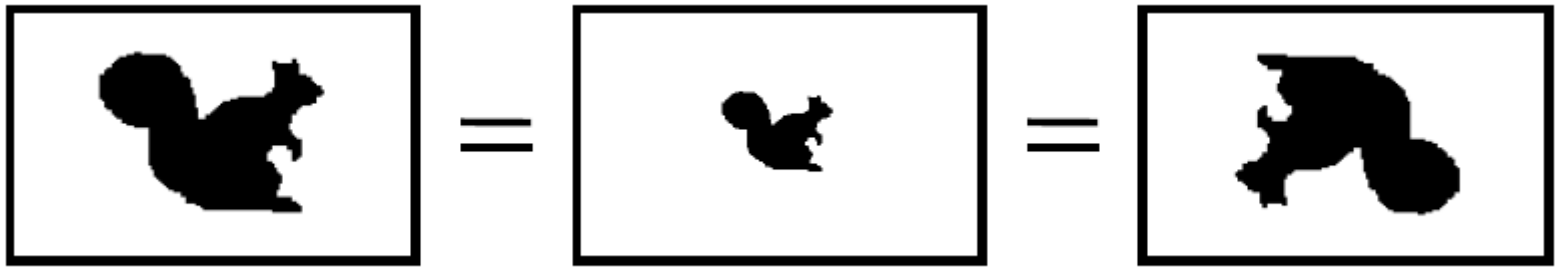
Object Descriptors

Object Descriptors

- Image regions (including segments) can be represented by either the border or the pixels of the region.
- These can be viewed as external or internal characteristics, respectively.
  - External characteristics – boundary
  - Internal characteristics-pixels comprising the region
  - Descriptors should be insensitive to changes in size, translation, rotation.

Object Descriptors

Most of the time we are interested to choose descriptors that are invariant of variations of scale, rotation and translation whenever possible



Regional Descriptors

- Purpose to describe regions or areas
- Area of the region: Number of pixels in the region
- Perimeter of a region: its length of its boundary
- Compactness: $(\text{perimeter})^2/\text{area}$
- Circularity ratio= $4*\pi*A/P^2$
- Other descriptors: Mean, median , minimum and maximum intensity values.

Topological Descriptors

- Useful for global descriptions of regions.
- Topology: It is the study of properties of the figure unaffected by any deformation

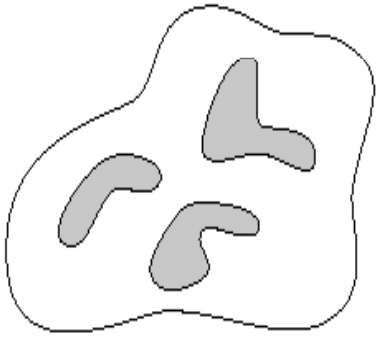


FIGURE 11.18 A region with three connected components.

Topological property 2: the number of connected components (C)

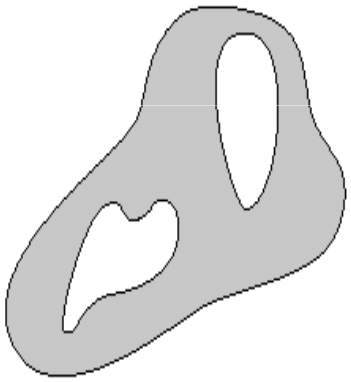


FIGURE 11.17 A region with two holes.

Topological property 1: the number of holes (H)

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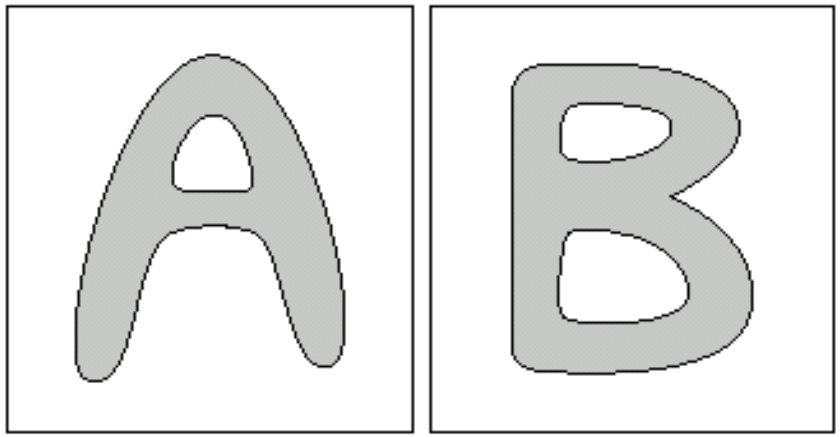
Regional Descriptors
Topological Descriptors

Topological property 3:
Euler number: the number of connected components subtract the number of holes
$E = C - H$

E=0

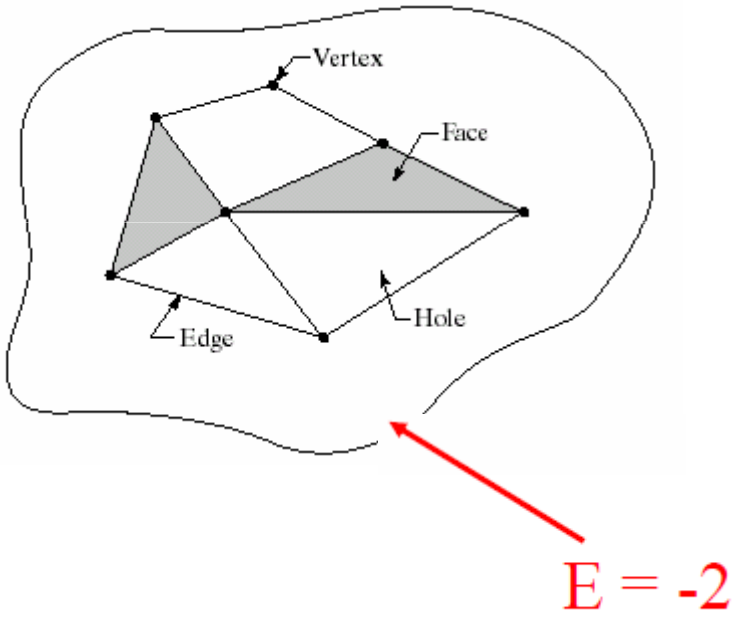


E= -1

a b

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

Regional Descriptors
Topological Descriptors



E = -2

Euler Formula

$$V - Q + F = C - H = E$$

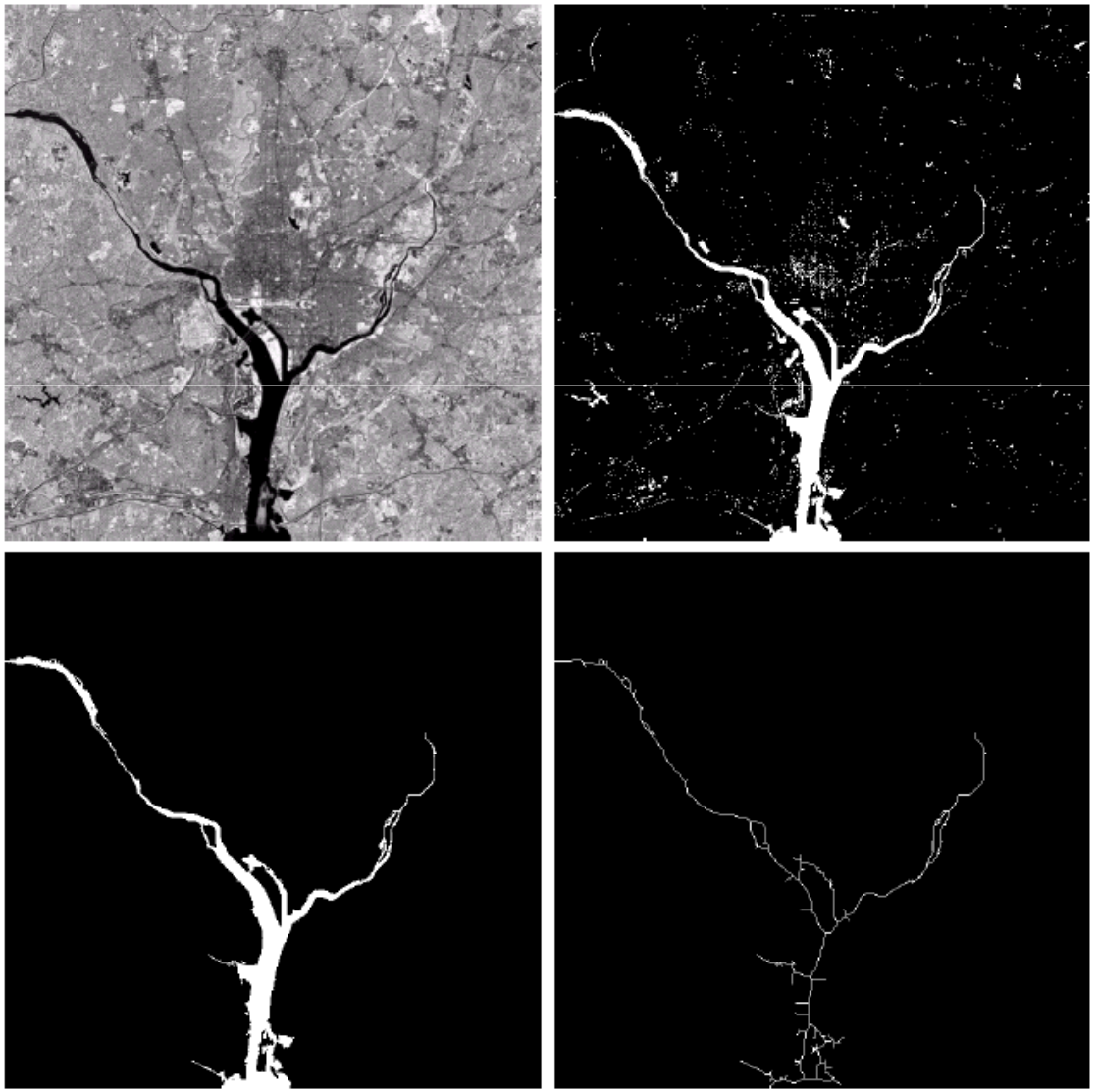
V = the number of vertices
Q = the number of edges
F = the number of faces

Regional Descriptors
Topological Descriptors

2.After intensity Thresholding (1591 connected components with 39 holes) Euler no. = 1552

3.The largest connected area (8479 Pixels) (Hudson river)

4.After thinning



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).

Regional Descriptors- Texture

- Texture is usually defined as the smoothness or roughness of a surface. In computer vision, it is the visual appearance of the uniformity or lack of uniformity of brightness and color.
- Approaches used in image processing to describe the texture of a region :
  - Statistical
    - Characterize texture as smooth, coarse,grainy
  - Structural
    - Deals with arrangement of image primitives such as description of texture as regularly spaced parallel lines
  - Spectral
    - Based on properties of Fourier spectrum describe the periodicity by identifying high-energy, narrow peaks in the spectrum

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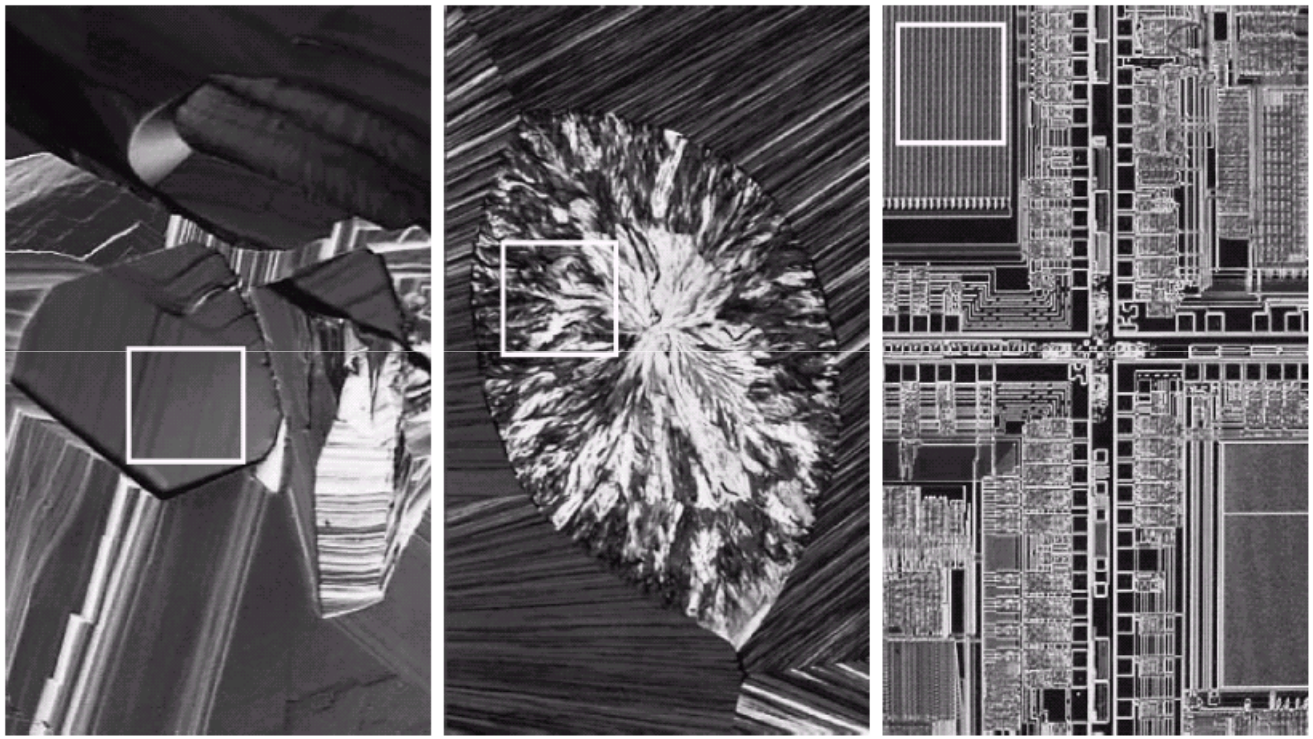
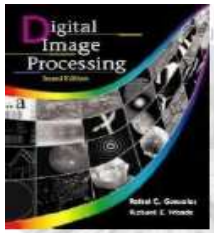
Regional Descriptors
Texture



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.)

Statistical Approaches



Statistical Approaches for Texture Descriptors

We can use statistical moments computed from an image histogram:

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

z = intensity
$p(z)$ = PDF or histogram of z

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

Example: The 2nd moment = variance → measure "smoothness"
The 3rd moment → measure "skewness"
The 4th moment → measure "uniformity" (flatness)

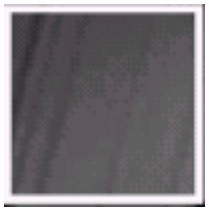
	Texture	Mean	Standard deviation	R (normalized)	Third moment	Uniformity	Entropy
A	Smooth	82.64	11.79	0.002	−0.105	0.026	5.434
B	Coarse	143.56	74.63	0.079	−0.151	0.005	7.783
C	Regular	99.72	33.73	0.017	0.750	0.013	6.674

(Images from Rafael C. Gonzalez and Richard E. Wood, Digital Image Processing, 2nd Edition.

Statistical Approaches

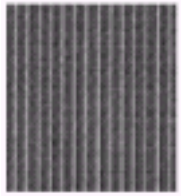
- The uniformity: $$U = \sum_{i=0}^{L-1} p^2(z_i)$$
- Measure U is maximum for an image in which all intensity values are equal
- The average entropy: $$e = -\sum_{i=0}^{L-1} p(z_i) \log_2 p(z_i)$$
- Entropy is the measure of variability and is 0 for constant image

Regional Descriptors
Statistical Approaches



Smooth

Coarse



Regular

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

Std:Smoothness of the texture

3rd moment : Degree of symmetry of histograms skewed left or right

Regional Descriptors
Statistical Approaches

- Texture analysis can be done by not only considering the distribution of intensities but also relative position of pixels.

- For an image with N graylevels, and P, a positional operator, generate A, a N × N matrix, where ai,j is the number of times a pixel with graylevel value zi is in relative position P to graylevel value zj

- Divide all elements in A with the sum of all elements in A. This gives a new matrix C where ci,j is the probability that a pair of pixels fulfilling P has graylevel values zi and zj which is called the co-occurrence matrix

Co-occurrence Matrix descriptors

1	0	1	2
1	0	2	1
0	1	2	1
2	1	0	1

$$\mathbf{A}_2 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \quad \mathbf{C}_2 = \begin{pmatrix} \frac{1}{12} & \frac{1}{12} & \frac{1}{12} \\ \frac{1}{12} & \frac{1}{3} & \frac{1}{12} \\ \frac{1}{12} & \frac{1}{12} & \frac{1}{12} \end{pmatrix}$$

- Maximum probability = 1/3
- Uniformity ≈ 0.167
- Entropy ≈ 2.918

$$\mathbf{C}_2 = \begin{pmatrix} \frac{1}{12} & \frac{1}{12} & \frac{1}{12} \\ \frac{1}{12} & \frac{1}{3} & \frac{1}{12} \\ \frac{1}{12} & \frac{1}{12} & \frac{1}{12} \end{pmatrix}$$

Co-occurrence Matrix descriptors

- Maximum probability (strongest response to P)

$$max_{i,j}(c_{ij})$$

- Uniformity

$$\sum_i \sum_j c_{ij}^2$$

- Entropy (randomness)

$$-\sum_i \sum_j c_{ij} \log_2 c_{ij}$$

Homogenity, Contrast and correlation measure can also used as descriptors

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Regional Descriptors
Structural Approaches

- Structural concepts:
  - Suppose that we have a rule of the form $S \rightarrow aS$, which indicates that the symbol S may be rewritten as aS.
  - If a represents a circle [Fig. 11.23(a)] and the meaning of "circle to the right" is assigned to a string of the form $aaaa\ldots$ [Fig. 11.23(b)] .

a
b
c

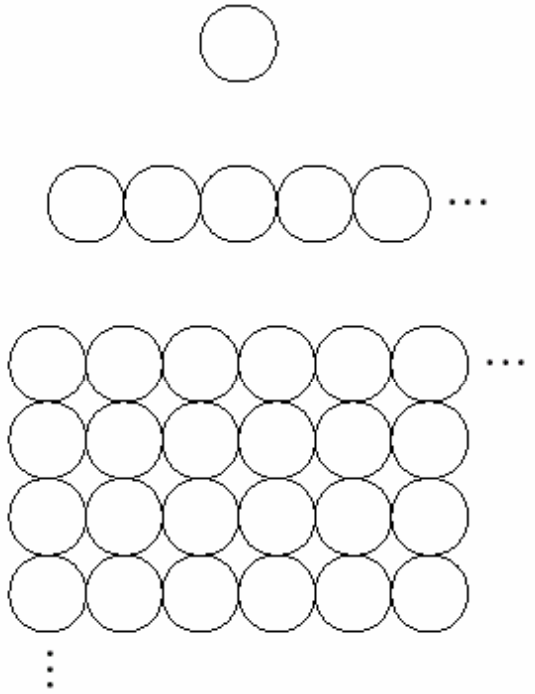


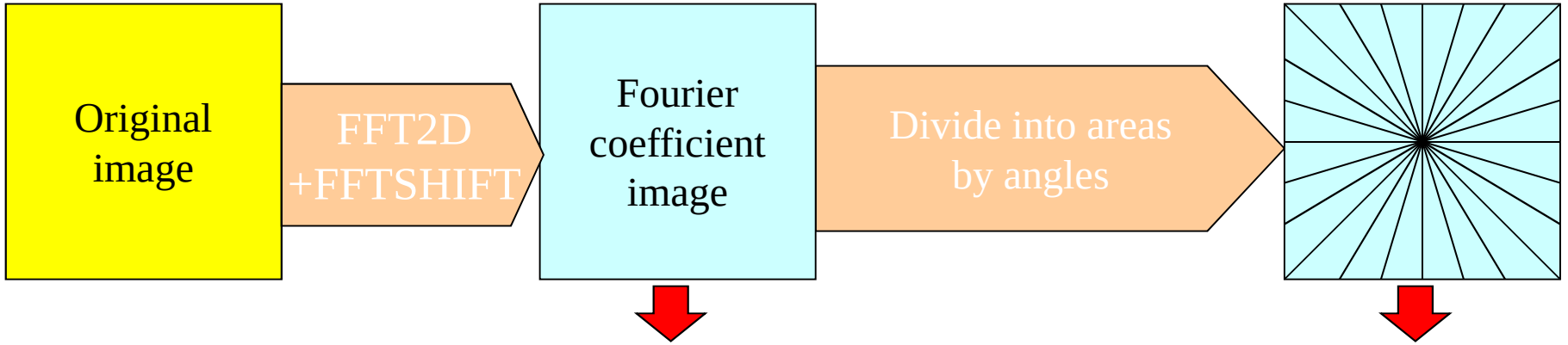
FIGURE 11.23
(a) Texture primitive.
(b) Pattern generated by the rule $S \rightarrow aS$.
(c) 2-D texture pattern generated by this and other rules.

Regional Descriptors
Structural Approaches

- For non-random primitive spatial patterns, the 2-dimensional Fourier transform allows the patterns to be analyzed in terms of spatial frequency components and direction.
- It may be more useful to express the spectrum in terms of polar coordinates, which directly give direction as well as frequency.
- Let $S(r,\theta)$ is the spectrum function, and r and θ are the variables in this coordinate system.

Fourier Approach for Texture Descriptor

Concept: convert 2D spectrum into 1D graphs



$$S(\theta) = \sum_{r=1}^{R_0} S_r(\theta)$$

$$S(r) = \sum_{\theta=0}^{\pi} S_\theta(r)$$

Regional Descriptors
Structural Approaches

- We deine three features of the Fourier Spectrum
- Promient speaks gives principal direction of the texture patterns
- Location of the peaks gives spatial period of the pattern
- Eliminating any periodic components via filtering leaves nonperiodic image elements which can be described by statistical techniques

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