Chapter 11
Representation & Description

The results of segmentation is a set of regions. Regions have then to be *represented* and *described*.

Two main ways of *representing* a region:
- external characteristics (its boundary): focus on shape
- internal characteristics (its internal pixels): focus on color, textures…

The next step: *description*
E.g.: a region may be *represented* by its boundary, and its boundary *described* by some features such as length, regularity…
Features should be insensitive to translation, rotation, and scaling.
Both *boundary* and *regional* descriptors are often used together.

Representation of boundaries

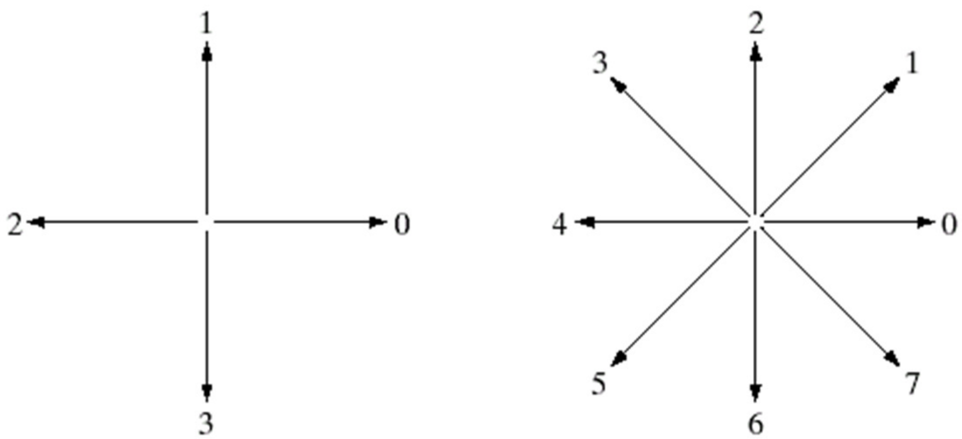
In order to represent a boundary, it is useful to compact the raw data (list of boundary pixels)

Chain codes: list of segments with defined length and direction

- 4-directional chain codes
- 8-directional chain codes

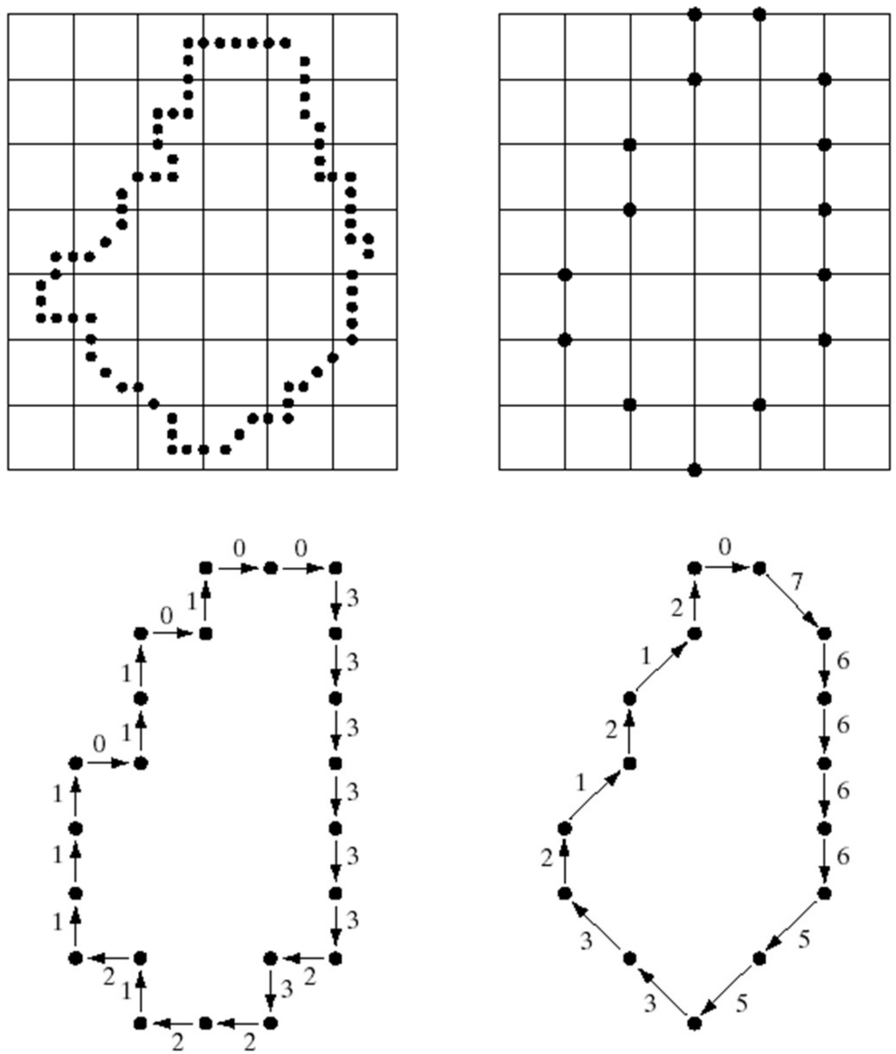
a b

FIGURE 11.1 Direction numbers for (a) 4-directional chain code, and (b) 8-directional chain code.



Representation of boundaries

It may be useful to downsample the data before computing the chain code
- to reduce the code dimension
- to remove small detail along the boundary



a b
c d

FIGURE 11.2 (a) Digital boundary with resampling grid superimposed. (b) Result of resampling. (c) 4-directional chain code. (d) 8-directional chain code.

Representation of boundaries

- To remove the dependence from the starting point:

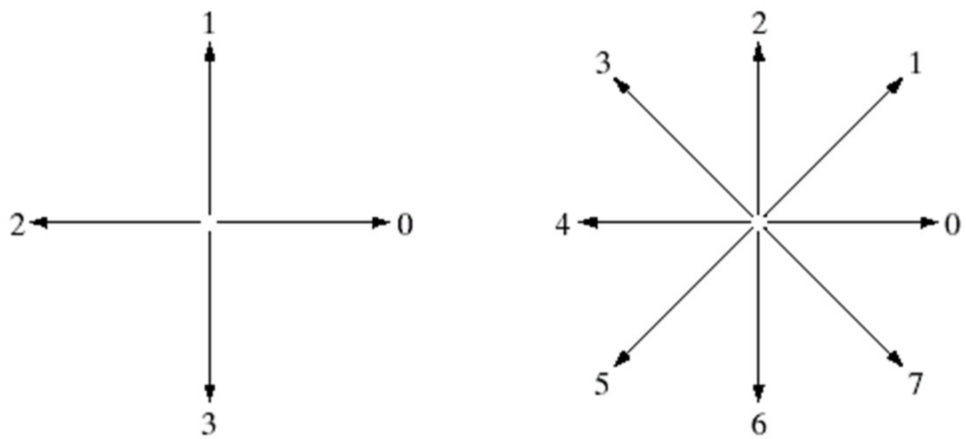
the code is a circular sequence, the new starting point is the one who gives a sequence of numbers giving the smallest integer

- To normalize wrt rotation:

first differences can be used

E.g., 10103322 -> 3133030 (counting ccw)

and adding the last transition (circular sequence: 2 -> 1) -> 31330303



a b

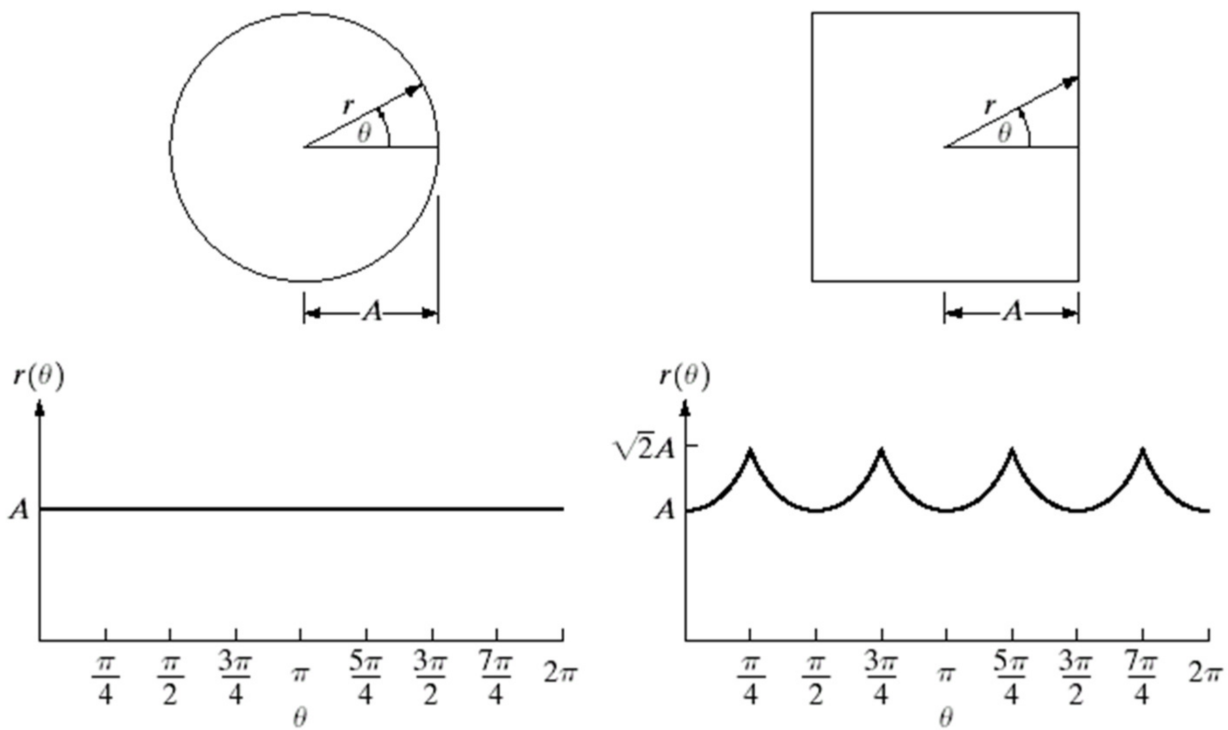
FIGURE 11.1 Direction numbers for (a) 4-directional chain code, and (b) 8-directional chain code.

Representation of boundaries

A *signature* is a 1-D representation of a boundary (which is a 2-D thing): it should be easier to describe.
E.g.: distance from the centroid vs angle.

a b

FIGURE 11.5 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 $0 \le \theta \le \pi/4$ and $r(\theta) = A\csc\theta$ for $\pi/4 < \theta \le \pi/2$.



Representation of boundaries

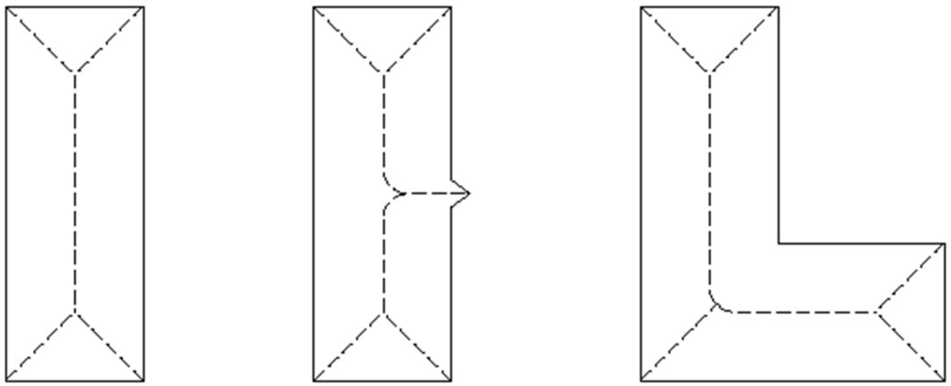
- Signatures are invariant to translation
- Invariance to rotation: depends on the starting point
  - the starting point could e.g. be the one farthest from the centroid
- Scaling varies the amplitude of the signature
  - invariance can be obtained by normalizing between 0 and 1, or
  - by dividing by the variance of the signature (does not work on Fig. 11.5(a)…)

Representation of a shape

One way to represent a shape is to reduce it to a graph, by obtaing its *skeleton* via thinning (*skeletonization*)

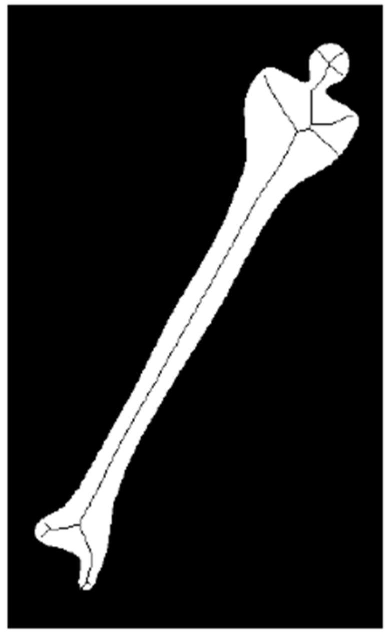
MAT (medial axis transformation) algorithm

- MAT is composed by all the points which have more than one closest boundary points ("prairie fire concept")



a b c

FIGURE 11.7 Medial axes (dashed) of three simple regions.



Boundary descriptors

Simple descriptors

- *length* (e.g., for chain code: hor+vert+$2^{1/2}$*diagonal)
- *diameter* (length of the *major axis*)
- basic rectangle (formed by the major and the *minor axis*; encloses the boundary) and its *eccentricity* (major/minor axis).

Boundary descriptors

Order of a shape: the number of digits
Shape number: the first difference of smallest magnitude (treating the chain code as a circular sequence)

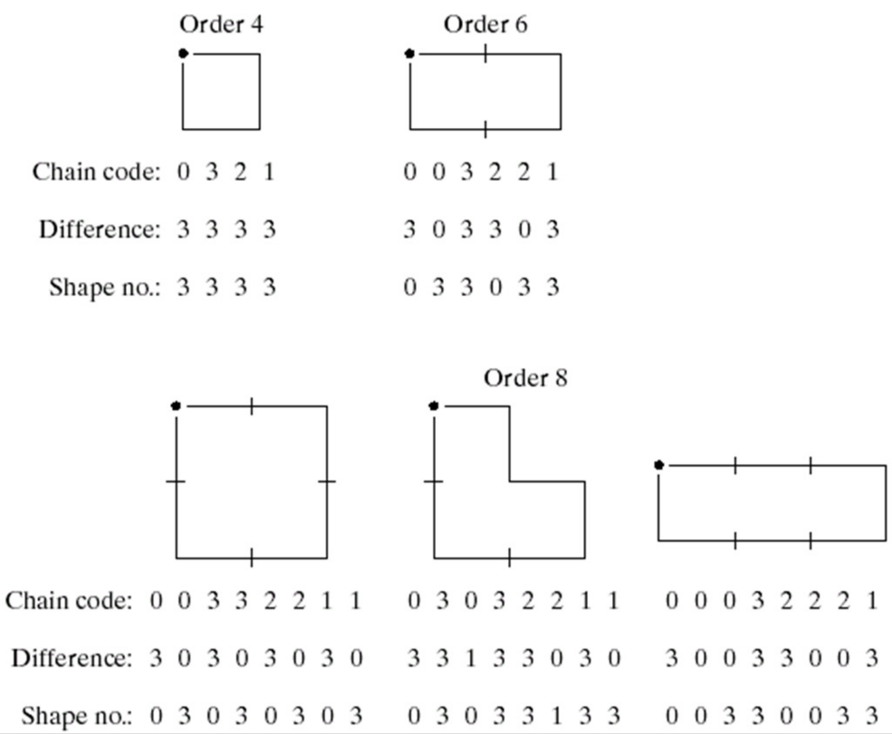
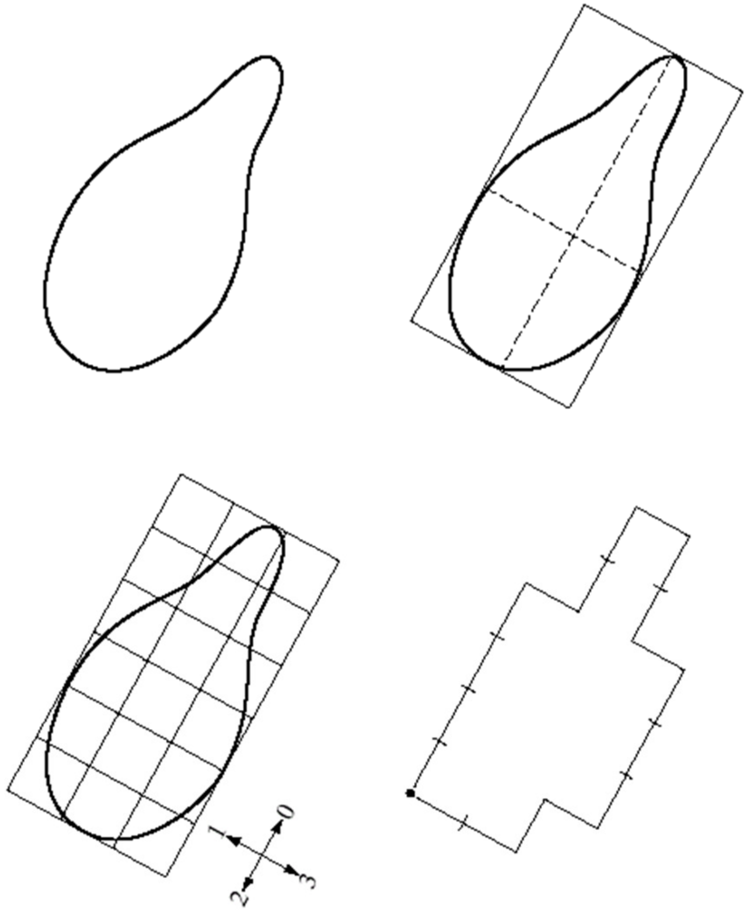


FIGURE 11.11 All shapes of order 4, 6, and 8. The directions are from Fig. 11.1(a), and the dot indicates the starting point.

Boundary descriptors

It is advisable to normalize the grid orientation by aligning the chain code grid to the basic rectangle



a b
c d

FIGURE 11.12 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

Boundary descriptors

The sequence of boundary points can be treated as a sequence of complex points in the complex plane
- It becomes a 1-D descriptor
- Can be DFT-transformed

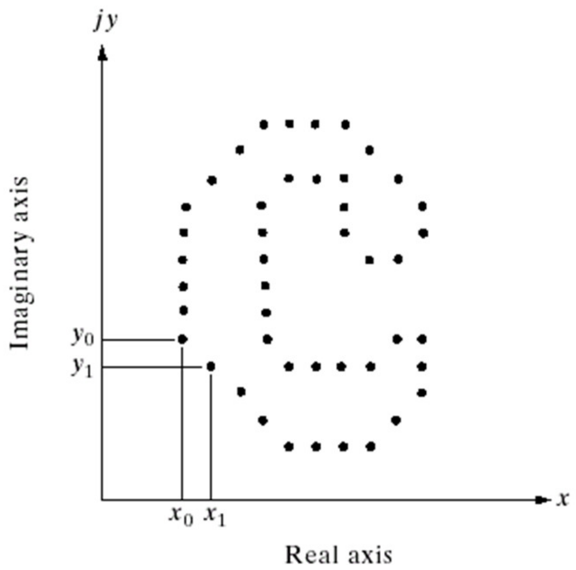


FIGURE 11.13 A digital boundary and its representation as a complex sequence. The points (x_0, y_0) and (x_1, y_1) shown are (arbitrarily) the first two points in the sequence.

Boundary descriptors

The boundary can be approximated (by dropping DFT coefficients)

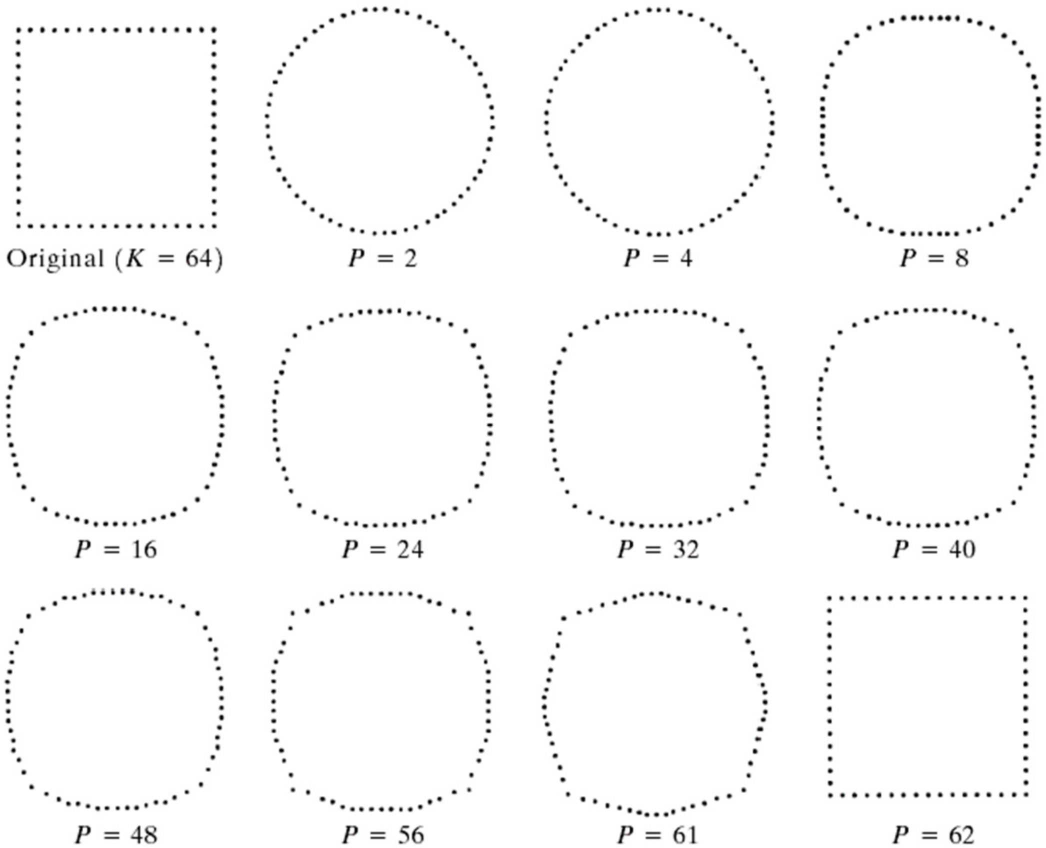


FIGURE 11.14 Examples of reconstruction from Fourier descriptors. P is the number of Fourier coefficients used in the reconstruction of the boundary.

Boundary descriptors

Fourier descriptors are not insensitive to translation..., but effects on the transform coefficients are known

Transformation	Boundary	Fourier Descriptor
Identity	$s(k)$	$a(u)$
Rotation	$s_r(k) = s(k)e^{j\theta}$	$a_r(u) = a(u)e^{j\theta}$
Translation	$s_t(k) = s(k) + \Delta_{xy}$	$a_t(u) = a(u) + \Delta_{xy}\delta(u)$
Scaling	$s_s(k) = \alpha s(k)$	$a_s(u) = \alpha a(u)$
Starting point	$s_p(k) = s(k - k_0)$	$a_p(u) = a(u)e^{-j2\pi k_0 u/K}$

TABLE 11.1 Some basic properties of Fourier descriptors.

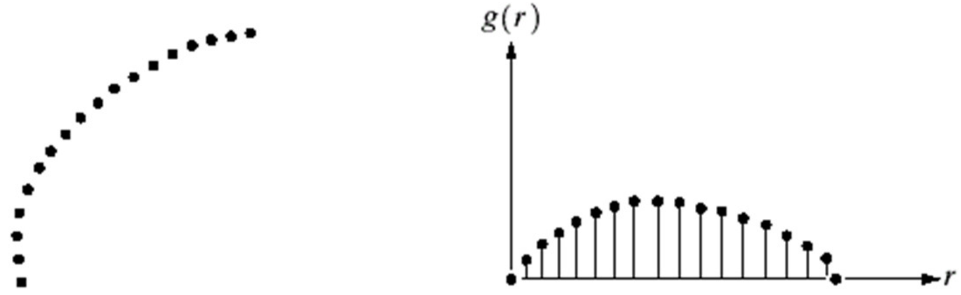
Boundary descriptors

Statistical moments

Once a boundary is described as a 1-D function,

a b

FIGURE 11.15
(a) Boundary segment.
(b) Representation as a 1-D function.



statistical moments (mean, variance, and a few higher-order central moments) can be used to describe it:

$$\mu_n(v)=\Sigma_i(v_i-m)^n p(v_i)$$

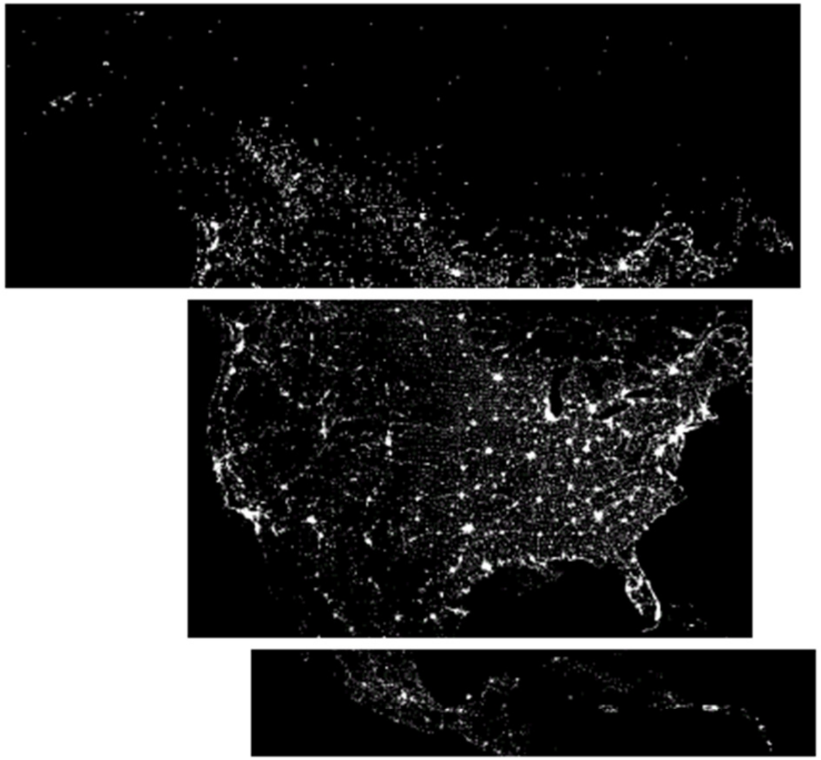
with

$$m=\Sigma_i v_i p(v_i)$$

Regional descriptors

Some simple descriptors
- *Area*
- *Compactness* =perimeter^2/area

- In the figure ->
(white area)/(total light area)
gives an idea of relative electrical energy consumption



Region no, (from top)	Ratio of lights per region to total lights
1	0.204
2	0.640
3	0.049
4	0.107

FIGURE 11.16 Infrared images of the Americas at night. (Courtesy of NOAA.)

Regional descriptors

Topology is the study of the properties which are unaffected by any deformation (*rubber-sheet* distortion)

- *number of holes H*
- *number of connected components C*
- *Euler number, E=C-H*

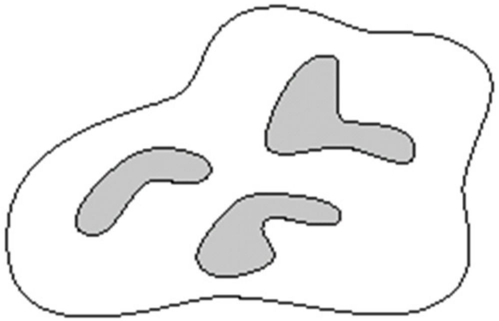


FIGURE 11.18 A region with three connected components.

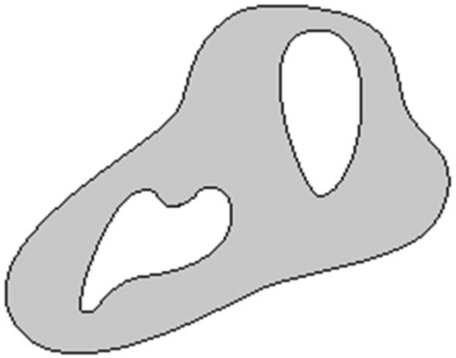
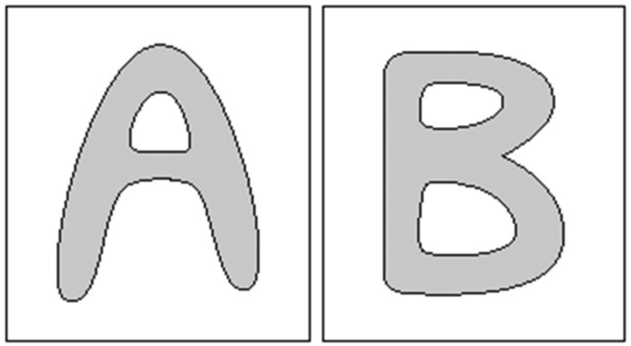


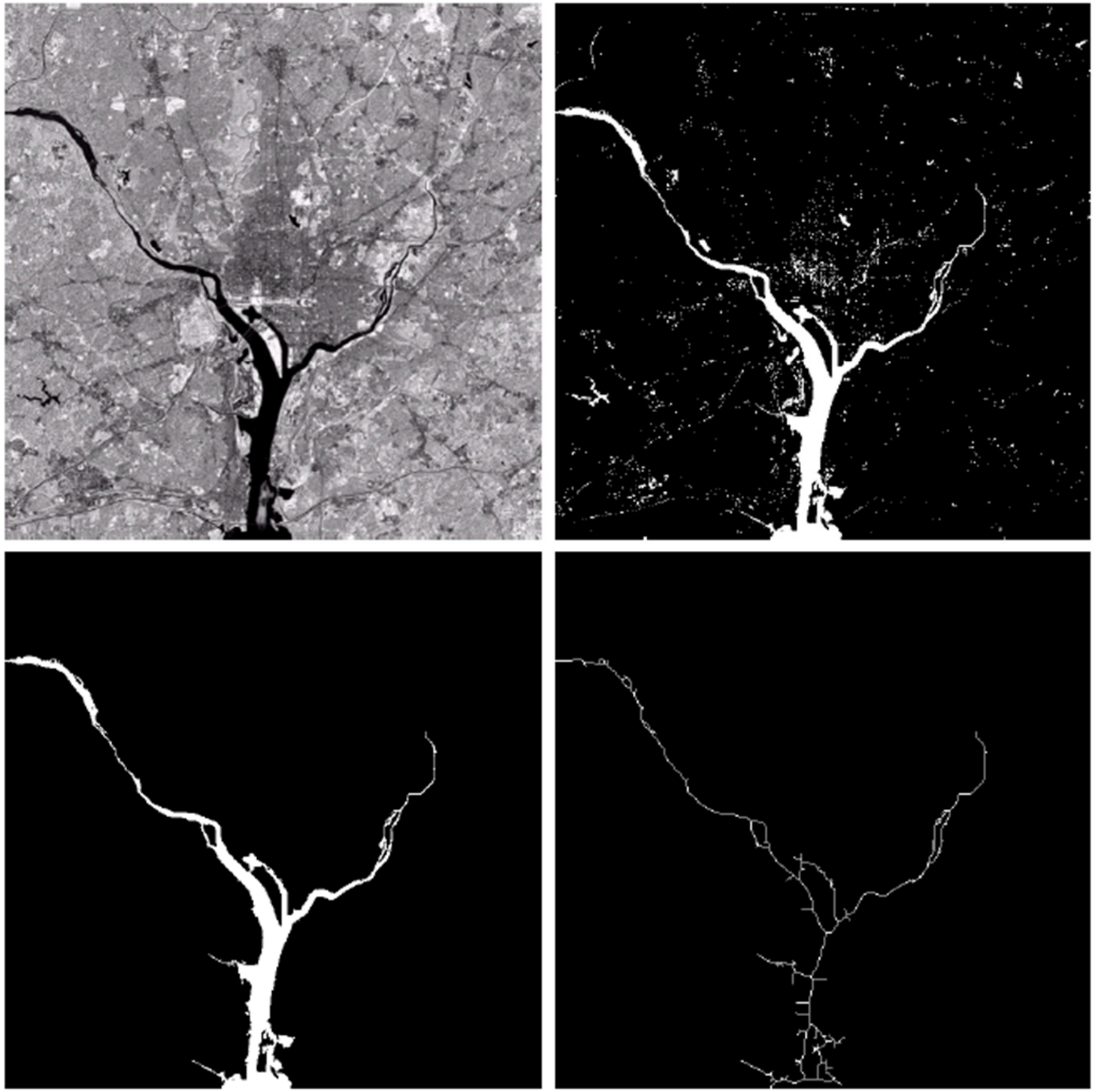
FIGURE 11.17 A region with two holes.



a b

FIGURE 11.19 Regions with Euler number equal to 0 and −1, respectively.

Regional descriptors



a b
c d

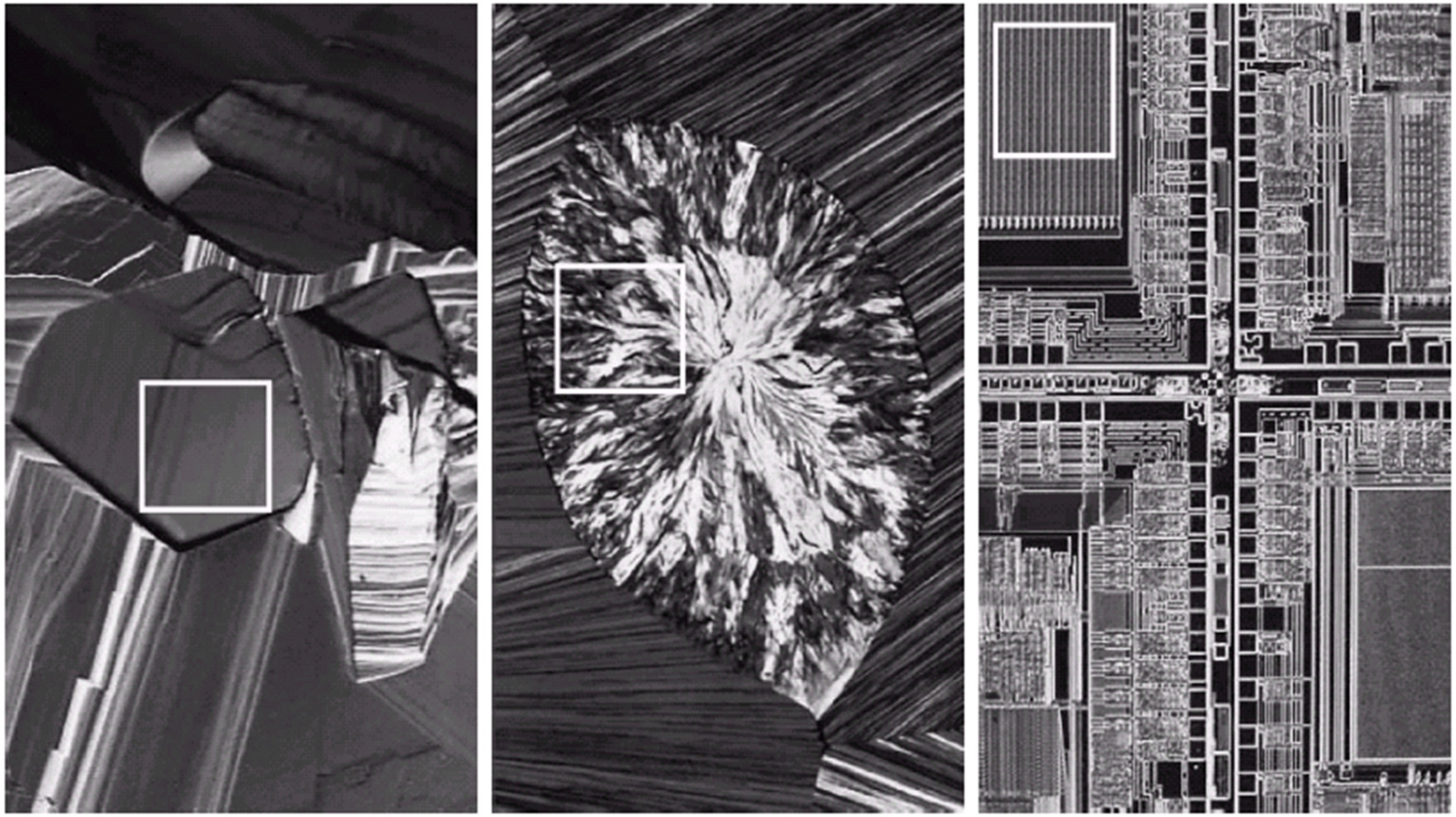
FIGURE 11.21 (a) Infrared image of the Washington, D.C. area. (b) Thresholded image. (c) The largest connected component of (b). Skeleton of (c).

Fig b: C=1591, E=1552 -> H=39

Fig. c: the connected component with the largest number of pixels, 8479

Regional descriptors

Texture descriptors are related to smoothness, coarseness, regularity…



a b c

FIGURE 11.22 The white squares mark, from left to right, smooth, coarse, and regular textures. These are optical microscope images of a superconductor, human cholesterol, and a microprocessor. (Courtesy of Dr. Michael W. Davidson, Florida State University.)

Regional descriptors

- *Statistical approaches* give indications such as smooth, coarse, grainy…
- *Spectral techniques* are related to DFT and can detect global periodicities
- …

Regional descriptors: some statistical descriptors

- *Statistical moments* of the gray-level histogram $p(z_i)$ — $\mu_n(z)=\Sigma(z_i-m)^n p(z_i)$
- R (R=0 in flat areas, -> 1 in "active" ones) — $R=1-[1+\sigma^2]^{-1}$
- *Uniformity* (maximum if all gray levels are equal) — $U=\Sigma p^2(z_i)$
- *Entropy* (is 0 for a constant image) — $e=-\Sigma p(z_i)\log_2 p(z_i)$

TABLE 11.2
Texture measures for the subimages shown in Fig. 11.22.

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

Regional descriptors

Fourier spectrum features:

- peaks give principal directions of the patterns
- location of the peaks gives the fundamental period(s)
- periodic components can be removed via filtering; the remaining non periodic image can be analyzed using statistical techniques

The spectrum can be also studied in polar coordinates

$S(r,\theta)$

For each pair r,θ, we can have two descriptors

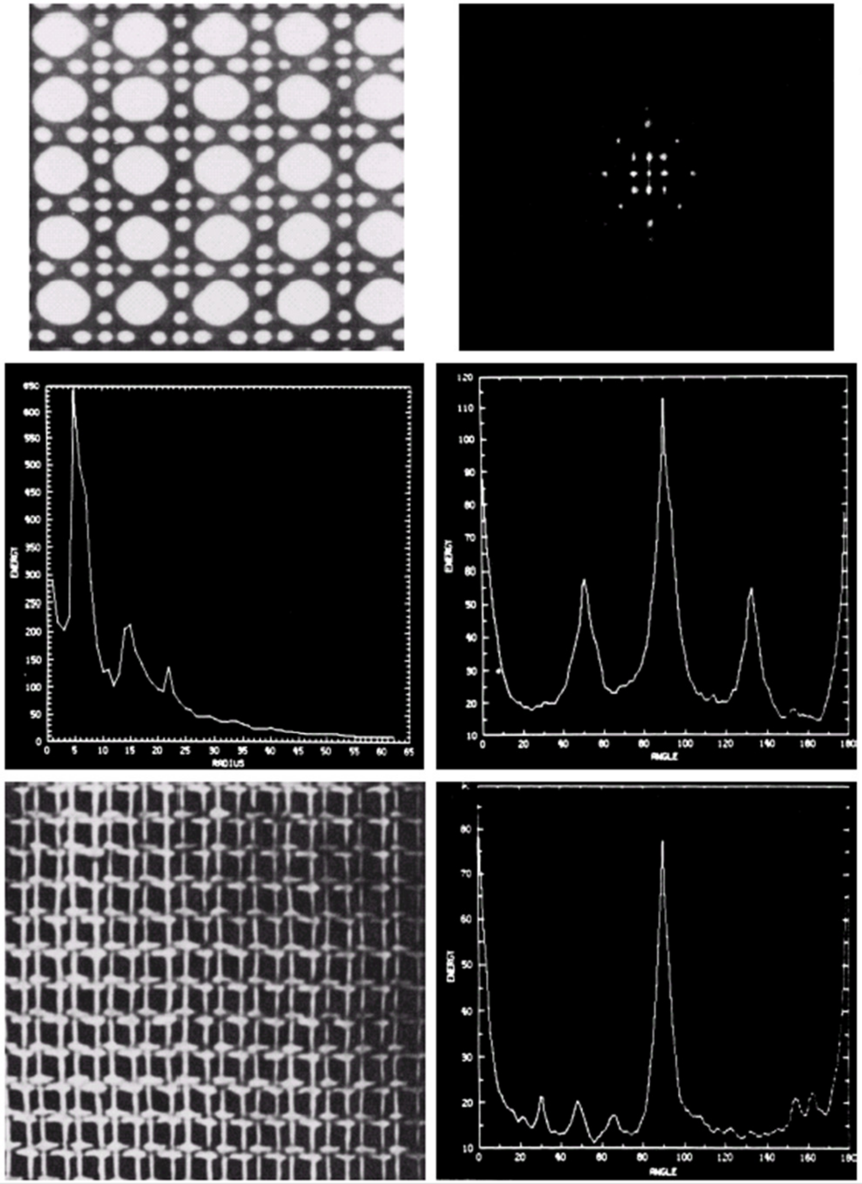
$S(r)=\Sigma_\theta S_\theta(r)$

$S(\theta)=\Sigma_r S_r(\theta)$

a b
c d
e f

FIGURE 11.24 (a) Image showing periodic texture. (b) Spectrum. (c) Plot of $S(r)$. (d) Plot of $S(\theta)$. (e) Another image with a different type of periodic texture. (f) Plot of $S(\theta)$. (Courtesy of Dr. Dragana Brzakovic, University of Tennessee.)

Regional descriptors



Regional descriptors

Moments of 2-D functions

Moment: $m_{pq}=\Sigma\Sigma x^p y^q f(x,y)$

Central moment: $\mu_{pq}=\Sigma\Sigma(x-x')^p(y-y')^q f(x,y)$

with $x'=m_{10}/m_{00}$ and $y'=m_{01}/m_{00}$

It may be found that, e.g.

$\mu_{11}=m_{11}-y'm_{10}$

$\mu_{30}=m_{30}-3x'm_{20}+2x'^2m_{10}\ldots$

If we define the *normalized central moments*

$\eta_{pq}=\mu_{pq}/\mu_{00}^{\gamma}$ with $\gamma=(p+q)/2+1$

some *invariant moments* can be defined, e.g.

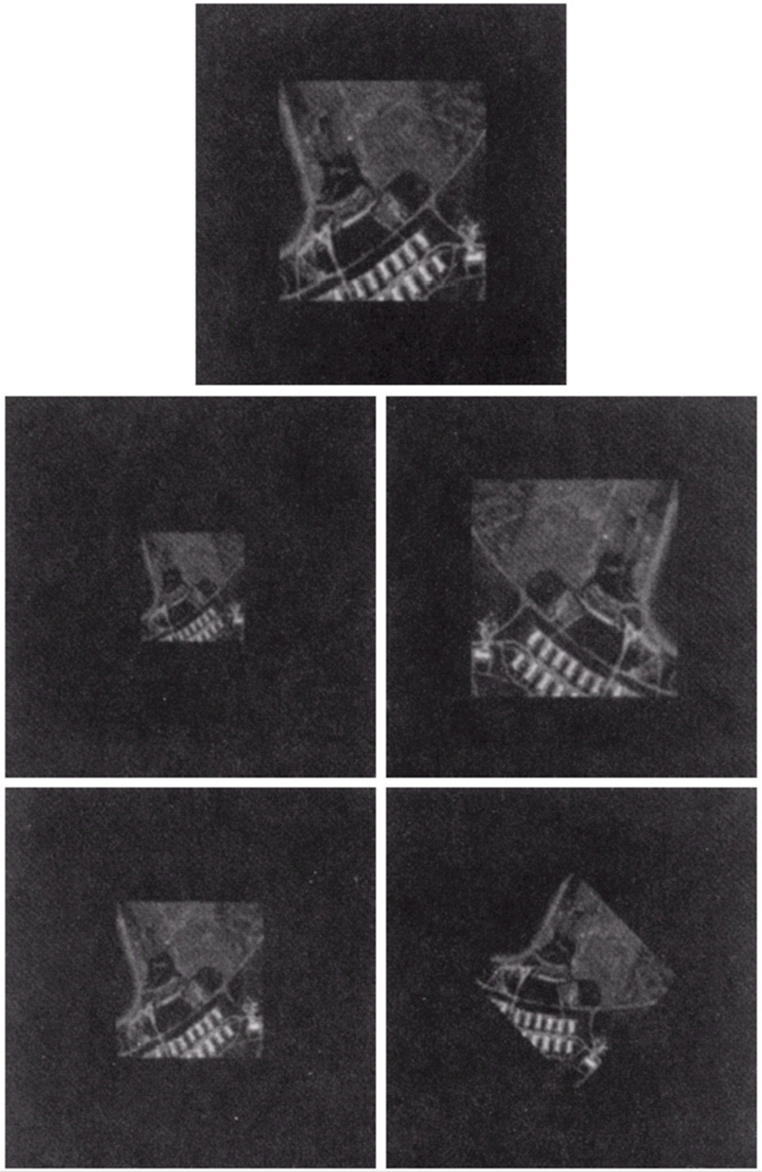
$\phi_1=\eta_{20}\eta_{02}$

$\phi_2=(\eta_{20}-\eta_{02})^2+4\eta_{11}^2\ldots$

which are invariant to translation, rotation, and scaling

Regional descriptors

Invariant (Log)	Original	Half Size	Mirrored	Rotated 2°	Rotated 45°
ϕ_1	6.249	6.226	6.919	6.253	6.318
ϕ_2	17.180	16.954	19.955	17.270	16.803
ϕ_3	22.655	23.531	26.689	22.836	19.724
ϕ_4	22.919	24.236	26.901	23.130	20.437
ϕ_5	45.749	48.349	53.724	46.136	40.525
ϕ_6	31.830	32.916	37.134	32.068	29.315
ϕ_7	45.589	48.343	53.590	46.017	40.470



Descriptors for video sequences

MPEG-1/2/4 make content available, whereas MPEG-7 allows you to find the content you need!

– A content description standard

  » Video/images: Shape, size, texture, color, movements, positions, etc…

  » Audio: Key, mood, tempo, changes, position in sound space, etc…

– Applications:

  » Digital Libraries

  » Multimedia Directory Services

  » Broadcast Media Selection

  » Editing, etc…

Example:

Draw an object and be able to find object with similar characteristics.

Play a note of music and be able to find similar type of music