Image and Video Processing

Description & Representation

Region description

- After segmentation, we get pixels along the boundary or pixels contained in a region.
- The next stage of the processing scheme is to extract characteristic information from these regions, that can be subsequently used to assign an identity to the region (by comparing with the information derived from known regions).

Region description (contd.)

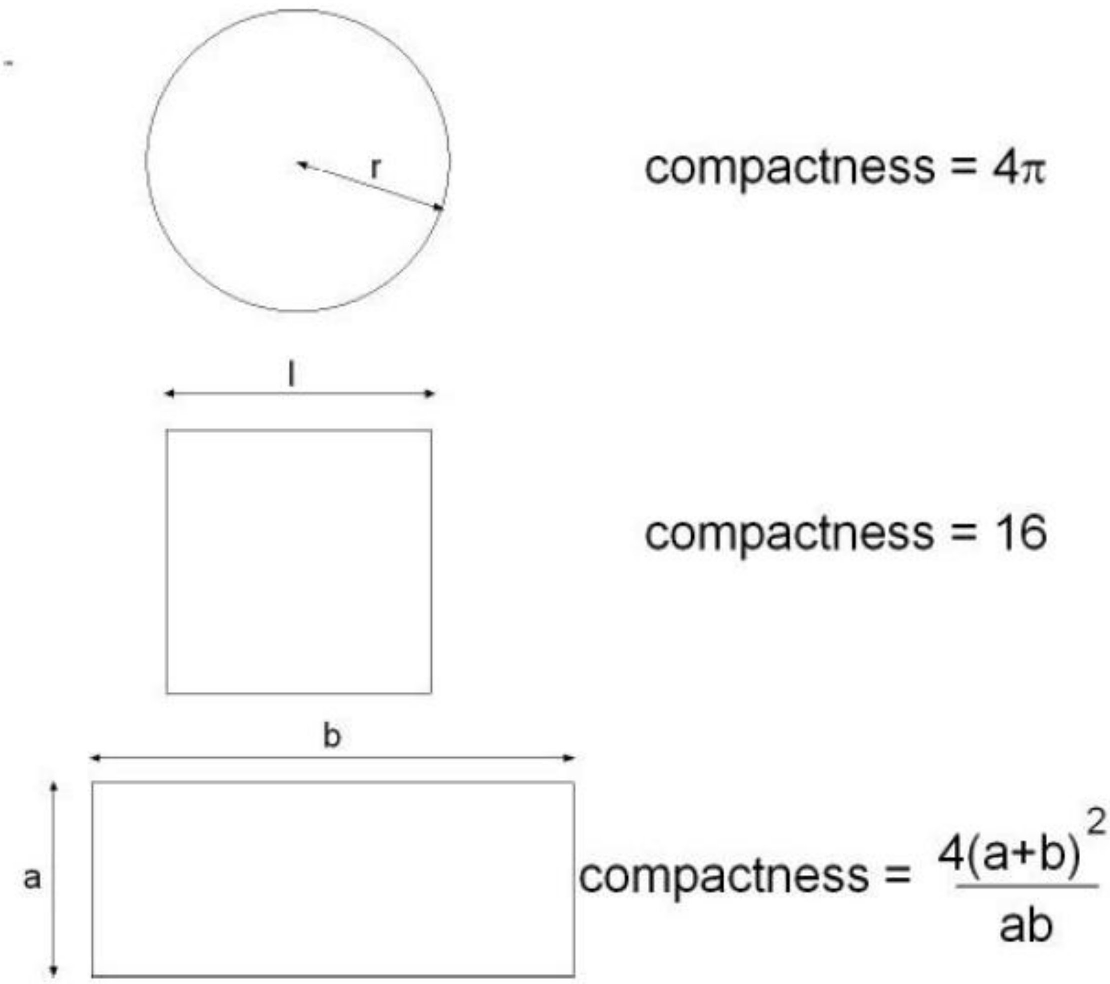
- The method chosen to describe a region will be closely coupled to the problem being solved.
- Ask following questions:
  - What problem am I trying to solve?
  - What information do I need to solve this problem?
  - How do I find that information from the image?

Region Descriptors

- Simple descriptors:
  - Area: # of pixels in the region (can compute histogram of labelled image)
  - Perimeter: length of its boundary (how to derive it ?)
  - Compactness: $(\text{perimeter})^2/\text{area}$
  - Diameter, Major/Minor axis, orientation etc.
  - Mean/Median, Min/Max of the intensity levels

Question

Q: What shape gives the minimal compactness ?



Region Representation

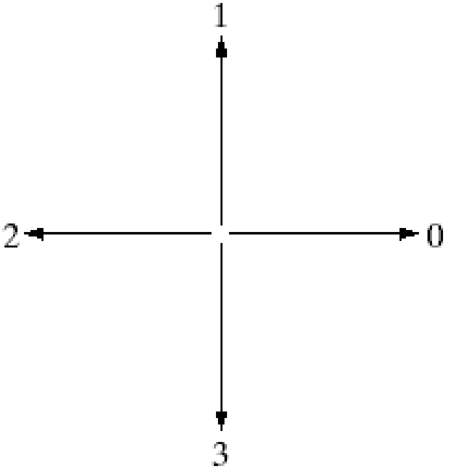
- Representing a region involves two choices:
  - Using external characteristics, e.g. boundary
  - Using internal characteristics, e.g. texture
- Common external representation methods are:
  - Chain code
  - Polygonal approximation
  - Signature
  - Boundary segments
  - Skeleton (medial axis)

Method 1: Chain Codes

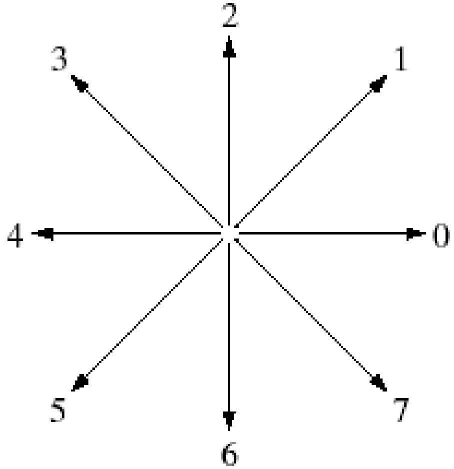
- Represent a boundary by a connected sequence of straight-line segments of specified length and direction.
- Directions are coded using the numbering scheme

a b

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



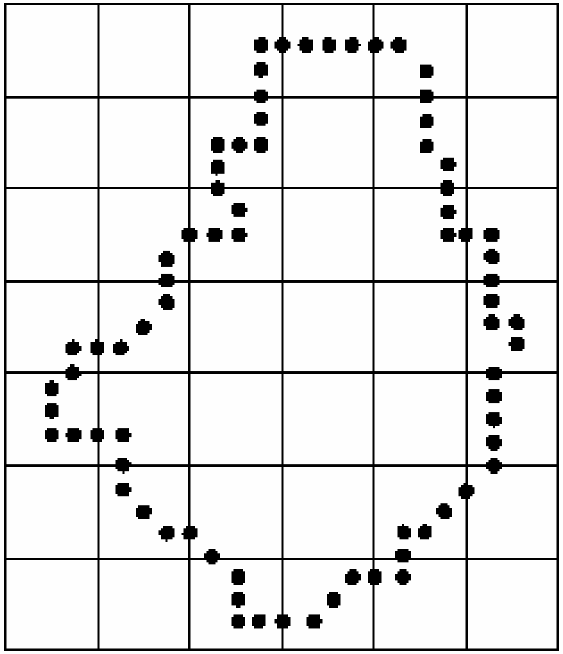
4-connectivity



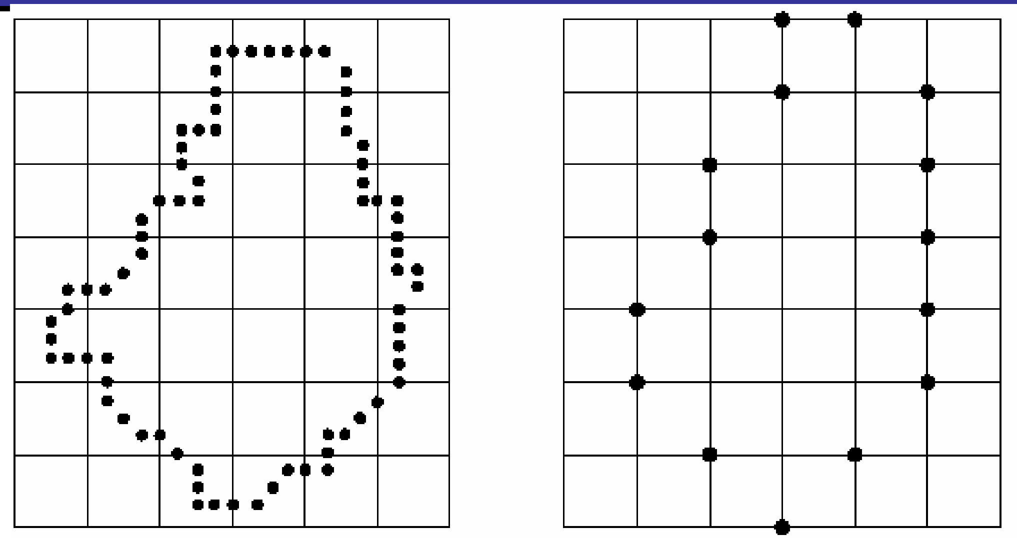
8 connectivity

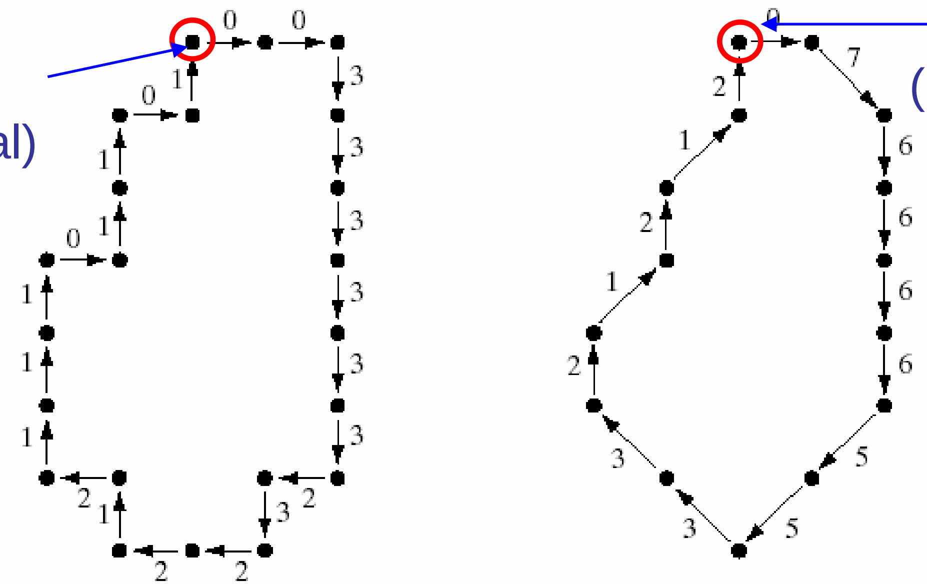
Generation of Chain Codes

- Walking along the boundary in clockwise direction, for every pair of pixels assign the direction.
- Problems:
  - Long chain
  - Sensitive to noise
- Remedies?
  - Resampling using larger grid spacing.



Resampling for Chain Codes





0033…01
(4-directional)

0766…12
(8-directional)

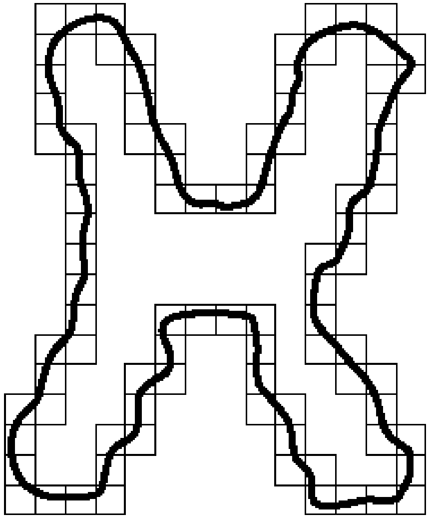
Spacing of the sampling grid affect the accuracy of the representation

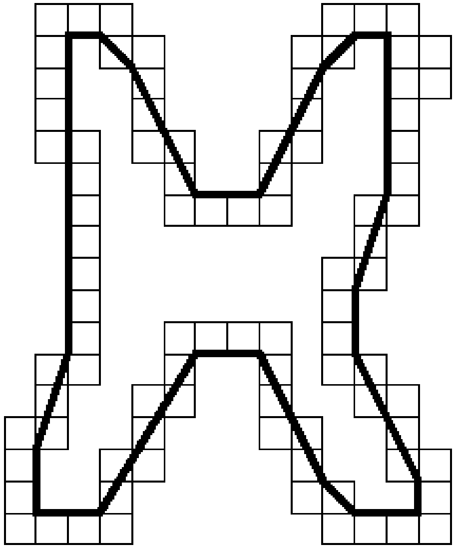
Normalization for Chain Codes

- With respect to starting point:
  - Make the chain code a circular sequence
  - Redefine the starting point which gives an integer of minimum magnitude
  - E.g. 101003333222 normalized to 003333222101
- For rotation:
  - Using first difference (FD) obtained by counting the number of direction changes in counterclockwise direction
  - E.g FD of a 4-direction chain code 10103322 is 3133030
- For scaling:
  - Altering the size of the resampling grid.

Method 2: Polygonal Approximation

- Major disadvantage of chain codes is that the noise directly affects the code.
- Replace approximately linear segments of the boundary by straight line segments.
- The boundary of an object is thereby reduced to a polygon.
- Goal: to capture the “essence” of the boundary shape with the fewest possible polygonal segments.



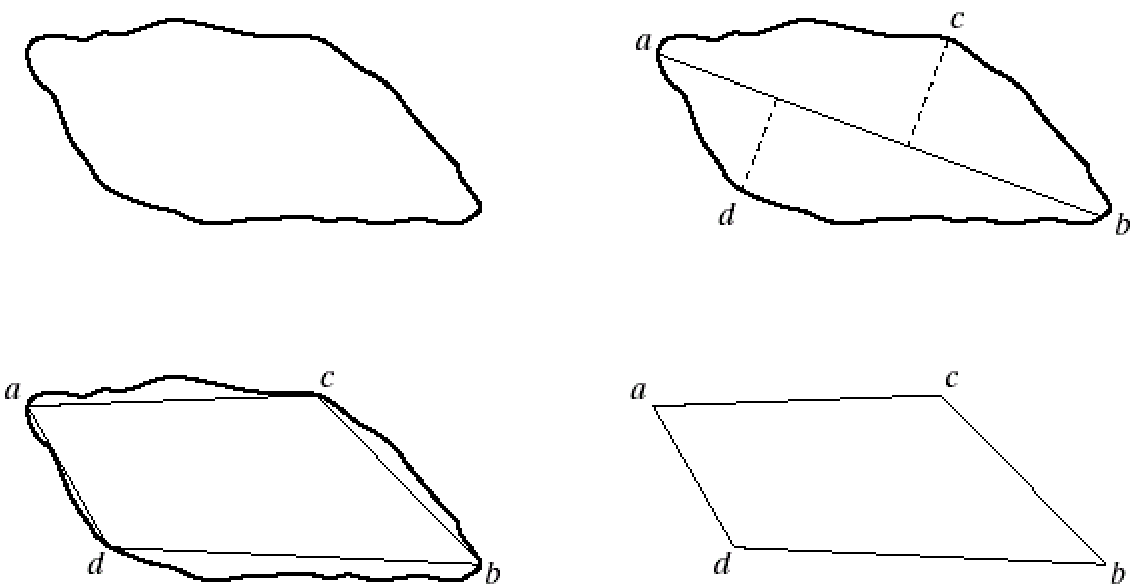


Merging Technique

- Repeat the following steps:
  - Merging unprocessed points along the boundary until the least-square error line fit exceed the threshold.
  - Store the parameters of the line
  - Reset the LS error to 0
- Intersections of adjacent line segments form vertices of the polygon.
- Problem: vertices of the polygon do not always correspond to inflections (e.g. corners) in the original boundary.

Splitting Technique

- Subdivide a segment successively into two parts until a specified criterion is met.
- For example

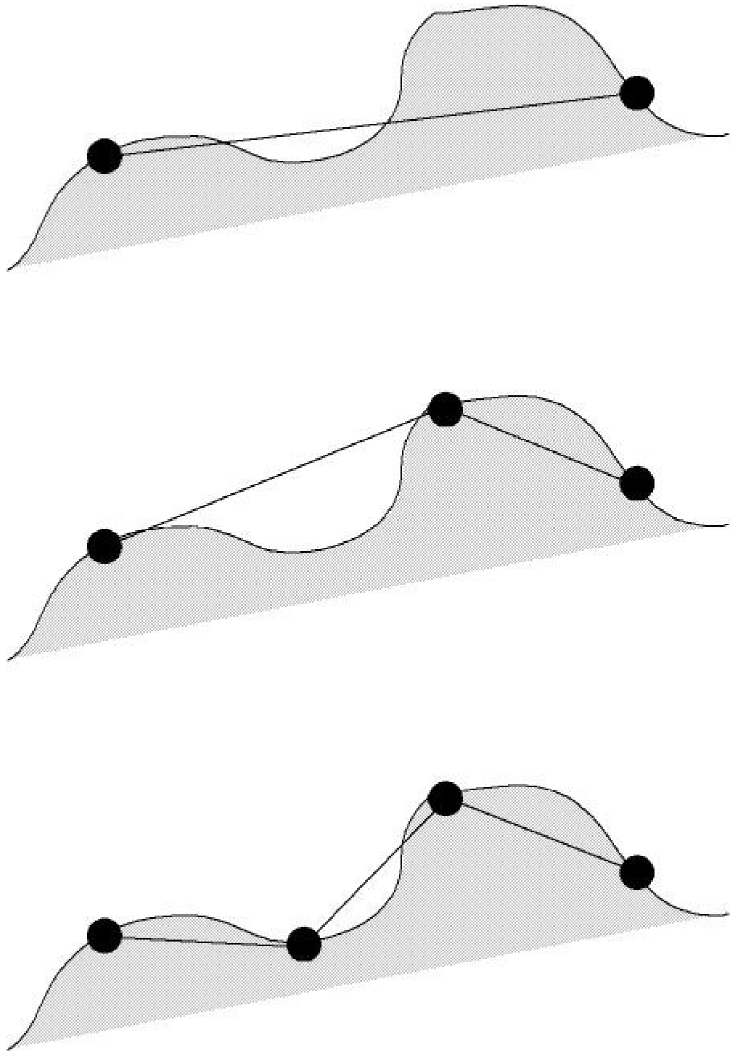


a	b
c	d

FIGURE 11.4 (a) Original boundary. (b) Boundary divided into segments based on extreme points. (c) Joining of vertices. (d) Resulting polygon.

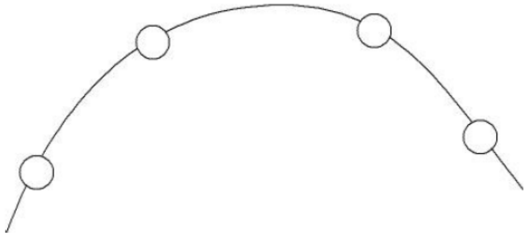
Polyline splitting

- Firstly compute the distance from each point onto the line.
- The maximum distance is found, if it exceeds some threshold, then a vertex is inserted to bisect the original line.
- The process is then repeated for the newly formed segments.



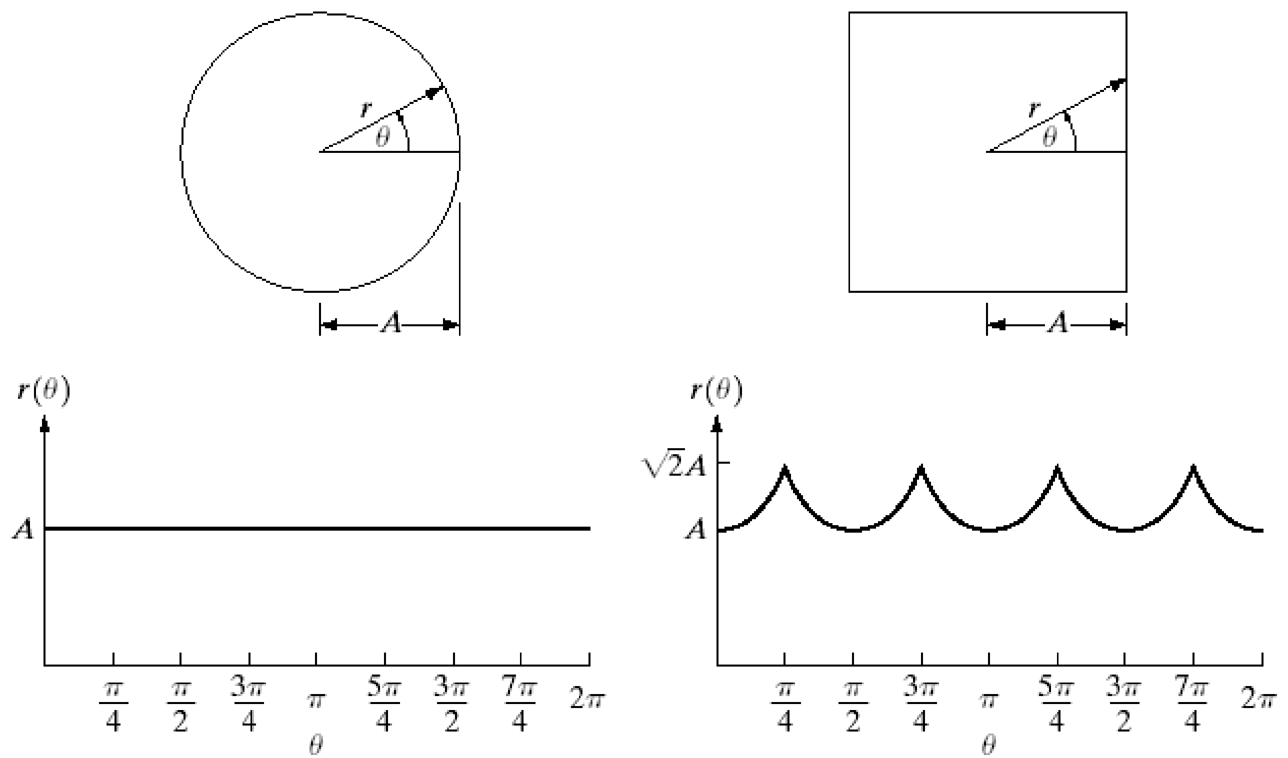
Spline curves

- If any portion of the boundary is curved, then polygon representation becomes inefficient, i.e. many small segments are generated.
- Inserting curved sections instead of linear ones may ameliorate this situation
- Splines provide a compact representation of curves using two end points and two intermediate control points.
- Adjacent curve sections will share end points to ensure continuity,



Method 3: Signature

- Reduce the boundary representation to a 1D function by creating a plot of distances from a point to the border as a radius is rotated about the point.

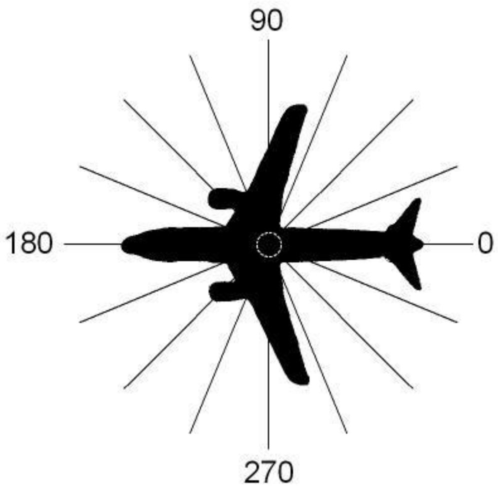


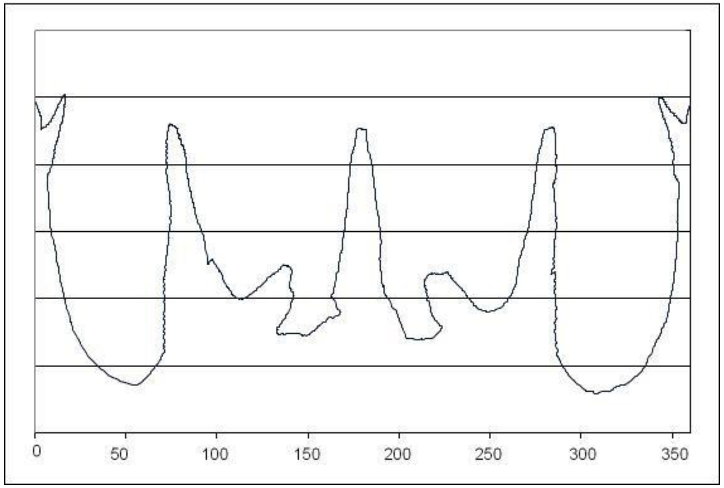
a b

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 $\pi/4 < \theta \le \pi/2$.

Contd.

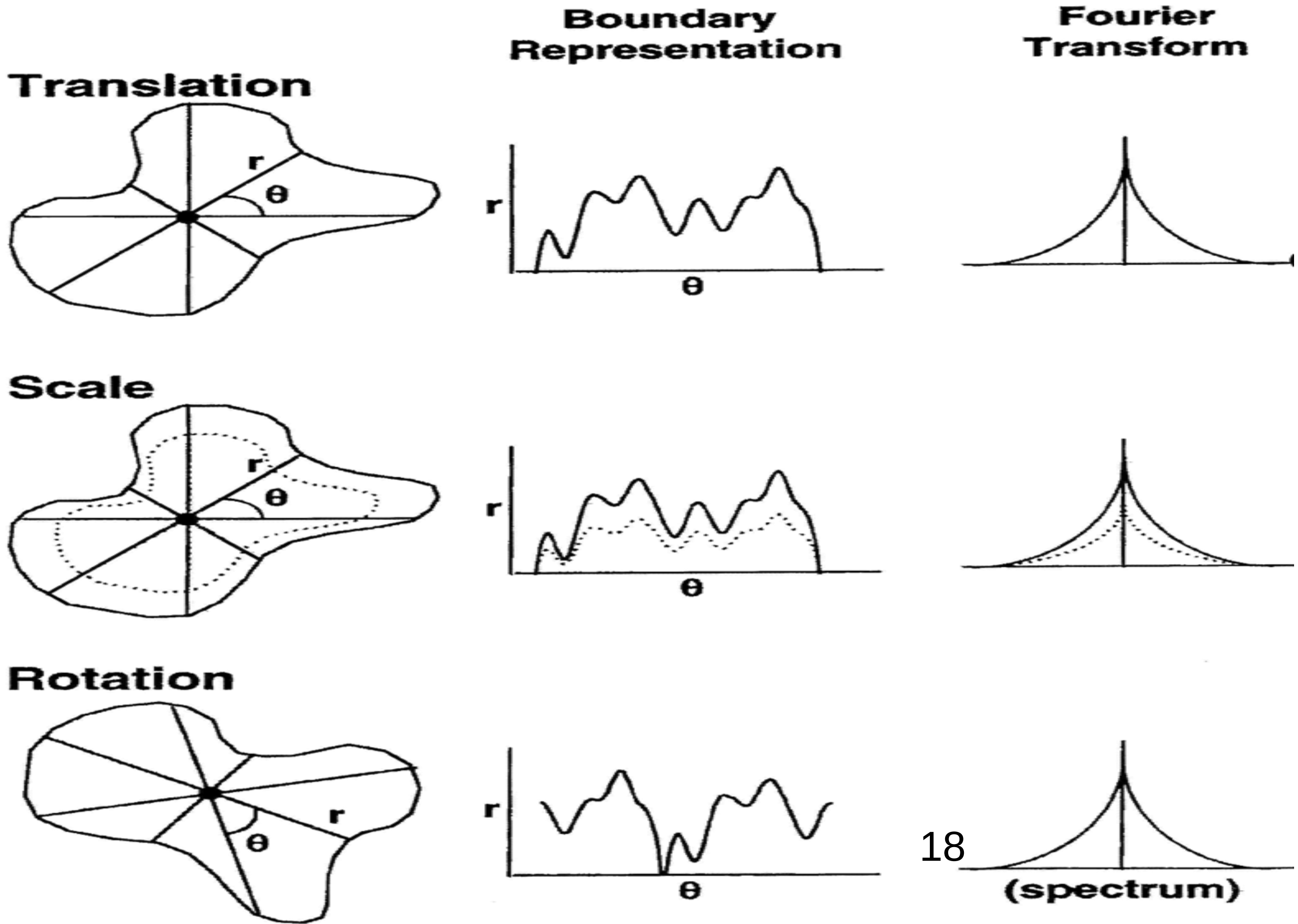
- Real objects will generate more complex curves, but they may still be recognisable,
- Recognition will be achieved by comparison of the curve with the curve derived from known objects.

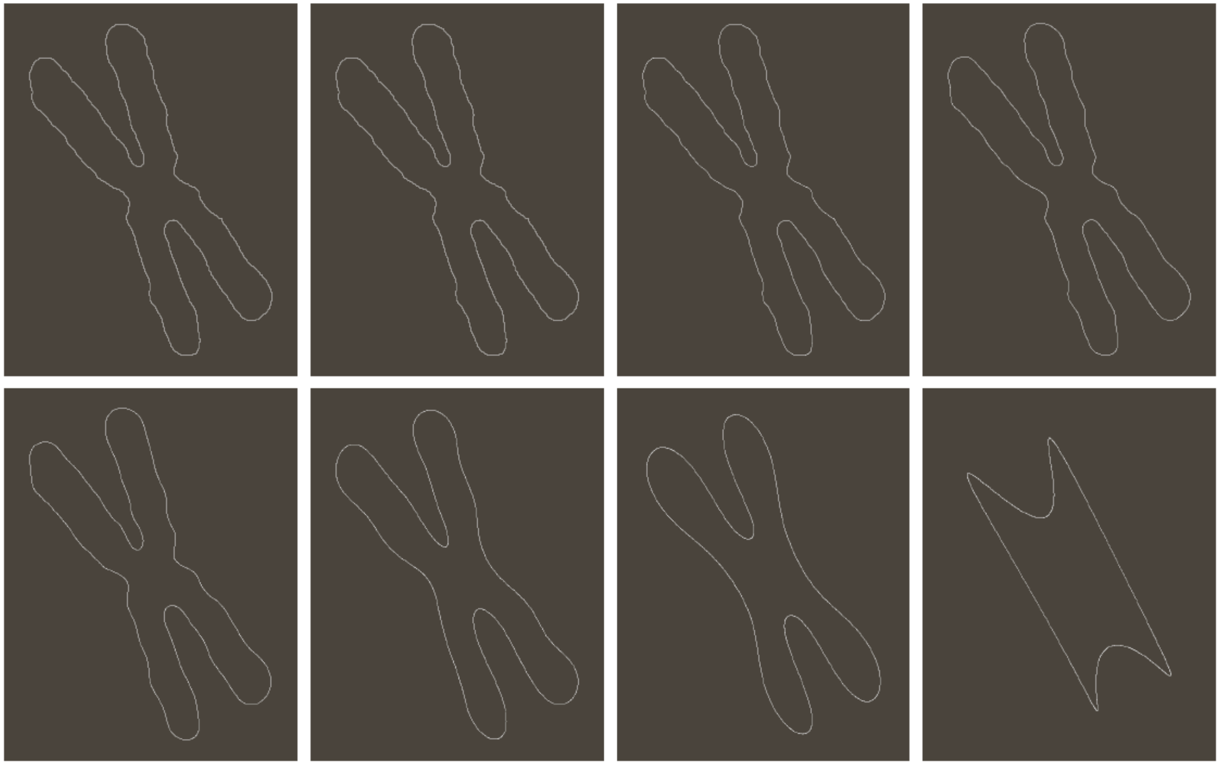




Fourier Descriptor

Taking the dist. vs. angle one step further we get ...



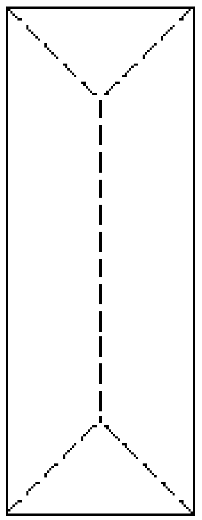


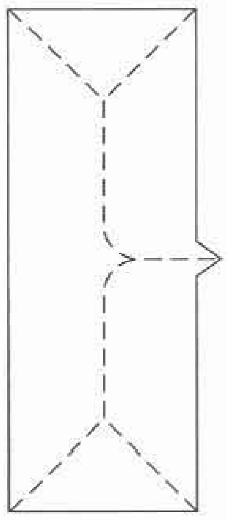
a	b	c	d
e	f	g	h

FIGURE 11.20 (a) Boundary of human chromosome (2868 points). (b)–(h) Boundaries reconstructed using 1434, 286, 144, 72, 36, 18, and 8 Fourier descriptors, respectively. These numbers are approximately 50%, 10%, 5%, 2.5%, 1.25%, 0.63%, and 0.28% of 2868, respectively.

Skeletons

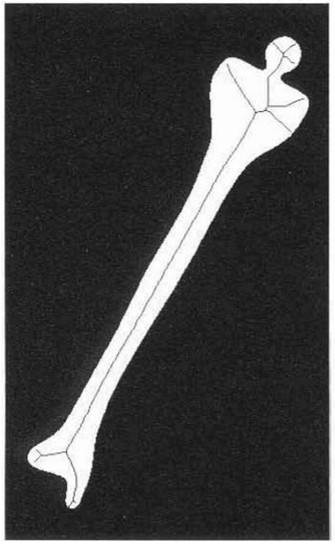
- Obtaining the skeleton of the region via thinning.
  - – By morphology: no provision for keeping the skeleton connected
  - – By Medial Axis Transformation (MAT): The MAT of region R with border B is found as:
    - For each point p in R, we find its closest neighbor in B.
    - If p has more than one, it belongs to the Medial Axis (skeleton) of R.





Skeletons

- To improve computational efficiency, edge points of a region are iteratively deleted if:
  - End points are not deleted
  - Connectedness is not broken
  - No excessive erosion is caused



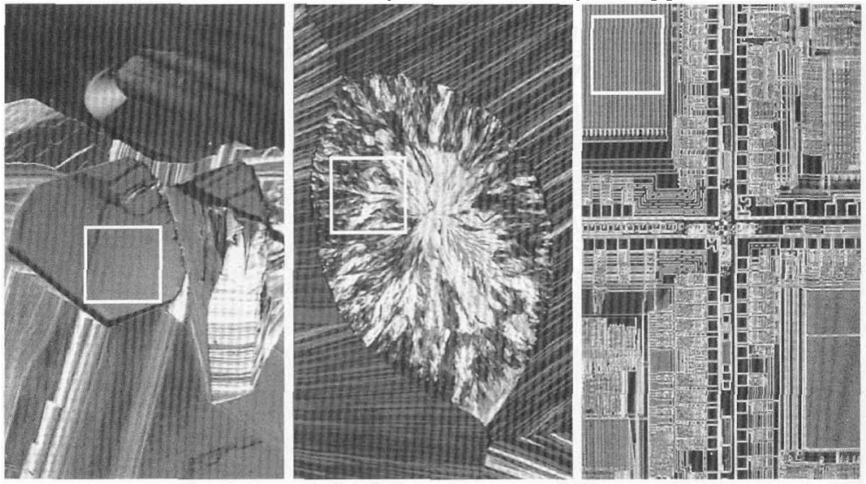
- Step1:
  - (a) $2 \le N(p_1) \le 6$
  - (b) $T(p_1) = 1$
  - (c) $p_2 \bullet p_4 \bullet p_6 = 0$
  - (d) $p_4 \bullet p_6 \bullet p_8 = 0$
- Step2:
  - (c') $p_2 \bullet p_4 \bullet p_8 = 0$
  - (d') $p_2 \bullet p_6 \bullet p_8 = 0$

p_9	p_2	p_3
p_8	p_1	p_4
p_7	p_6	p_5

0	0	1
0	p_1	1
0	0	1

Statistical Moments for Texture

- Statistical approaches
  - smooth, coarse, regular



- nth moment:

$$u_n(z) = \sum_{i=0}^{L-1} (z_i - m)^n p(z_i)$$

$$m = \sum_{i=0}^{L-1} z_i p(z_i)$$

  - 2th moment:
    - is a measure of gray level contrast(relative smoothness)
  - 3th moment:
    - is a measure of the skewness of the histogram
  - 4th moment:
    - is a measure of its relative flatness
  - 5th and higher moments:
    - are not so easily related to histogram shape

Moment Invariant

2D Moment of order (p+q)

$$m_{pq}(S) = \sum_{(x,y)\in S} x^p y^q f(x,y)$$

Central moment

$$\mu_{pq}(S) = \sum_{(x,y)\in S} (x-\bar{x})^p (y-\bar{y})^q f(x,y), where$$

$$\bar{x} = \frac{m_{10}(S)}{m_{00}(S)}, \bar{y} = \frac{m_{01}(S)}{m_{00}(S)}$$

Normalized central moment

$$\eta_{pq}(S) = \frac{\mu_{pq}}{\mu_{00}^{\gamma}}, \gamma = \frac{p+q}{2} + 1, p+q = 2,3,..$$

$$M_{H1} = \eta_{20} + \eta_{02}$$

$$M_{H2} = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}{}^2$$

$$M_{H3} = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2$$

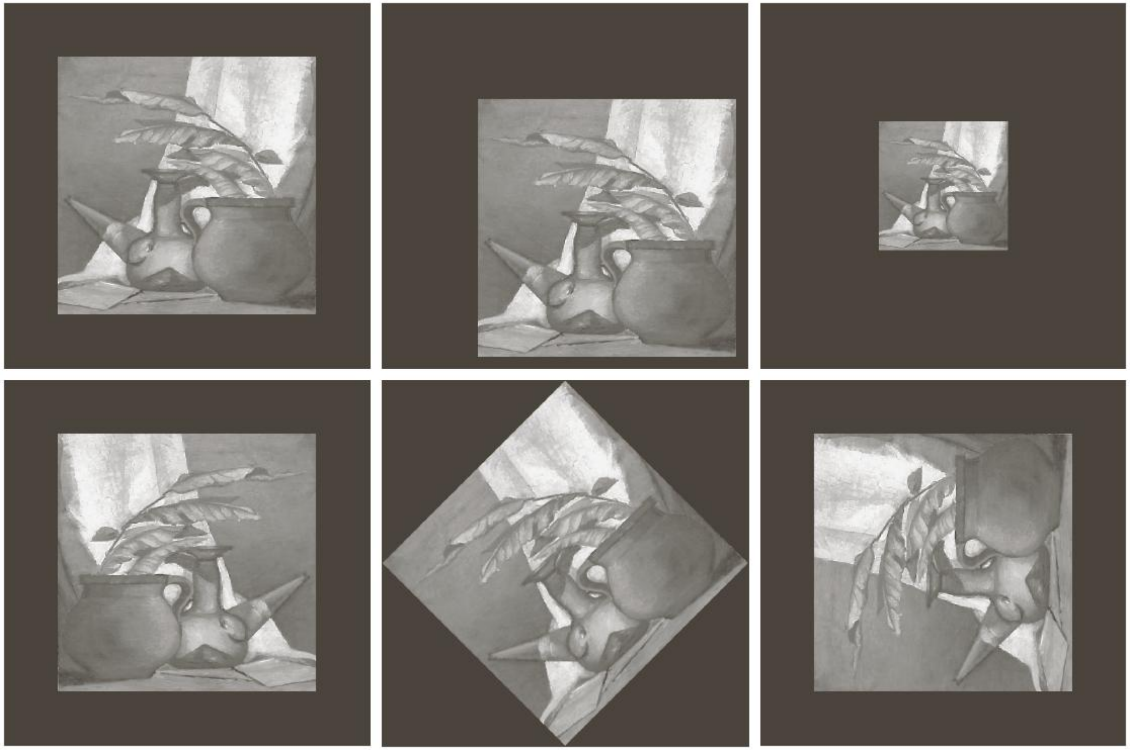
$$M_{H4} = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2$$

$$\begin{aligned} M_{H5} &= (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\ &+ (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[(\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2] \end{aligned}$$

$$\begin{aligned} M_{H6} &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \\ &+ 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \end{aligned}$$

$$\begin{aligned} M_{H7} &= (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\ &+ (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \end{aligned}$$

Moment Invariant



Moment Invariant	Original Image	Translated	Half Size	Mirrored	Rotated 45°	Rotated 90°
ϕ_1	2.8662	2.8662	2.8664	2.8662	2.8661	2.8662
ϕ_2	7.1265	7.1265	7.1257	7.1265	7.1266	7.1265
ϕ_3	10.4109	10.4109	10.4047	10.4109	10.4115	10.4109
ϕ_4	10.3742	10.3742	10.3719	10.3742	10.3742	10.3742
ϕ_5	21.3674	21.3674	21.3924	21.3674	21.3663	21.3674
ϕ_6	13.9417	13.9417	13.9383	13.9417	13.9417	13.9417
ϕ_7	−20.7809	−20.7809	−20.7724	20.7809	−20.7813	−20.7809

Summary

- Common external representation methods are:
  - Chain code
  - Polygonal approximation
  - Signature
  - skeleton
- Descriptors
  - Boundary descriptor
  - Region descriptor