# Sharpening Filters

# Sharpening (change detection)

1. First derivative
   a) must be zero in areas of constant intensity
   b) must be nonzero at the onset of an intensity step or ramp
   c) must be nonzero along ramps
2. Second derivative
   a) must be zero in constant areas
   b) must be nonzero at the onset and end of an intensity step or ramp
   c) must be zero along ramps of constant slope

# Sharpening (change detection)

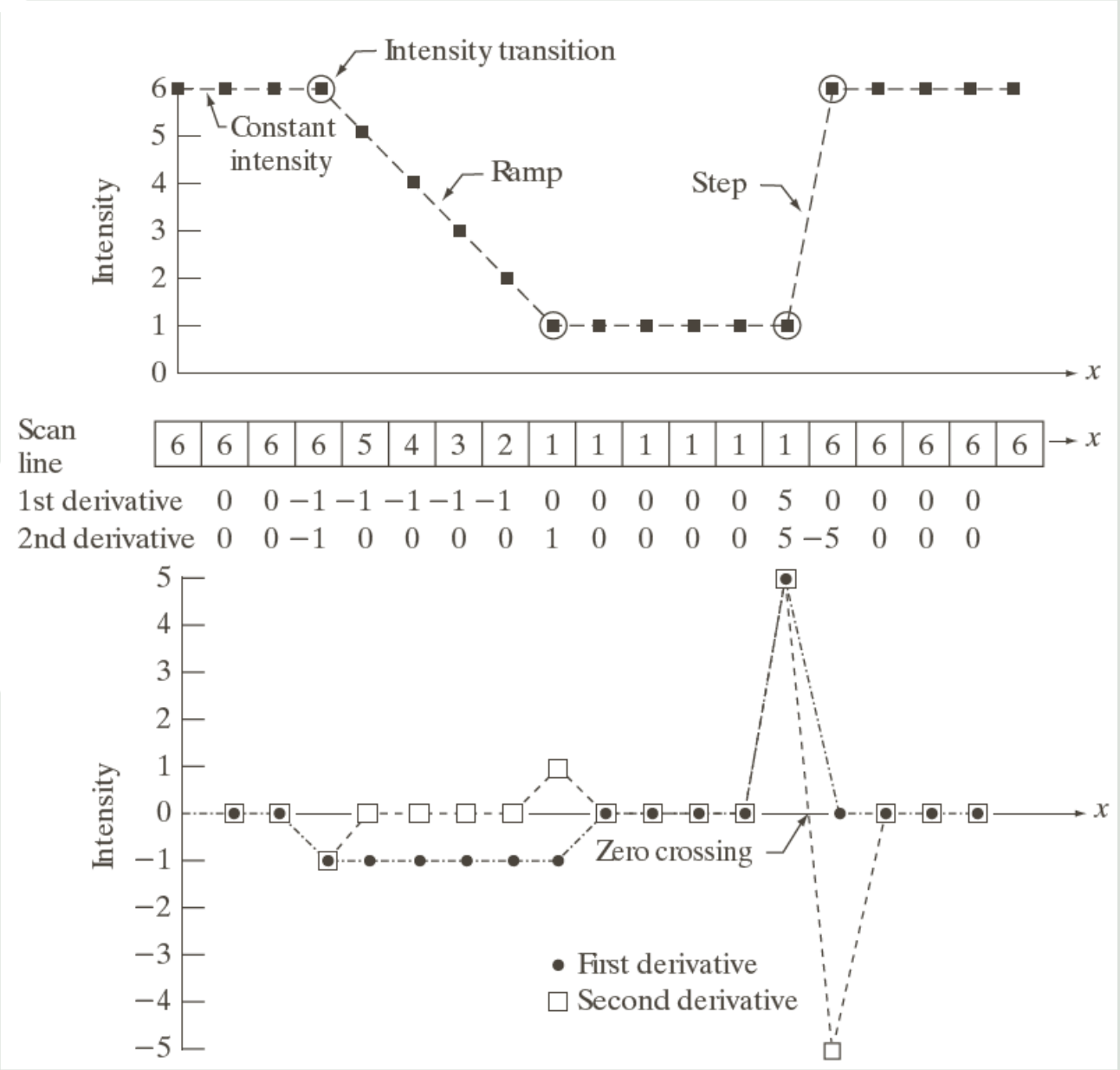
1. First derivative

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

2. Second derivative

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

# Performance of derivatives




a
b
c

**FIGURE 3.36** Illustration of the first and second derivatives of a 1-D digital function representing a section of a horizontal intensity profile from an image. In (a) and (c) data points are joined by dashed lines as a visualization aid.

# Gradient (first derivative)

$$\nabla f \equiv \text{grad}(f) \equiv \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

$$M(x, y) = \text{mag}(\nabla f) = \sqrt{g_x^2 + g_y^2}$$

$$M(x, y) \approx |g_x| + |g_y|$$

$$\alpha(x, y) = \tan^{-1}\left[\frac{g_y}{g_x}\right]$$

# Gradient operators

$$g_x = \frac{\partial f(x, y)}{\partial x} = f(x + 1, y) - f(x, y)$$

$$g_y = \frac{\partial f(x, y)}{\partial y} = f(x, y + 1) - f(x, y)$$

# Gradient operators

| | | |
|---|---|---|
| $z_1$ | $z_2$ | $z_3$ |
| $z_4$ | $z_5$ | $z_6$ |
| $z_7$ | $z_8$ | $z_9$ |

| | |
|---|---|
| −1 | 0 |
| 0 | 1 |

| | |
|---|---|
| 0 | −1 |
| 1 | 0 |

Roberts

| | | |
|---|---|---|
| −1 | −1 | −1 |
| 0 | 0 | 0 |
| 1 | 1 | 1 |

| | | |
|---|---|---|
| −1 | 0 | 1 |
| −1 | 0 | 1 |
| −1 | 0 | 1 |

Prewitt

| | | |
|---|---|---|
| −1 | −2 | −1 |
| 0 | 0 | 0 |
| 1 | 2 | 1 |

| | | |
|---|---|---|
| −1 | 0 | 1 |
| −2 | 0 | 2 |
| −1 | 0 | 1 |

Sobel

a
b c
d e
f g

**FIGURE 10.14**
A 3 × 3 region of an image (the $z$'s are intensity values) and various masks used to compute the gradient at the point labeled $z_5$.

# Gradient operators

| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 1 | −1 | −1 | 0 |
| −1 | 0 | 1 | −1 | 0 | 1 |
| −1 | −1 | 0 | 0 | 1 | 1 |

Prewitt

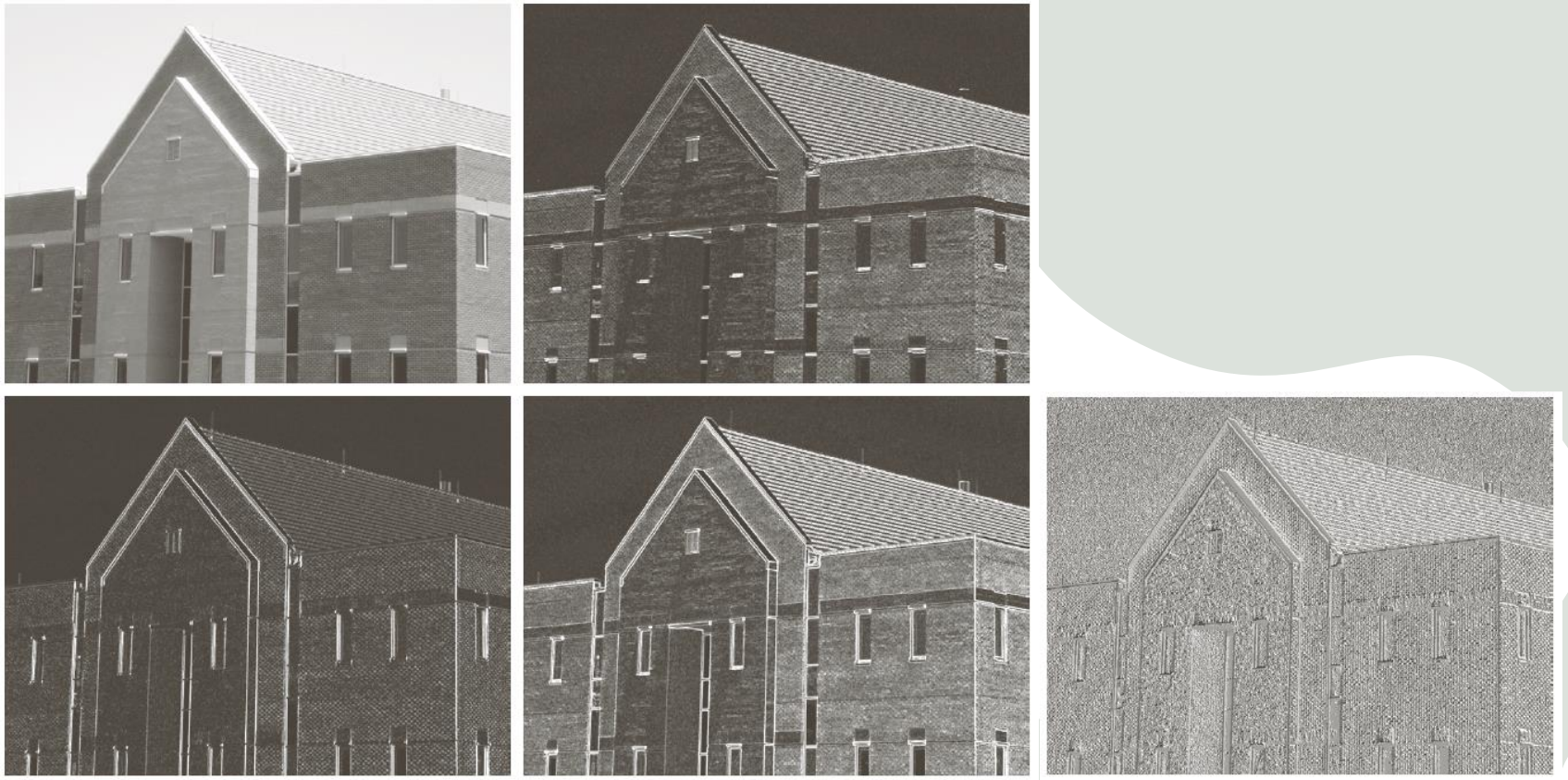
| | | | | | |
|---|---|---|---|---|---|
| 0 | 1 | 2 | −2 | −1 | 0 |
| −1 | 0 | 1 | −1 | 0 | 1 |
| −2 | −1 | 0 | 0 | 1 | 2 |

Sobel

a b
c d

**FIGURE 10.15** Prewitt and Sobel masks for detecting diagonal edges.

# Gradient operators

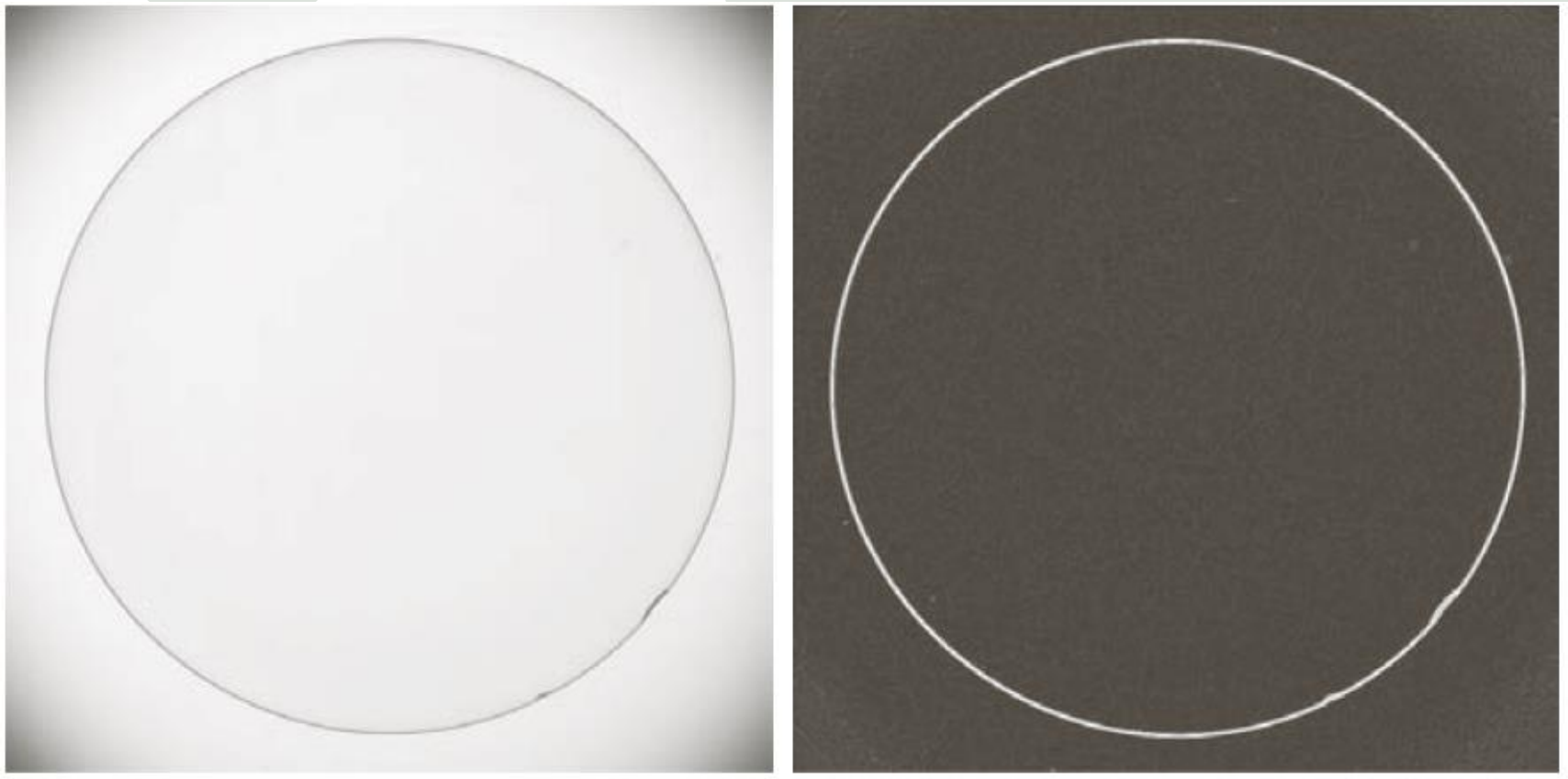


a b
c d

**FIGURE 10.16**
(a) Original image of size 834 × 1114 pixels, with intensity values scaled to the range [0, 1]. (b) $|g_x|$, the component of the gradient in the $x$-direction, obtained using the Sobel mask in Fig. 10.14(f) to filter the image. (c) $|g_y|$, obtained using the mask in Fig. 10.14(g). (d) The gradient image, $|g_x| + |g_y|$.

**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.

# Gradient operators



a b

**FIGURE 3.42**
(a) Optical image of contact lens (note defects on the boundary at 4 and 5 o'clock). (b) Sobel gradient. (Original image courtesy of Pete Sites, Perceptics Corporation.)

# Sobel Gradient operator in OpenCV

Sobel(src, dst, ddepth, dx, dy)

Sobel(input, horizontal_derivative, CV_32F, 1, 0);

Sobel(input, vertical_derivative, CV_32F, 0, 1);