0

1. Start with Gradient and “angles” map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map
2. Mark values above T_H (=strong edge), set values below T_L to zero (=weak edge)
3. Compare neighbors along edge direction; if neighbor to strong edge is above T_L = strong edge
4. Repeat point 3. (Chain ”reaction”)

Canny Edge Detector Example – hysteresis thresholding

0	0	0	0	0	0
29	0	58	64	56	40
0	45	0	0	56	0
0	51	0	0	53	0
64	77	0	0	77	62
0	84	94	92	79	0
0	0	0	0	0	0

90	90	90	90	90	90
90	90	90	90	90	90
135	135	90	90	45	45
45	0	0	0	0	135
45	45	90	135	135	135
45	45	90	90	135	135
45	90	90	90	90	135



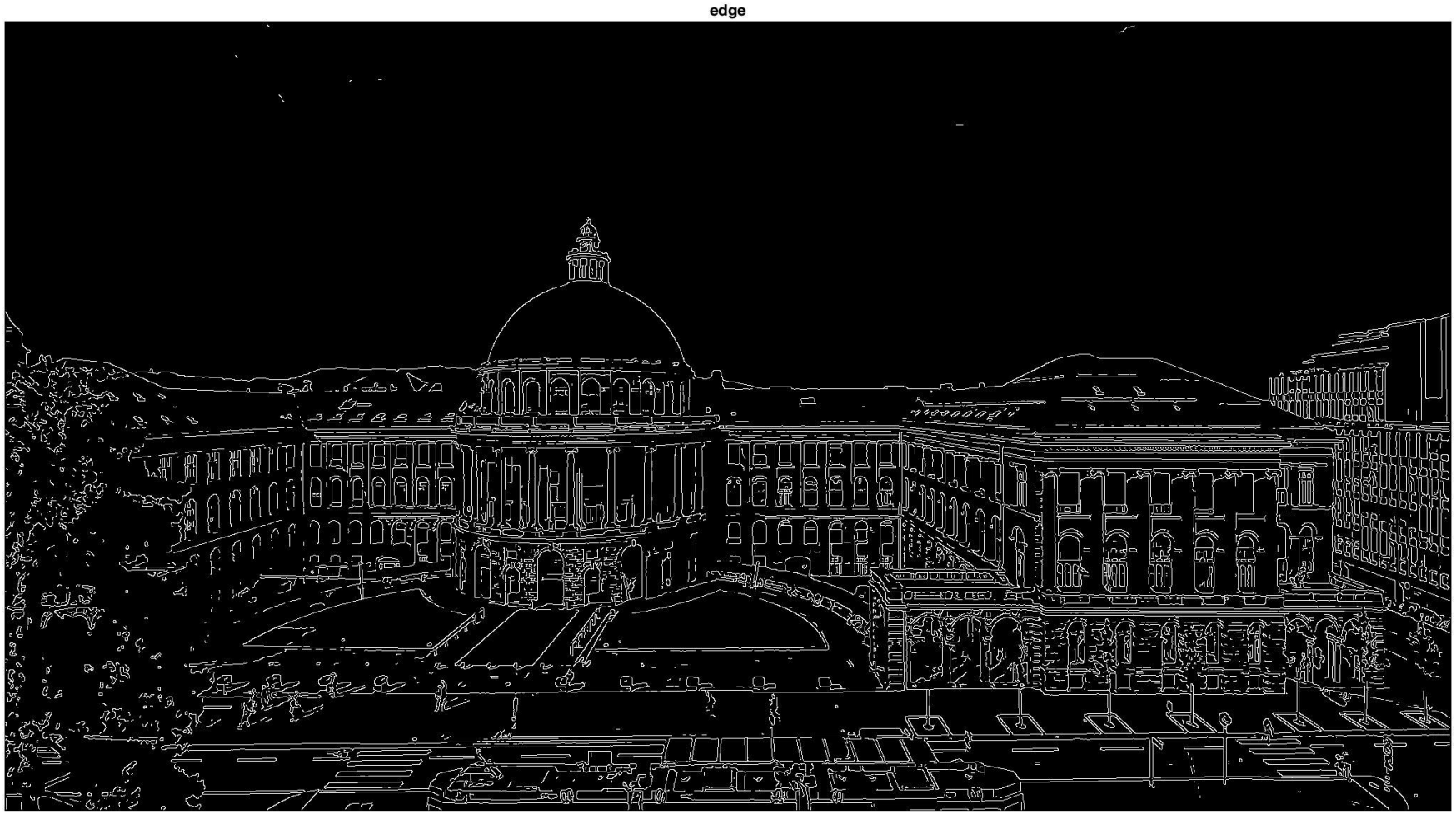
T_H = 90
T_L = 40

Final "strong edge" map

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

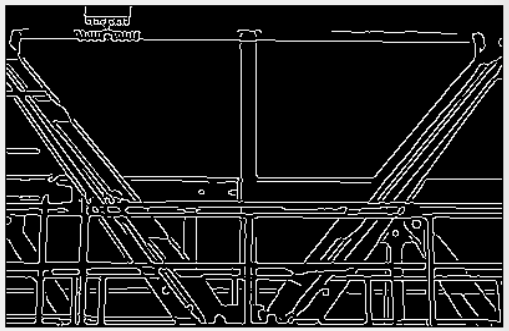
1. Start with Gradient and "angles" map, compare neighbors perpendicular along edge direction (erosion) -> non-maxima suppression map
2. Mark values above T_H (=strong edge), set values below T_L to zero (=weak edge)
3. Compare neighbors along edge direction; if neighbor to strong edge is above T_L = strong edge
4. Repeat point 3. (Chain "reaction")

Canny Edge Detector Example – hysteresis thresholding



Hough Transform

original image



Canny edge detector

Hough transform

- Feature Extraction technique
- E.g. use normal representation of line:

  $x \cos \theta + y \sin \theta = \rho$
- For each edge point (x,y), plot normal representation for all θ → Hough space
- Intensities in Hough plot accumulate

  → overlapping points get brighter; peak values describe lines in the image
- Extract (ρ, θ) of points with higher intensity