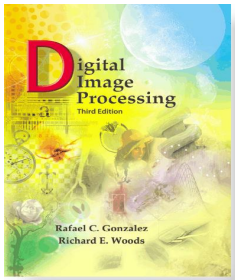

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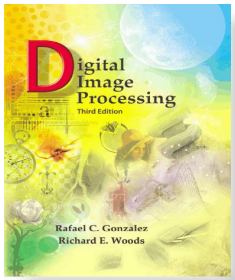
Basically, representing a region involves two choices: (1) We can represent the region in terms of its external characteristics (its boundary), or (2) we can represent it in terms of its internal characteristics (the pixels comprising the region).

An external representation is chosen when the primary focus is on shape characteristics. An internal representation is selected when the primary focus is on regional properties, such as color and texture.



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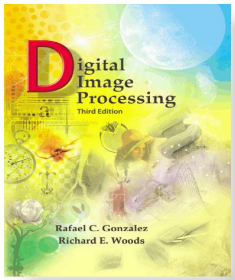
. The next task is to *describe* the region based on the chosen representation. For example, a region may be *represented* by its boundary, and the boundary *described* by features such as its length, the orientation of the straight line joining its extreme points, and the number of concavities in the boundary.



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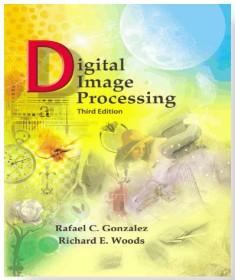
11.1 Representation

11.1.1 Boundary (Border) Following

Several of the algorithms discussed in this chapter require that the points in the boundary of a region be ordered in a clockwise (or counterclockwise) direction. Consequently, we begin our discussion by introducing a boundary-following algorithm whose output is an *ordered* sequence of points. We assume



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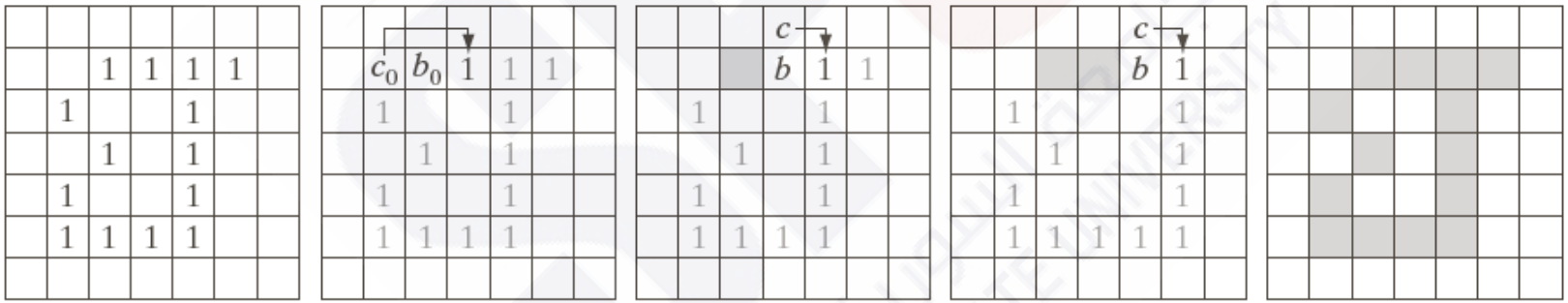
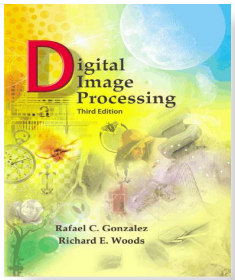


a b c d e

FIGURE 11.1 Illustration of the first few steps in the boundary-following algorithm. The point to be processed next is labeled in black, the points yet to be processed are gray, and the points found by the algorithm are labeled as gray squares.



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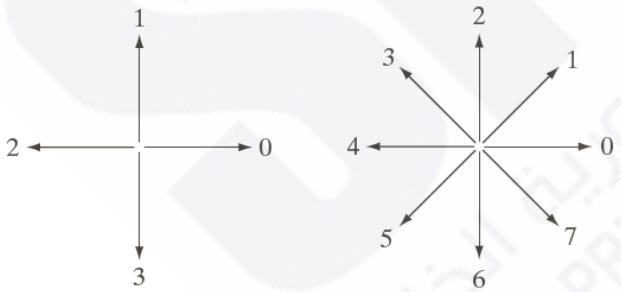
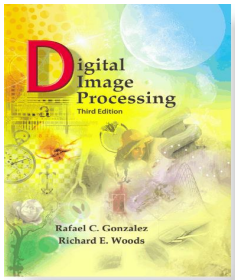
11.1.2 Chain Codes

Chain codes are used to represent a boundary by a connected sequence of straight-line segments of specified length and direction.

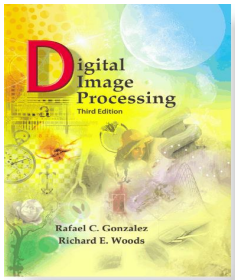


a b

FIGURE 11.3 Direction numbers for (a) 4-directional chain code, and (b) 8-directional chain code.



This method generally is unacceptable for two principal reasons: (1) The resulting chain tends to be quite long and (2) any small disturbances along the boundary due to noise or imperfect segmentation cause changes in the code that may not be related to the principal shape features of the boundary.



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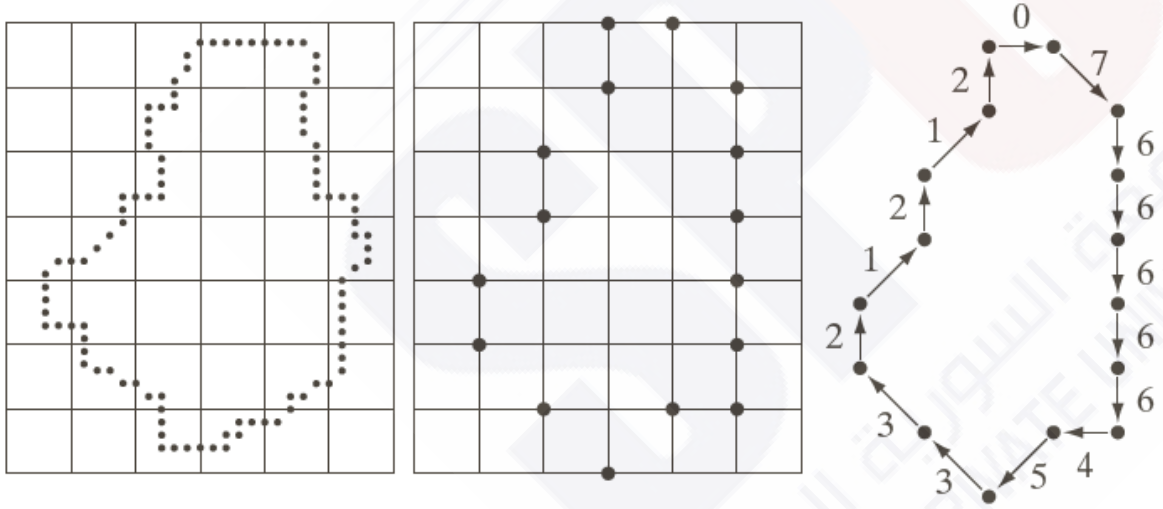
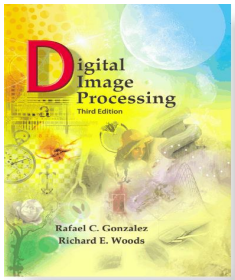


a b c

FIGURE 11.4 (a) Digital boundary with resampling grid superimposed. (b) Result of resampling. (c) 8-directional chain-coded boundary.



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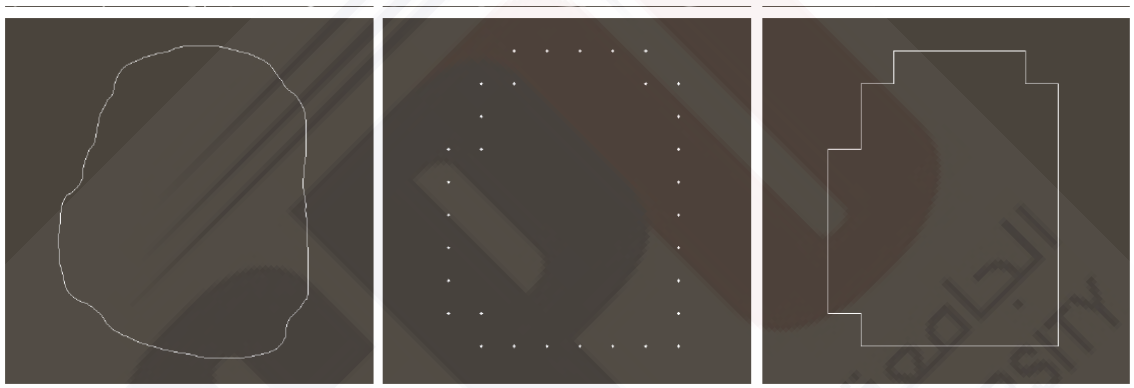


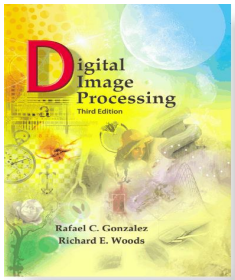
a b c
d e f

FIGURE 11.5 (a) Noisy image. (b) Image smoothed with a 9×9 averaging mask. (c) Smoothed image, thresholded using Otsu's method. (d) Longest outer boundary of (c). (e) Subsampled boundary (the points are shown enlarged for clarity). (f) Connected points from (e).

0 0 0 0 6 0 6 6 6 6 6 6 6 4 4 4 4 4 2 4 2 2 2 2 2 0 2 2 0 2

The first difference of either code is

0 0 0 6 2 6 0 0 0 0 0 0 0 6 0 0 0 0 6 2 6 0 0 0 0 6 2 0 6 2 6



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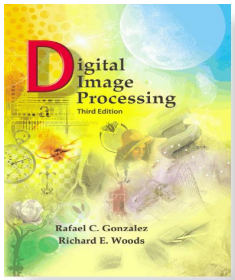
11.1.3 Polygonal Approximations Using Minimum-Perimeter Polygons

. The goal of a polygonal approximation is to capture the essence of the shape in a given boundary using the fewest possible number of segments. This problem is not trivial in



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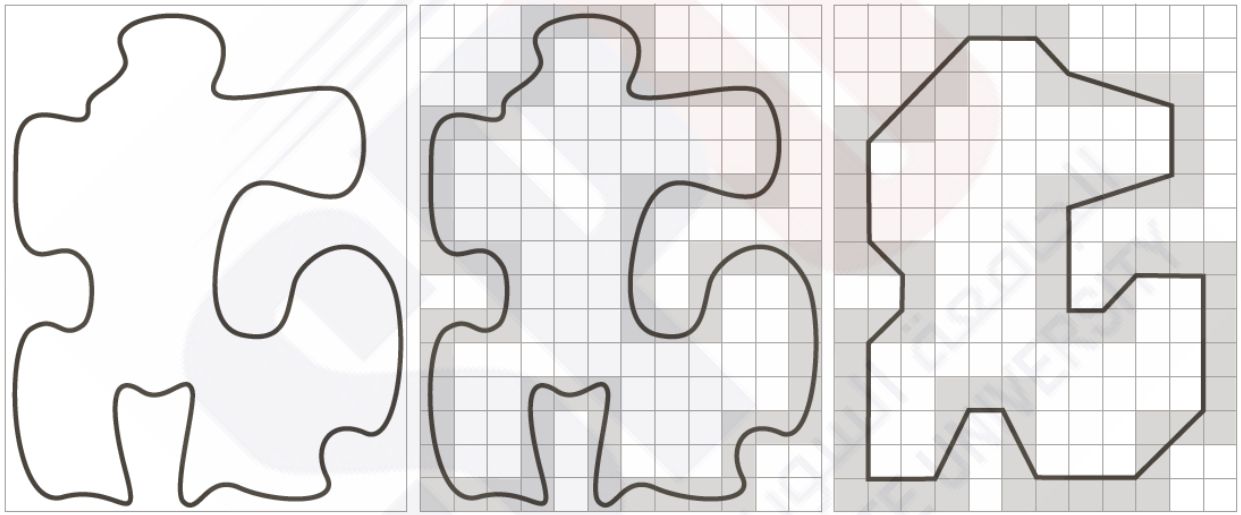


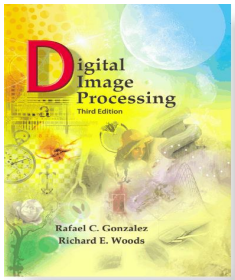
a b c

FIGURE 11.6 (a) An object boundary (black curve). (b) Boundary enclosed by cells (in gray). (c) Minimum-perimeter polygon obtained by allowing the boundary to shrink. The vertices of the polygon are created by the corners of the inner and outer walls of the gray region.

11.1.4 Other Polygonal Approximation Approaches

Merging techniques

Merging techniques based on average error or other criteria have been applied to the problem of polygonal approximation. One approach is to merge points along a boundary until the least square error line fit of the points merged so far exceeds a preset threshold.



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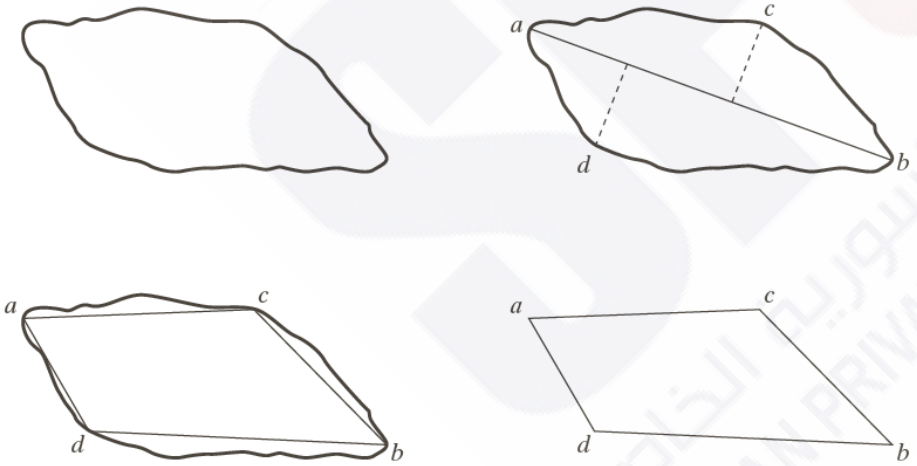
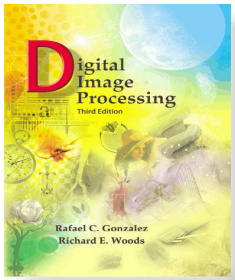
Splitting techniques



a b
c d

FIGURE 11.9 (a) Original boundary. (b) Boundary divided into segments based on extreme points. (c) Joining of vertices. (d) Resulting polygon.



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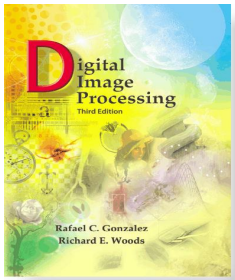
11.1.5 Signatures

A signature is a 1-D functional representation of a boundary and may be generated in various ways. One of the simplest is to plot the distance from the centroid to the boundary as a function of angle, as illustrated in Fig. 11.10.



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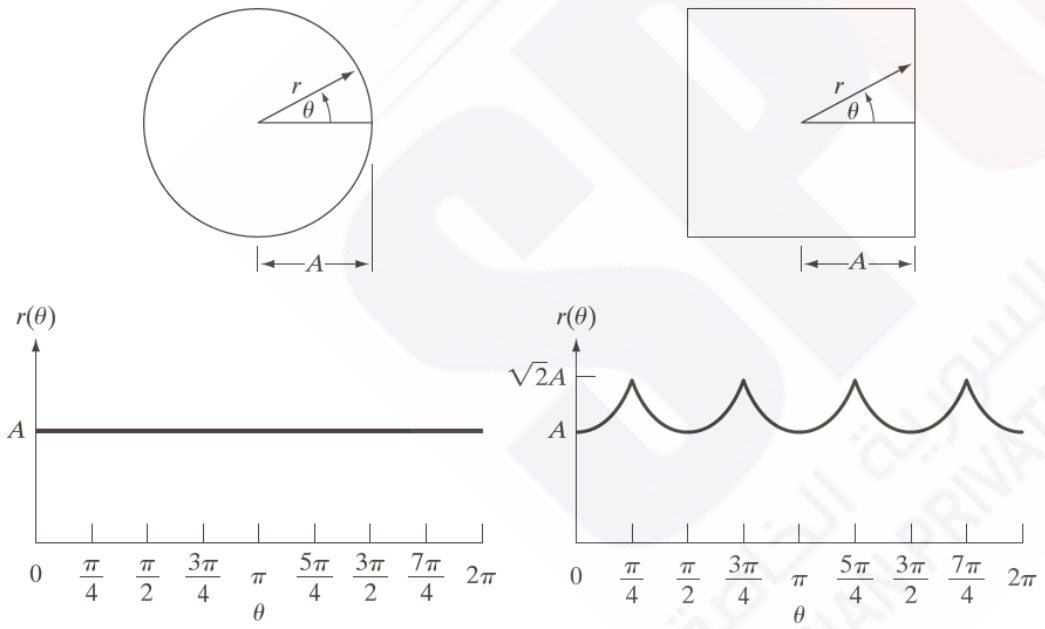
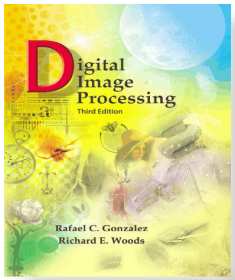


a b

FIGURE 11.10 Distance-versus-angle signatures. In (a) $r(\theta)$ is constant. In (b), the signature consists of repetitions of the pattern $r(\theta) = A \sec \theta$ for $0 \leq \theta \leq \pi/4$ and $r(\theta) = A \csc \theta$ for $\pi/4 < \theta \leq \pi/2$.



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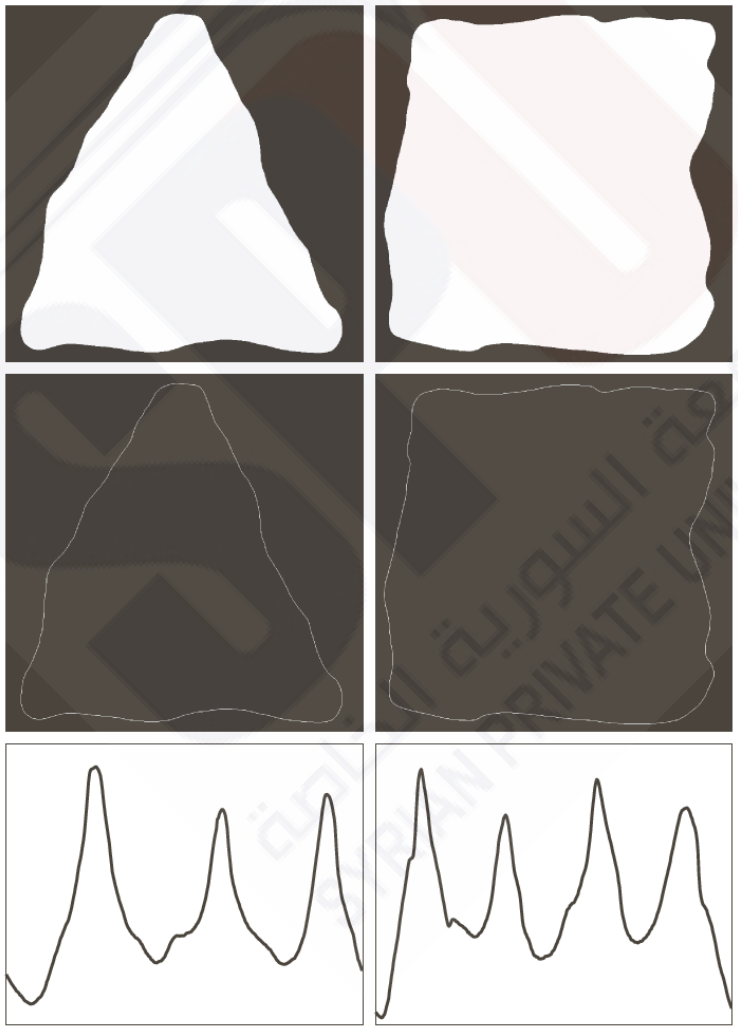
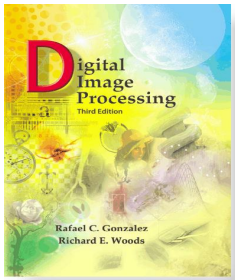


a b
c d
e f

FIGURE 11.11
Two binary regions, their external boundaries, and their corresponding $r(\theta)$ signatures. The horizontal axes in (e) and (f) correspond to angles from 0° to 360°, in increments of 1°.



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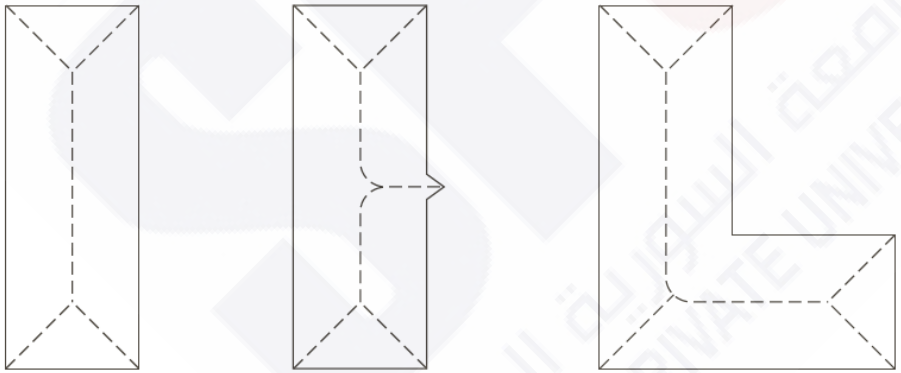
11.1.7 Skeletons

The medial axe transformation



a b c

FIGURE 11.13 Medial axes (dashed) of three simple regions.

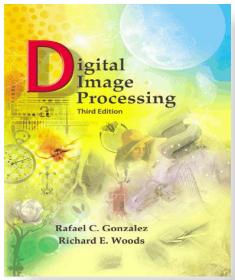


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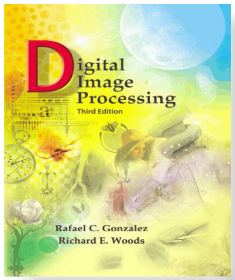
FIGURE 11.16 Human leg bone and skeleton of the region shown superimposed.



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Boundary Descriptors

11.2.1 Some Simple Descriptors:

- The length of a boundary
- The diameter

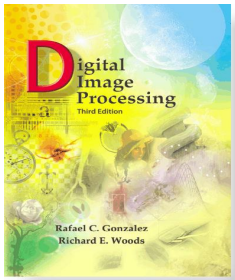
$$\text{Diam}(B) = \max_{i,j}\left[D(p_i, p_j)\right]$$

- Major axis and minor axis and eccentricity

11.2.2 Shape Numbers

The **order n** of shape number of digits in its representation.

Shape number is the first difference of smallest magnitude.



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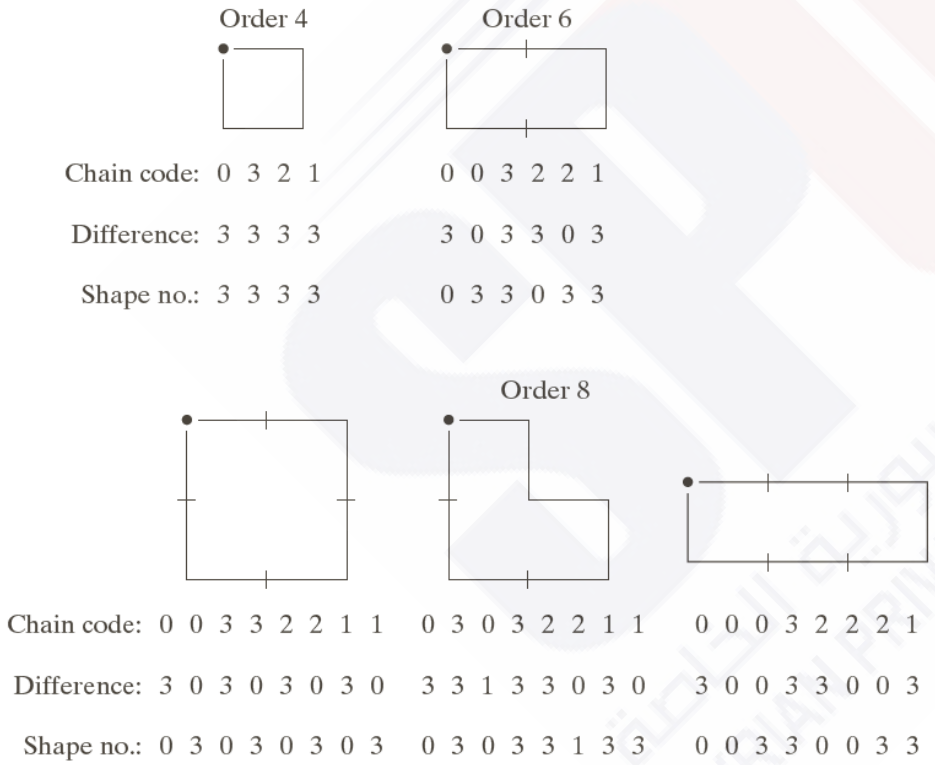
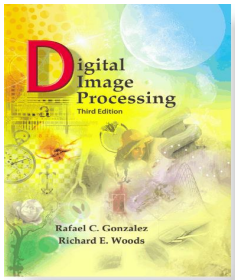


FIGURE 11.17
All shapes of order 4, 6, and 8. The directions are from Fig. 11.3(a), and the dot indicates the starting point.



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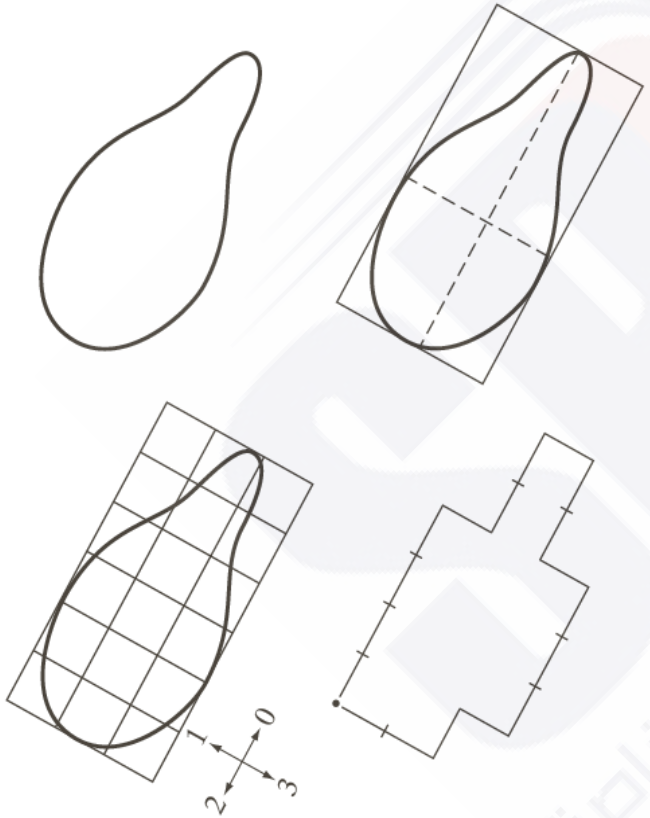


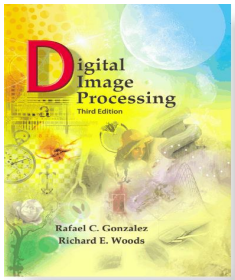
a b
c d

FIGURE 11.18 Steps in the generation of a shape number.

Chain code: 0 0 0 0 3 0 0 3 2 2 3 2 2 2 1 2 1 1

Difference: 3 0 0 0 3 1 0 3 3 0 1 3 0 0 3 1 3 0

Shape no.: 0 0 0 3 1 0 3 3 0 1 3 0 0 3 1 3 0 3



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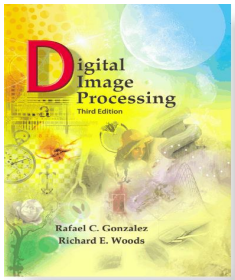
11.3 Regional Descriptors

11.3.1 Some Simple Descriptors

- Area
- Perimeter
- Compactness = square(perimeter)/area
- Circularity Ratio =area of region/area of circle having the same perimeter.
- Mean and median of intensity levels.
- Min, max, number of pixels above or below the mean intensity



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11.3.2 Topological Descriptors

Simply defined, *topology* is the study of properties of a figure that are unaffected by any deformation, as long as there is no tearing or joining of the figure (sometimes these are called *rubber-sheet* distortions).

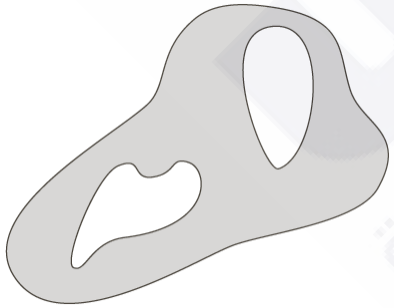

FIGURE 11.23
A region with two holes.

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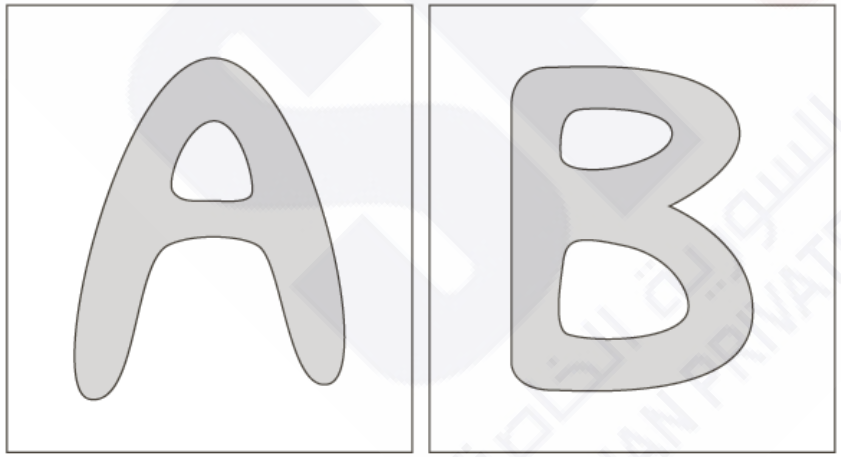
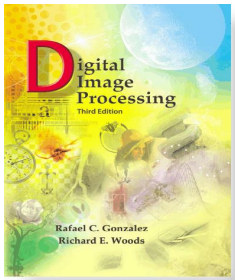
The number of holes H and connected components C in a figure can be used to define the *Euler number* E:

$$E = C - H \tag{11.3-2}$$



a b

FIGURE 11.25 Regions with Euler numbers equal to 0 and −1, respectively.



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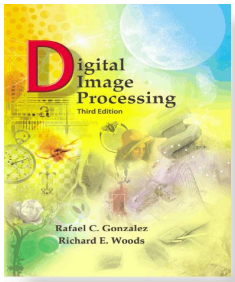
11.3.3 Texture

measures of properties such as smoothness, coarseness, and regularity

Texture	Mean	Standard deviation	R (normalized)	Third moment	Uniformity	Entropy
Smooth	82.64	11.79	0.002	−0.105	0.026	5.434
Coarse	143.56	74.63	0.079	−0.151	0.005	7.783
Regular	99.72	33.73	0.017	0.750	0.013	6.674

TABLE 11.2
Texture measures for the subimages shown in Fig. 11.28.



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CONCLUSION

The representation and description of objects or regions that have been segmented out of an image are early steps in the operation of most automated processes involving images. These descriptions, for example, constitute the input to the object recognition methods developed in the following chapter. As indicated by the range of description techniques covered in this chapter, the choice of one method over another is determined by the problem under consideration. The objective is to choose descriptors that "capture" essential differences between objects, or classes of objects, while maintaining as much independence as possible to changes in location, size, and orientation.