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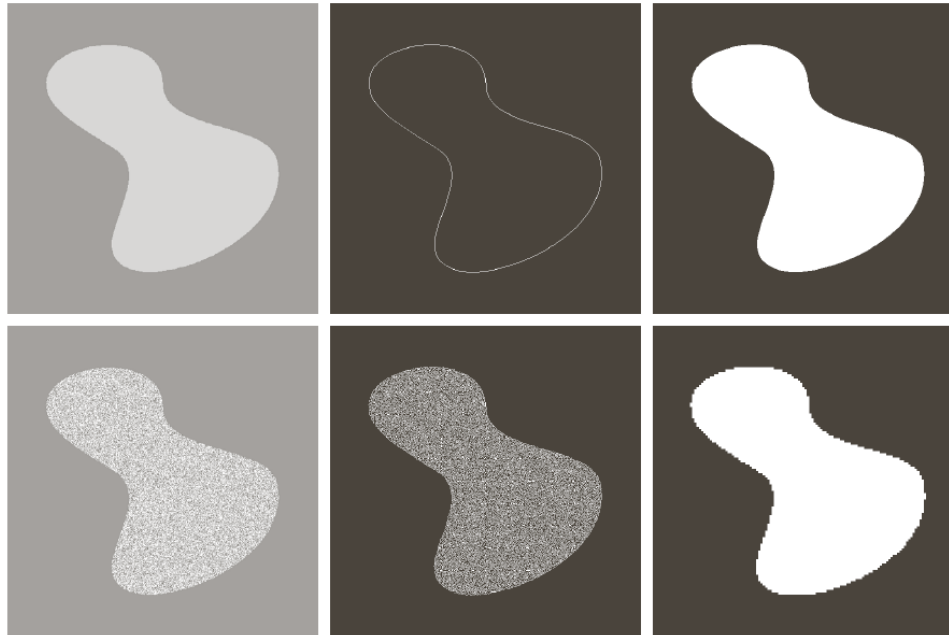


FIGURE 10.1 (a) Image containing a region of constant intensity. (b) Image showing the boundary of the inner region, obtained from intensity discontinuities. (c) Result of segmenting the image into two regions. (d) Image containing a textured region. (e) Result of edge computations. Note the large number of small edges that are connected to the original boundary, making it difficult to find a unique boundary using only edge information. (f) Result of segmentation based on region properties.



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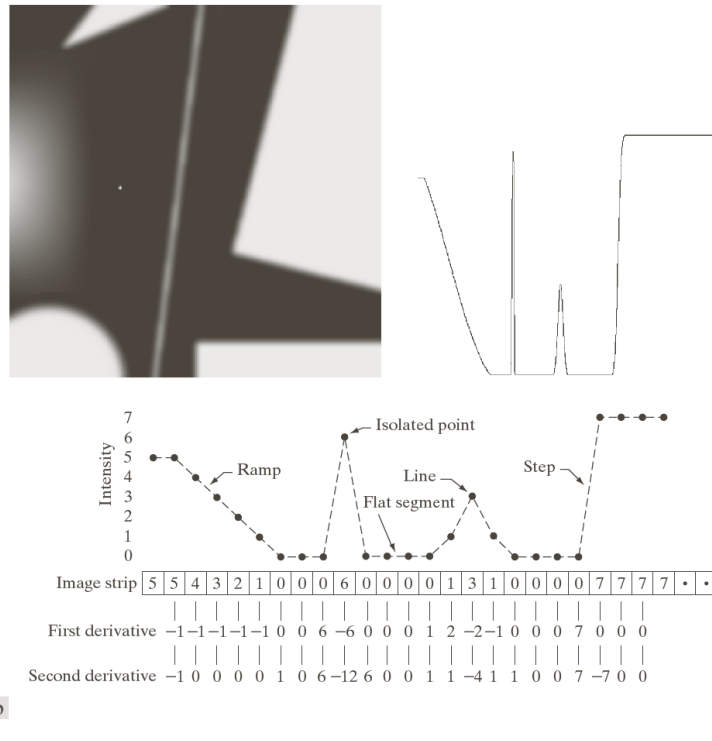
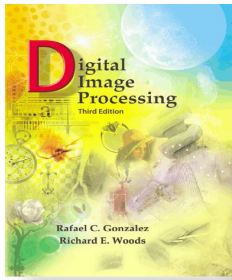


FIGURE 10.2 (a) Image. (b) Horizontal intensity profile through the center of the image, including the isolated noise point. (c) Simplified profile (the points are joined by dashes for clarity). The image strip corresponds to the intensity profile, and the numbers in the boxes are the intensity values of the dots shown in the profile. The derivatives were obtained using Eqs. (10.2-1) and (10.2-2).



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w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

FIGURE 10.3

A general 3×3
spatial filter mask.



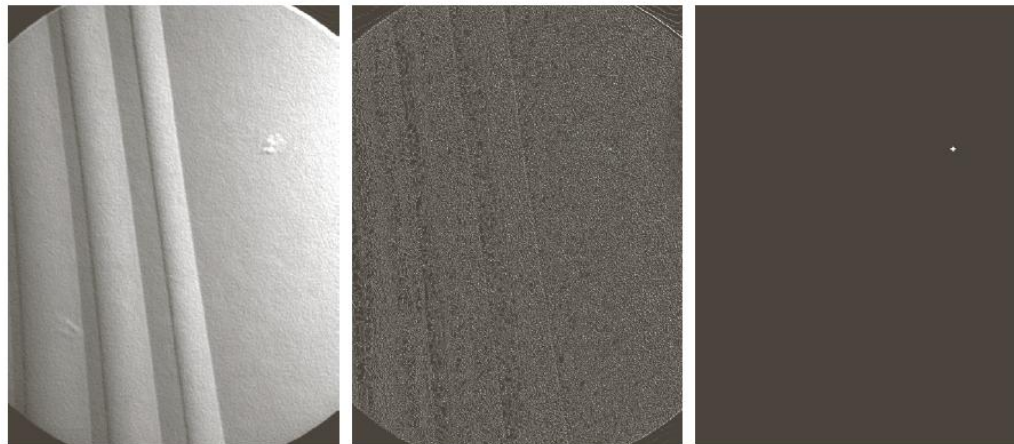
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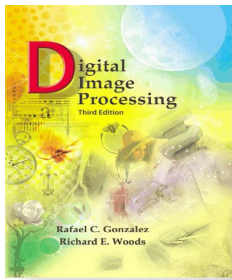
1	1	1
1	-8	1
1	1	1



a
b c d

FIGURE 10.4

(a) Point detection (Laplacian) mask. (b) X-ray image of turbine blade with a porosity. The porosity contains a single black pixel. (c) Result of convolving the mask with the image. (d) Result of using Eq. (10.2-8) showing a single point (the point was enlarged to make it easier to see). (Original image courtesy of X-TEK Systems, Ltd.)



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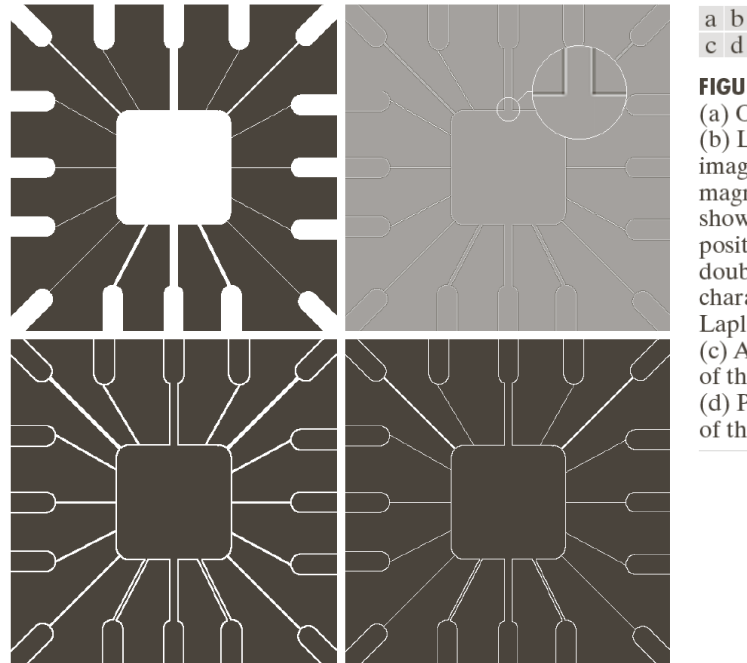
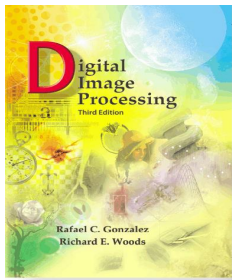


FIGURE 10.5

(a) Original image.
(b) Laplacian image; the magnified section shows the positive/negative double-line effect characteristic of the Laplacian.
(c) Absolute value of the Laplacian.
(d) Positive values of the Laplacian.



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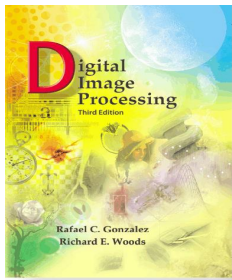
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-1	-1	-1	2	-1	-1	-1	2	-1	-1	-1	2
2	2	2	-1	2	-1	-1	2	-1	-1	2	-1
-1	-1	-1	-1	-1	2	-1	2	-1	2	-1	-1
Horizontal			+45°			Vertical			-45°		

FIGURE 10.6 Line detection masks. Angles are with respect to the axis system in Fig. 2.18(b).

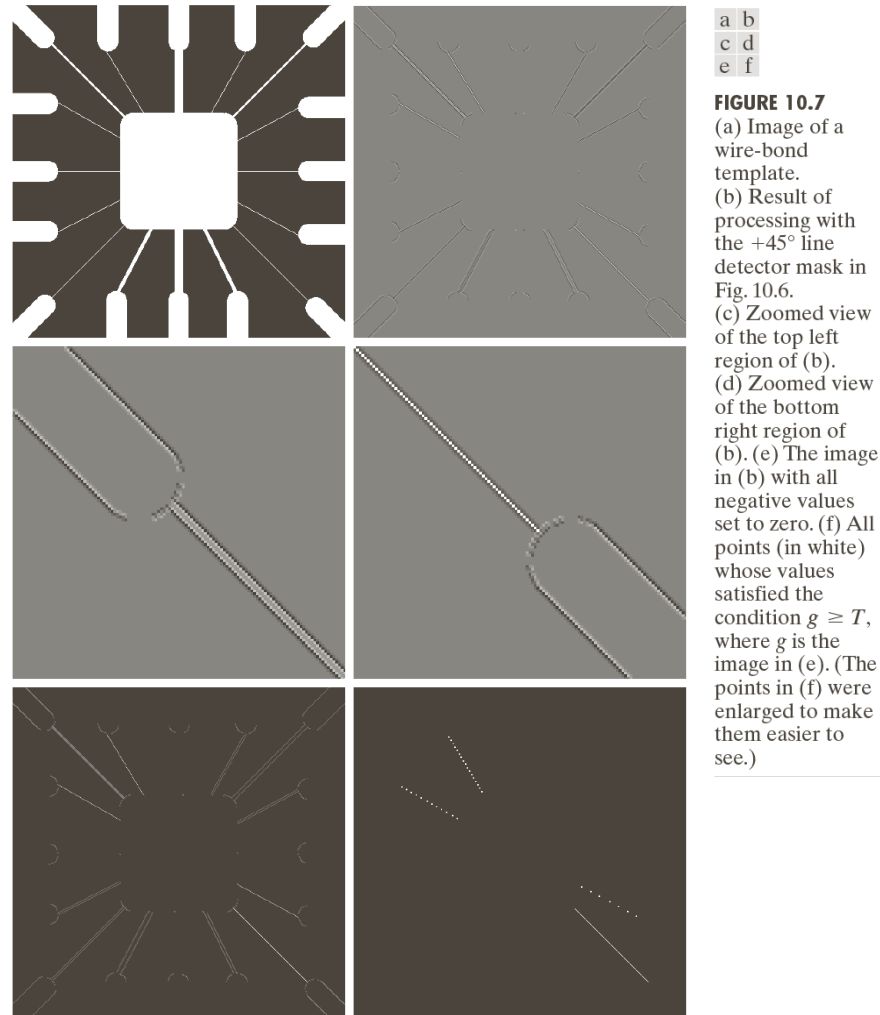


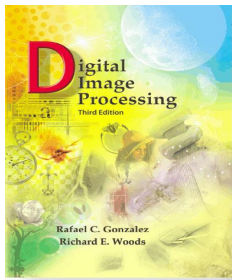
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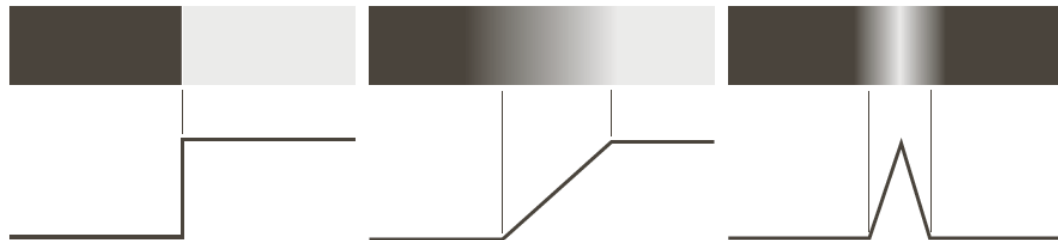


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a b c

FIGURE 10.8

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



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FIGURE 10.9 A 1508×1970 image showing (zoomed) actual ramp (bottom, left), step (top, right), and roof edge profiles. The profiles are from dark to light, in the areas indicated by the short line segments shown in the small circles. The ramp and “step” profiles span 9 pixels and 2 pixels, respectively. The base of the roof edge is 3 pixels. (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

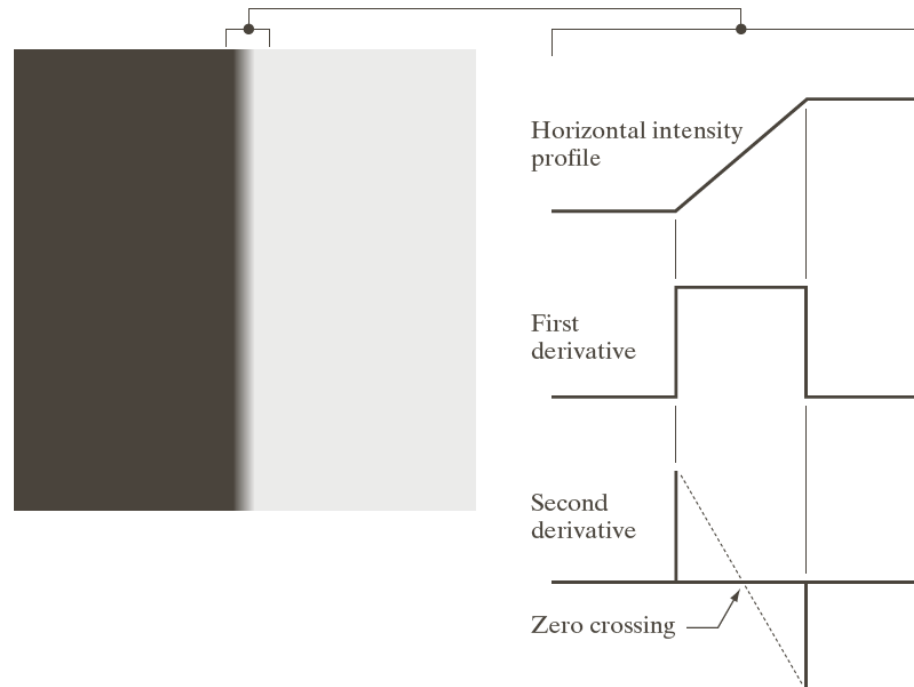


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a b

FIGURE 10.10

(a) Two regions of constant intensity separated by an ideal vertical ramp edge.

(b) Detail near the edge, showing a horizontal intensity profile, together with its first and second derivatives.



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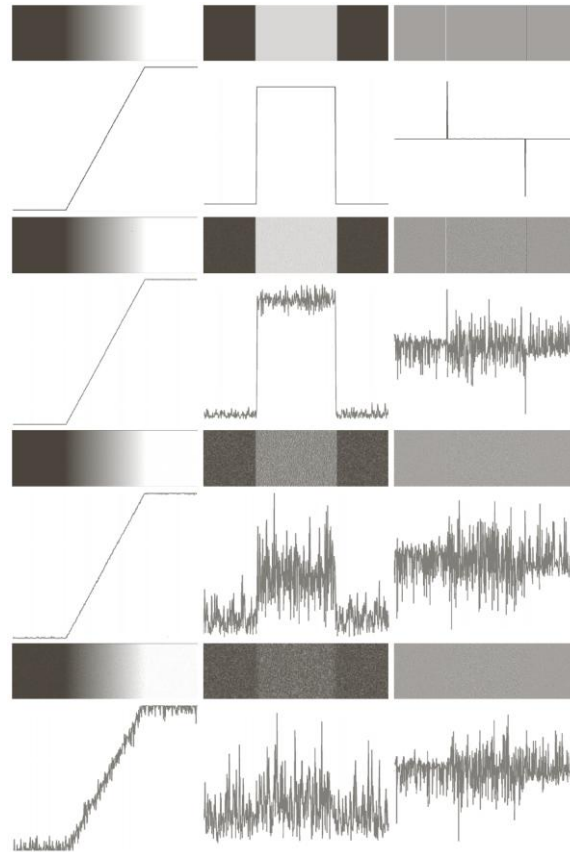


FIGURE 10.11 First column: Images and intensity profiles of a ramp edge corrupted by random Gaussian noise of zero mean and standard deviations of 0.0, 0.1, 1.0, and 10.0 intensity levels, respectively. Second column: First-derivative images and intensity profiles. Third column: Second-derivative images and intensity profiles.



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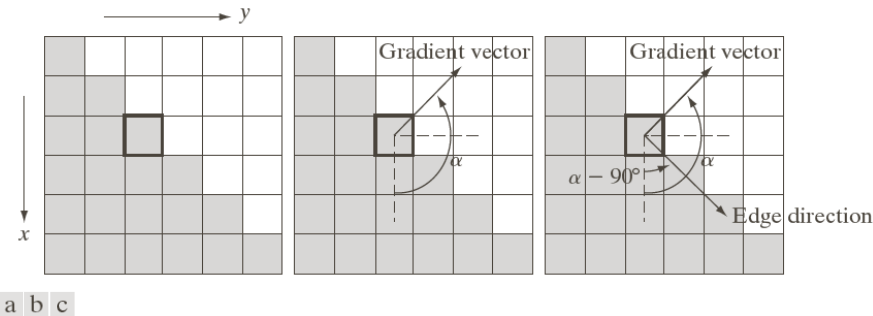
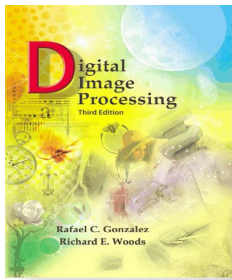


FIGURE 10.12 Using the gradient to determine edge strength and direction at a point. Note that the edge is perpendicular to the direction of the gradient vector at the point where the gradient is computed. Each square in the figure represents one pixel.



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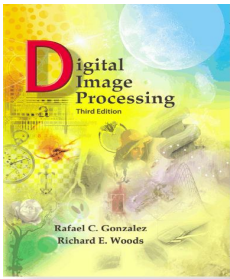
Chapter 10 Segmentation

-1
1

-1	1
----	---

a b

FIGURE 10.13
One-dimensional
masks used to
implement Eqs.
(10.2-12) and
(10.2-13).



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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	-1	0	1
0	0	0	-1	0	1
1	1	1	-1	0	1

Prewitt

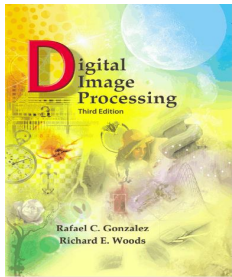
-1	-2	-1	-1	0	1
0	0	0	-2	0	2
1	2	1	-1	0	1

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 .



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0	1	1	-1	-1	0
-1	0	1	-1	0	1
-1	-1	0	0	1	1

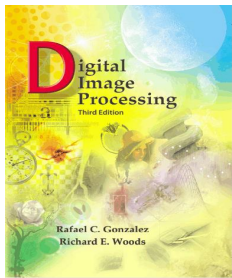
Prewitt

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.



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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, $|g_x| + |g_y|$.



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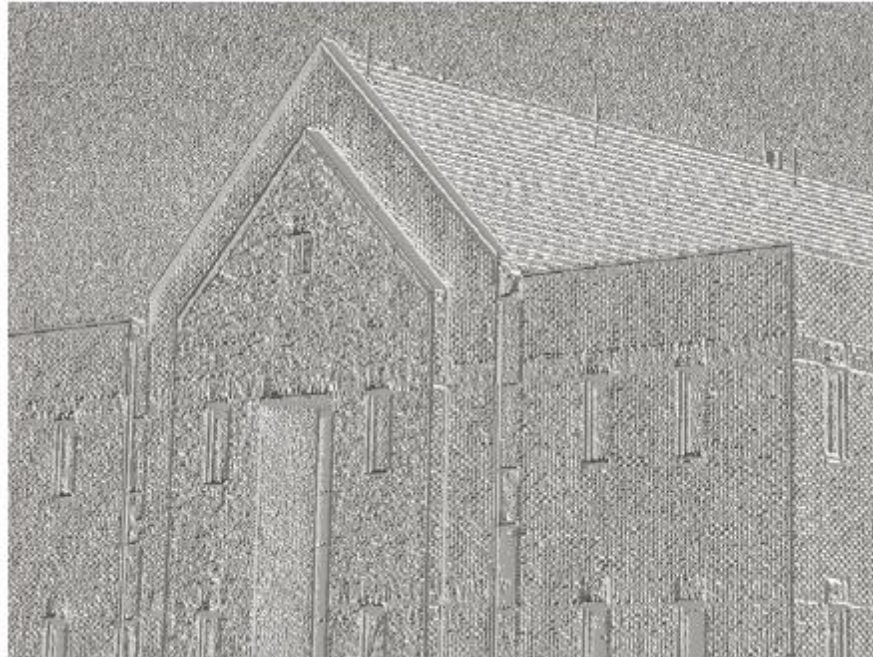
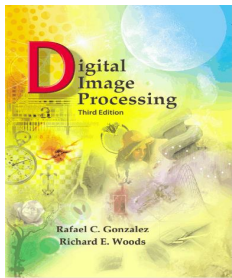


FIGURE 10.17

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.



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a	b
c	d

FIGURE 10.18

Same sequence as in Fig. 10.16, but with the original image smoothed using a 5×5 averaging filter prior to edge detection.



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a b

FIGURE 10.19
Diagonal edge
detection.

(a) Result of
using the mask in
Fig. 10.15(c).
(b) Result of
using the mask in
Fig. 10.15(d). The
input image in
both cases was
Fig. 10.18(a).

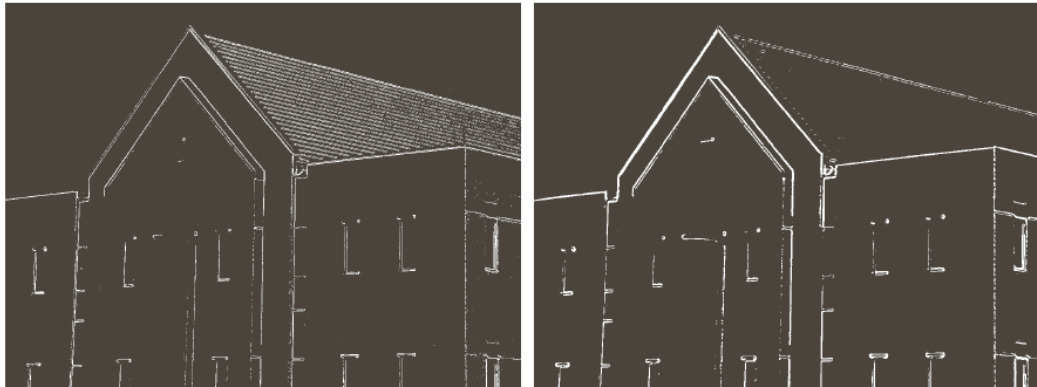


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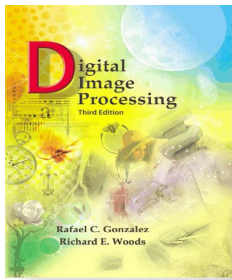
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a b

FIGURE 10.20 (a) Thresholded version of the image in Fig. 10.16(d), with the threshold selected as 33% of the highest value in the image; this threshold was just high enough to eliminate most of the brick edges in the gradient image. (b) Thresholded version of the image in Fig. 10.18(d), obtained using a threshold equal to 33% of the highest value in that image.

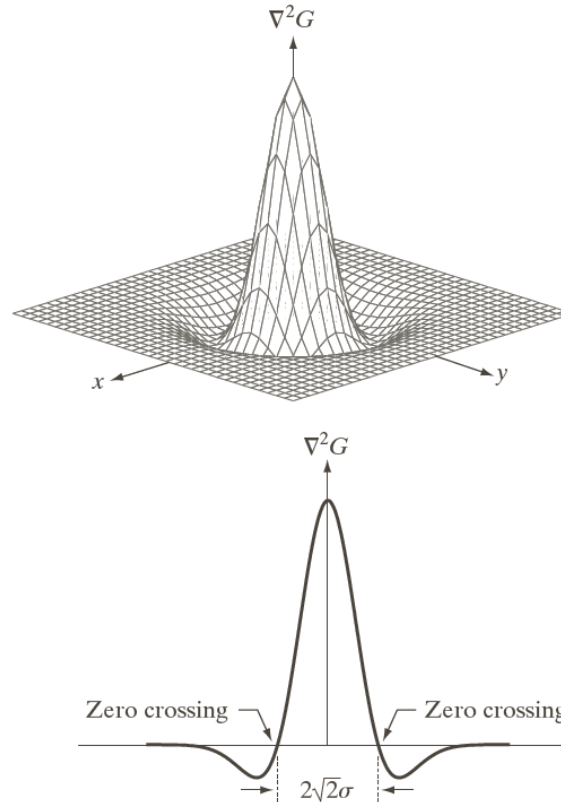


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a b
c d

FIGURE 10.21

(a) Three-dimensional plot of the *negative* of the LoG. (b) Negative of the LoG displayed as an image. (c) Cross section of (a) showing zero crossings. (d) 5×5 mask approximation to the shape in (a). The negative of this mask would be used in practice.

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

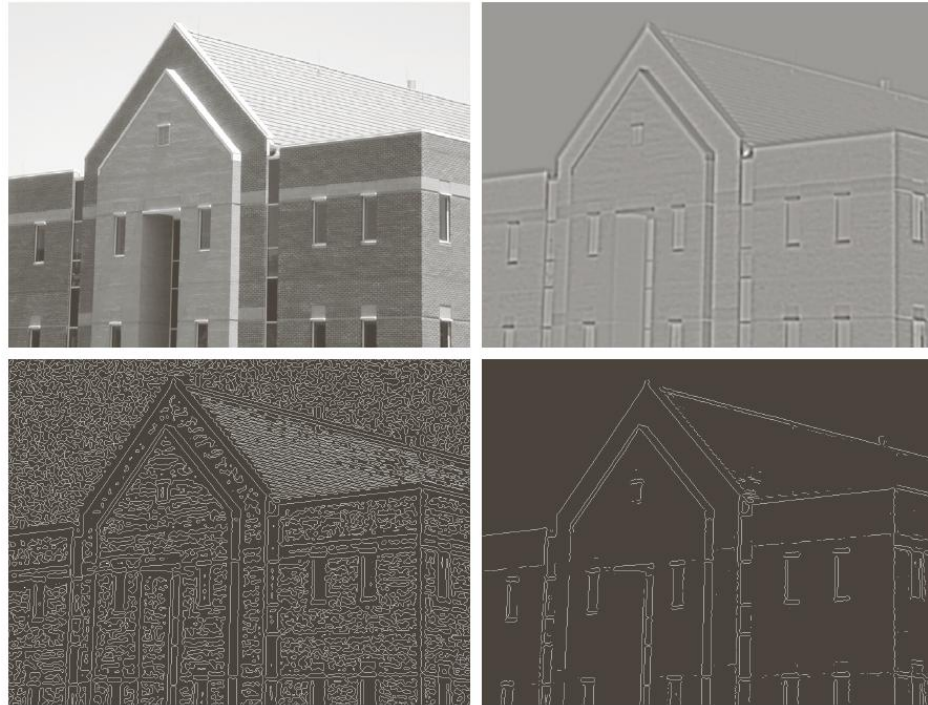


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a	b
c	d

FIGURE 10.22

(a) Original image of size 834×1114 pixels, with intensity values scaled to the range $[0, 1]$. (b) Results of Steps 1 and 2 of the Marr-Hildreth algorithm using $\sigma = 4$ and $n = 25$. (c) Zero crossings of (b) using a threshold of 0 (note the closed-loop edges). (d) Zero crossings found using a threshold equal to 4% of the maximum value of the image in (b). Note the thin edges.



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a	b
c	d

FIGURE 10.25

(a) Original image of size 834×1114 pixels, with intensity values scaled to the range $[0, 1]$.

(b) Thresholded gradient of smoothed image.

(c) Image obtained using the Marr-Hildreth algorithm.

(d) Image obtained using the Canny algorithm. Note the significant improvement of the Canny image compared to the other two.

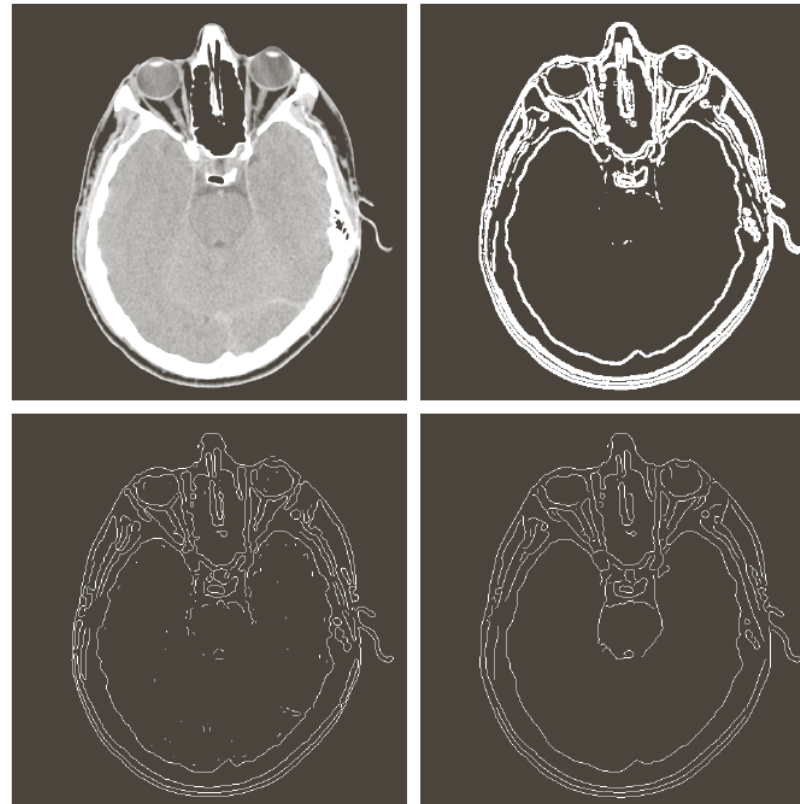


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a	b
c	d

FIGURE 10.26

(a) Original head CT image of size 512×512 pixels, with intensity values scaled to the range $[0, 1]$.

(b) Thresholded gradient of smoothed image.

(c) Image obtained using the Marr-Hildreth algorithm.

(d) Image obtained using the Canny algorithm.

(Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

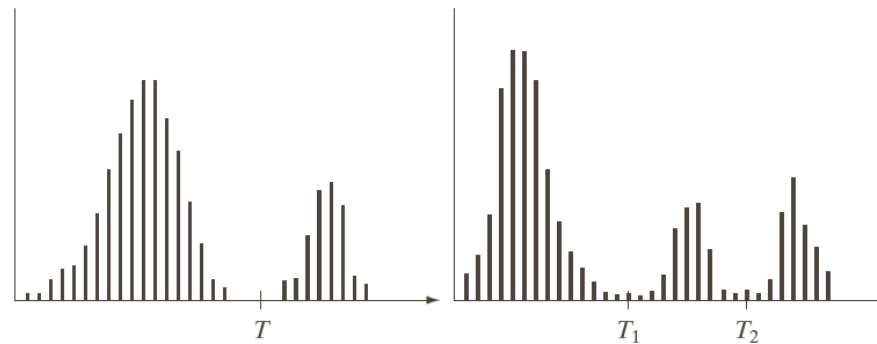


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a b

FIGURE 10.35

Intensity histograms that can be partitioned (a) by a single threshold, and (b) by dual thresholds.



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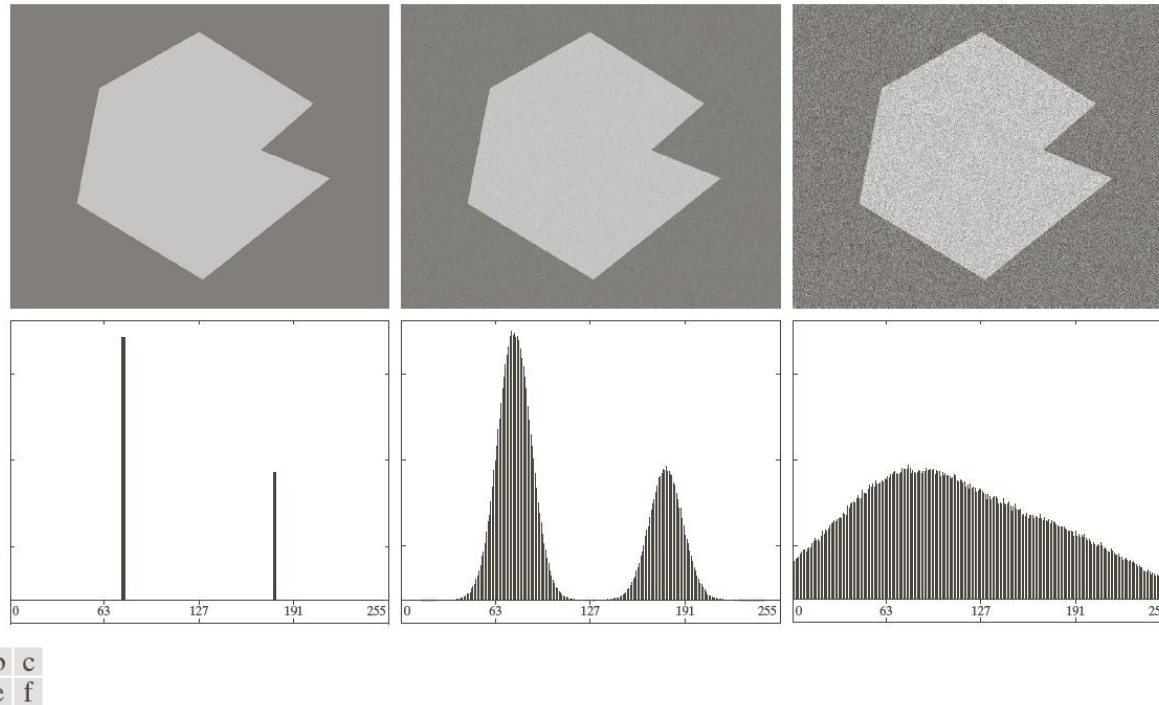


FIGURE 10.36 (a) Noiseless 8-bit image. (b) Image with additive Gaussian noise of mean 0 and standard deviation of 10 intensity levels. (c) Image with additive Gaussian noise of mean 0 and standard deviation of 50 intensity levels. (d)–(f) Corresponding histograms.



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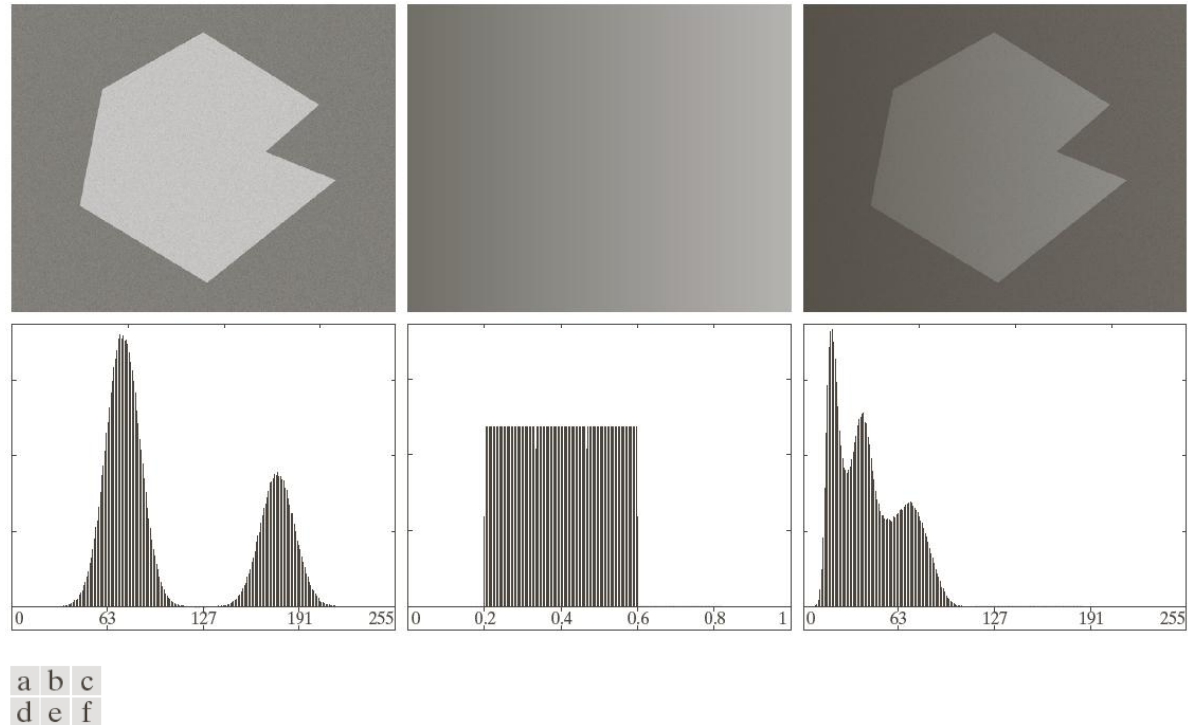


FIGURE 10.37 (a) Noisy image. (b) Intensity ramp in the range $[0.2, 0.6]$. (c) Product of (a) and (b). (d)–(f) Corresponding histograms.



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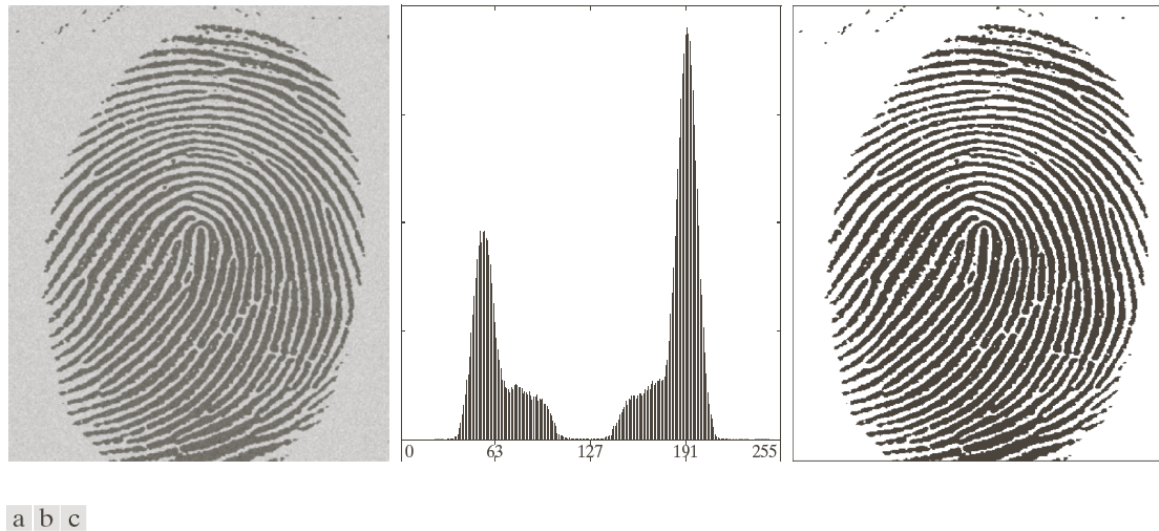
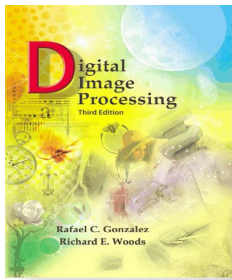


FIGURE 10.38 (a) Noisy fingerprint. (b) Histogram. (c) Segmented result using a global threshold (the border was added for clarity). (Original courtesy of the National Institute of Standards and Technology.)

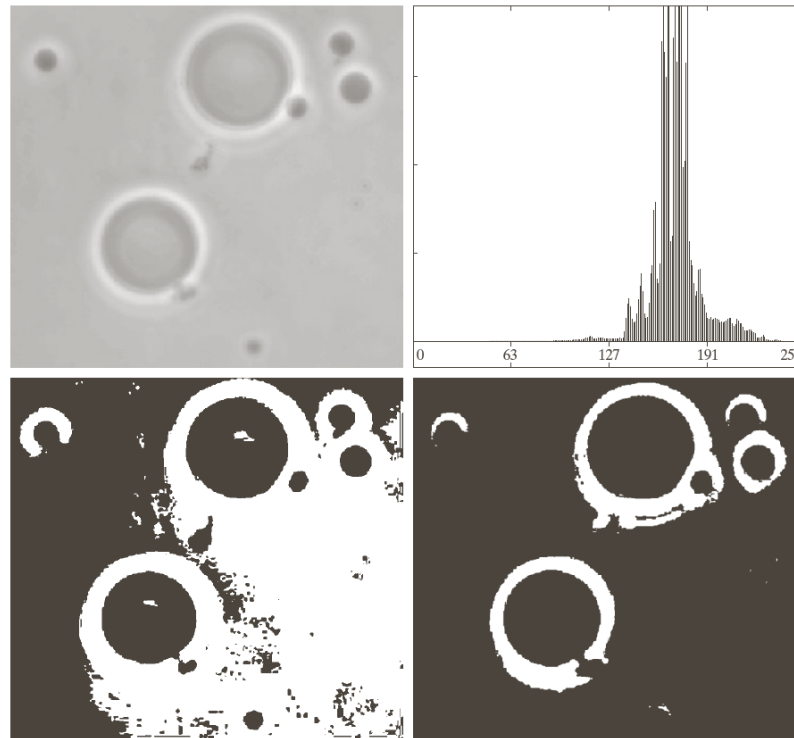


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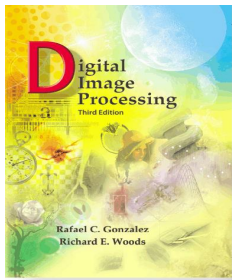
Chapter 10 Segmentation



a b
c d

FIGURE 10.39

(a) Original image.
(b) Histogram (high peaks were clipped to highlight details in the lower values).
(c) Segmentation result using the basic global algorithm from Section 10.3.2.
(d) Result obtained using Otsu's method. (Original image courtesy of Professor Daniel A. Hammer, the University of Pennsylvania.)



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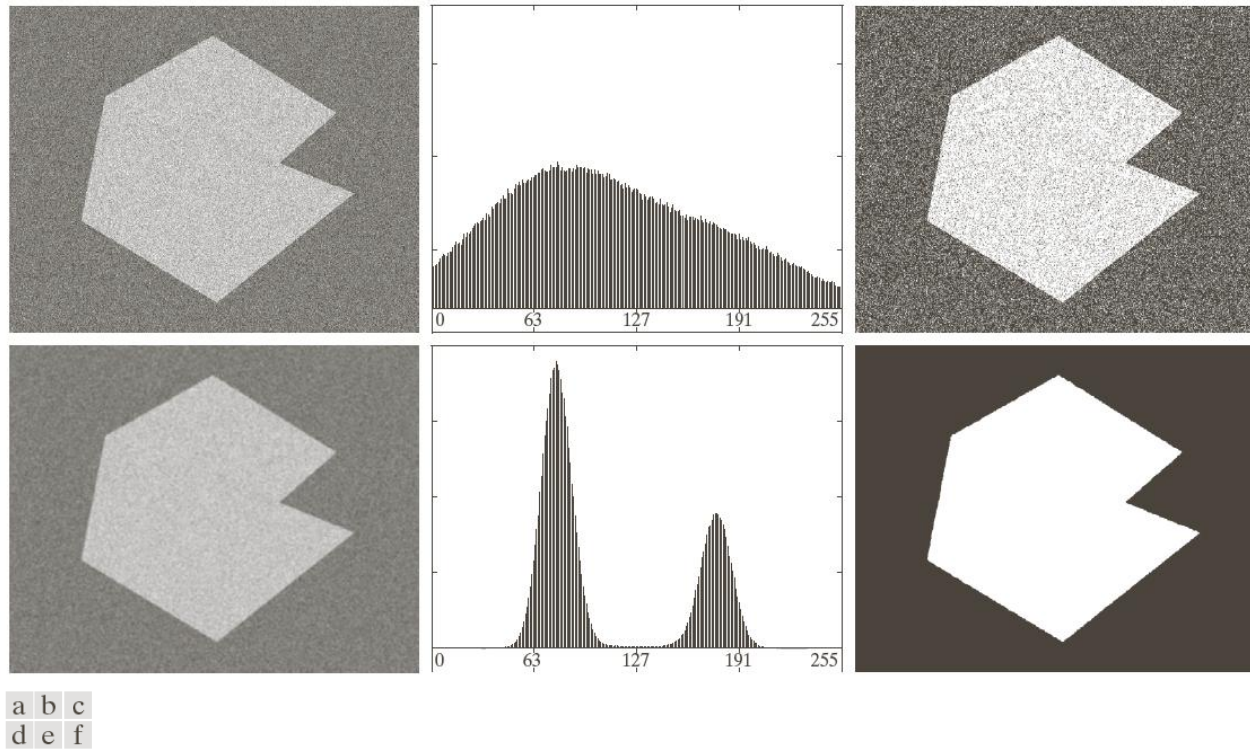
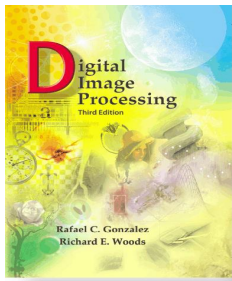


FIGURE 10.40 (a) Noisy image from Fig. 10.36 and (b) its histogram. (c) Result obtained using Otsu's method. (d) Noisy image smoothed using a 5×5 averaging mask and (e) its histogram. (f) Result of thresholding using Otsu's method.



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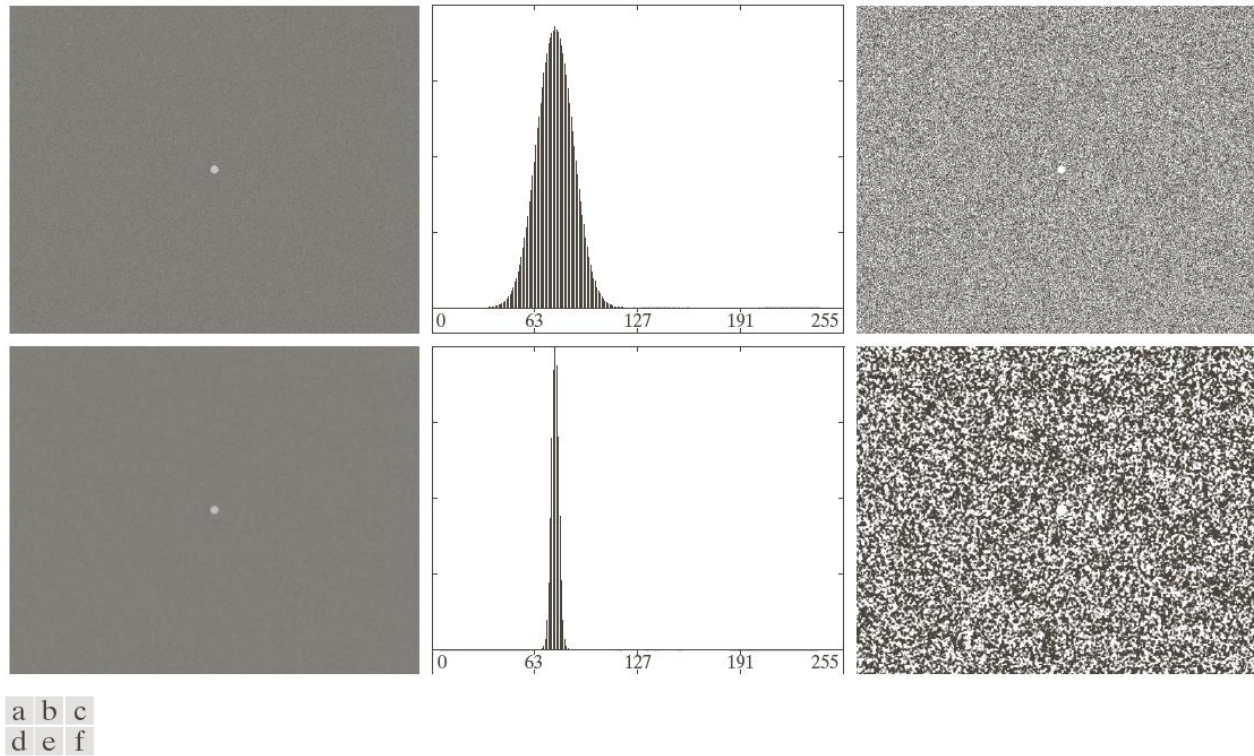


FIGURE 10.41 (a) Noisy image and (b) its histogram. (c) Result obtained using Otsu's method. (d) Noisy image smoothed using a 5×5 averaging mask and (e) its histogram. (f) Result of thresholding using Otsu's method. Thresholding failed in both cases.



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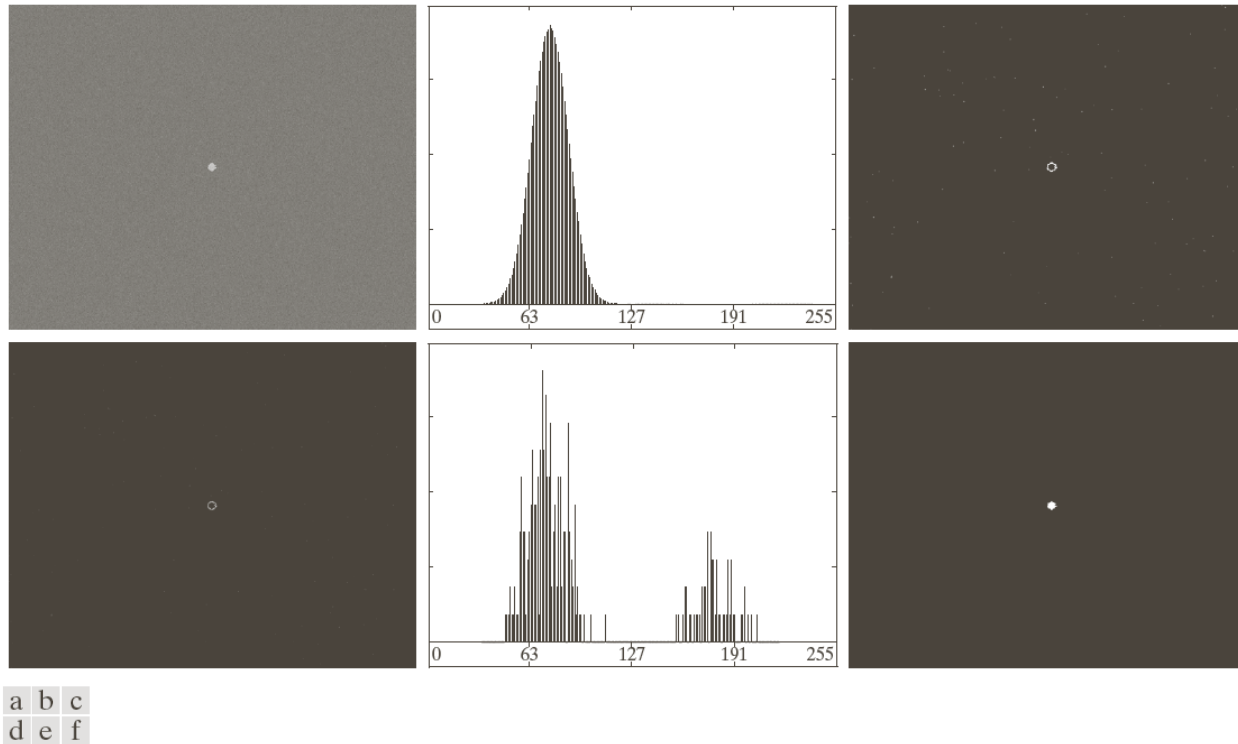


FIGURE 10.42 (a) Noisy image from Fig. 10.41(a) and (b) its histogram. (c) Gradient magnitude image thresholded at the 99.7 percentile. (d) Image formed as the product of (a) and (c). (e) Histogram of the nonzero pixels in the image in (d). (f) Result of segmenting image (a) with the Otsu threshold based on the histogram in (e). The threshold was 134, which is approximately midway between the peaks in this histogram.



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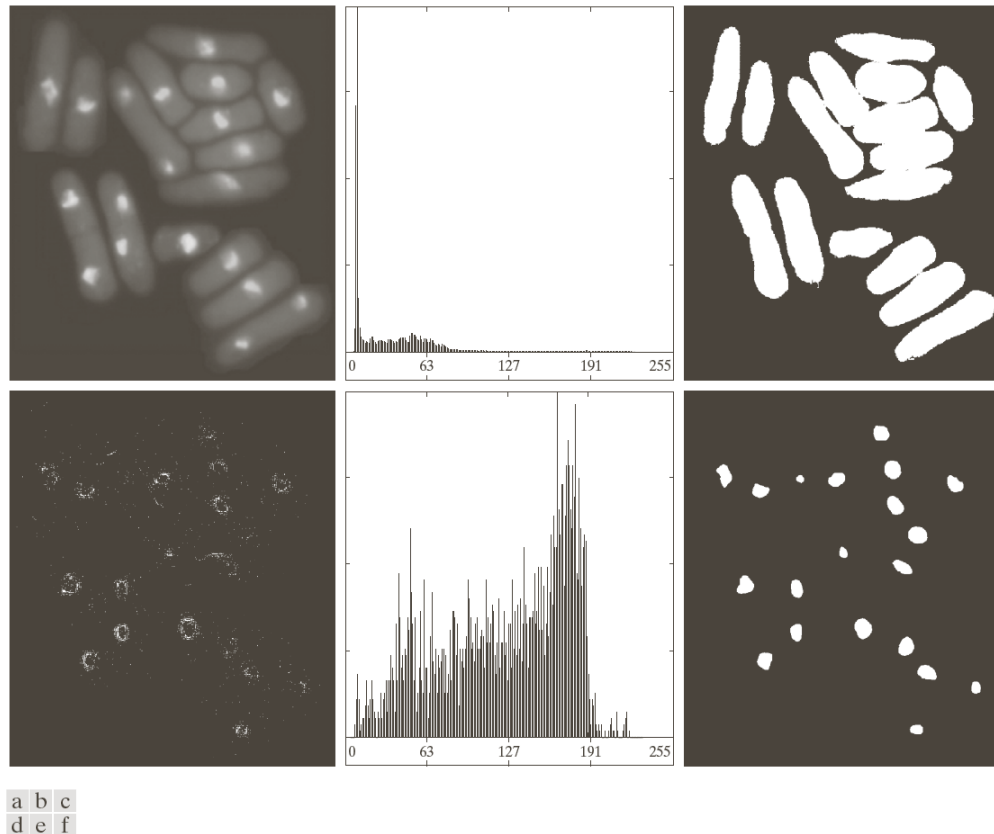


FIGURE 10.43 (a) Image of yeast cells. (b) Histogram of (a). (c) Segmentation of (a) with Otsu's method using the histogram in (b). (d) Thresholded absolute Laplacian. (e) Histogram of the nonzero pixels in the product of (a) and (d). (f) Original image thresholded using Otsu's method based on the histogram in (e). (Original image courtesy of Professor Susan L. Forsburg, University of Southern California.)



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FIGURE 10.44

Image in Fig. 10.43(a) segmented using the same procedure as explained in Figs. 10.43(d)–(f), but using a lower value to threshold the absolute Laplacian image.



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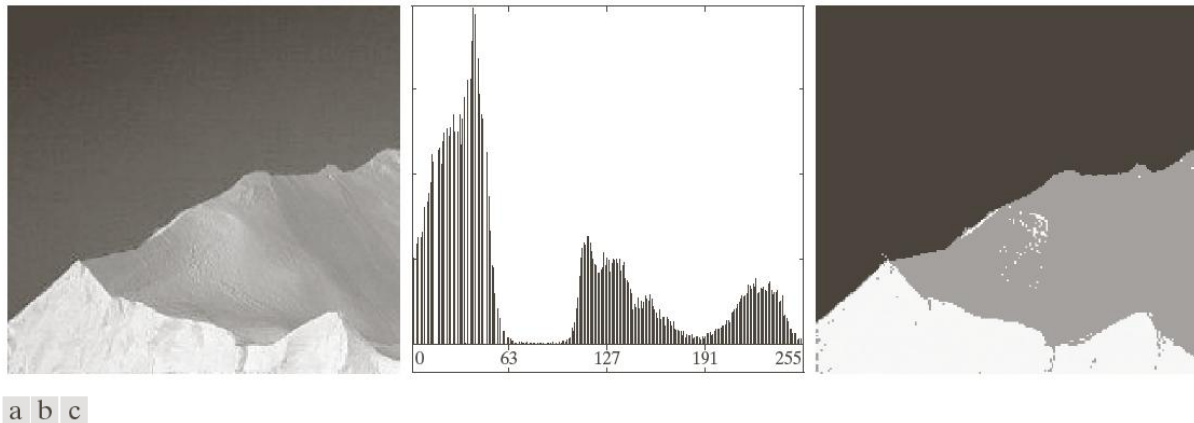


FIGURE 10.45 (a) Image of iceberg. (b) Histogram. (c) Image segmented into three regions using dual Otsu thresholds. (Original image courtesy of NOAA.)