Image Segmentation

It is the process that partitions a digital image into disjoint regions, each of which typically corresponds to one object.

Different approaches for Image segmentation:

- Discontinuity based – partition image based on abrupt changes in intensity

Examples: Detection of Isolated points, lines, edges etc.

- Similarity based - partition image into regions that are similar according to set of predefined criteria. Examples: Thresholding.

Discontinuity based approach

- Edge pixels are pixels at which intensity of an image changes abruptly
- A line may be viewed as an edge segment in which the intensity of the background on either side of the line is either much higher or much lower than the intensity of the line pixel
- Similarly, isolated point may be viewed as a line whose length and width are equal to one pixel

First and Second Order Derivatives

- First order derivatives produces thicker edges
- Second order derivatives have stronger response to fine details such as thin lines & isolated points
- Second order derivatives produce a double response at step transitions in intensity
- The sign of the second derivative can be used to determine whether a transition into an edge is from light to dark or dark to light

- Consider a one dimensional image

  f(x)= [60 60 60 100 100 100]

  What are the first and second derivatives?

  The first derivative is f(x+1)-f(x).

  First derivative: 0 0 40 0 0

  The highest magnitude 40 shows the presence of an edge in the first derivative.

  The second derivative is the difference in values of the first derivatives.

  Second derivative: 0 40 -40 0

  Sign change in second derivative represent the edge.

  This sign change is important and is called zero-crossing.

Point Detection

- An isolated point is a point whose grey level is significantly different from its background in a homogeneous area
- A 3 x 3 point detection mask

1	**1**	**1**
1	-8	1
1	1	1

Line Detection

- 3 x 3 Laplacian mask: horizontal, vertical and two diagonals

-1	**-1**	**-1**
2	2	2
-1	-1	-1

2	**-1**	**-1**
-1	2	-1
-1	-1	2

-1	**2**	**-1**
-1	2	-1
-1	2	-1

-1	**-1**	**2**
-1	2	-1
2	-1	-1

Edge Detection

- Gradient of an Image f(x,y)

$$\nabla f(x,y) = \begin{bmatrix} \dfrac{\partial f(x,y)}{\partial x} \\ \dfrac{\partial f(x,y)}{\partial y} \end{bmatrix} \qquad \nabla f(x,y) = \begin{bmatrix} g_x \\ g_y \end{bmatrix}$$

$$mag(\nabla f(x,y)) = \left[(g_x)^2 + (g_y)^2 \right]^{1/2}$$

- Edge strength is indicated by the edge magnitude
- The direction of the gradient vector is useful in detecting a sudden change in image intensity
- Gradient with absolute values that are simpler to implement

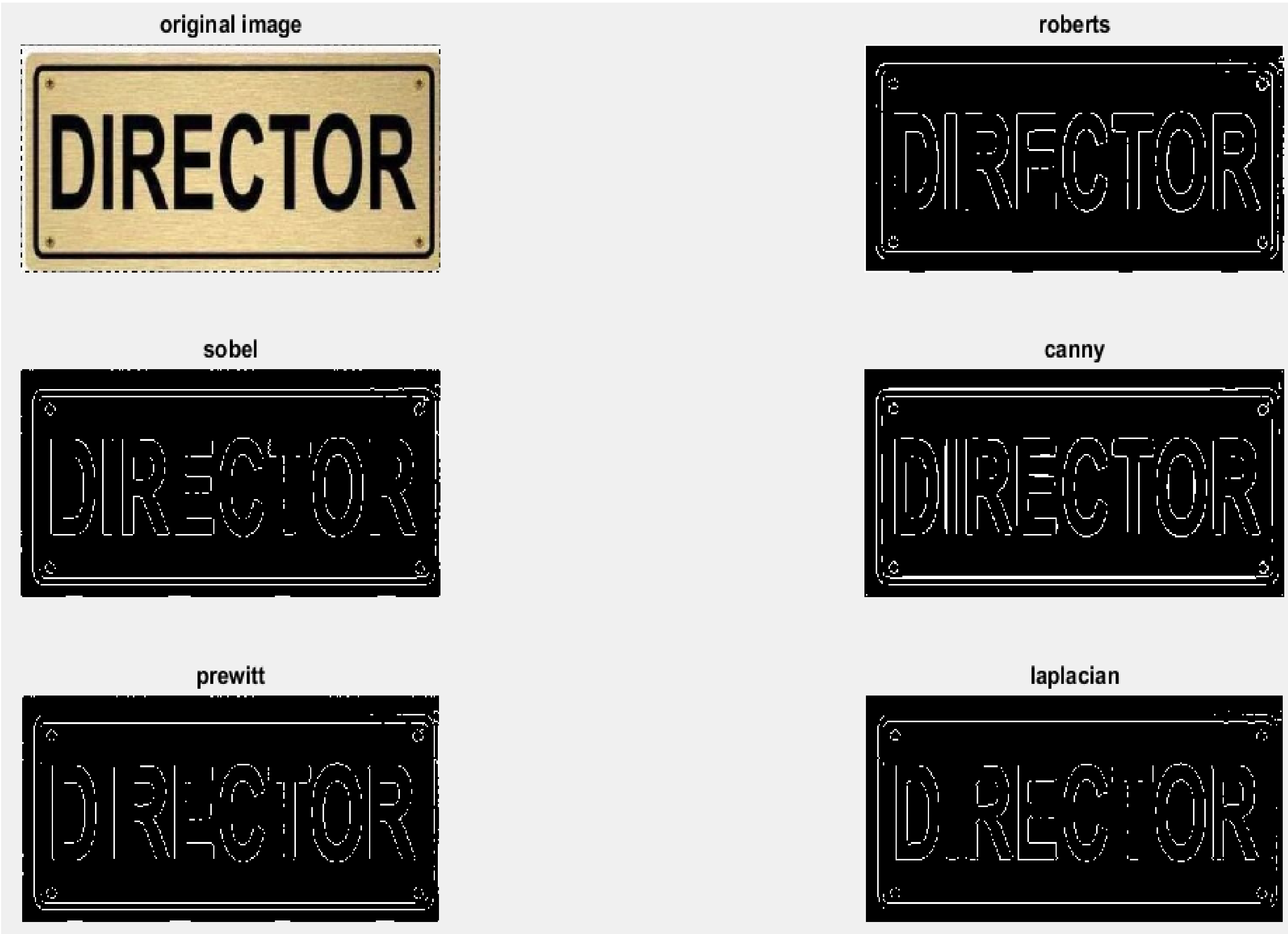
$$\nabla f(x, y) \cong |g_x| + |g_y|$$

- The gradient direction can be given as

$$\theta = \tan^{-1}\left(\frac{g_x}{g_y}\right)$$

Edge Detection

- The goal of edge detection is to mark the pixels in an image at which the gray level changes sharply.
- Gradient operators(First derivatives)
  - Prewitt, Sobel
- Laplacian operators (second derivatives)


original image
DIRECTOR
roberts
sobel
canny
prewitt
laplacian

- The gradient-based algorithm
  - The original image is convolved with both masks separately and the absolute values of the two outputs of the convolutions are added
  - Compute the edge magnitude and edge orientation
  - Compare the edge magnitude with a threshold value. If the edge magnitude is higher, assign it as a possible edge point

Prewitt Operator

- The prewitt method takes the central difference of the neighboring pixels
- This difference can be represented mathematically as

$$\frac{\partial f}{\partial x} = \frac{f(x+1) - f(x-1)}{2}$$

- The central difference can be obtained using the mask [-1 0 1]
- The prewitt approximation using 3 X 3 mask

$$\nabla f \cong \left|(z_7 + z_8 + z_9) - (z_1 + z_2 + z_3)\right| + \left|(z_3 + z_6 + z_9) - (z_1 + z_4 + z_7)\right|$$

$$M_x = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \qquad M_y = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

Sobel Operator

- The Sobel operator also relies on central differences

- Sobel operator is given as

$$\nabla f \cong \left|(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)\right| + \left|(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)\right|$$

Prewitt and Sobel

Prewitt

-1	**-1**	**-1**
0	0	0
1	1	1

-1	**0**	**1**
-1	0	1
-1	0	1

0	**1**	**1**
-1	0	1
-1	-1	0

-1	**-1**	**0**
-1	0	1
0	1	1

Sobel

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

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

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

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

- Prewitt masks are simpler to implement than the sobel mask
- Sobel masks have better noise suppression(smoothing) characteristics
- Sum of all coefficients in all the masks to zero, giving a response of zeros in areas of constant intensity

Second-order Derivative Filters

- Edge pixel is present at a location where the second derivative is zero.
- This can be observed as a sign change in pixel difference
- The Laplacian algorithm is one such zero crossing algorithm
- Very sensitive to noise- even small ripple causes the generation of edge point

- The second-order derivative is

$$\nabla \times \nabla = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

This ∇^2 operator is called Laplacian operator

The laplacian of f(x,y) is also defined as

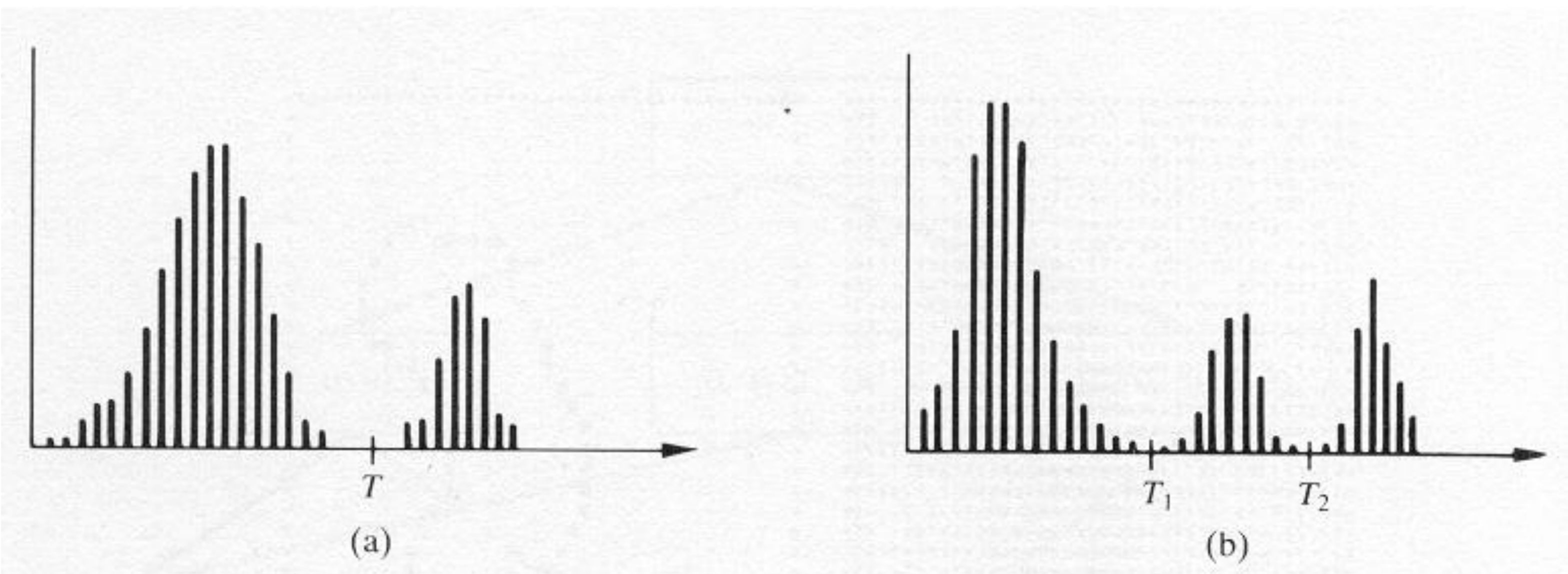
$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}$$

Laplacian Operators

0	**1**	**0**
1	-4	1
0	1	0

Thresholding

- Simple image segmentation techniques that is based on the grey level histogram of an image



- A thresholded image:

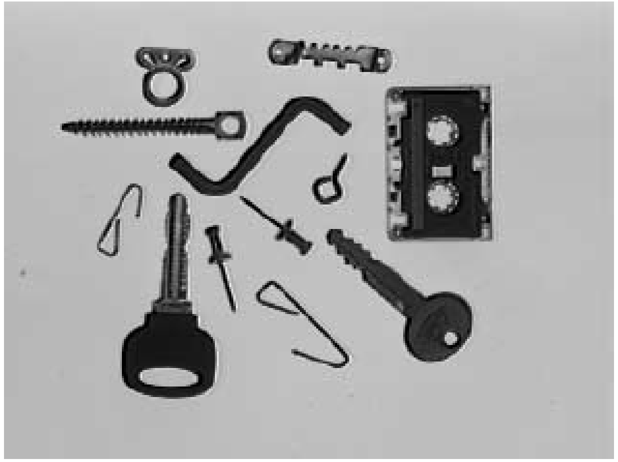
$$g(x,y)=\begin{cases}1 & \text{if} \quad f(x,y)>T & \text{(objects)}\\ 0 & \text{if} \quad f(x,y)\le T & \text{(background)}\end{cases}$$

- Thresholding can be viewed as an operation that involves tests against a function T of the form:

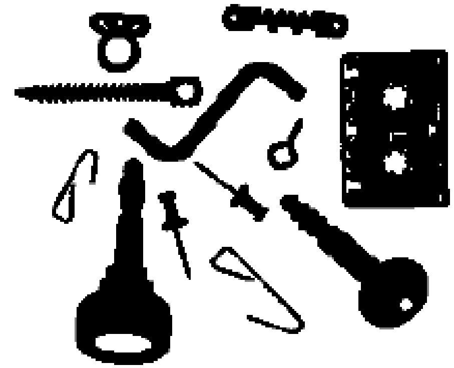
$$T = T[x, y, p(x,y), f(x,y)]$$

where p(x,y) denotes local property in a neighborhood centered at (x,y).

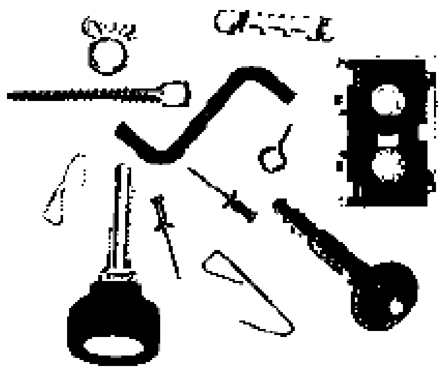
- When T depends only on f(x,y) → Global threshold
- When T depends on both f(x,y) and p(x,y) → Local threshold
- When T depends on x, y, f(x,y) and p(x,y) → Adaptive/Dynamic threshold



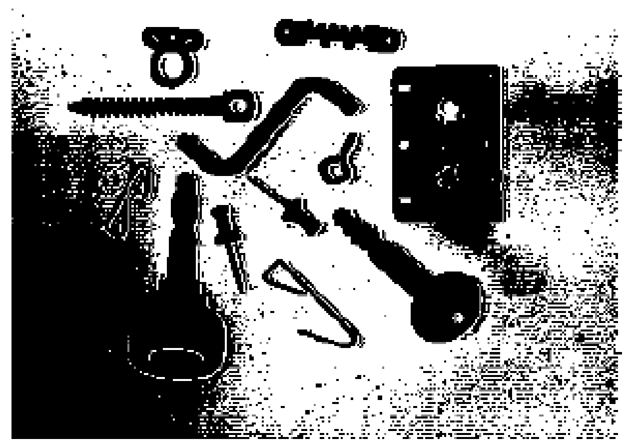
Original image.



Threshold segmentation.



Threshold too low.



Threshold too high.

Basic Global Thresholding

- Threshold midway between maximum and minimum gray levels
- Automatic algorithm (iterative algorithm)
  - Segment with initial *T into regions G1 and G2*
  - Compute the average gray level *m1 and m2*
  - Compute new $T=0.5(m1+m2)$
  - Repeat until reach an acceptably small change of *T* in successive iterations is smaller than a predefined parameter ΔT
  - ΔT is used to control the number of iterations