

# Canny Edge Detector

- 1) **Smooth** image with a Gaussian
  - optimizes the trade-off between noise filtering and edge localization
- 2) Compute the **Gradient** magnitude using approximations of partial derivatives
  - 2x2 filters
- 3) **Thin edges** by applying non-maxima suppression to the gradient magnitude
- 4) Detect edges by **double thresholding**

# Gradient

- At each point convolve with

$$G_x = \begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix} \quad G_y = \begin{bmatrix} 1 & 1 \\ -1 & -1 \end{bmatrix}$$

- magnitude and orientation of the Gradient are computed as

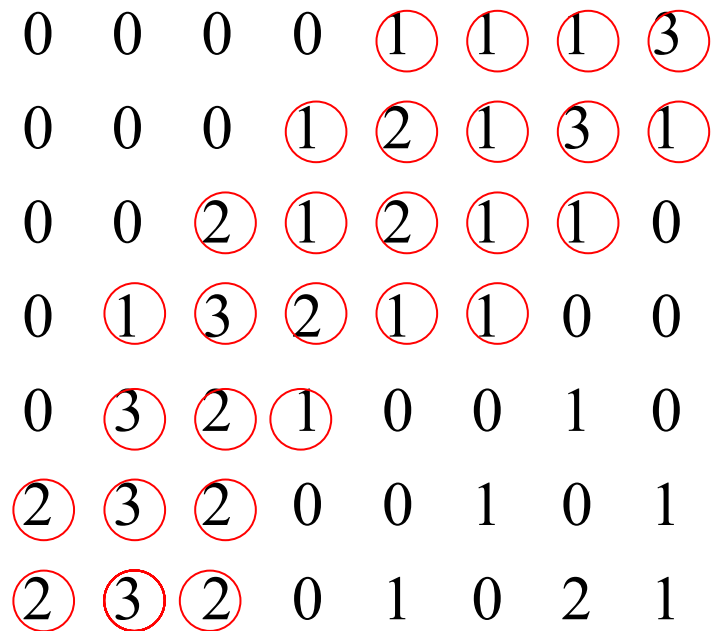
$$M[i, j] = \sqrt{P[i, j]^2 + Q[i, j]^2}$$

$$\theta[i, j] = \tan^{-1}(Q[i, j], P[i, j])$$

- Avoid floating point arithmetic for fast computation

# Non-Maxima Suppression

- Thin edges by keeping large values of Gradient
  - not always at the location of an edge
  - there are many **thick** edges



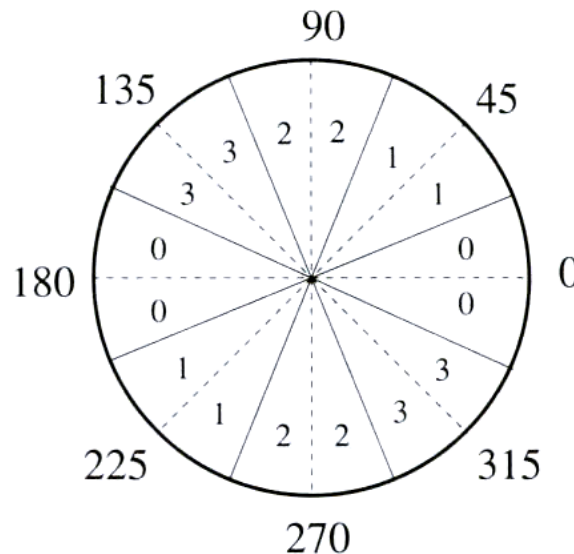
# Non-Maxima Suppression (2)

- Thin the broad ridges in  $M[i,j]$  into ridges that are **only one pixel wide**
- Find local maxima in  $M[i,j]$  by suppressing all values along the line of the Gradient that are not peak values of the ridge

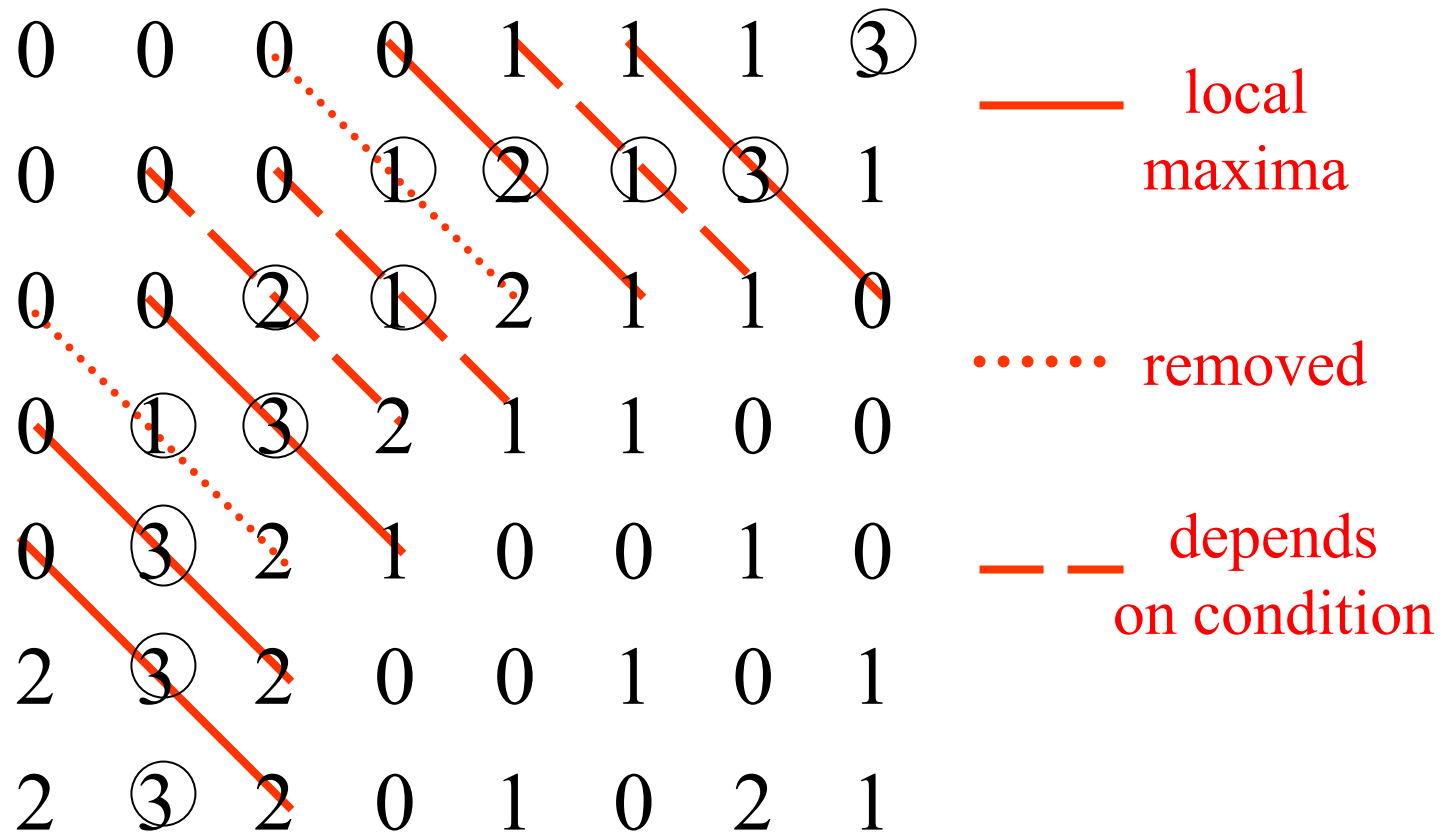


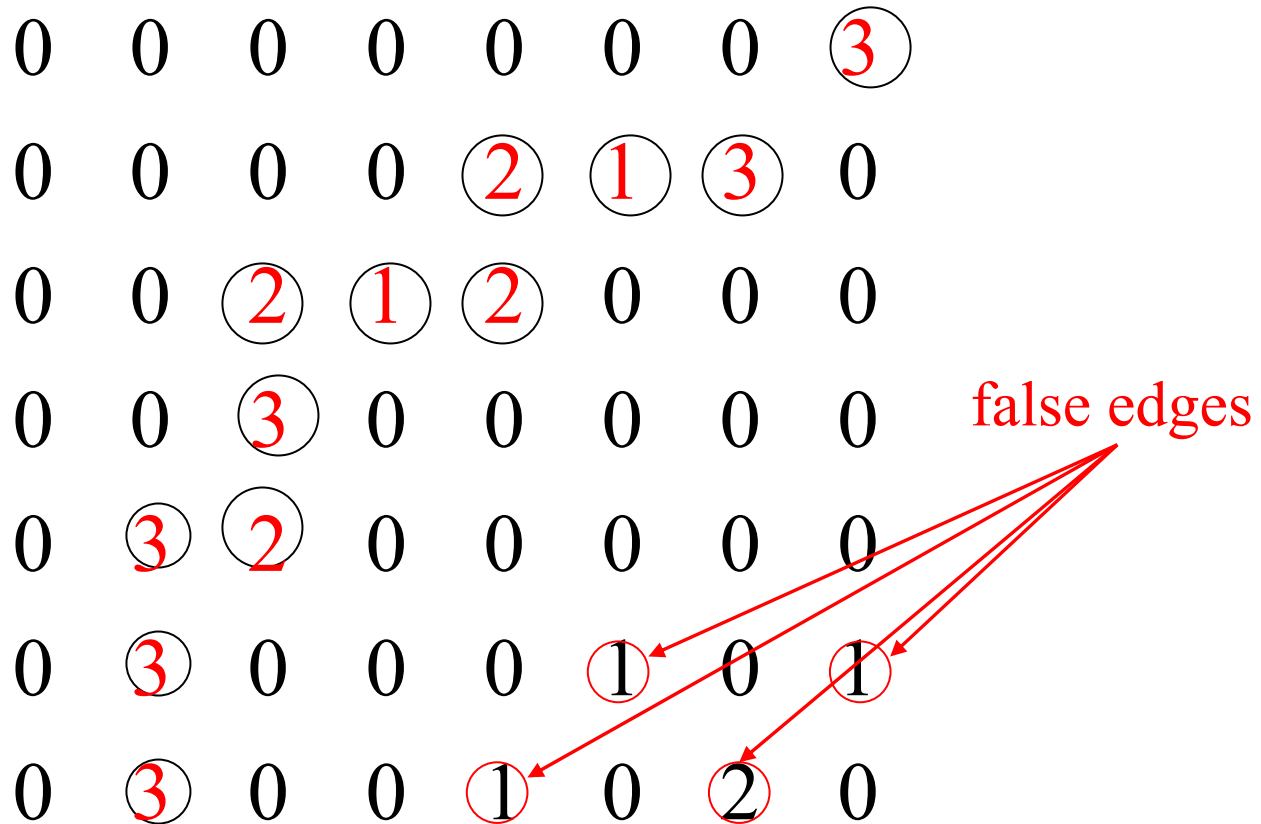
# Gradient Orientation

- Reduce angle of Gradient  $\theta[i,j]$  to one of the 4 sectors
- Check the 3x3 region of each  $M[i,j]$
- If the value **at the center** is not greater than the 2 values along the gradient, then  $M[i,j]$  is set to 0



Canny Edge Detector





- The suppressed magnitude image will contain many false edges caused by noise or fine texture

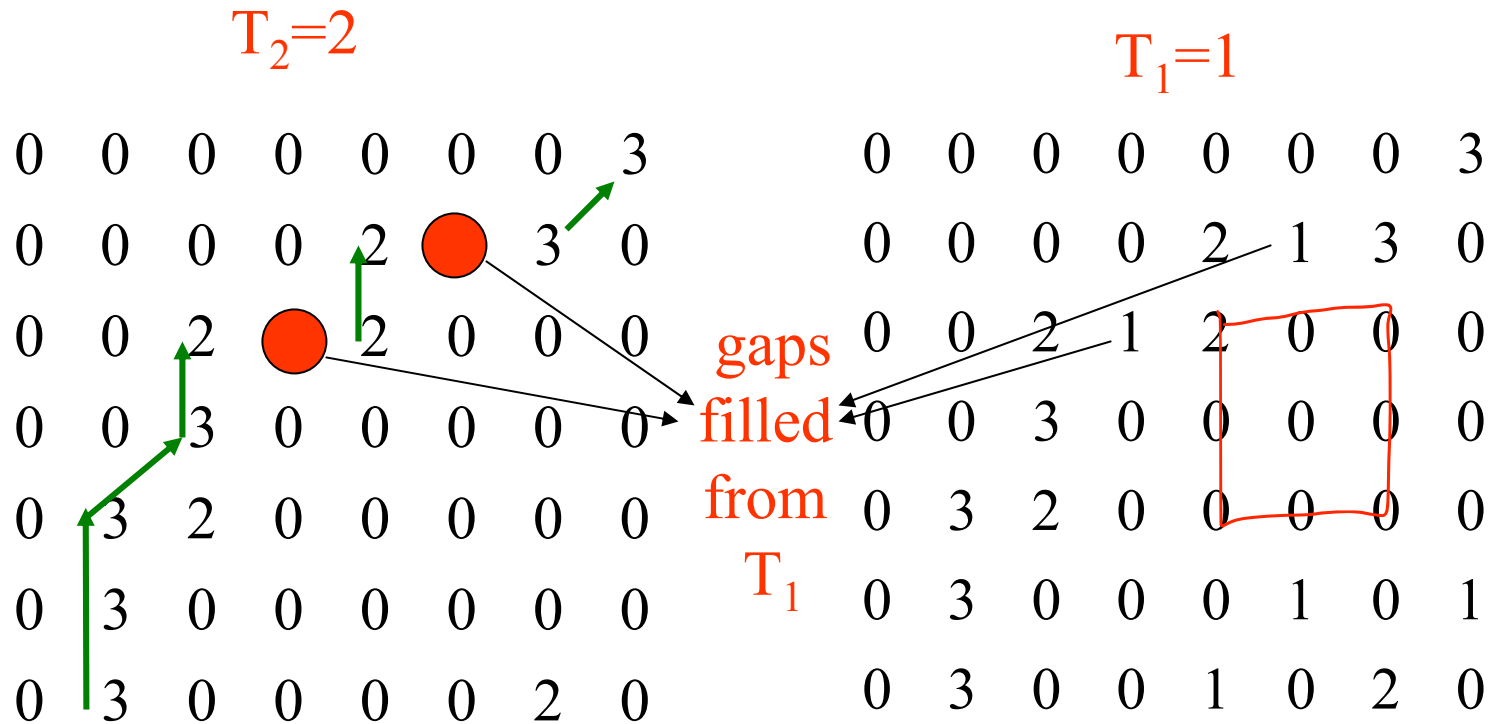
# Thresholding

- Reduce number of false edges by applying a threshold  $T$ 
  - all values below  $T$  are changed to 0
  - selecting a good values for  $T$  is difficult
  - some false edges will remain if  $T$  is too low
  - some edges will disappear if  $T$  is too high
  - some edges will disappear due to softening of the edge contrast by shadows



# Double Thresholding

- Apply two thresholds in the suppressed image
  - $T_2 = 2T_1$
  - two images in the output
  - the image from  $T_2$  contains fewer edges but has gaps in the contours
  - the image from  $T_1$  has many false edges
  - **combine** the results from  $T_1$  and  $T_2$
  - link the edges of  $T_2$  into contours until we reach a gap
  - link the edge from  $T_2$  with edge pixels from a  $T_1$  contour until a  $T_2$  edge is found again



- A  $T_2$  contour has pixels along the green arrows
- **Linking:** search in a 3x3 of each pixel and connect the pixel at the center with the one having greater value
- Search in the direction of the edge (direction of Gradient)

# Edge Linking

- Fill gaps in the Canny edge
  - e.g., after thresholding follow edge

4       $T_2=8$

9       $T_1=4 \rightarrow 4$  is lost!!

5

6

- scan bottom-up and combine the edges
- scan left-to-right and right-to-left
- scan across the diagonals

# Line Detection

- **Model of a line:** two edges with opposite polarity in distance less than the size of the smoothing filter
  - edge detection filters respond to step edges
  - they do not provide meaningful response to lines
- Apply nonmaxima suppression on the smoothed output
  - a line is the derivative of a step → the derivative step of the Canny algorithm is not necessary