Image Segmentation

In previous modules we tried to improve the image for better visualization

Now we will try to retrieve some information from image for high level analysis

Image segmentation

- Division of an image into regions or categories, which correspond to different objects or parts of objects

To represent meaningful areas

Other applications such as number Plate detection, satelite imaging etc.

Image segmentation

Discontinuity based

- Partition is carried out based on abrupt change in intensity values

Focus is on identifying

1. Points
2. Lines
3. Edges

Similarity based

- Group those pixels which are similar in some sense

Techniques used such as

1. Thresholding
2. Region growing
3. Region splitting and merging

Discontinuity based image segmentation

- Main focus is to find isolated points, lines and edges in the image
- This can be achieved by application of mask like we have discussed in spatial filtering

$$R = w_1z_1 + w_2z_2 + \ldots + w_9z_9 = \sum_{i=1}^{9} w_i z_i$$

FIGURE 10.1 A general 3×3 mask.

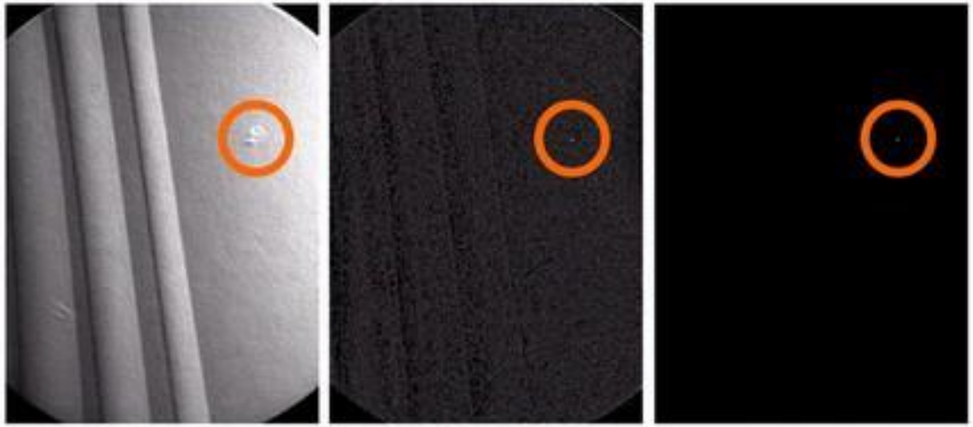
w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

OR

$$R = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

Discontinuity based image segmentation

- Isolated point detection



X-ray image of a turbine blade

Result of point detection

Result of thresholding

$$|R| > T$$

T is threshold value (non negative)

Discontinuity based image segmentation

- Line detection

Moving first mask over entire image
Detects points lying on horizontal line
We can apply all masks over image and Find the R value

$$|R_i| > |R_j| \ \forall \ \ i \neq j$$

Then line is having angle more likely
To the i^{th} mask

FIGURE 10.3 Line masks.

−1	−1	−1
2	2	2
−1	−1	−1

Horizontal

−1	−1	2
−1	2	−1
2	−1	−1

+45°

−1	2	−1
−1	2	−1
−1	2	−1

Vertical

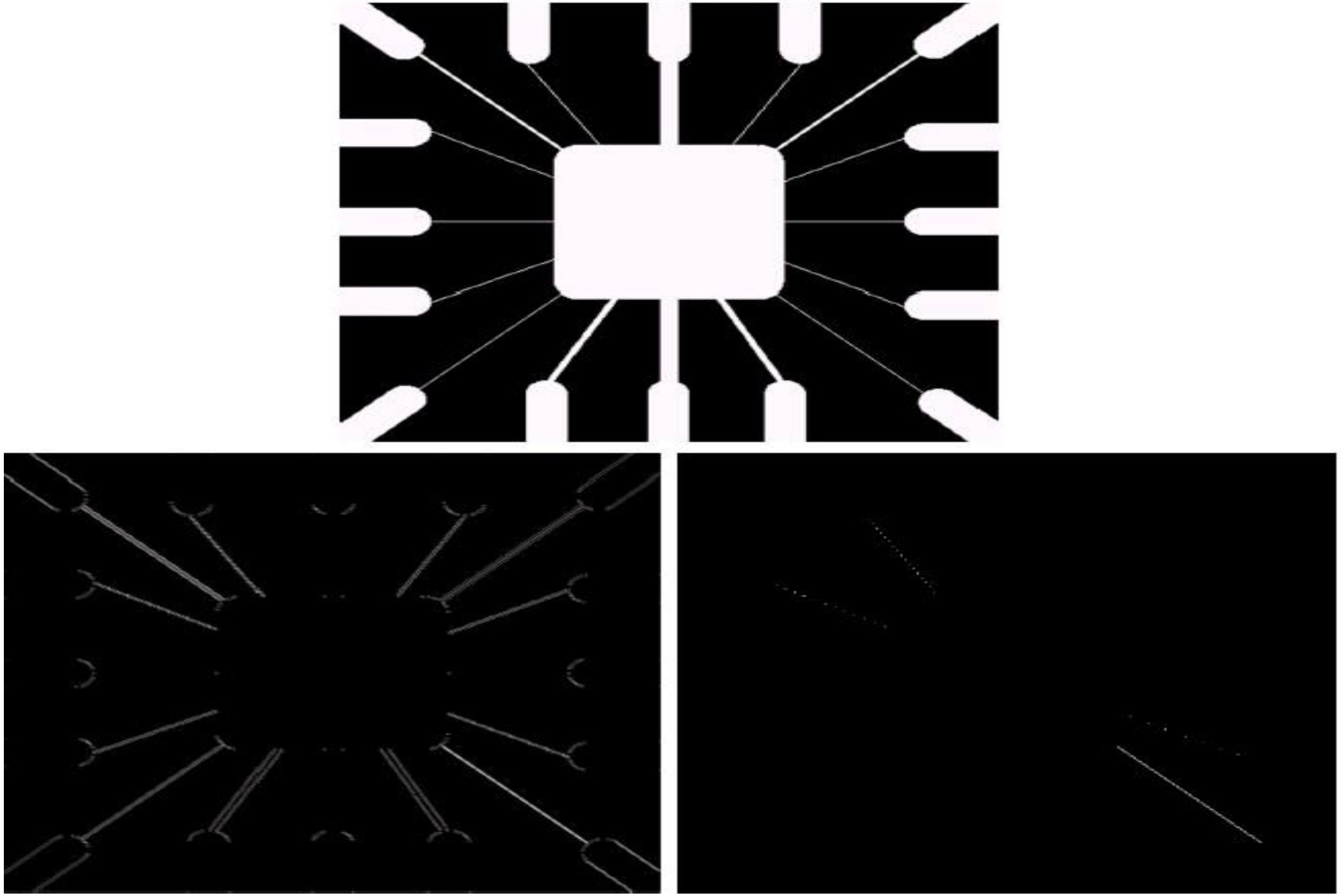
2	−1	−1
−1	2	−1
−1	−1	2

−45°

Discontinuity based image segmentation

- Edge detection: Detecting the discontinuity in image
- Edge: Boundary between two regions having distinct intensity values

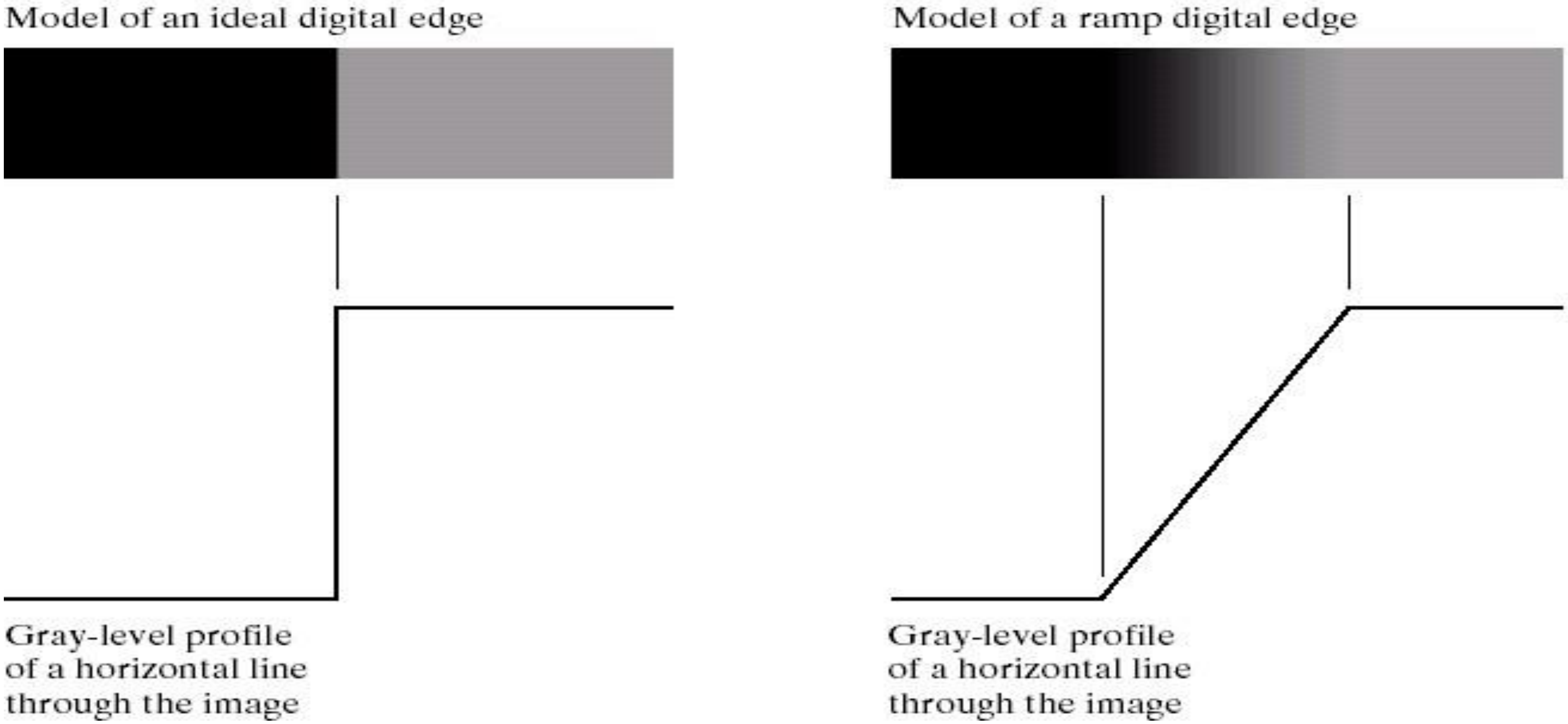
Detection of Discontinuities Line Detection



a
b c

FIGURE 10.4
Illustration of line detection.
(a) Binary wire-bond mask.
(b) Absolute value of result after processing with −45° line detector.
(c) Result of thresholding image (b).

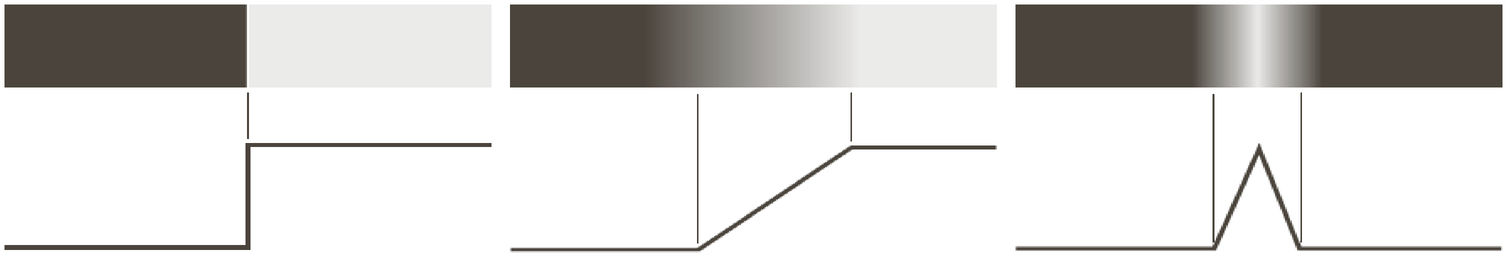
Detection of Discontinuities
Edge Detection



a b

FIGURE 10.5 (a) Model of an ideal digital edge. (b) Model of a ramp edge. The slope of the ramp is proportional to the degree of blurring in the edge.

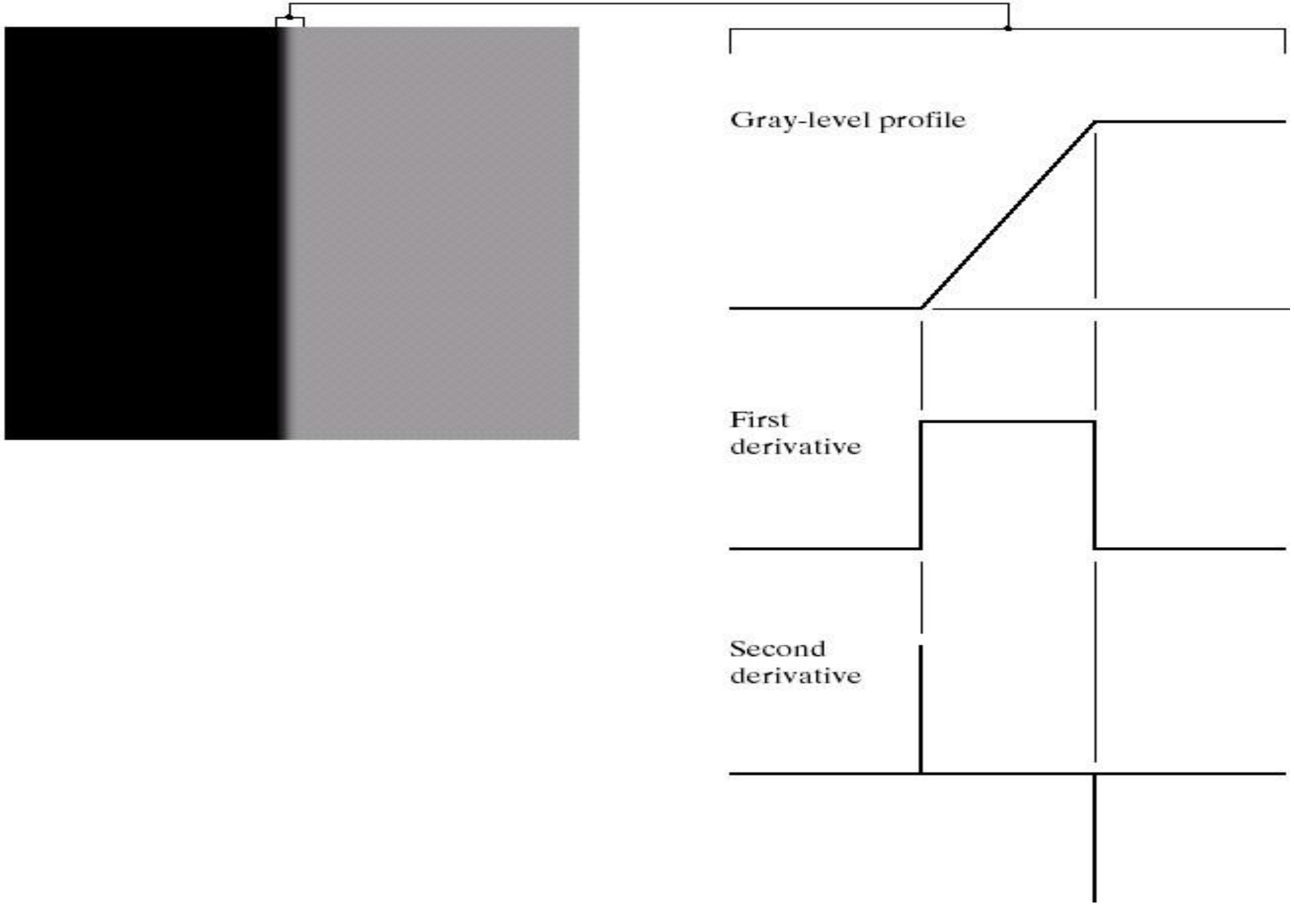
Detection of Discontinuities
Edge Detection



a b c

FIGURE 10.8 From left to right, models (ideal representations) of a step, a ramp, and a roof edge, and their corresponding intensity profiles.

Detection of Discontinuities
Edge Detection



a b

FIGURE 10.6
(a) Two regions separated by a vertical edge.
(b) Detail near the edge, showing a gray-level profile, and the first and second derivatives of the profile.

Detection of Discontinuities
Edge Detection

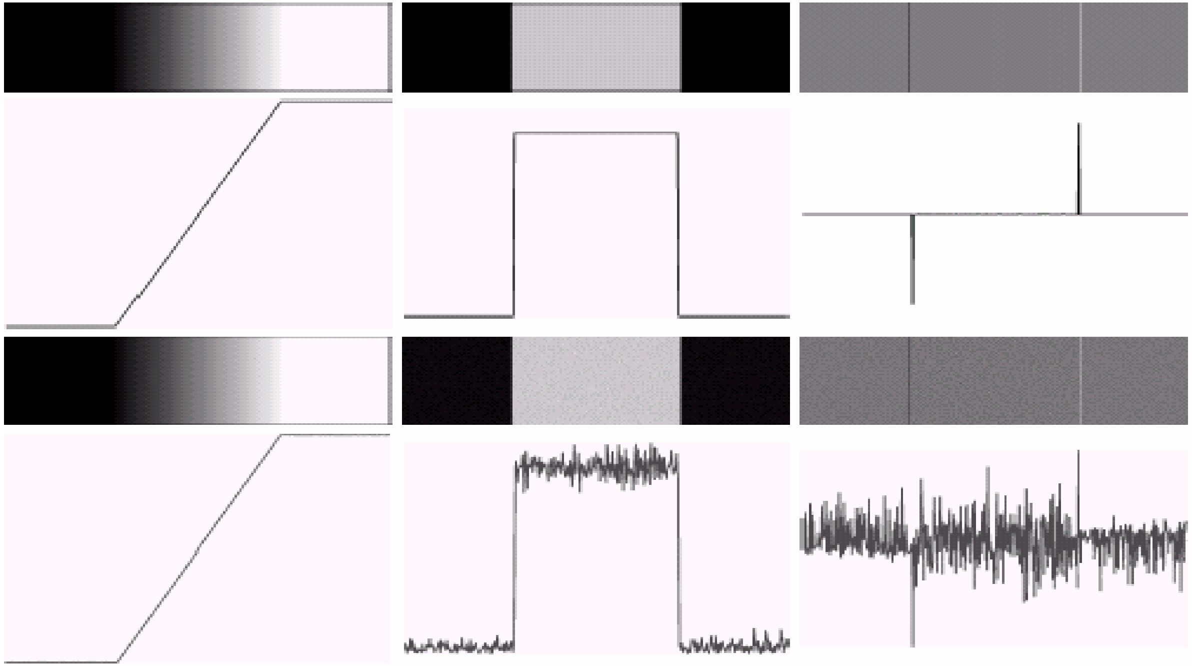


FIGURE 10.7 First column: images and gray-level profiles of a ramp edge corrupted by random Gaussian noise of mean 0 and σ = 0.0, 0.1, 1.0, and 10.0, respectively. Second column: first-derivative images and gray-level profiles. Third column: second-derivative images and gray-level profiles.

a b c d

Detection of Discontinuities
Gradient Operators

- First-order derivatives:
  - The gradient of an image *f*(*x*,*y*) at location (*x*,*y*) is defined as the vector:

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

  - The magnitude of this vector: $\nabla f = \text{mag}(\nabla \mathbf{f}) = \left[G_x^2 + G_y^2\right]^{1/2}$
  - The direction of this vector: $\alpha(x, y) = \tan^{-1}\left(\frac{G_x}{G_y}\right)$
  - It points in the direction of the greatest rate of change of *f* at location (x,y)

Detection of Discontinuities
Gradient Operators

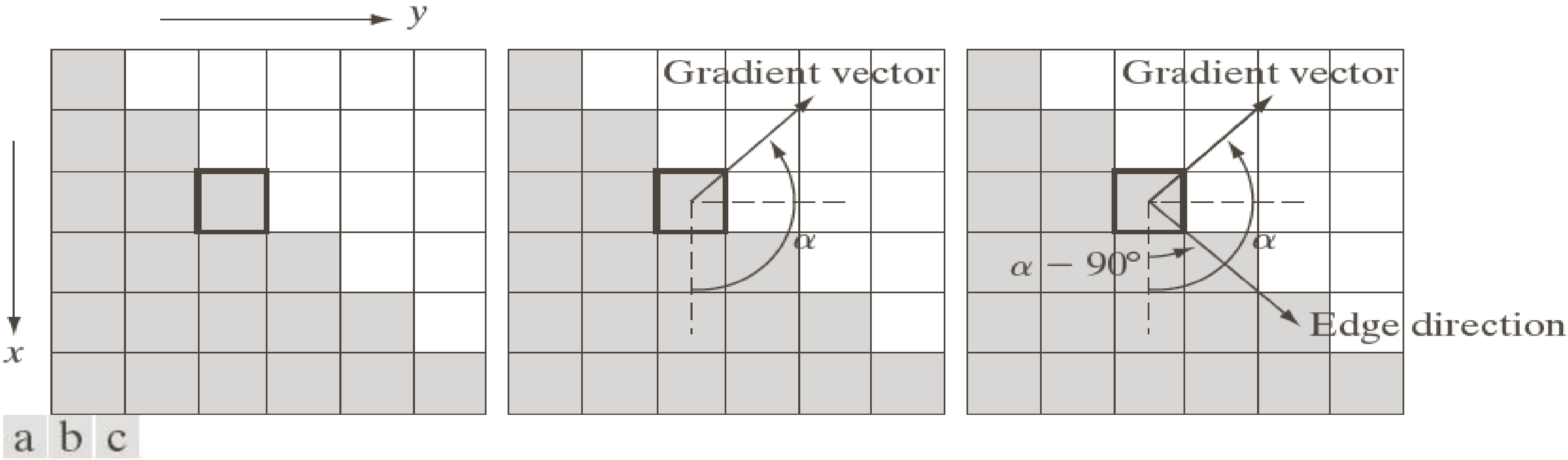


FIGURE 10.12 Using the gradient to determine edge strength and direction at a point. Note that the edge is perpendicular to the direction of the gradient vector at the point where the gradient is computed. Each square in the figure represents one pixel.

Detection of Discontinuities
Gradient Operators

Roberts cross-gradient operators

−1	0		0	−1
0	1		1	0

Roberts

Prewitt operators

−1	−1	−1		−1	0	1
0	0	0		−1	0	1
1	1	1		−1	0	1

Prewitt

Sobel operators

−1	−2	−1		−1	0	1
0	0	0		−2	0	2
1	2	1		−1	0	1

Sobel

Detection of Discontinuities
Gradient Operators

Prewitt masks for detecting diagonal edges

Sobel masks for detecting diagonal edges

0	1	1
−1	0	1
−1	−1	0

−1	−1	0
−1	0	1
0	1	1

Prewitt

0	1	2
−1	0	1
−2	−1	0

−2	−1	0
−1	0	1
0	1	2

Sobel

a	b
c	d

FIGURE 10.9 Prewitt and Sobel masks for detecting diagonal edges.

Edge detection

- Prewitt edge operator

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

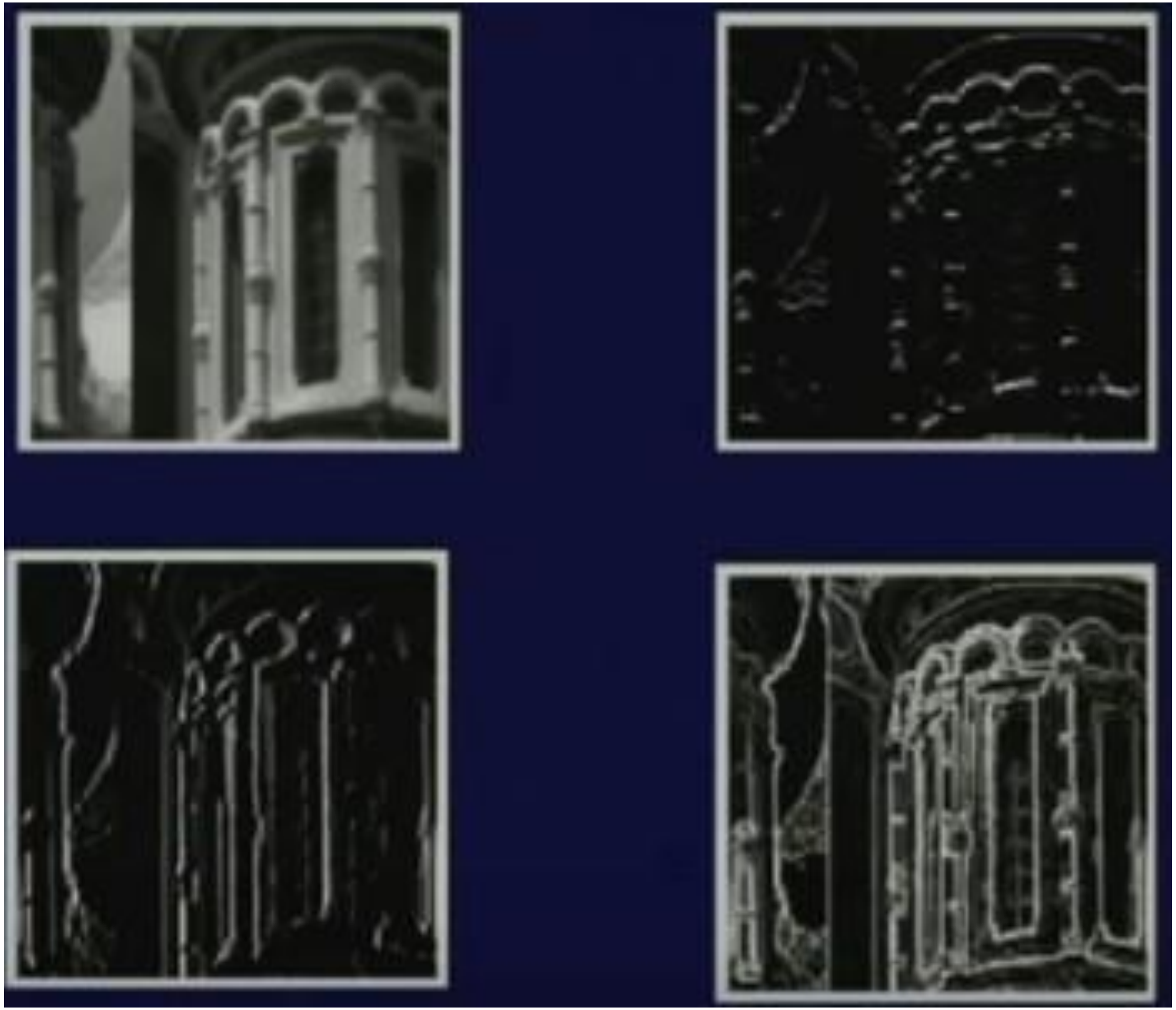
Horizontal Vertical

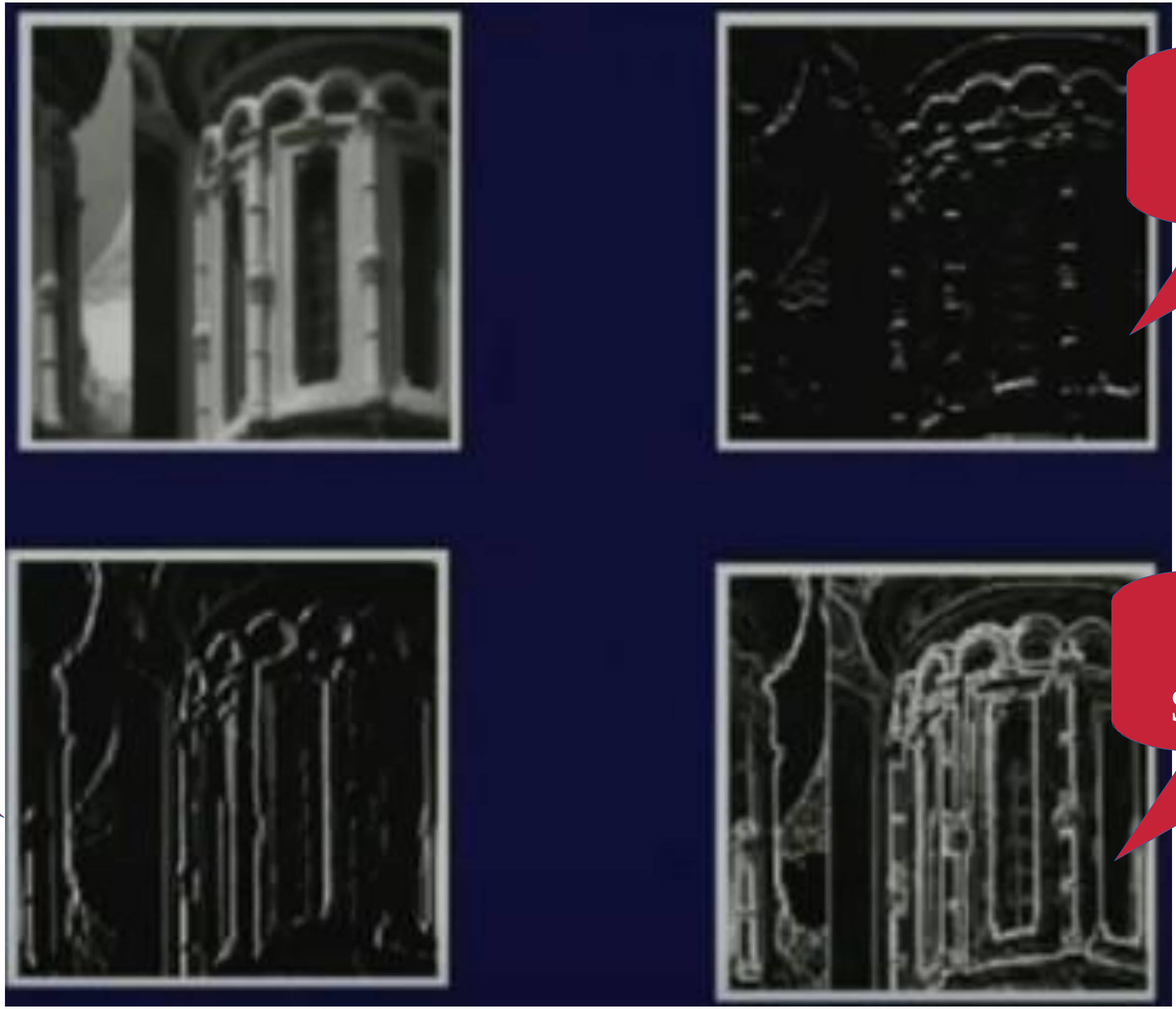
sobel edge operator

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Horizontal Vertical

These are first order derivative operators





Input Image

Output Image
By horizontal
Sobel operator

Output Image
By vertical
Sobel operator

Output Image
By combined
Sobel operator

Detection of Discontinuities
Gradient Operators: Example

a b
c d

FIGURE 10.10 (a) Original image. (b) $|G_x|$, component of the gradient in the x-direction. (c) $|G_y|$, component in the y-direction. (d) Gradient image, $|G_x| + |G_y|$.

$$\nabla f \approx |G_x| + |G_y|$$

Detection of Discontinuities
Gradient Operators: Example

FIGURE 10.11 Same sequence as in Fig. 10.10, but with the original image smoothed with a 5 × 5 averaging filter.

Detection of Discontinuities
Gradient Operators: Example

a b

FIGURE 10.12 Diagonal edge detection. (a) Result of using the mask in Fig. 10.9(c). (b) Result of using the mask in Fig. 10.9(d). The input in both cases was Fig. 10.11(a).

0	1	2
−1	0	1
−2	−1	0

−2	−1	0
−1	0	1
0	1	2

Detection of Discontinuities
Gradient Operators: Example

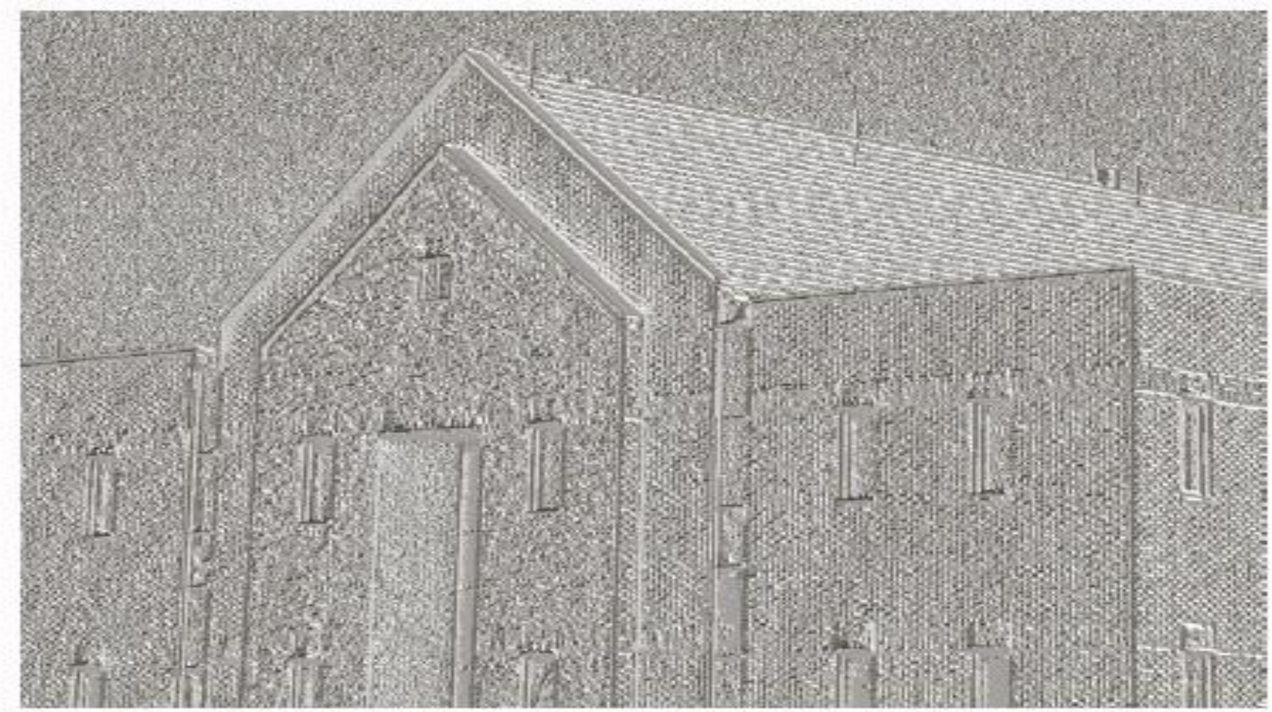


FIGURE 10.17
Gradient angle image computed using Eq. (10.2-11). Areas of constant intensity in this image indicate that the direction of the gradient vector is the same at all the pixel locations in those regions.

Detection of Discontinuities
Gradient Operators

- Second-order derivatives: (The Laplacian)
  - The Laplacian of an 2D function *f*(*x*,*y*) is defined as

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

  - Two forms in practice:

FIGURE 10.13 Laplacian masks used to implement Eqs. (10.1-14) and (10.1-15), respectively.

0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

Edge detection

- Second derivative operator -Laplacian

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

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

- Generally not used, because it is very sensetive to noise
- To reduce the effect of noise first image is smoothened

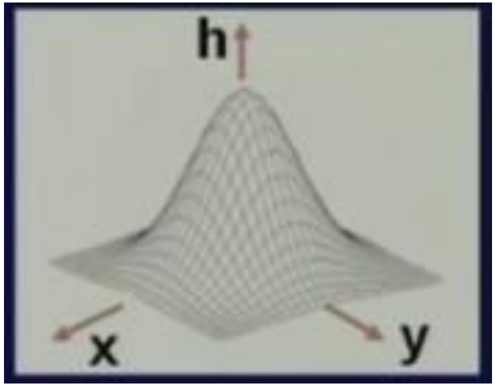
Edge detection

- For smoothening purpose Gaussian operator is used
- After smoothening Laplacian operator is applied
- This is called as Laplacian of Gaussian (LoG)
- This will reduces the effect of noise

Edge detection

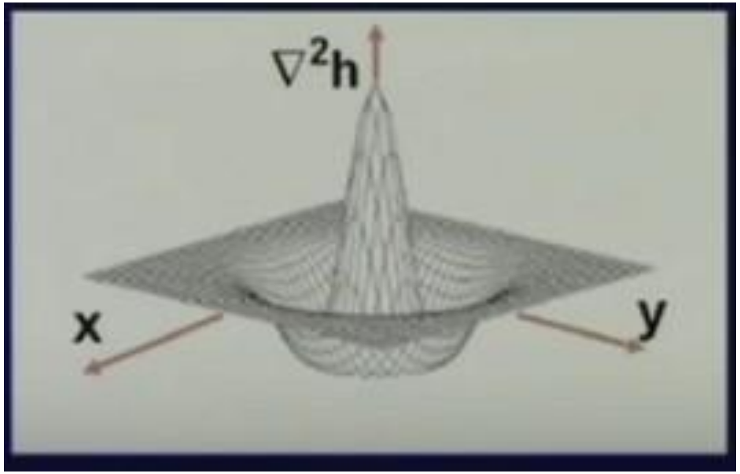
- Gaussian mask:

$$h(x,y) = e^{\frac{-x^2 + y^2}{2\sigma^2}}$$



- Laplacian of Gaussian

$$\nabla^2 h(x,y) = \frac{(r^2 - \sigma^2)}{\sigma^4} \cdot e^{\frac{-x^2 + y^2}{2\sigma^2}}$$



Ref: https: //en.wikipedia.org/wiki/Laplace%27s_equation

Edge detection

LoG identifies location
Of edge in image

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

LoG mask

Input Image

Sobel Output Image

LoG Output Image