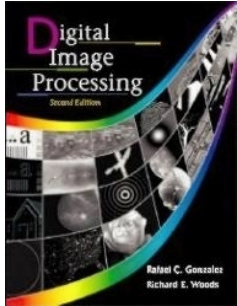


Chapter 10 Image Segmentation

**The whole is equal to the sum of its parts.
-Euclid**

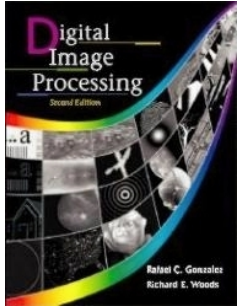
**The whole is greater than the sum of its parts.
-Max Wertheimer**

**The Whole is Not Equal to the Sum of Its Parts:
An Approach to Teaching the Research Paper.
-by Mangum, Bryant**



Chapter 10 Image Segmentation

- 10.1 Detection of Discontinuities**
- 10.2 Edge Linking and Boundary Detection**
- 10.3 Thresholding**
- 10.4 Region-Based Segmentation**
- 10.5 Segmentation by Morphological Watersheds (x)**
- 10.6 The Use of Motion in Segmentation**



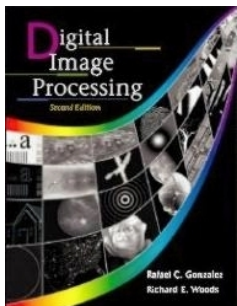
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10.1.1 Point Detection 569

10.1.2 Line Detection 570

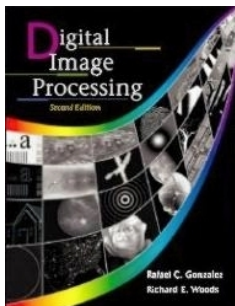
10.1.3 Edge Detection 572



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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



Chapter 10 Image Segmentation

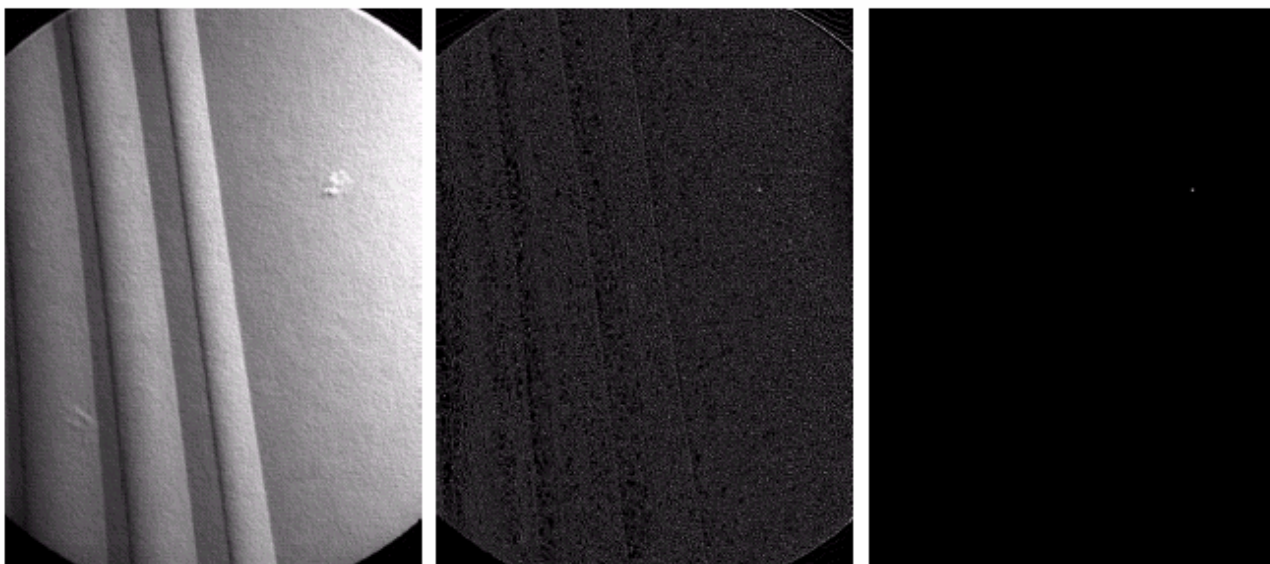
Point Detection

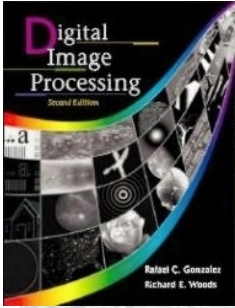
-1	-1	-1
-1	8	-1
-1	-1	-1

a
b c d

FIGURE 10.2

(a) Point detection mask.
(b) X-ray image of a turbine blade with a porosity.
(c) Result of point detection.
(d) Result of using Eq. (10.1-2).
(Original image courtesy of X-TEK Systems Ltd.)





Chapter 10 Image Segmentation

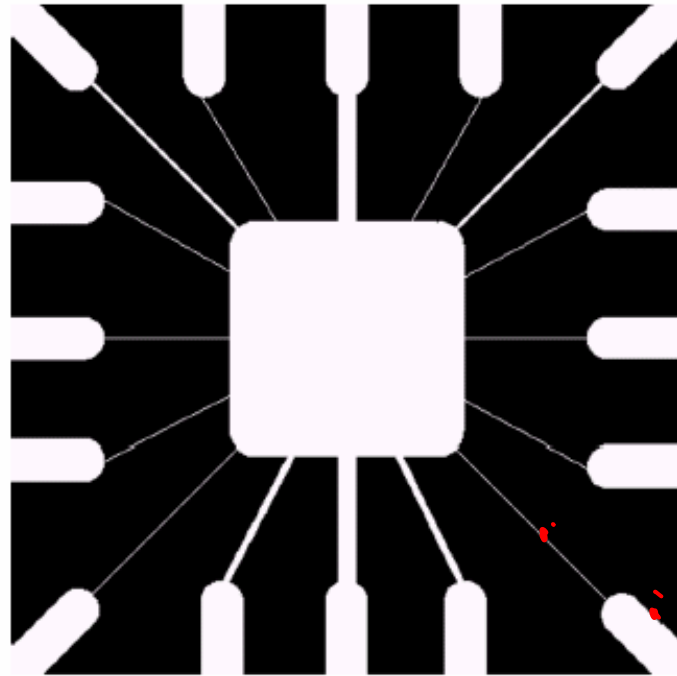
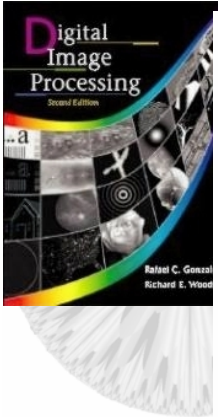


Line Detection

FIGURE 10.3 Line masks.

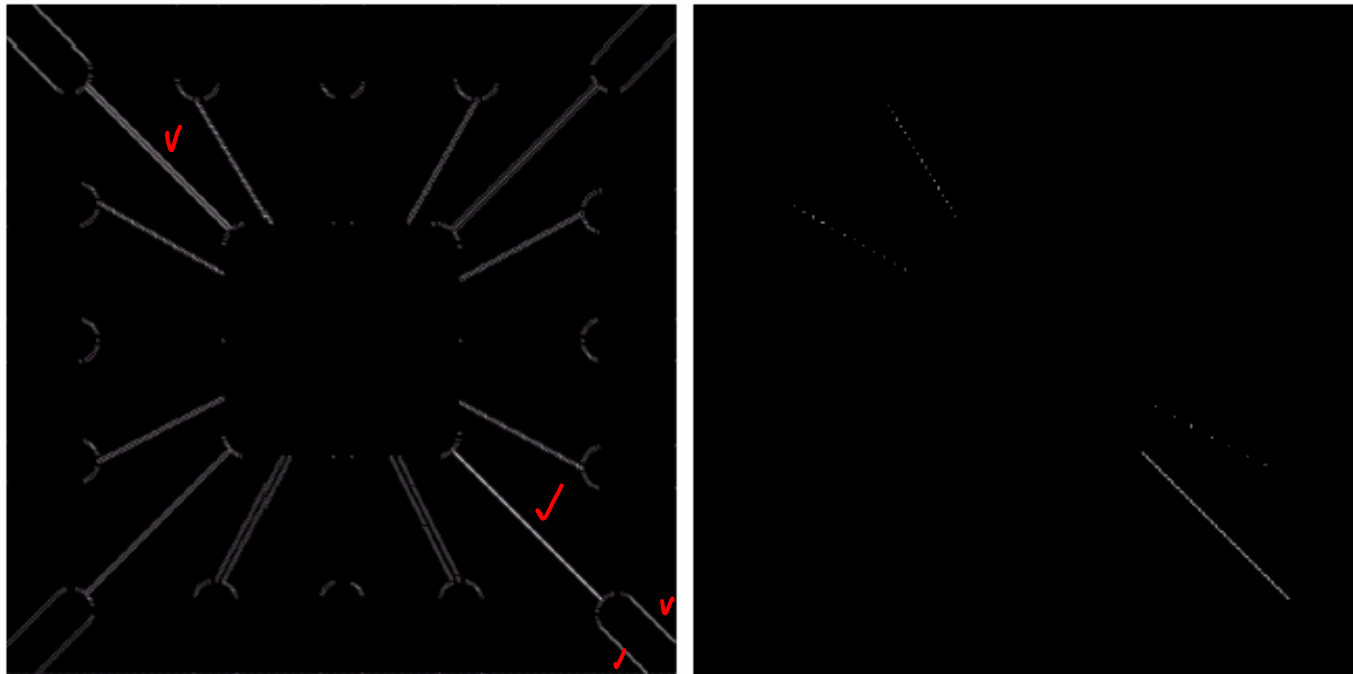
-1	-1	-1	-1	-1	2	-1	2	-1	2	-1	-1
-2	-2	-2	-1	2	-1	-1	2	-1	-1	2	-1
-1	-1	-1	2	-1	-1	-1	2	-1	-1	-1	2
Horizontal			+45°			Vertical			-45°		

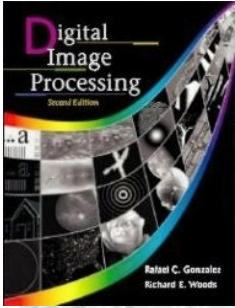
$$60 - 3 \times 200 - 3 \times 10 \\ = -1140$$



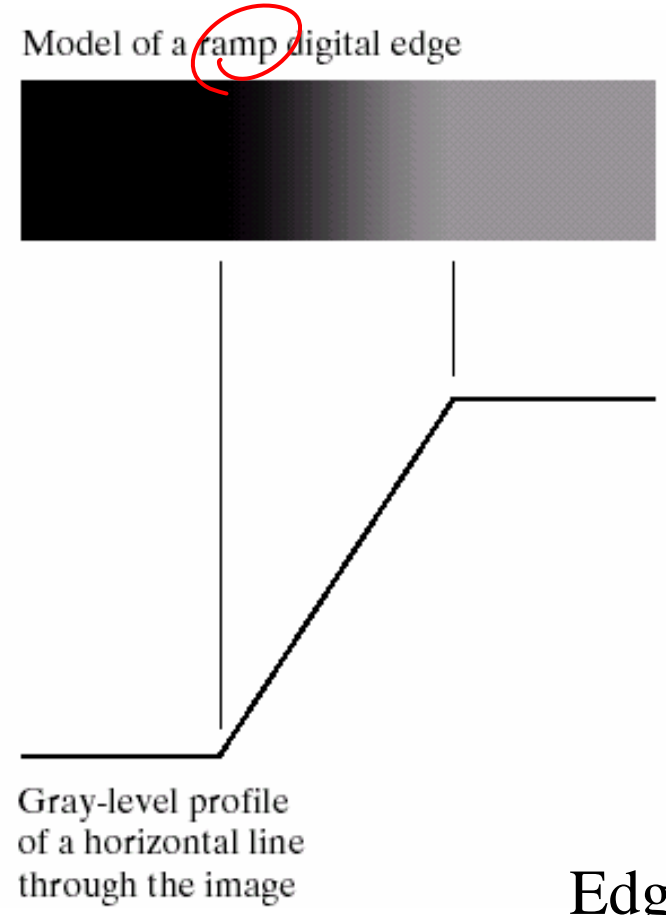
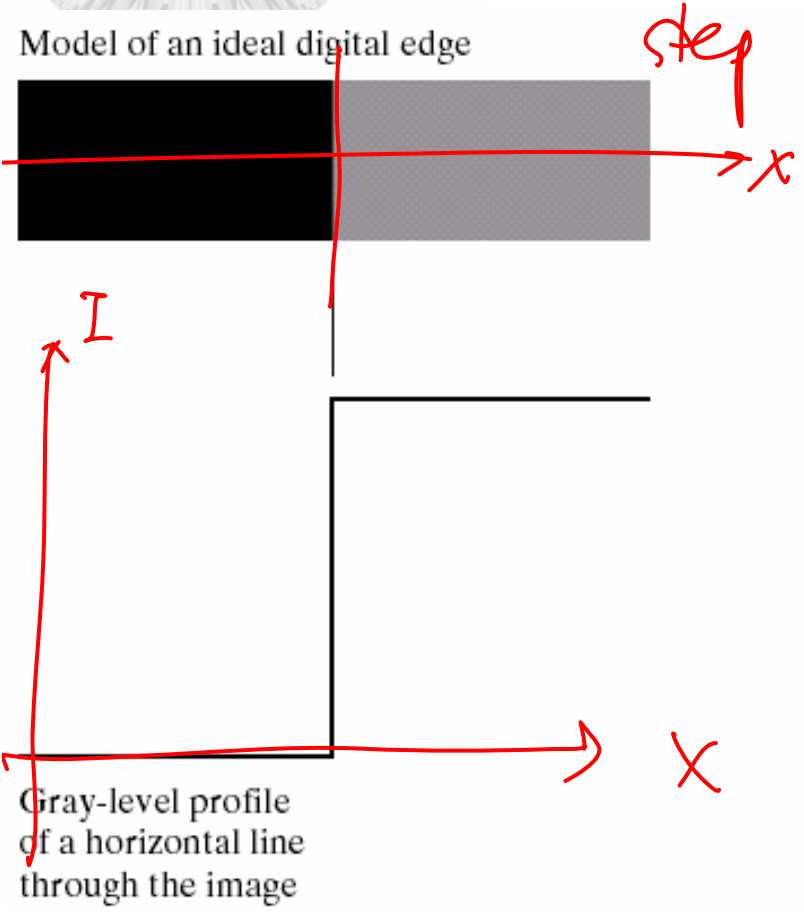
a
b c

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).





Chapter 10 Image Segmentation



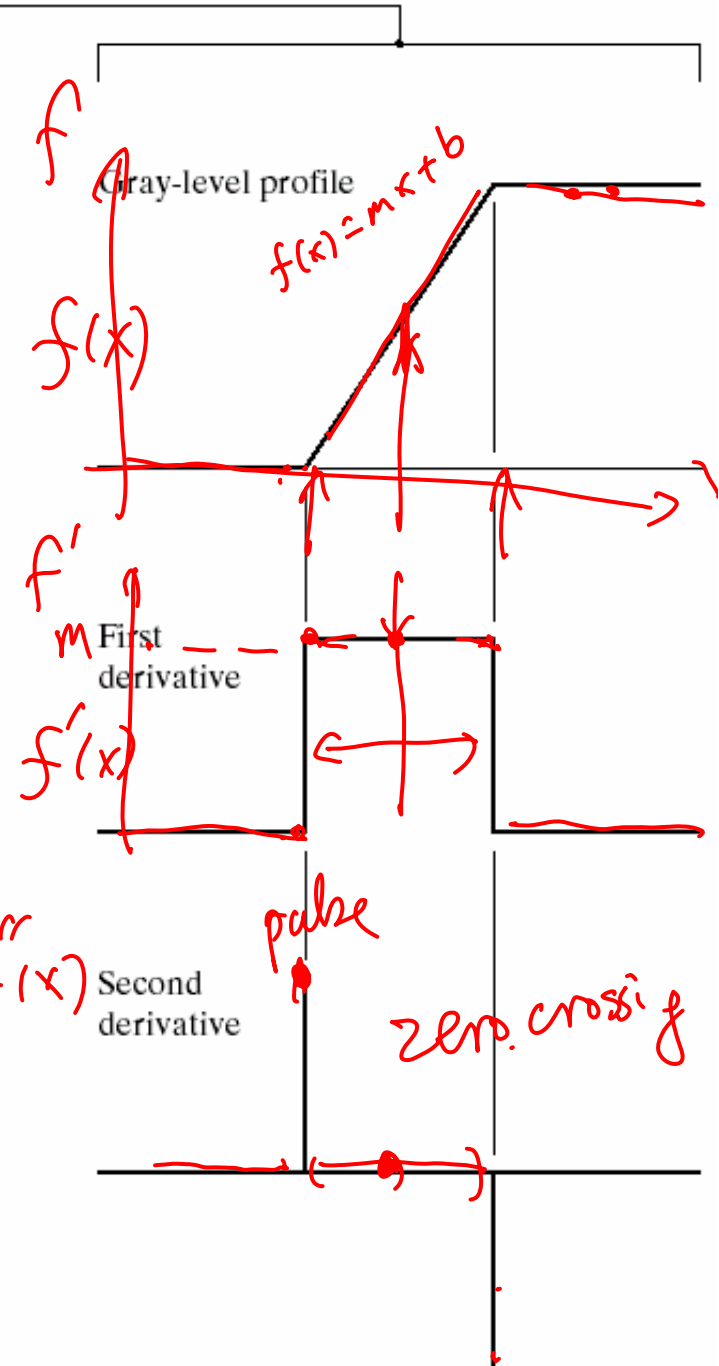
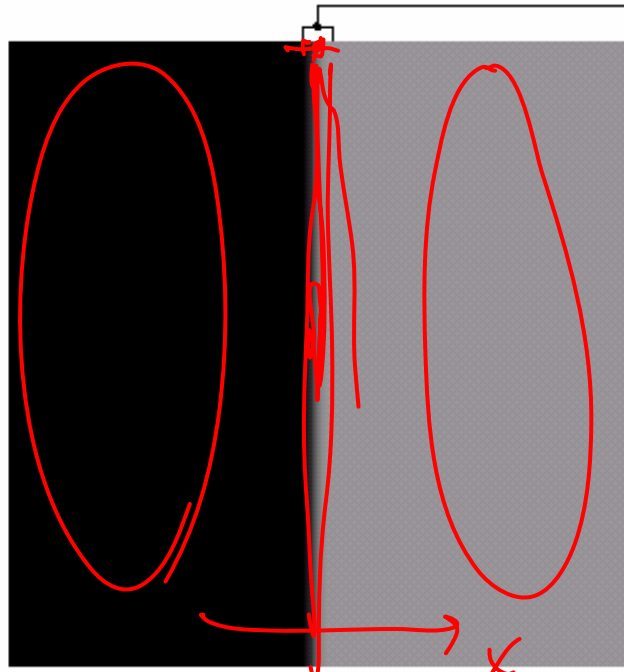
a b
FIGURE 10.5
(a) Model of an ideal digital edge.
(b) Model of a ramp edge. The slope of the ramp is proportional to the degree of blurring in the edge.

Edge Detection

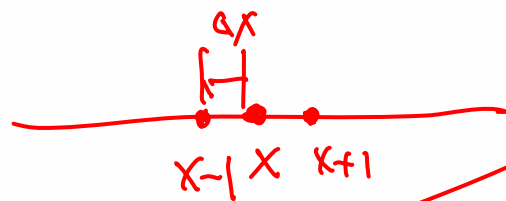
a b

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.



$$f'(x) = \frac{\partial f}{\partial x} \approx \frac{\Delta f}{\Delta x} = \lim_{\Delta x \rightarrow 0} \frac{f(x) - f(x - \Delta x)}{\Delta x}$$

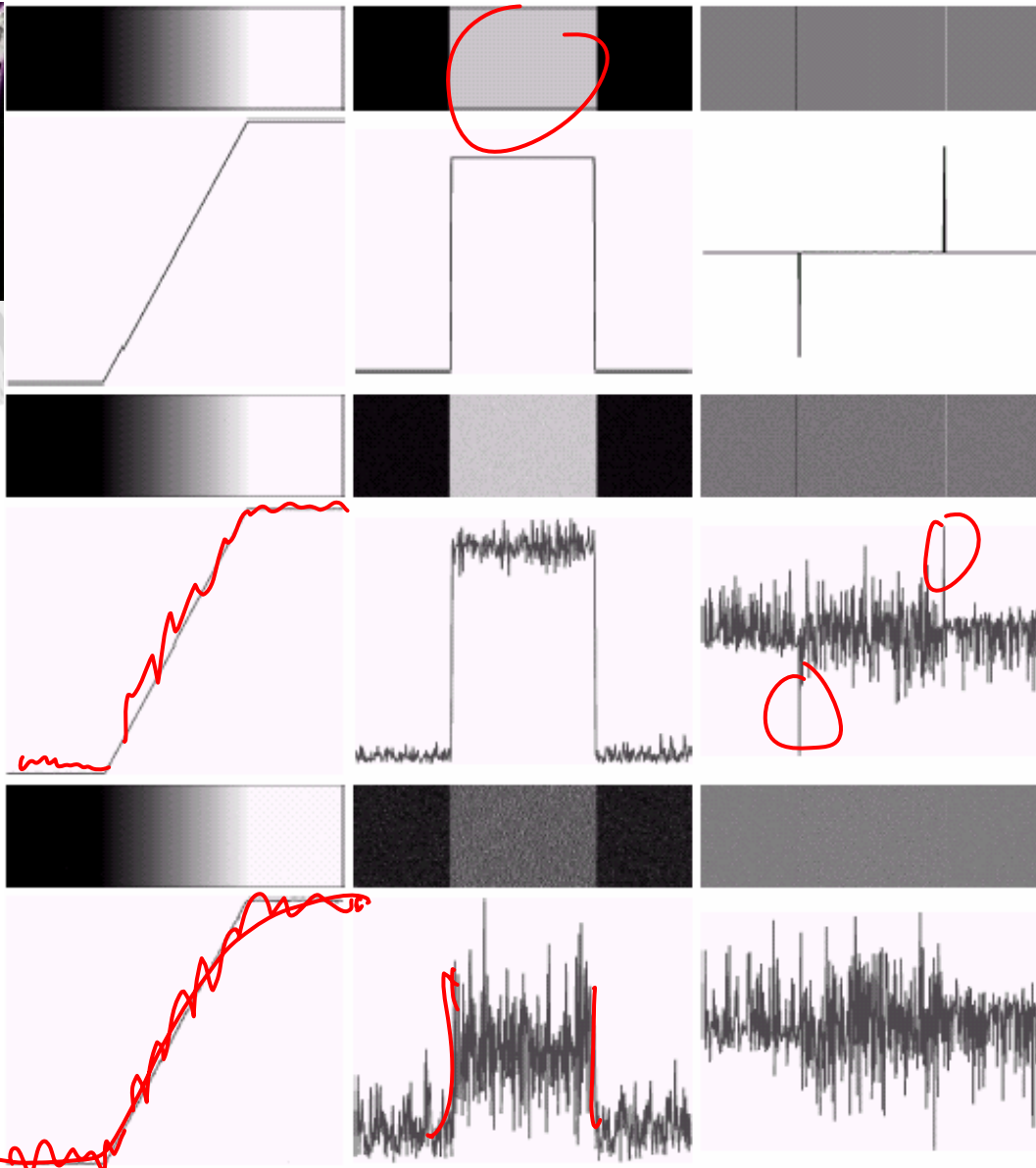
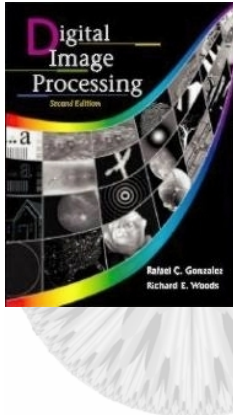


$$\approx \frac{f(x) - f(x-1)}{1} \quad f''(x)$$

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

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

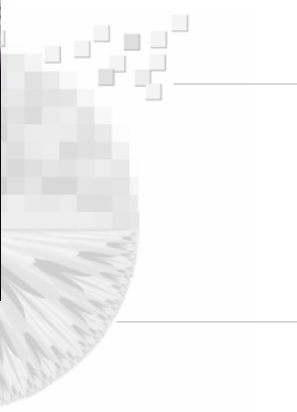
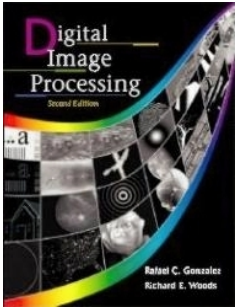
$$\approx \frac{f(x+1) - f(x-1)}{2}$$



d.

FIGURE 10.7 First column: images and gray-level profiles of a ramp edge corrupted by random Gaussian noise of mean 0 and $\sigma = 0.0, 0.1, 1.0,$ 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



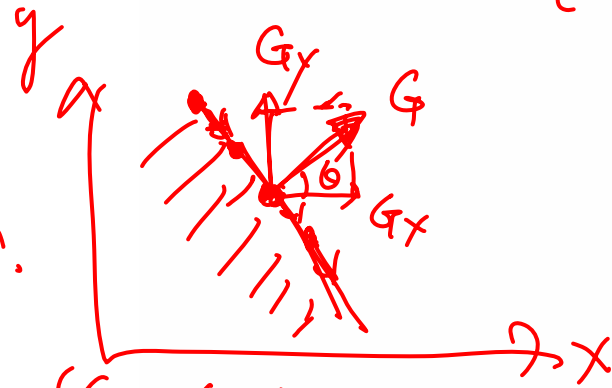
a
b c
d e
f g

FIGURE 10.8
A 3×3 region of an image (the z 's are gray-level values) and various masks used to compute the gradient at point labeled z_5 .

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

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

Gradient



$$G = (G_x, G_y)$$

$$|G| = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \tan^{-1} \frac{G_y}{G_x}$$



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

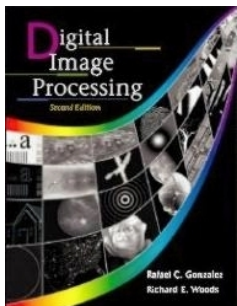
H Roberts V

-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



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

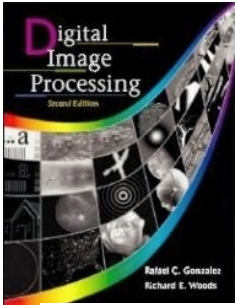
Prewitt

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

Sobel

a b
c d

FIGURE 10.9 Prewitt and Sobel masks for detecting diagonal edges.

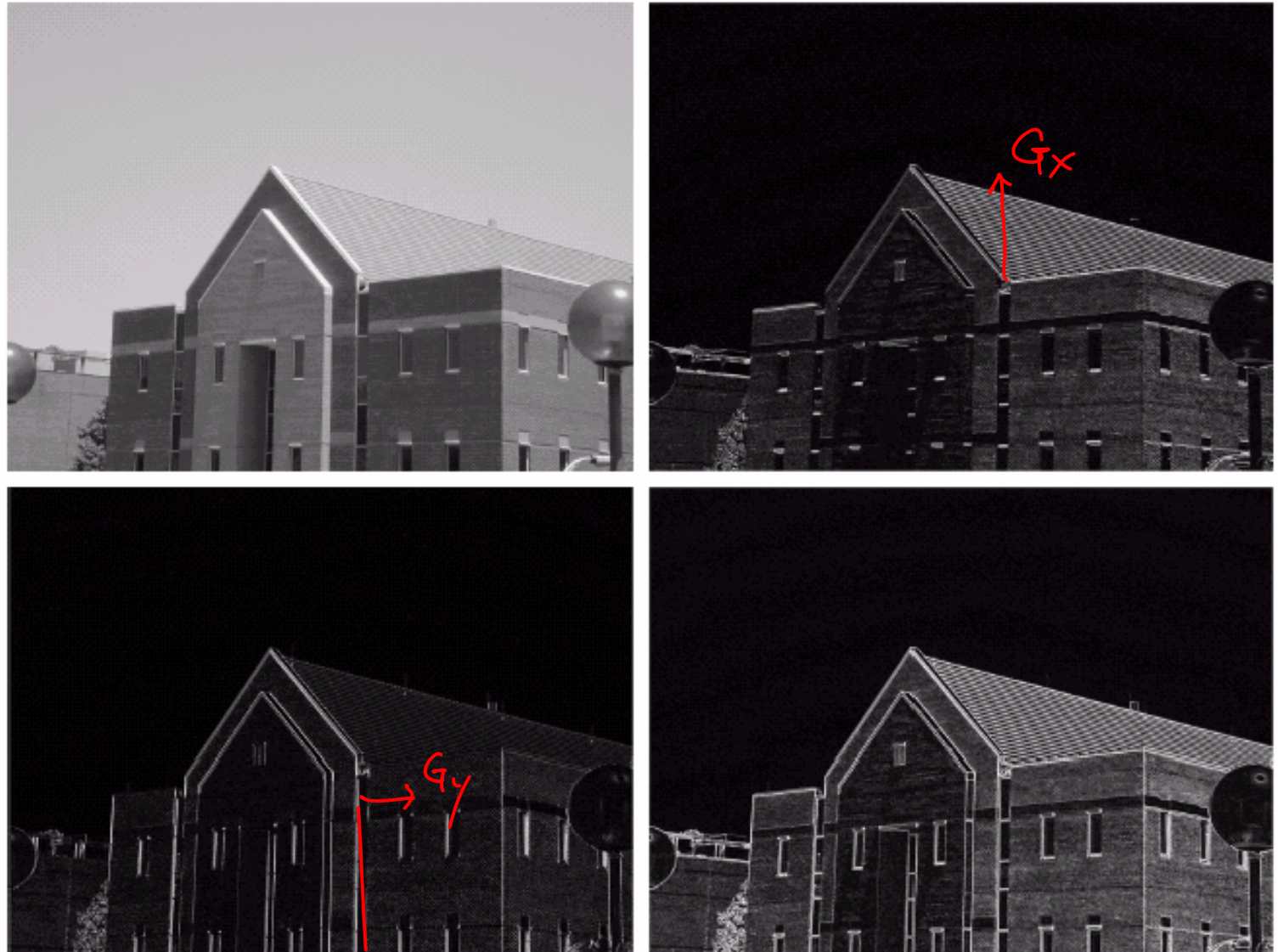


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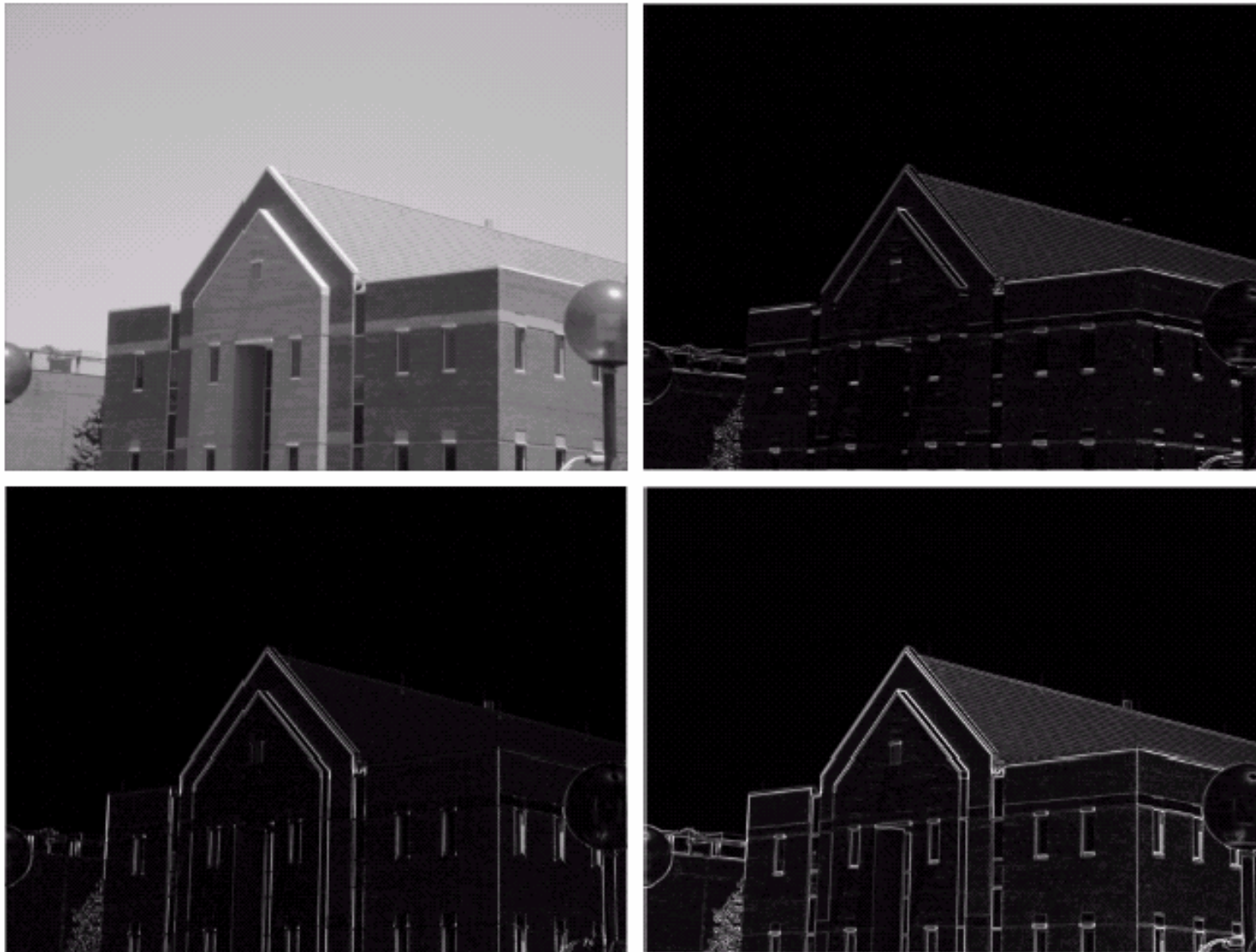
a b
c d

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, $|G_x| + |G_y|$.

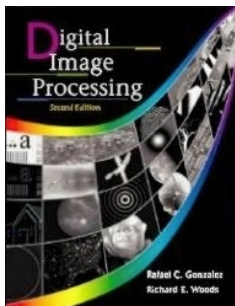


Chapter 10



a	b
c	d

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



Chapter 10 Image Segmentation



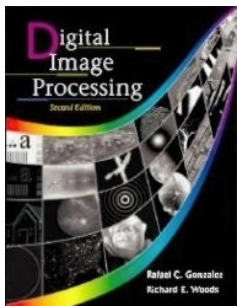
a b

FIGURE 10.12

Diagonal edge detection.

(a) Result of using the mask in Fig. 10.9(c).

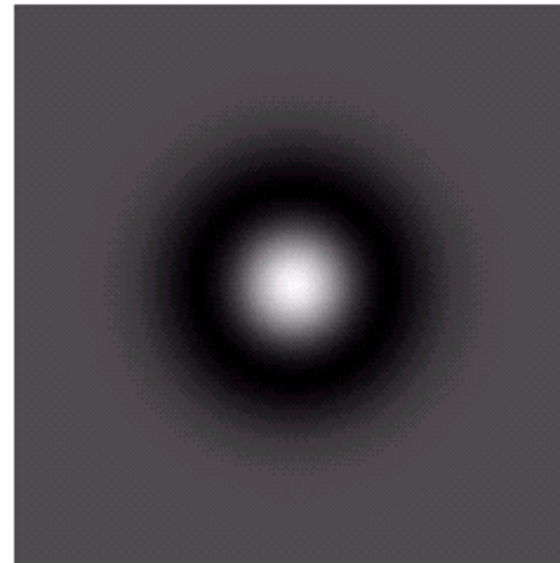
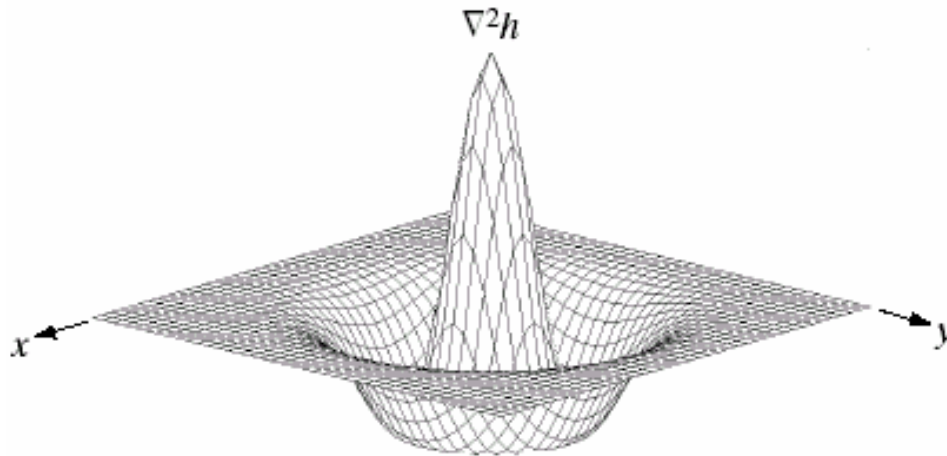
(b) Result of using the mask in Fig. 10.9(d). The input in both cases was Fig. 10.11(a).



Chapter 10 Image Segmentation

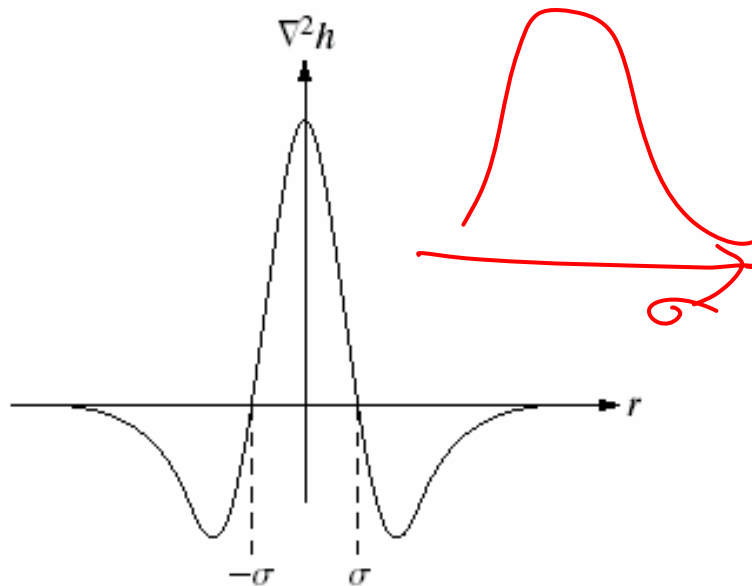
FIGURE 10.13
Laplacian masks
used to
implement
Eqs. (10.1-14) and
(10.1-15),
respectively.

0	-1	0	-1	-1	-1
-1	4	-1	-1	8	-1
0	-1	0	-1	-1	-1

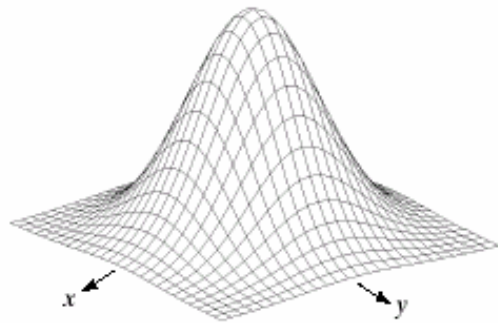
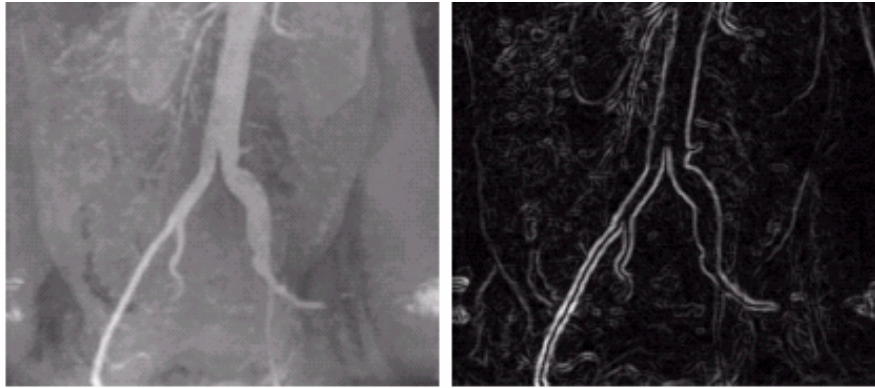


a b
c d

FIGURE 10.14
Laplacian of a Gaussian (LoG).
(a) 3-D plot.
(b) Image (black is negative, gray is the zero plane, and white is positive).
(c) Cross section showing zero crossings.
(d) 5×5 mask approximation to the shape of (a).



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

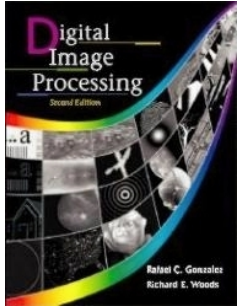


-1	-1	-1
-1	8	-1
-1	-1	-1



a b
c d
e f g

FIGURE 10.15 (a) Original image. (b) Sobel gradient (shown for comparison). (c) Spatial Gaussian smoothing function. (d) Laplacian mask. (e) LoG. (f) Thresholded LoG. (g) Zero crossings. (Original image courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)



Chapter 10

Image Segmentation

10.2 Edge Linking and Boundary Detection 585

10.2.1 Local Processing 585

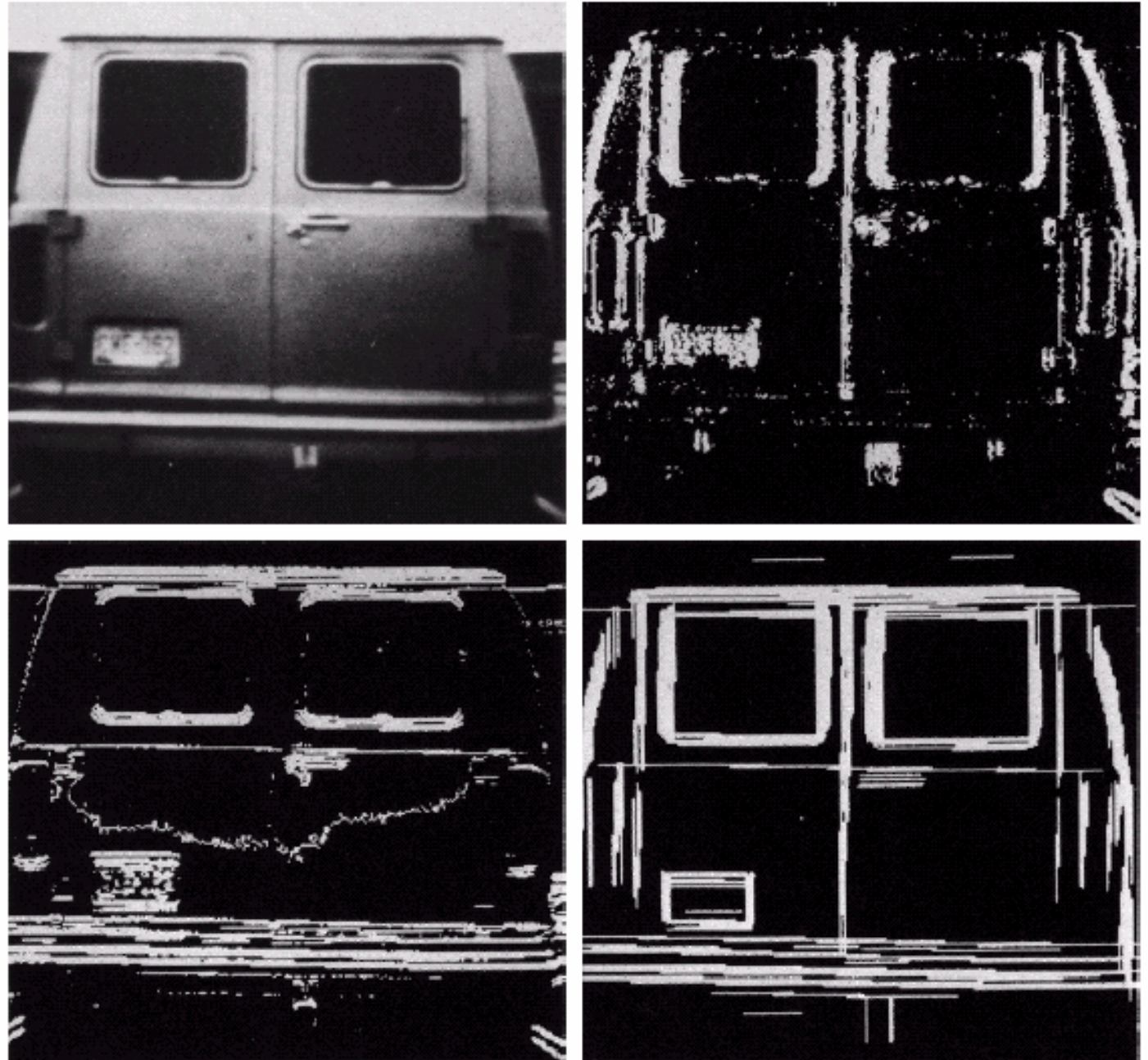
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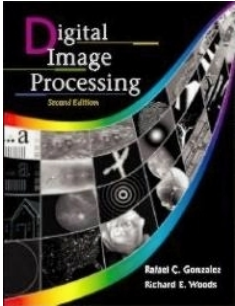
a b
c d

FIGURE 10.16

(a) Input image.
(b) G_y component of the gradient.
(c) G_x component of the gradient.
(d) Result of edge linking. (Courtesy of Perceptics Corporation.)

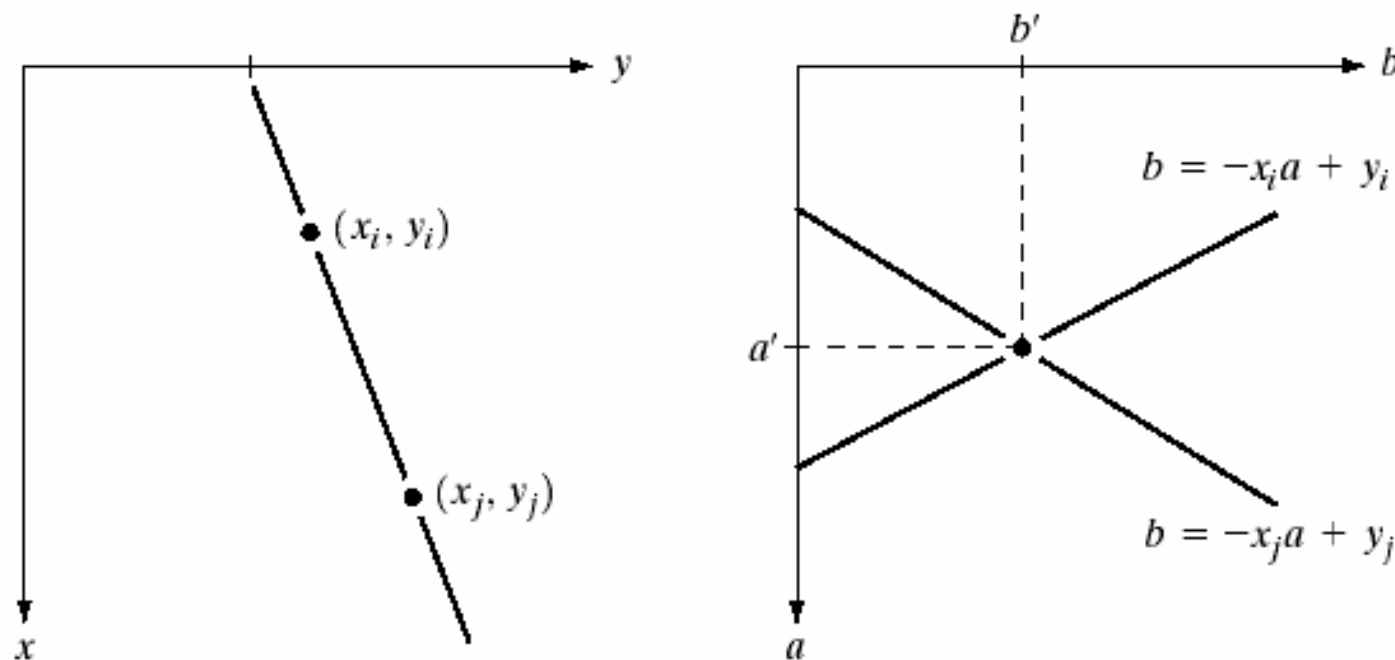


Local Processing

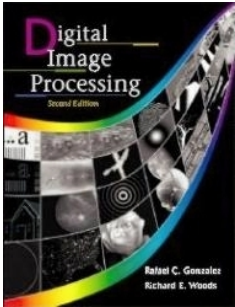


Chapter 10 Image Segmentation

Global Processing via the Hough Transform

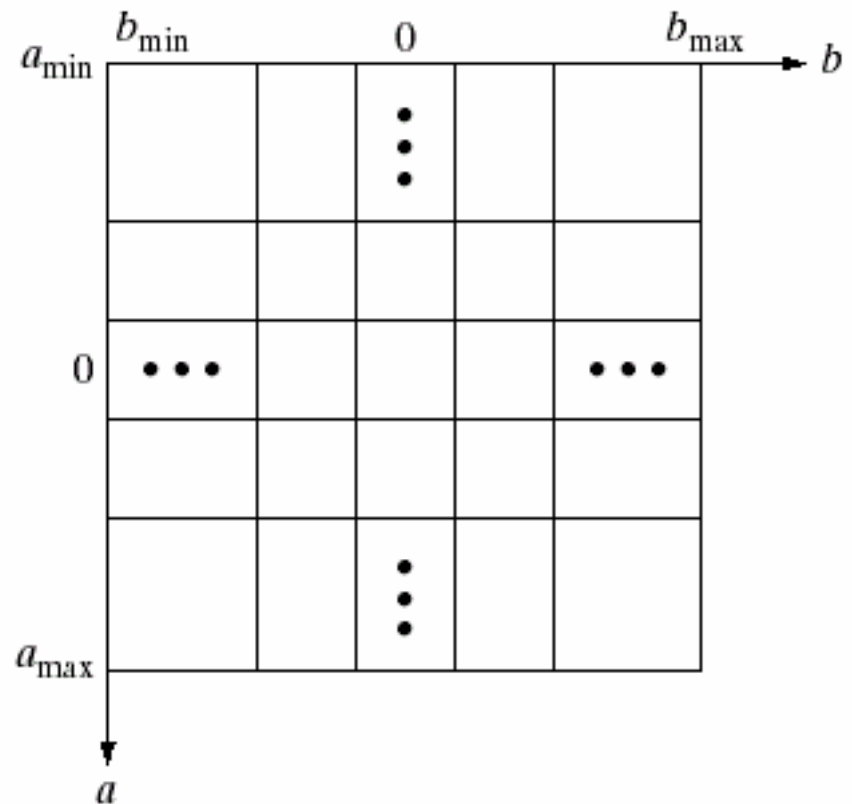


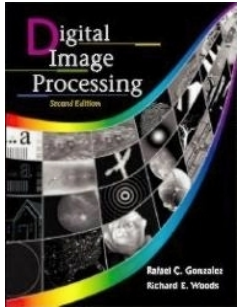
a b
FIGURE 10.17
(a) xy -plane.
(b) Parameter space.



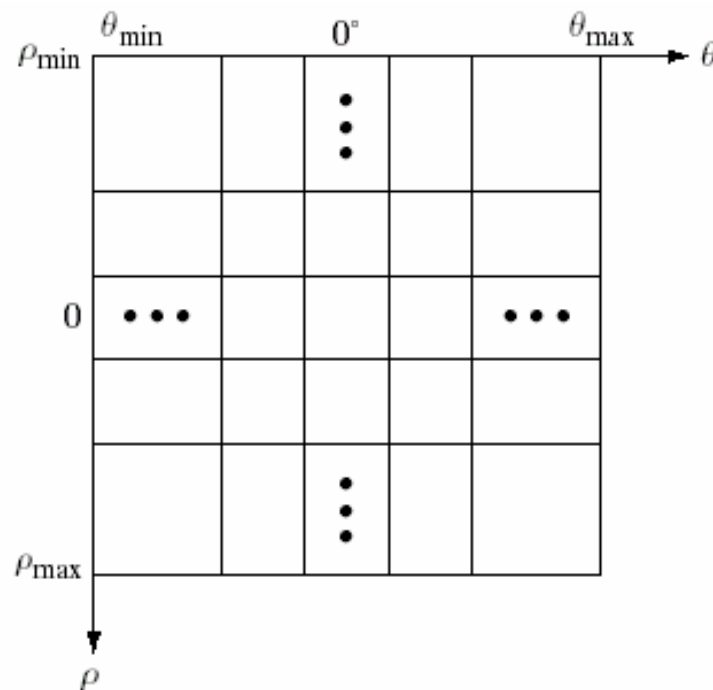
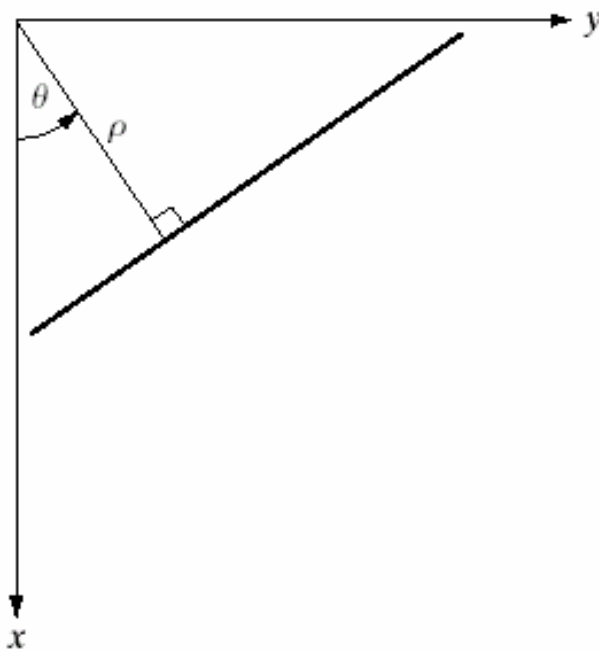
Chapter 10 Image Segmentation

FIGURE 10.18
Subdivision of the
parameter plane
for use in the
Hough transform.





Chapter 10 Image Segmentation

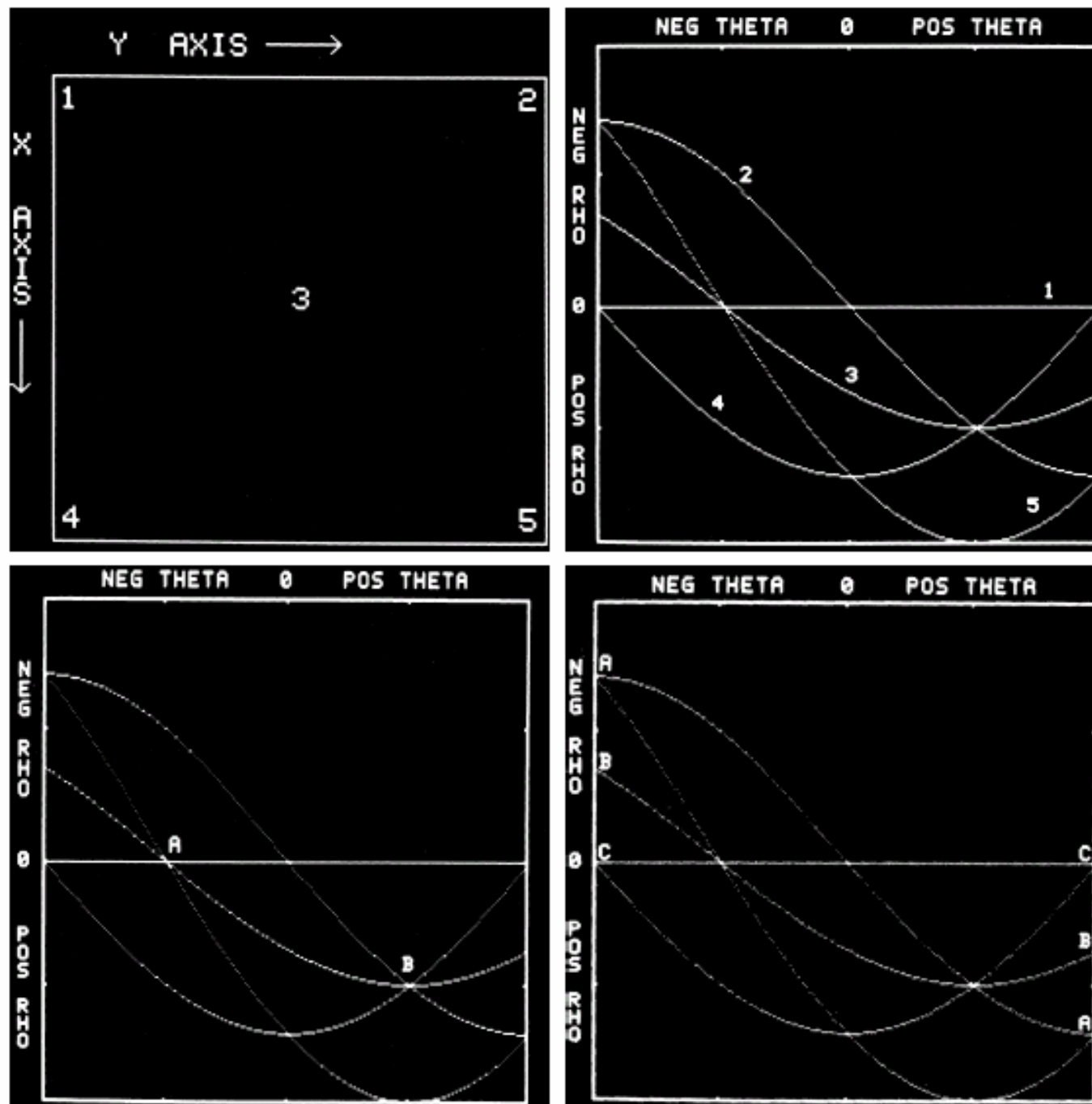


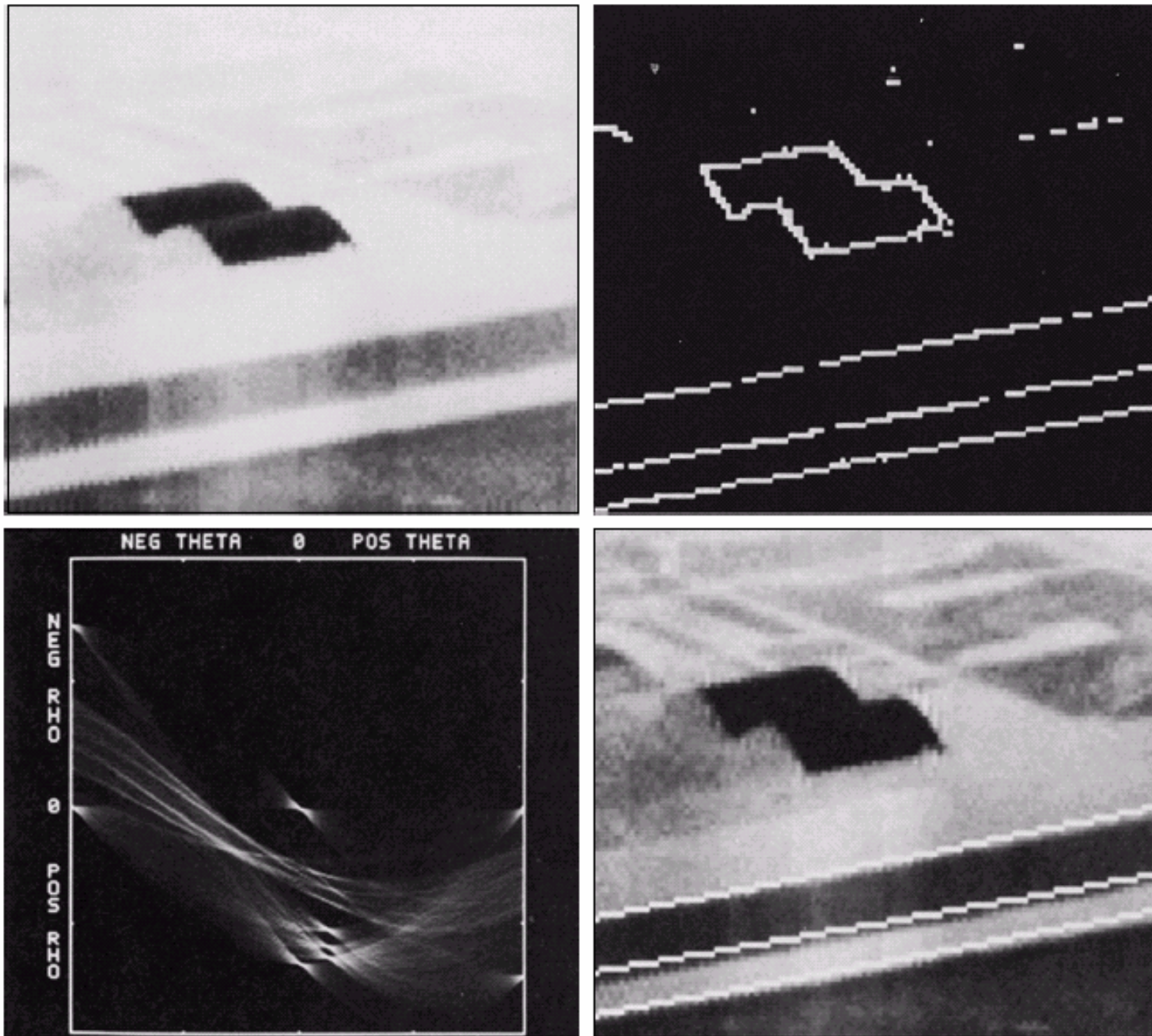
a b

FIGURE 10.19
(a) Normal representation of a line.
(b) Subdivision of the $\rho\theta$ -plane into cells.

a b
c d

FIGURE 10.20
Illustration of the
Hough transform.
(Courtesy of Mr.
D. R. Cate, Texas
Instruments, Inc.)

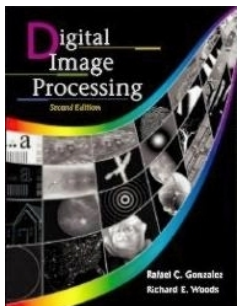




a	b
c	d

FIGURE 10.21

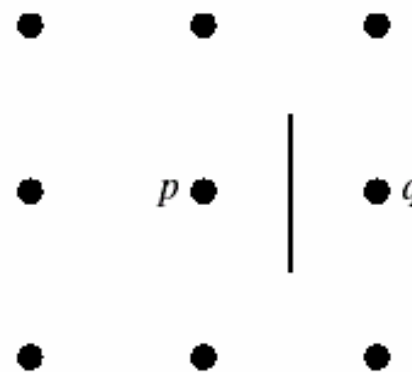
(a) Infrared image.
(b) Thresholded gradient image.
(c) Hough transform.
(d) Linked pixels.
(Courtesy of Mr. D. R. Cate, Texas Instruments, Inc.)

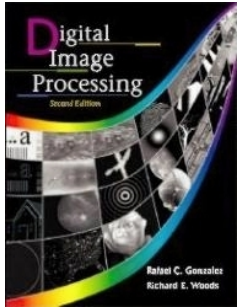


Chapter 10 Image Segmentation

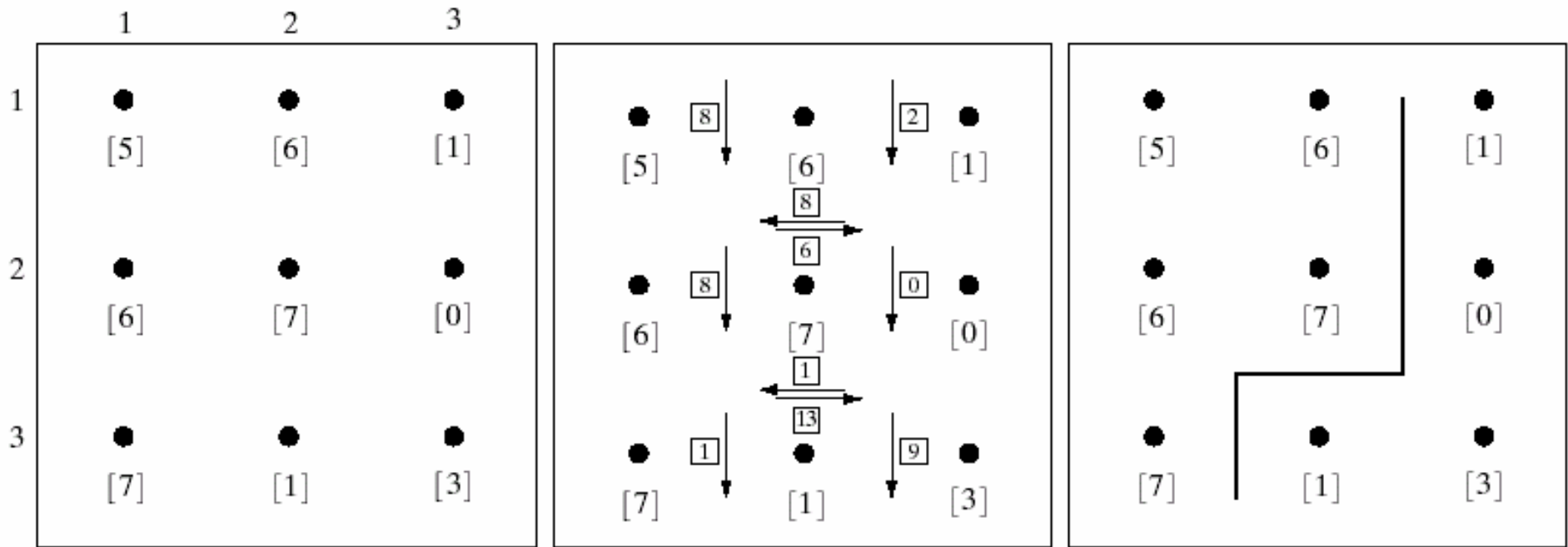
Global Processing via Graph-Theoretic Techniques

FIGURE 10.22
Edge element
between pixels p
and q .





Chapter 10 Image Segmentation



a b c

FIGURE 10.23 (a) A 3×3 image region. (b) Edge segments and their costs. (c) Edge corresponding to the lowest-cost path in the graph shown in Fig. 10.24.

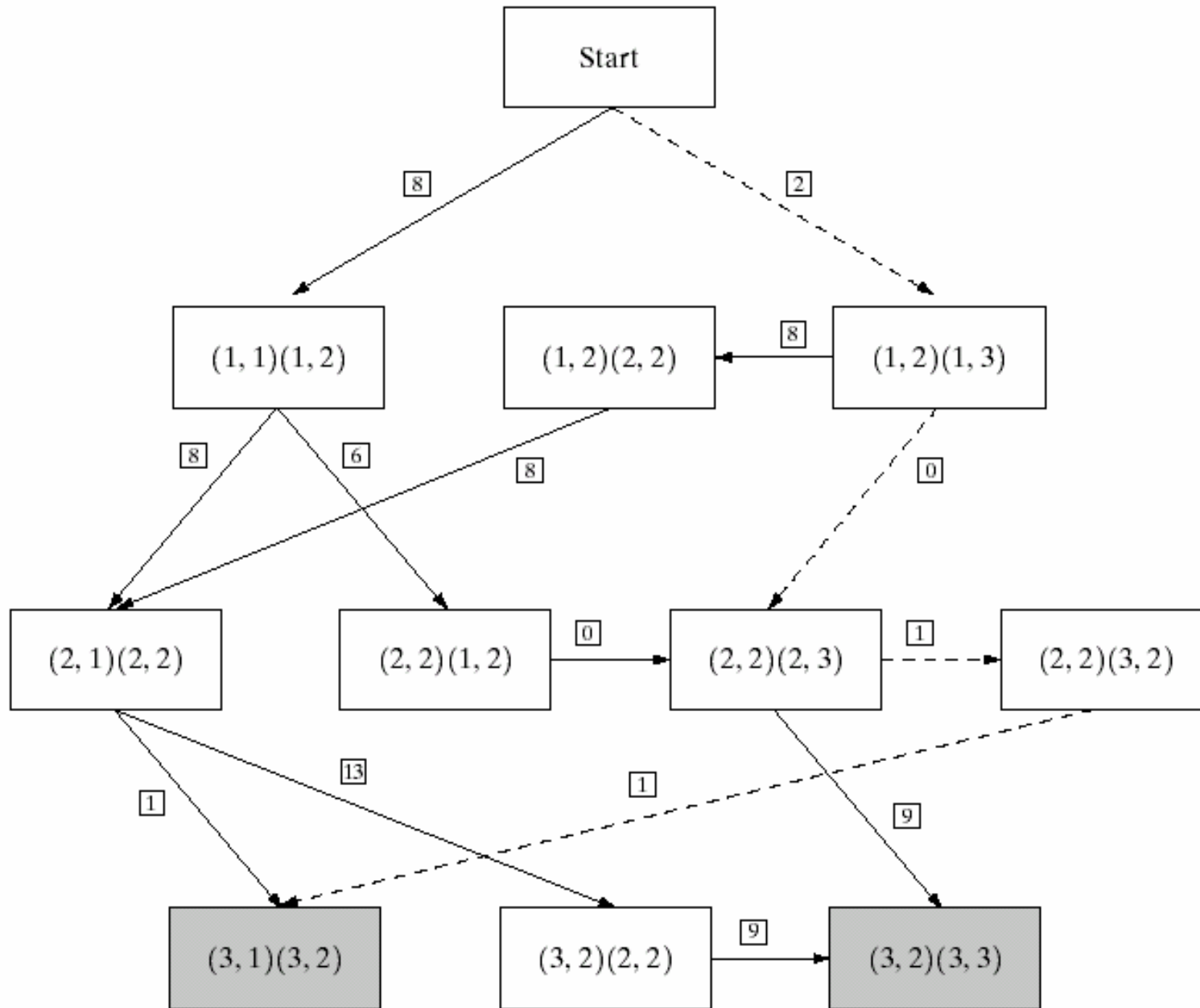
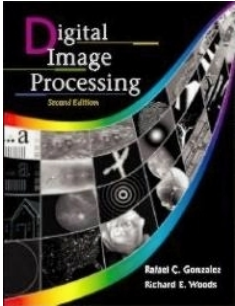


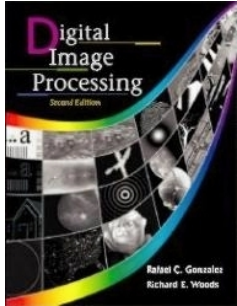
FIGURE 10.24
Graph for the image in Fig. 10.23(a). The lowest-cost path is shown dashed.



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FIGURE 10.25
Image of noisy
chromosome
silhouette and
edge boundary
(in white)
determined by
graph search.



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10.3 Thresholding 595

10.3.1 Foundation 595

10.3.2 The Role of Illumination 596

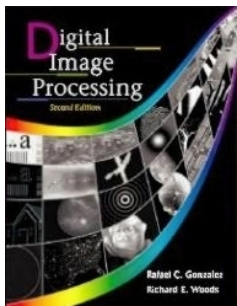
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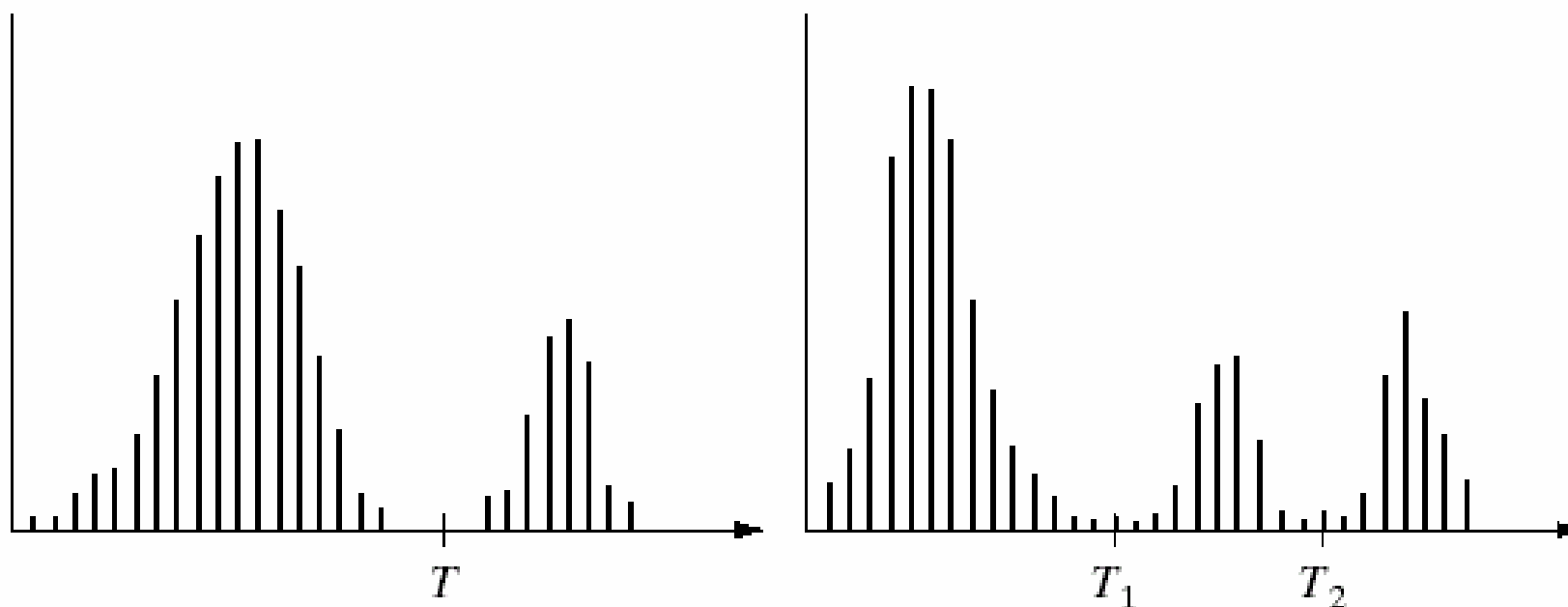
10.3.6 Use of Boundary Characteristics for Histogram Improvement and Local Thresholding 608

10.3.7 Thresholds Based on Several Variables 611



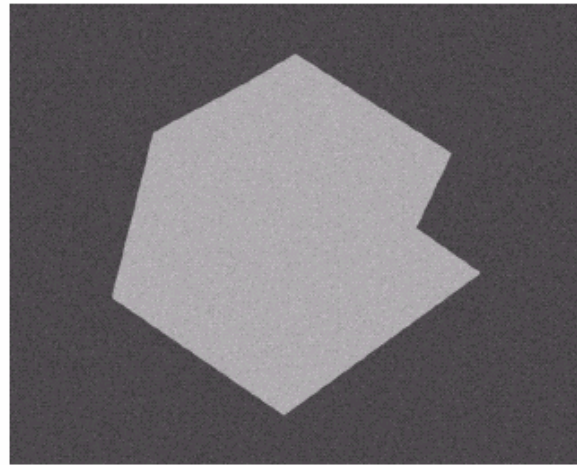
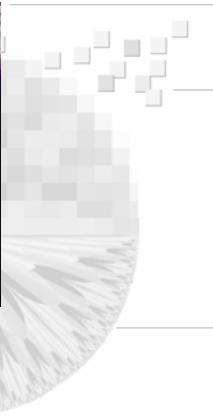
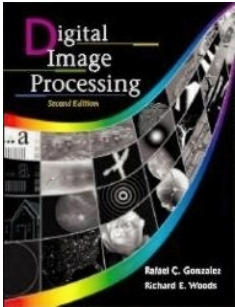
Chapter 10 Image Segmentation

Foundation



a b

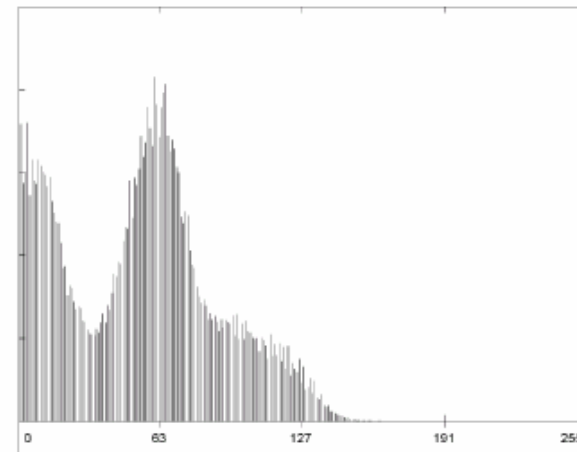
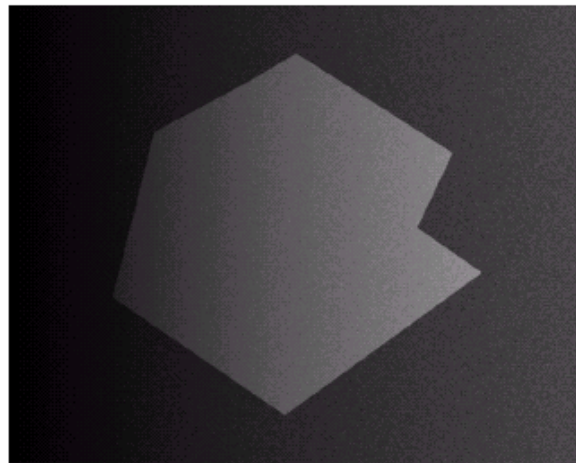
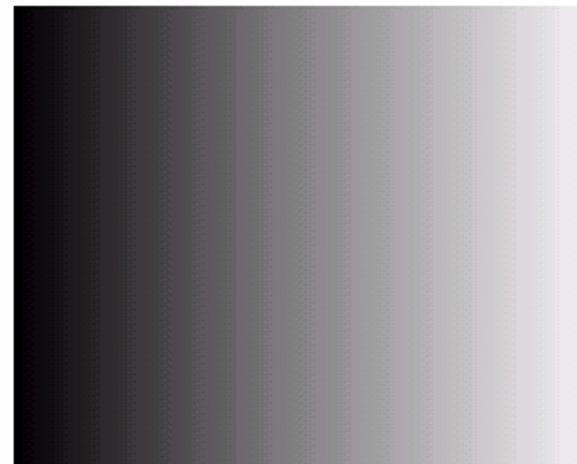
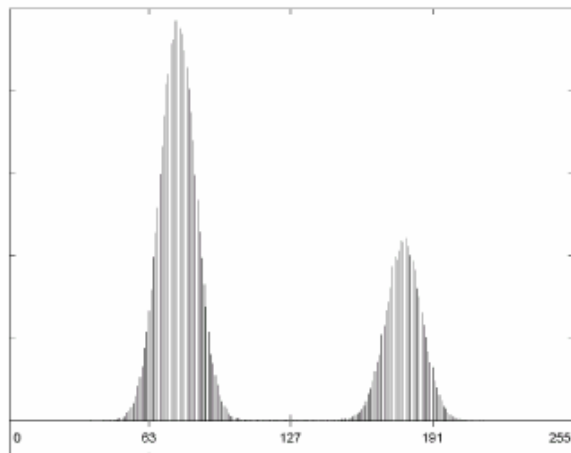
FIGURE 10.26 (a) Gray-level histograms that can be partitioned by (a) a single threshold, and (b) multiple thresholds.

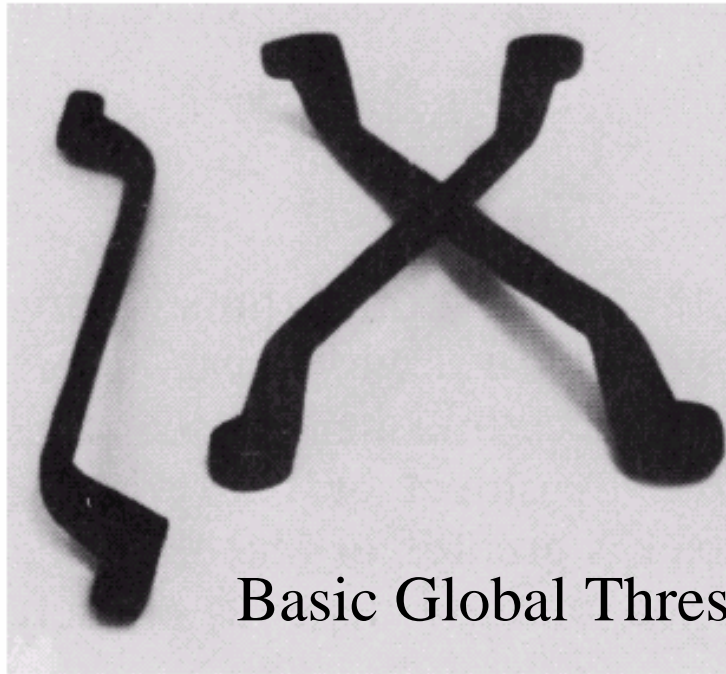


a
b c
d e

FIGURE 10.27
(a) Computer generated reflectance function.
(b) Histogram of reflectance function.
(c) Computer generated illumination function.
(d) Product of (a) and (c).
(e) Histogram of product image.

The Role of Illumination

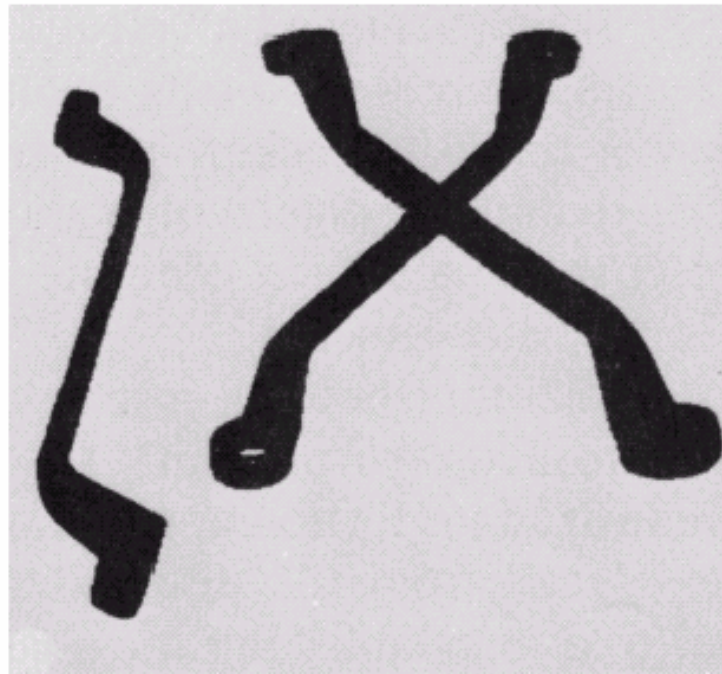
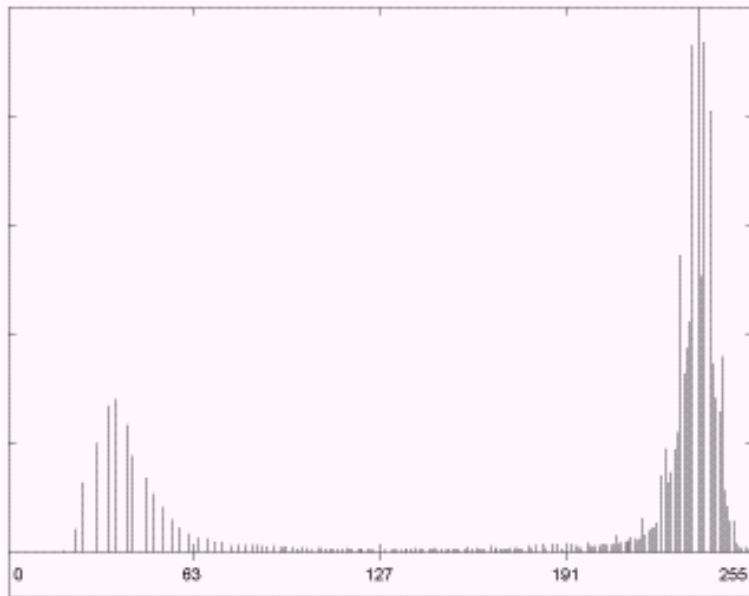


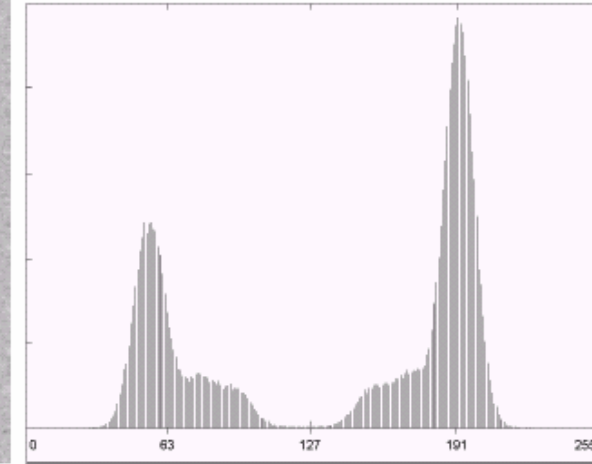
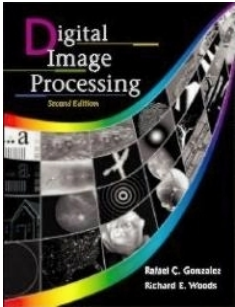


Basic Global Thresholding

a
b c

FIGURE 10.28
(a) Original image. (b) Image histogram. (c) Result of global thresholding with T midway between the maximum and minimum gray levels.

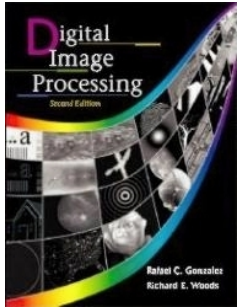




a b
c

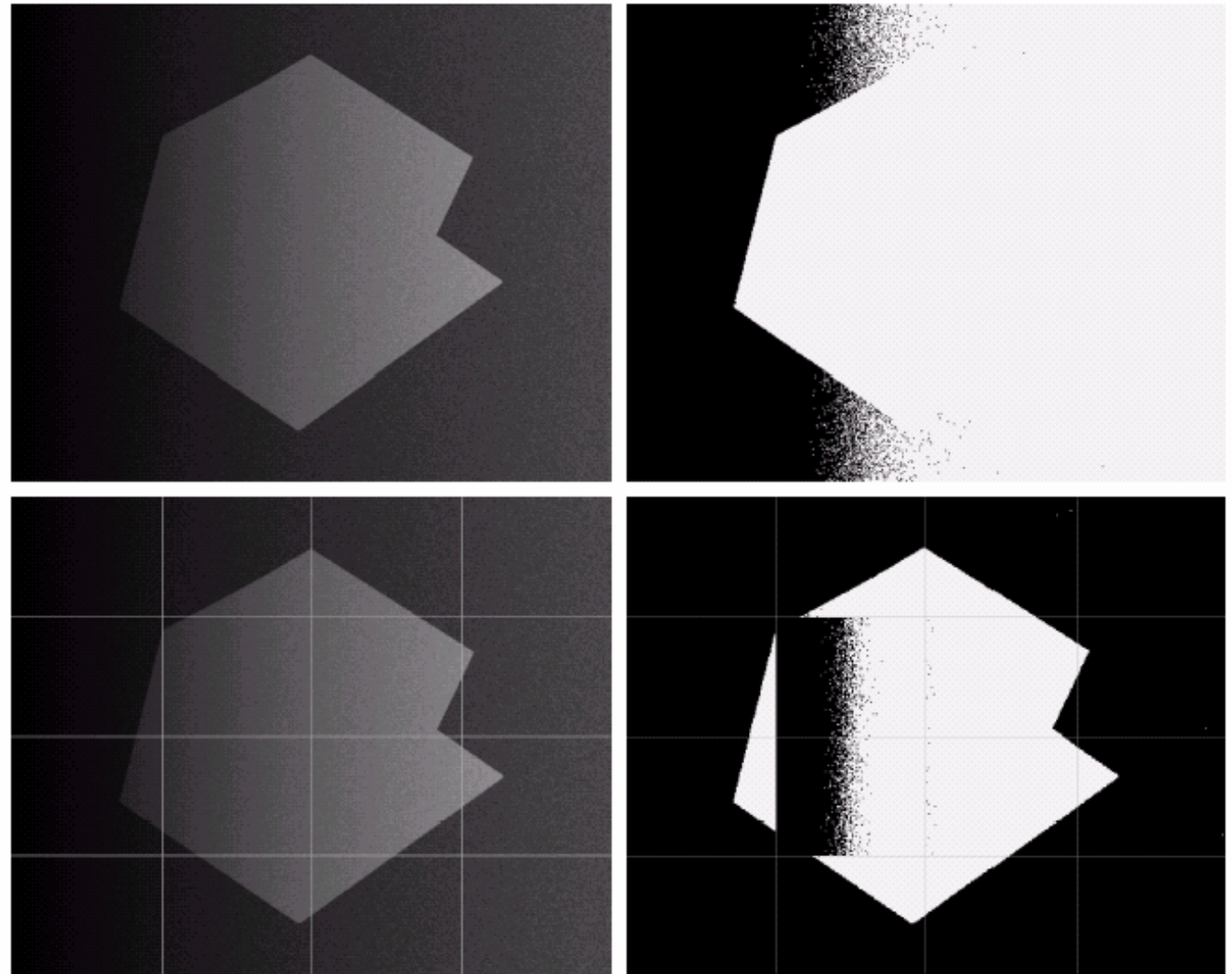
FIGURE 10.29
(a) Original image. (b) Image histogram. (c) Result of segmentation with the threshold estimated by iteration. (Original courtesy of the National Institute of Standards and Technology.)



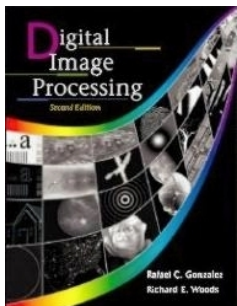


a b
c d

FIGURE 10.30
(a) Original image. (b) Result of global thresholding. (c) Image subdivided into individual subimages. (d) Result of adaptive thresholding.

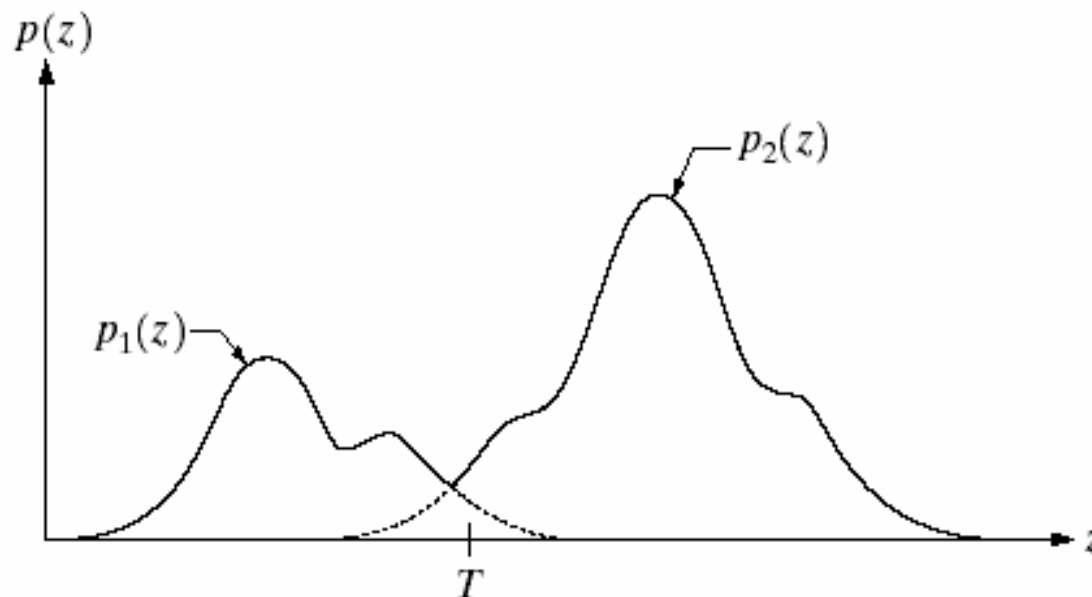


Basic Adaptive Thresholding

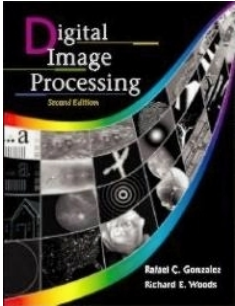


Chapter 10 Image Segmentation

FIGURE 10.32
Gray-level
probability
density functions
of two regions in
an image.



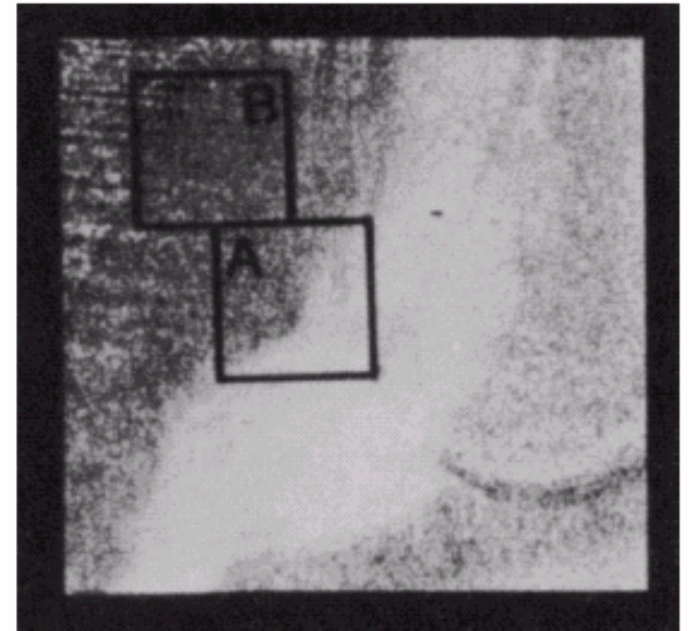
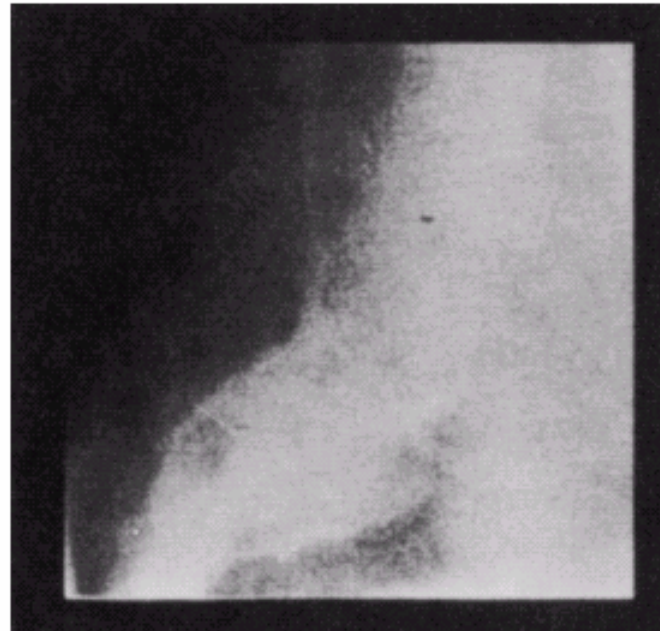
Optimal Global and Adaptive Thresholding

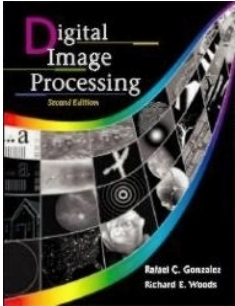


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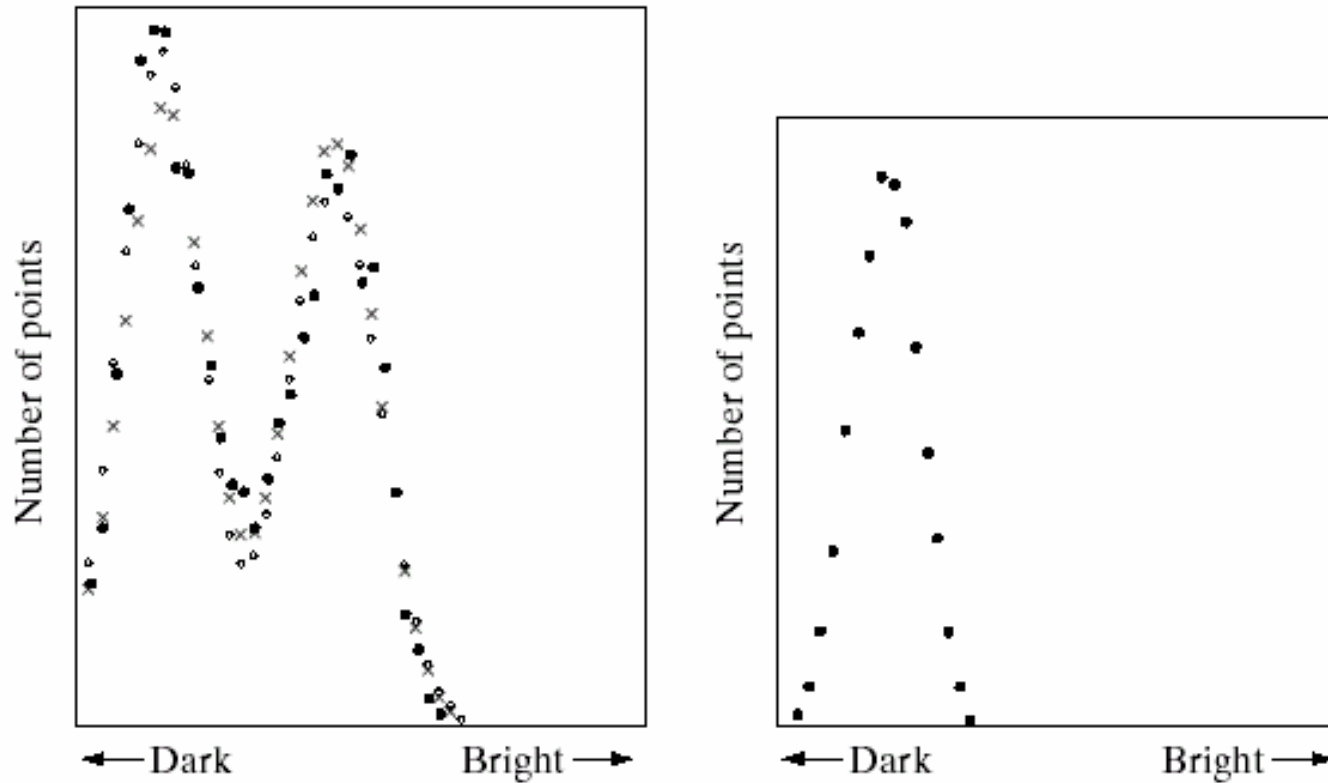
a b

FIGURE 10.33 A cardioangiogram before and after preprocessing. (Chow and Kaneko.)

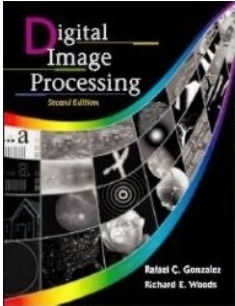




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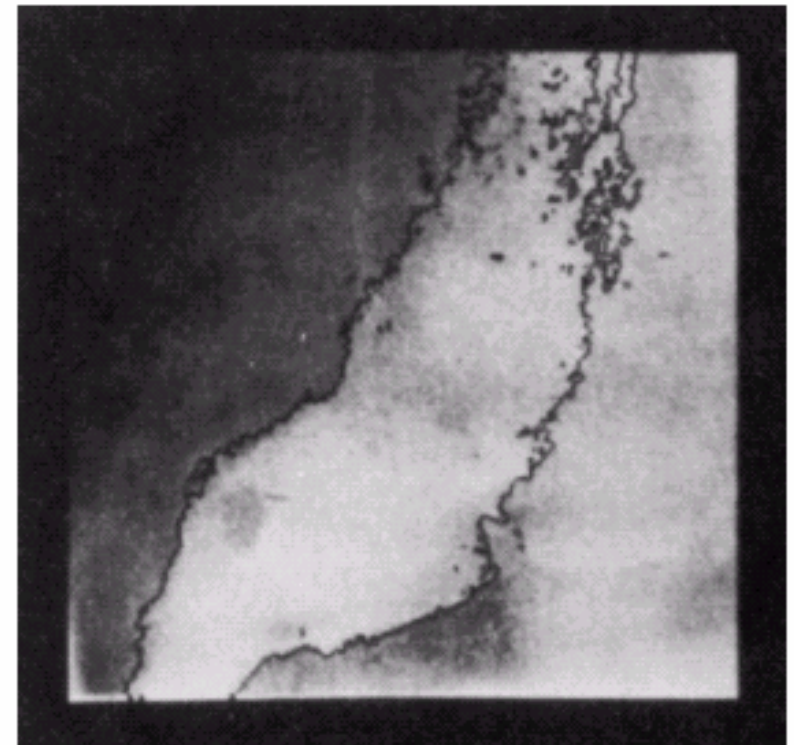


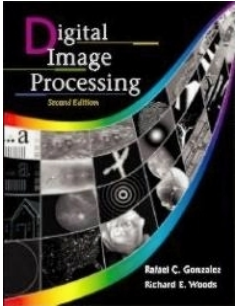
a b
FIGURE 10.34
Histograms (black dots) of (a) region *A*, and (b) region *B* in Fig. 10.33(b). (Chow and Kaneko.)



Chapter 10 Image Segmentation

FIGURE 10.35
Cardioangiogram
showing
superimposed
boundaries.
(Chow and
Kaneko.)



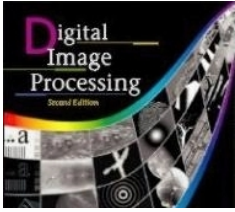


Chapter 10 Image Segmentation

Use of Boundary Characteristics for Histogram Improvement and Local Thresholding



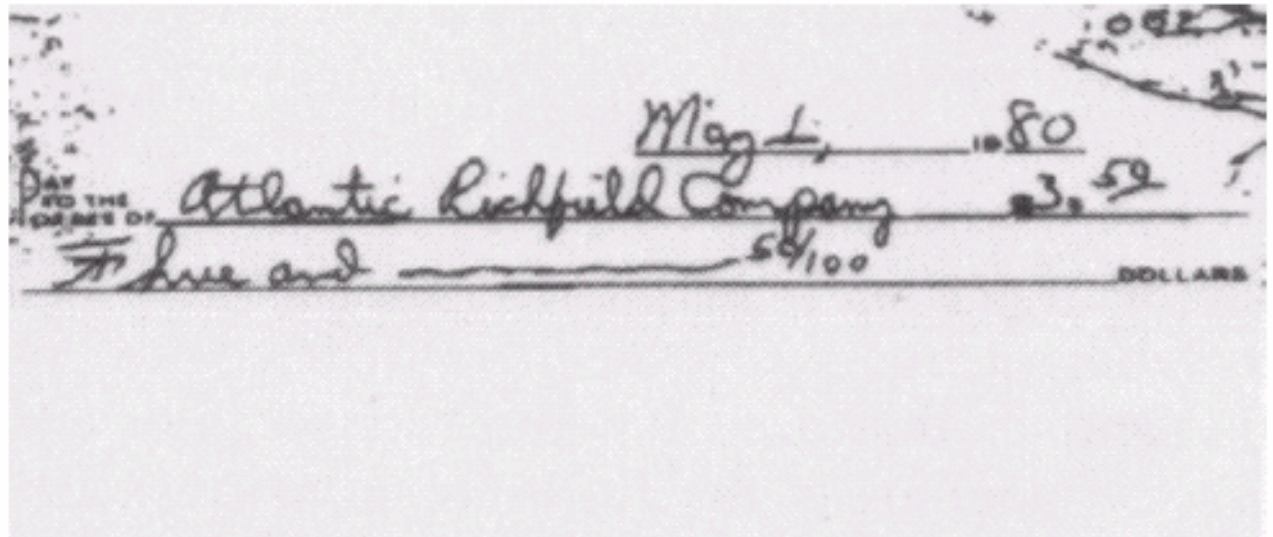
FIGURE 10.36
Image of a handwritten stroke coded by using Eq. (10.3-16). (Courtesy of IBM Corporation.)

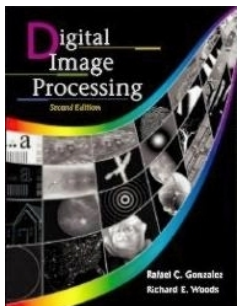


Chapter 10

a
b

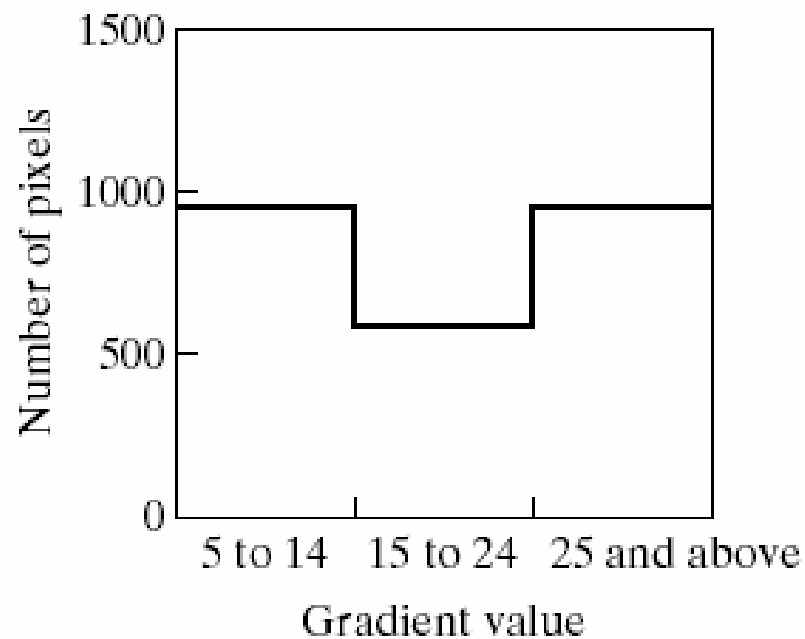
FIGURE 10.37
(a) Original image. (b) Image segmented by local thresholding. (Courtesy of IBM Corporation.)

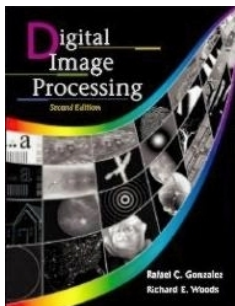




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FIGURE 10.38
Histogram of pixels with gradients greater than 5. (Courtesy of IBM Corporation.)



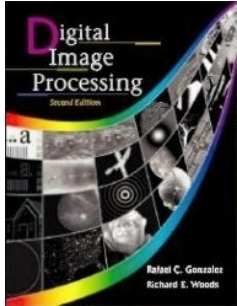


Chapter 10 Image Segmentation



a b c

FIGURE 10.39 (a) Original color image shown as a monochrome picture. (b) Segmentation of pixels with colors close to facial tones. (c) Segmentation of red components.



Chapter 10 Image Segmentation

10.4 Region-Based Segmentation 612

10.4.1 Basic Formulation 612

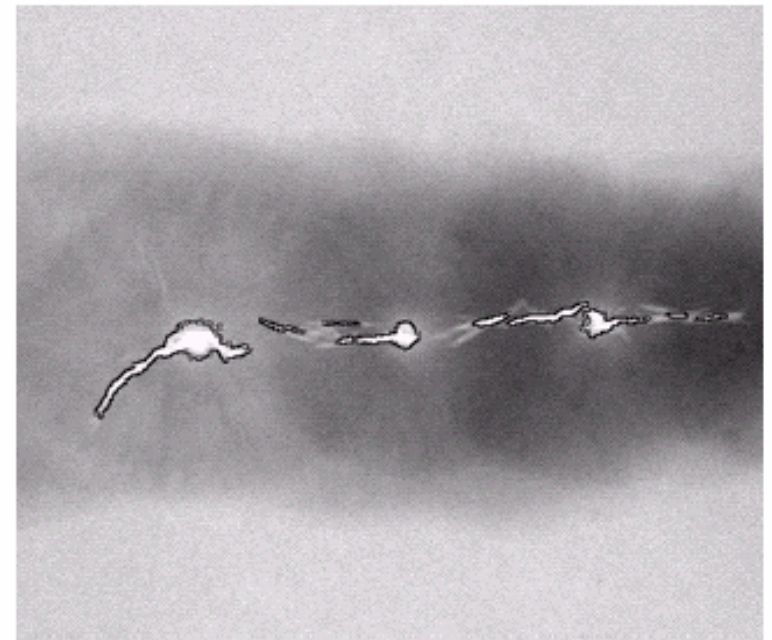
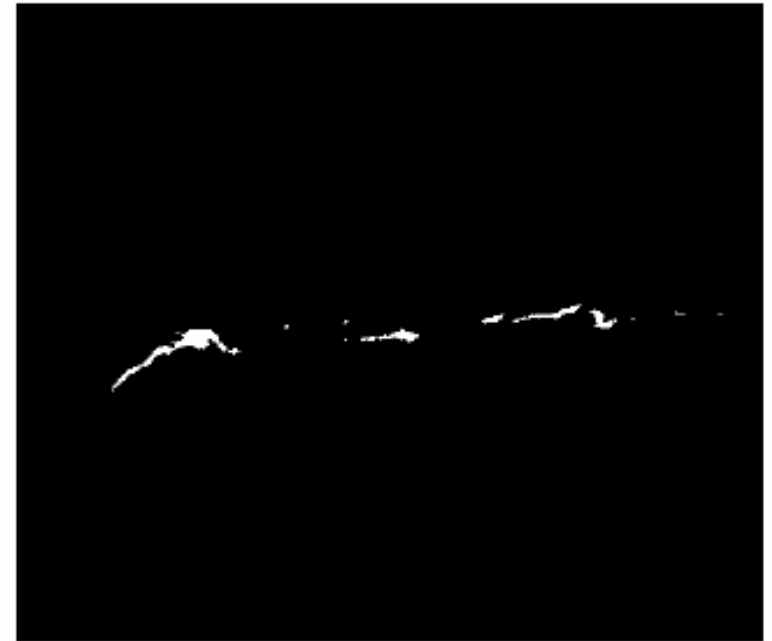
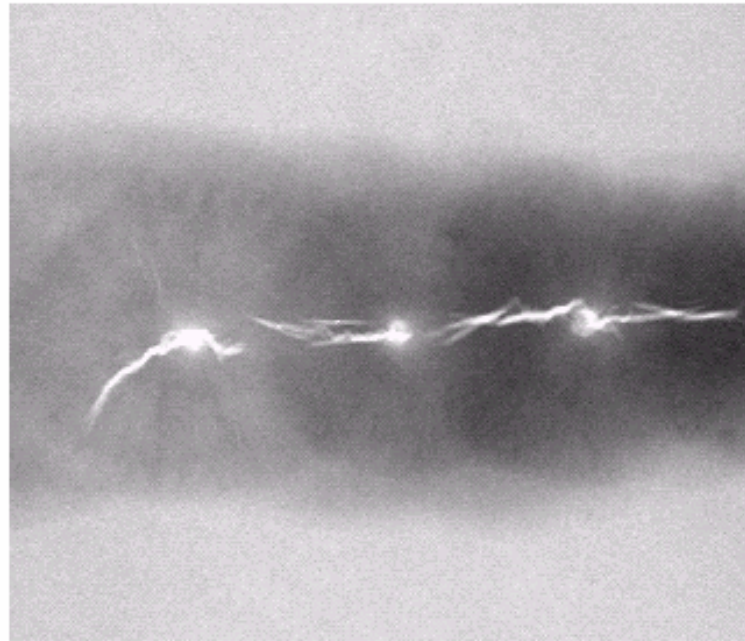
10.4.2 Region Growing 613

10.4.3 Region Splitting and Merging 615

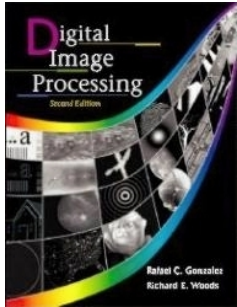
a b
c d

FIGURE 10.40

(a) Image showing defective welds. (b) Seed points. (c) Result of region growing. (d) Boundaries of segmented defective welds (in black). (Original image courtesy of X-TEK Systems, Ltd.).



Region Growing



Chapter 10

Image Segmentation

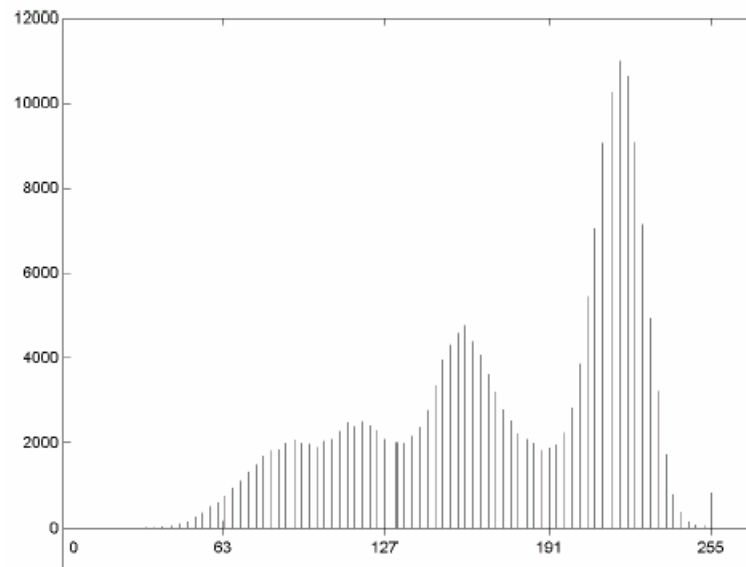
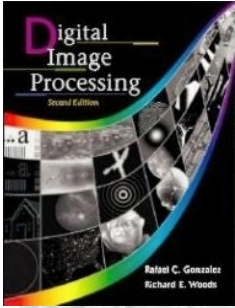


FIGURE 10.41
Histogram of
Fig. 10.40(a).



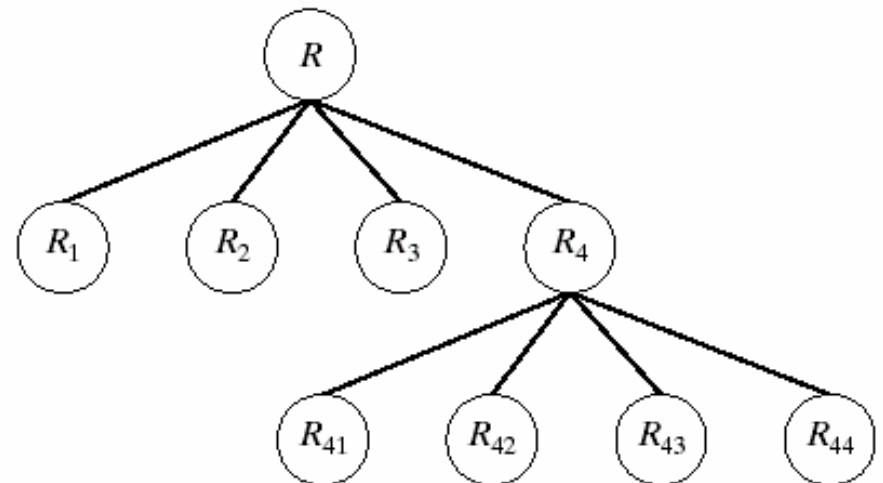
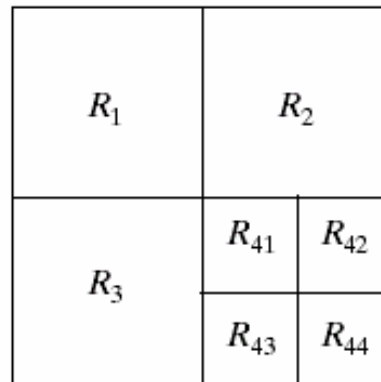
Chapter 10 Image Segmentation

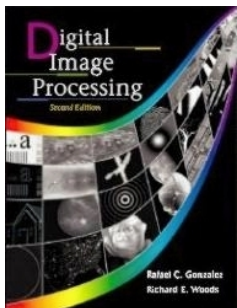
Region Splitting and Merging

a b

FIGURE 10.42

(a) Partitioned image.
(b) Corresponding quadtree.





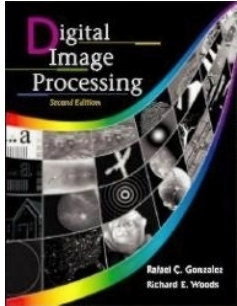
Chapter 10 Image Segmentation

a b c

FIGURE 10.43

(a) Original image. (b) Result of split and merge procedure. (c) Result of thresholding (a).





Chapter 10 Image Segmentation

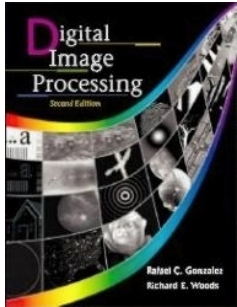
10.5 Segmentation by Morphological Watersheds 617

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10.5.3 Watershed Segmentation Algorithm 622

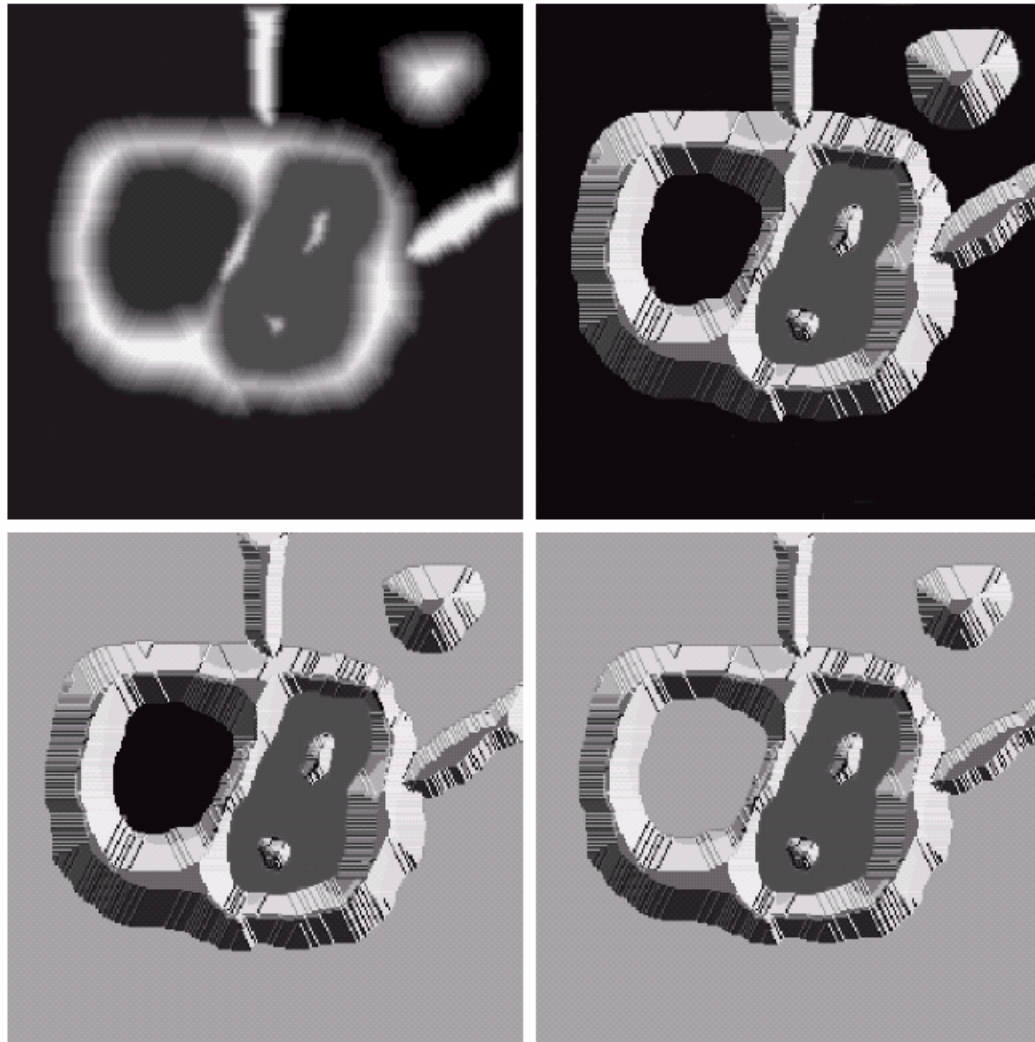
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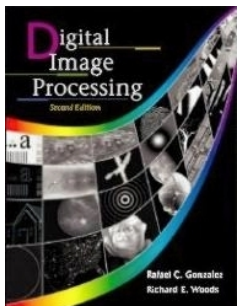


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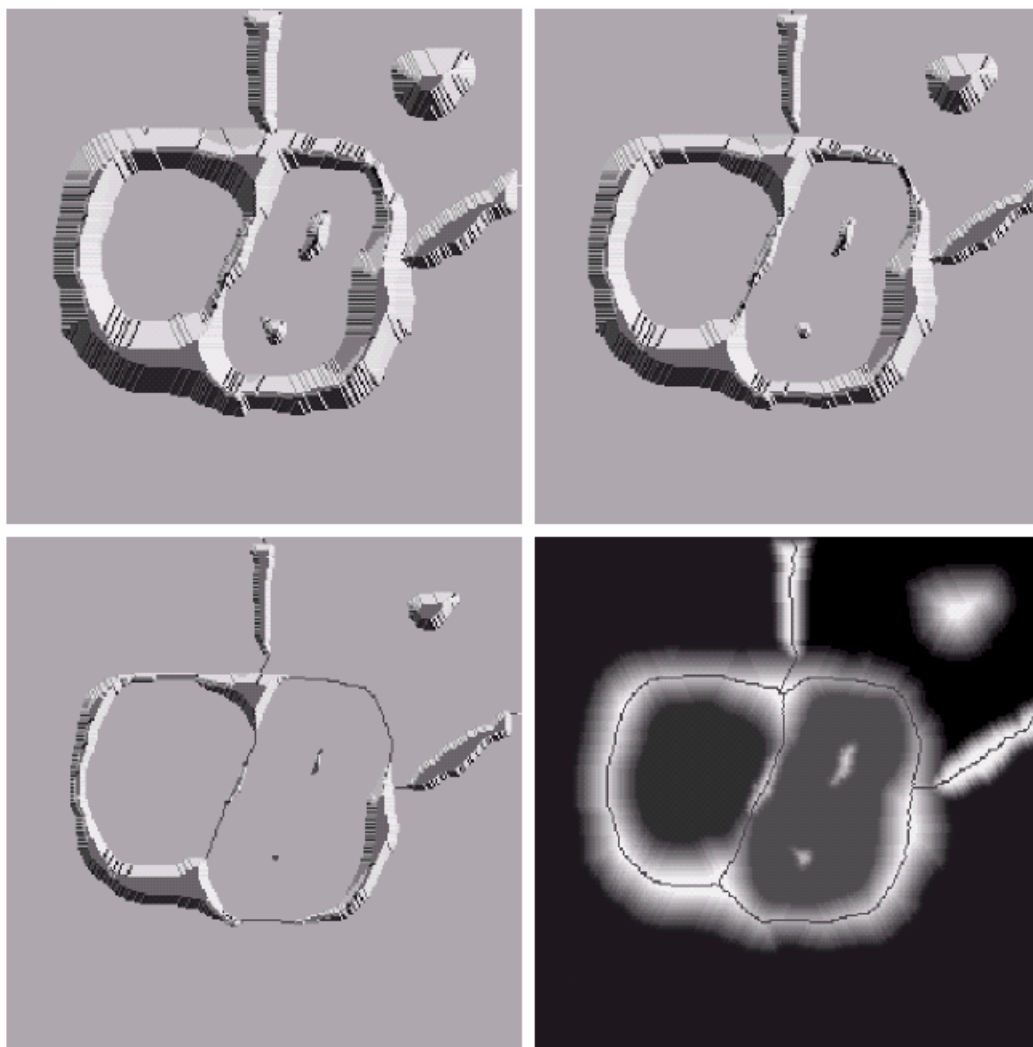
a b
c d

FIGURE 10.44
(a) Original image.
(b) Topographic view.
(c)–(d) Two stages of flooding.





Chapter 10 Image Segmentation

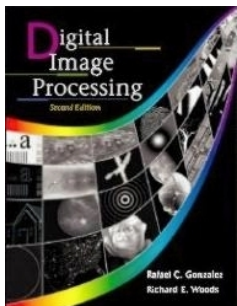


e f
g h

FIGURE 10.44

(Continued)

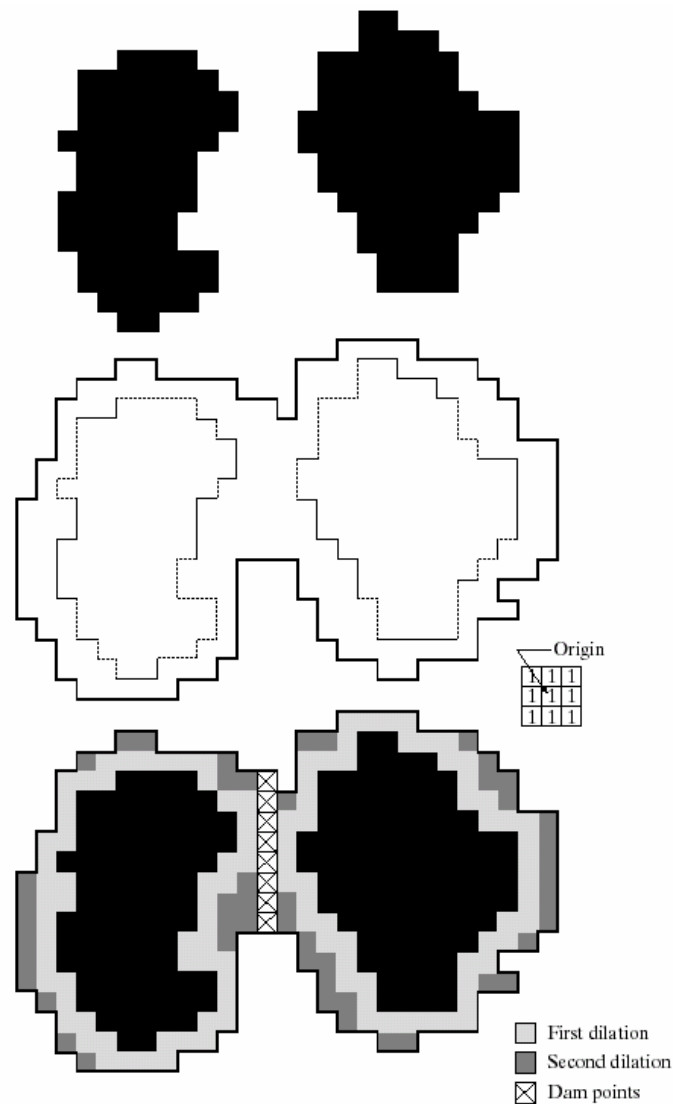
(e) Result of further flooding. (f) Beginning of merging of water from two catchment basins (a short dam was built between them). (g) Longer dams. (h) Final watershed (segmentation) lines. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)

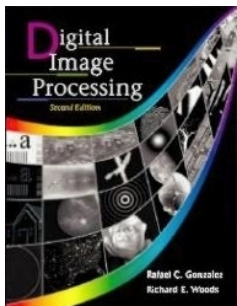


Chapter 10 Image Segmentation

a
b
d c

FIGURE 10.45 (a) Two partially flooded catchment basins at stage $n - 1$ of flooding. (b) Flooding at stage n , showing that water has spilled between basins (for clarity, water is shown in white rather than black). (c) Structuring element used for dilation. (d) Result of dilation and dam construction.

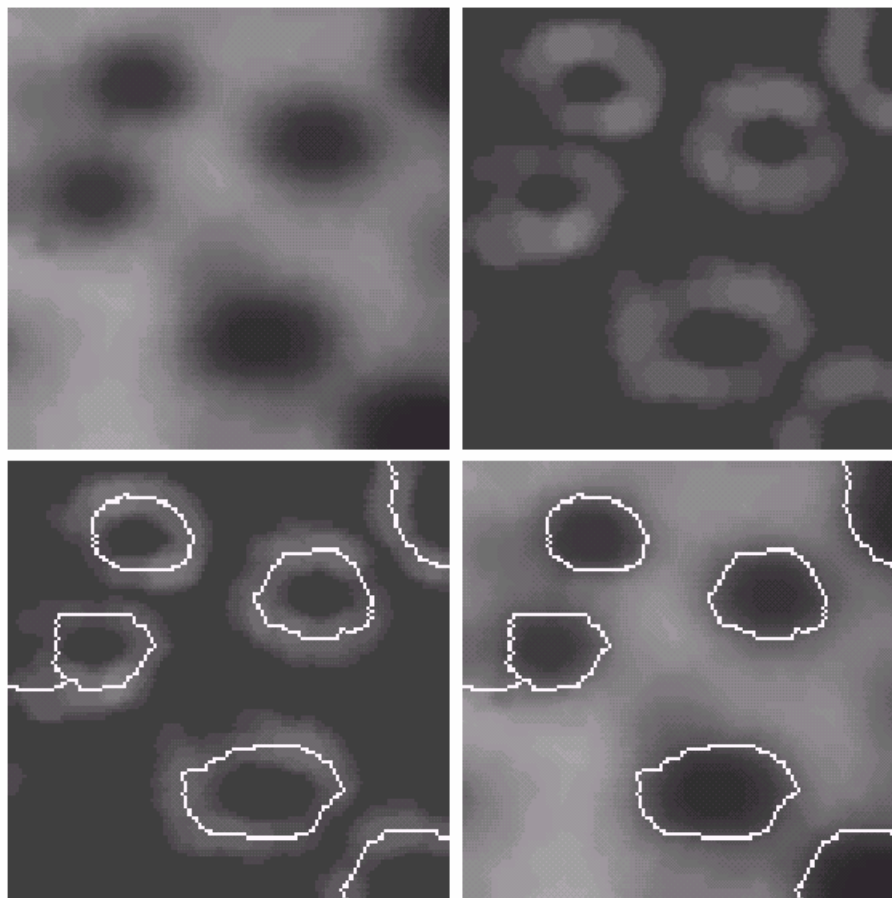


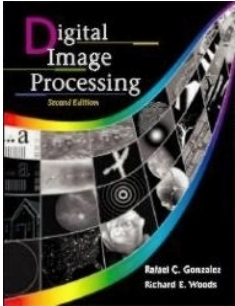


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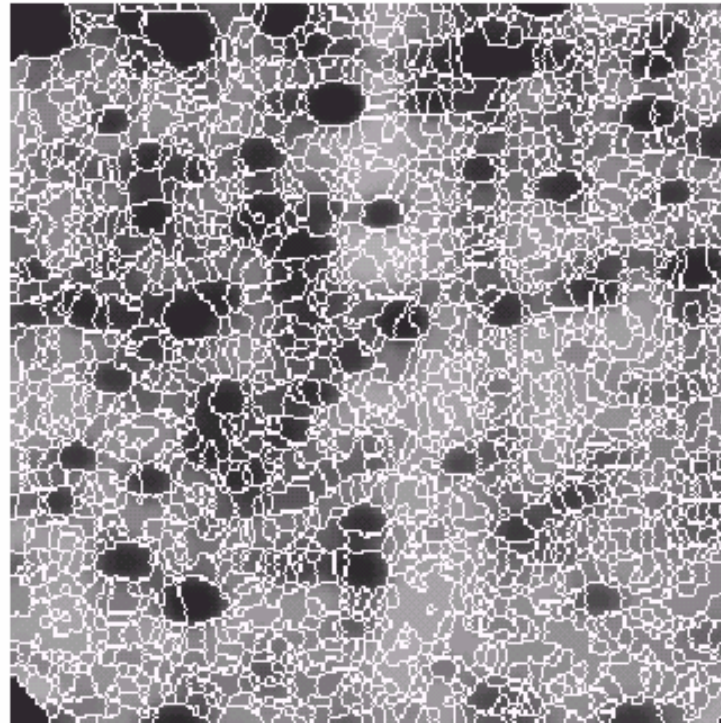
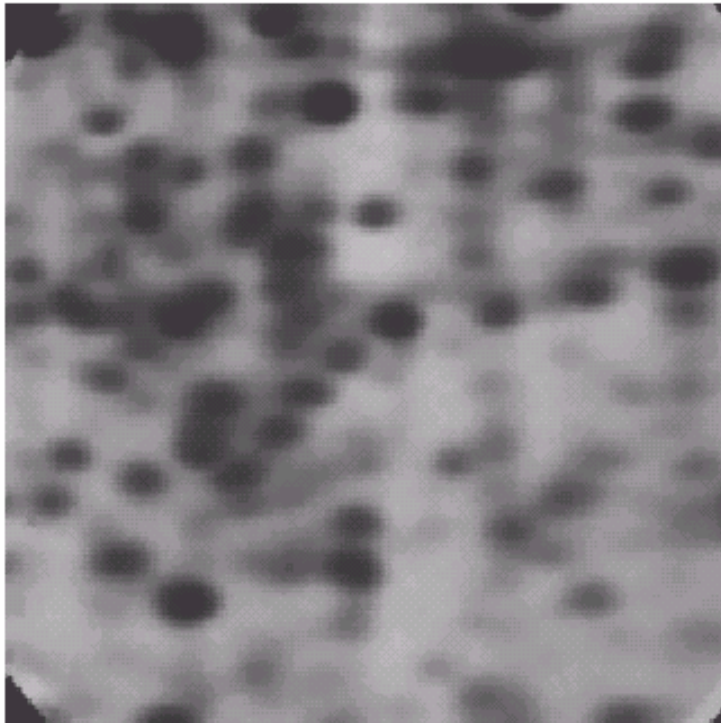
a b
c d

FIGURE 10.46
(a) Image of blobs. (b) Image gradient.
(c) Watershed lines.
(d) Watershed lines superimposed on original image.
(Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)





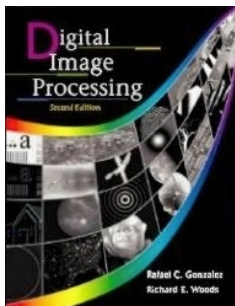
Chapter 10 Image Segmentation



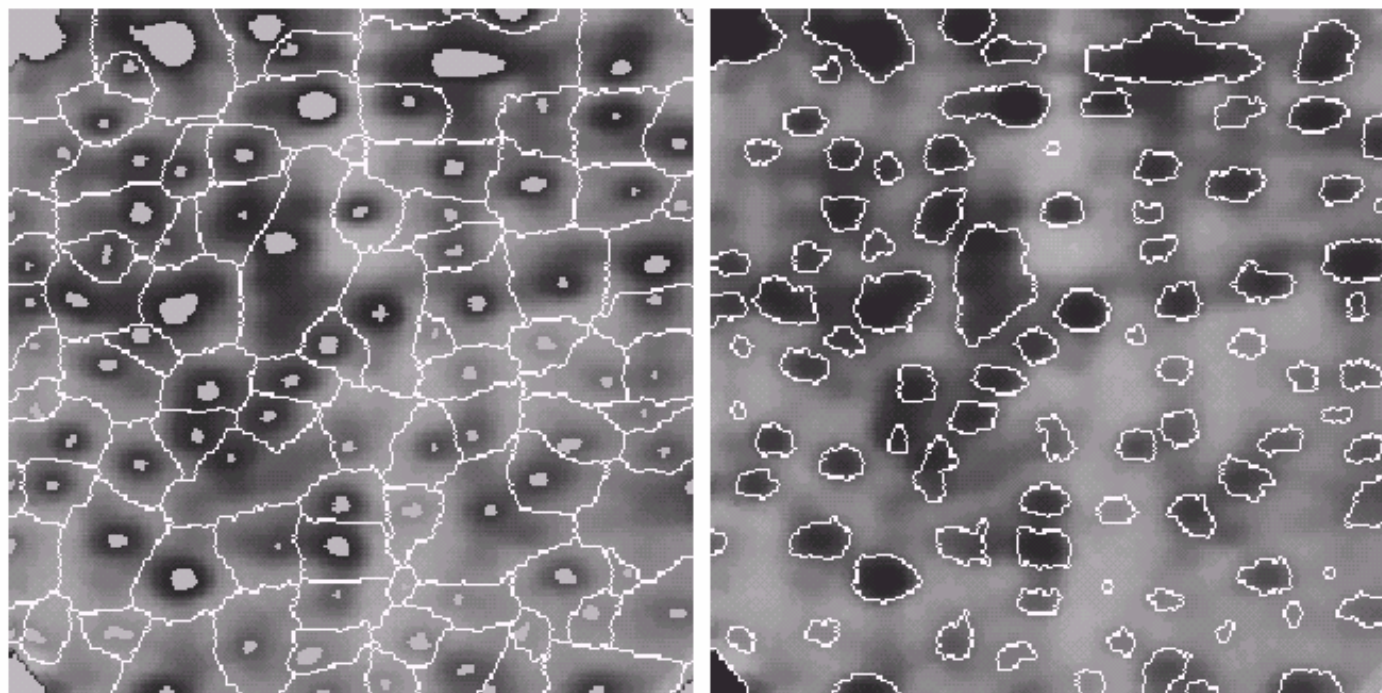
a b

FIGURE 10.47

(a) Electrophoresis image. (b) Result of applying the watershed segmentation algorithm to the gradient image. Oversegmentation is evident. (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)



Chapter 10 Image Segmentation

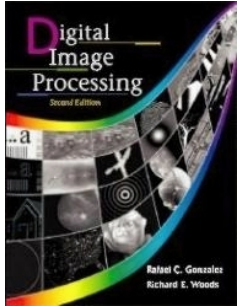


a b

FIGURE 10.48

(a) Image showing internal markers (light gray regions) and external markers (watershed lines).

(b) Result of segmentation. Note the improvement over Fig. 10.47(b). (Courtesy of Dr. S. Beucher, CMM/Ecole des Mines de Paris.)



Chapter 10 Image Segmentation

10.6 The Use of Motion in Segmentation

Stationary camera

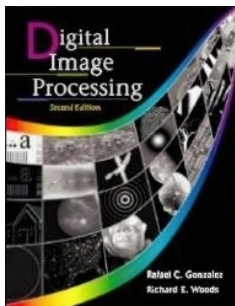
- Background modeling

- Human tracking & extraction

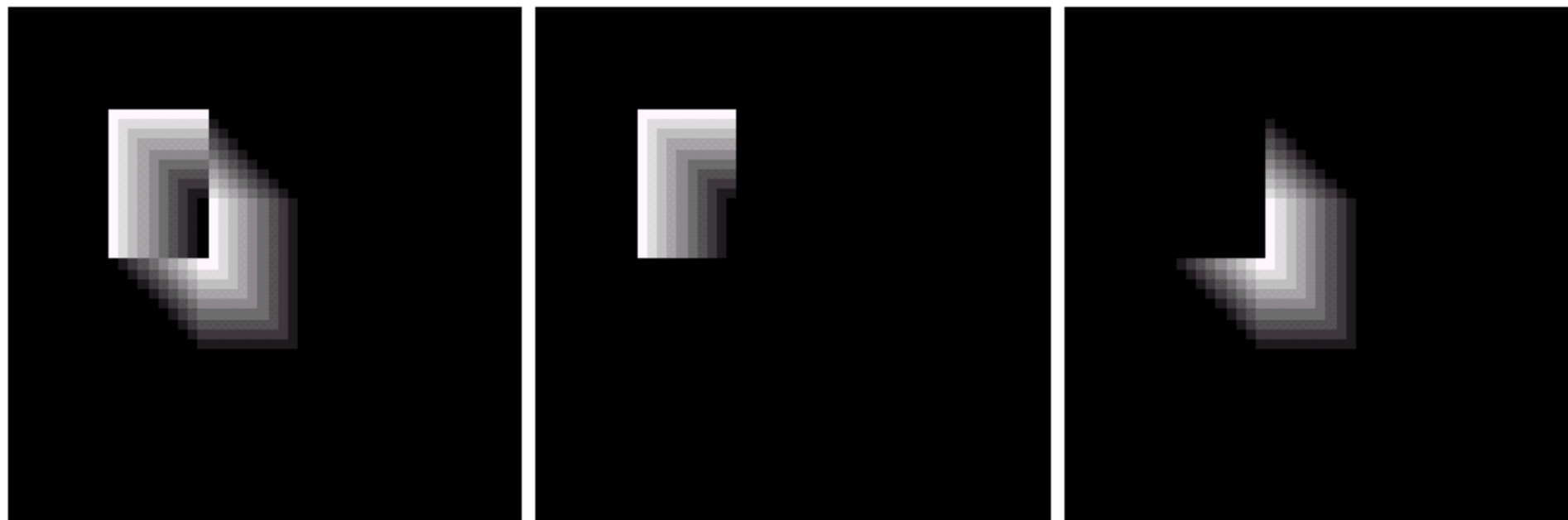
Moving camera

- 3D Reconstruction

- Moving target detecting

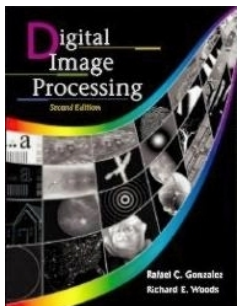


Chapter 10 Image Segmentation



a b c

FIGURE 10.49 ADIs of a rectangular object moving in a southeasterly direction. (a) Absolute ADI. (b) Positive ADI. (c) Negative ADI.

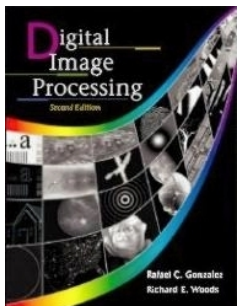


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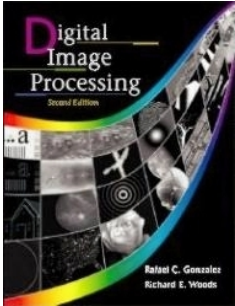
a b c

FIGURE 10.50 Building a static reference image. (a) and (b) Two frames in a sequence. (c) Eastbound automobile subtracted from (a) and the background restored from the corresponding area in (b). (Jain and Jain.)



Chapter 10 Image Segmentation



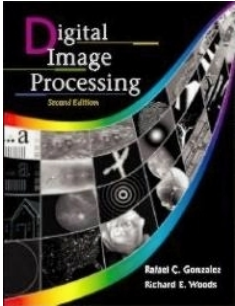


Digital Image Processing, 2nd ed.

www.imageprocessingbook.com

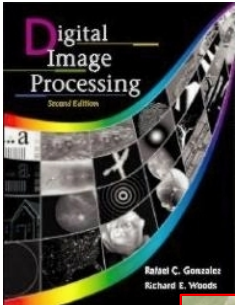
Chapter 10 Image Segmentation



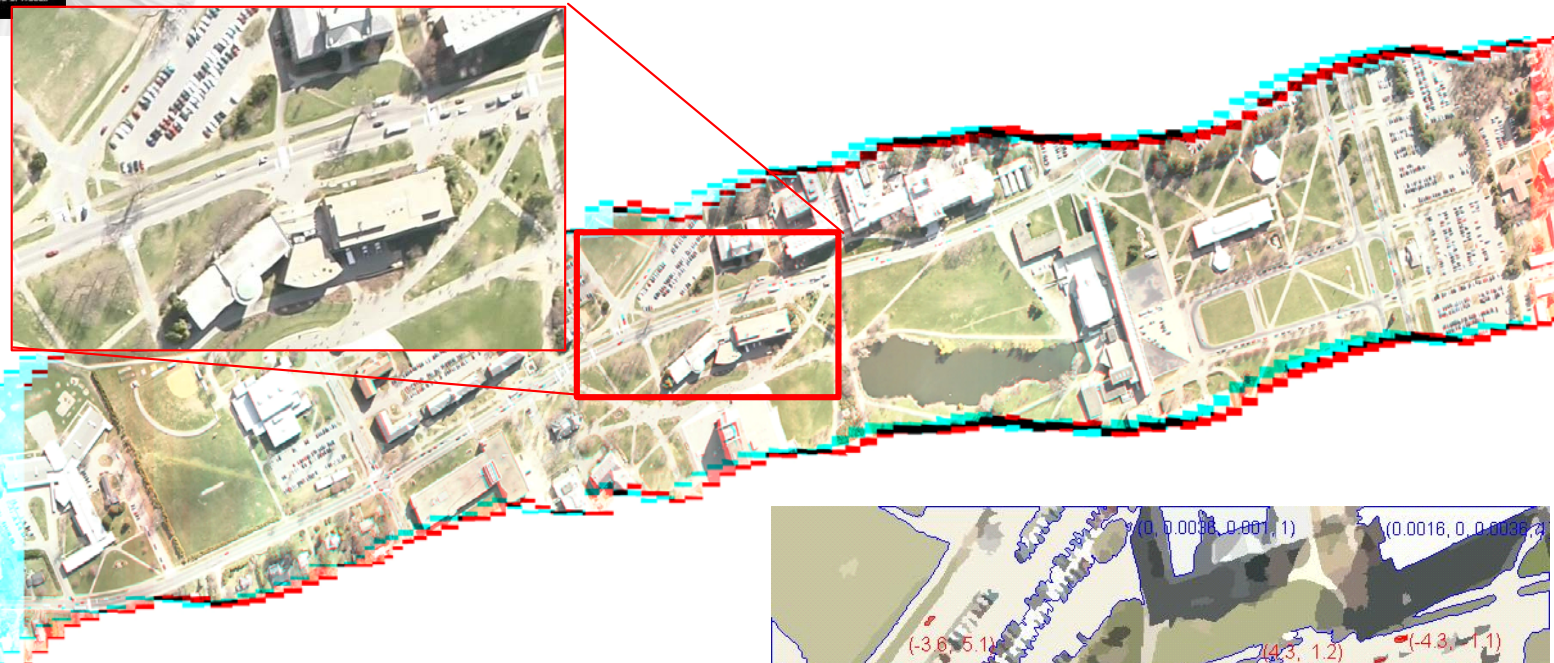


Chapter 10 Image Segmentation

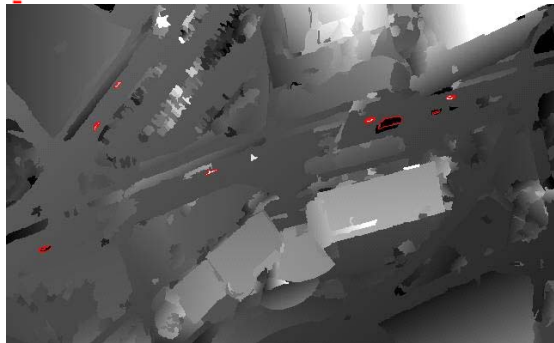




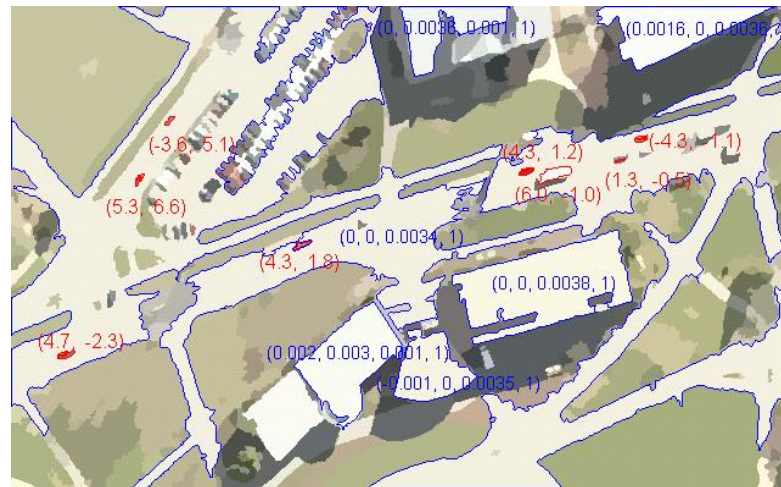
Chapter 10 Image Segmentation



a



b



c

Plane parameters in blue and motion in red
compression ratio is 10,000:1