PROPERTIES OF IMAGE OBJECTS

Features in images

- 1D structures:
  lines, open curves, closed curves (boundaries)

- 2D structures: regions

- Complementary

- Representation
  - pictorial
  - **functional**

Properties

Geometric
- size (length, area)
- shape

Topological
- adjacency structure

Tonal
- grey level / colour statistics

Textural
- relationship between tonal and spatial components

Geomertic properties

Size

- Area
- Length

Shape

- boundary re-representation

From pictorial to functional representation for boundaries

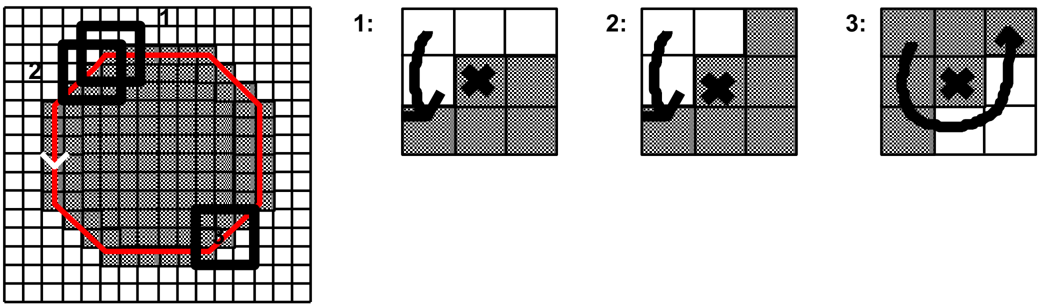
- Input: Image
- Output: (x,y) coordinates

Deriving object boundaries from grey level images

- Contour following
- Graph searching

Deriving object boundaries from binary or labelled images

- Region outlining



Simple boundary representations

- (x,y) coordinates
- polar coordinates
- chain codes

Further boundary representations

From the principles of perceptual organisation the curve is best partitioned by detecting <u>“local discontinuity”</u>, i.e. at points which show a rapid change of slope.

Polylines

- list of endpoints

- can approximate any curve

- problem of finding breakpoints

    - differentiation
    - split-and-merge techniques
    - tolerance bands

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Strip trees

- A hierarchical data structure for the representation of curves
- A binary tree where each node represents a 'strip segment' - a rectangle covering a segment of the curve
- The orientation depends on the line joining two endpoints
- Width of the rectangle is the minimum width which gives a rectangle covering the segment.

ψ-s curves

- the angle between a fixed line and a tangent to the boundary
- horizontal lines in ψ-s space correspond to straight lines in the boundary
- non-horizontal lines correspond to segments of circles (y changing at a constant rate)
- Input: coordinates
- Output: functional description of the boundary in terms of line segments and arcs

Fourier descriptors

- boundary represented as a periodic function which can be expanded in a Fourier series (a frequency domain description)

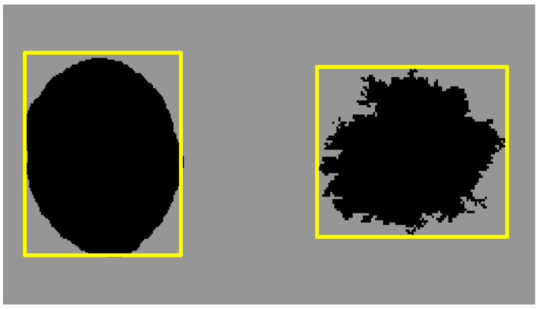
- the more coefficients used the better approximated the shape

Geometric shape descriptors

Eccentricity (elongation)

x to y ratio of the **bounding rectangle**

ratio of the length of the maximum chord to a maximum chord perpendicular to it



Compactness

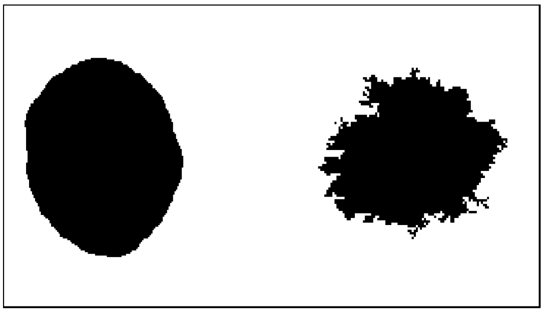
ratio of perimeter^2 to area, minimised by a disk

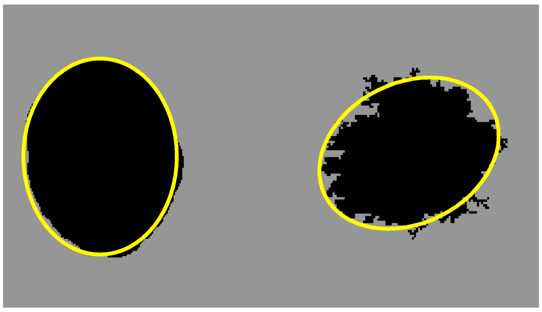
Bulkiness

- Dimensionless shape factor used to characterise the dynamics of rigid bodies

$$\text{Bulkiness} = \frac{\text{area of equivalent ellipse}}{\text{area of the original figure}}$$

- "equivalent ellipse": an ellipse with the same moment of gyration (moment of inertia about the centre of gravity) as a given figure





Bending energy

$$E = 1/P \int_0^P | k(s)|^2 \, ds$$

Curvature

$$| \kappa(s) |^2 = (\frac{d^2x}{ds^2}) + (\frac{d^2y}{ds^2})$$

Slope density function

The histogram of y collected over the boundary

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Fractal dimension

- term coined by Mandelbrot

- Characterises the plane-filling ability of a curve

- derived by using different step lengths to measure the perimeter of the figure

- The estimated perimeter increases as the step length decreases

For a given step s the estimated perimeter length L can be expressed by the equation:

$$L(s) = s \; N(s)$$

N(s) is the number of sides of length s of a polygon which approximates the perimeter.

The number of polygon sides for a given perimeter is a function of the step length:

$$N(s) = \lambda \, s^{-D}$$

Final expression for the estimated perimeter length:

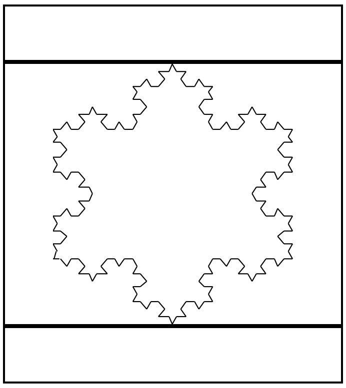
$$L(s) = \lambda\, s^{1 - D}$$

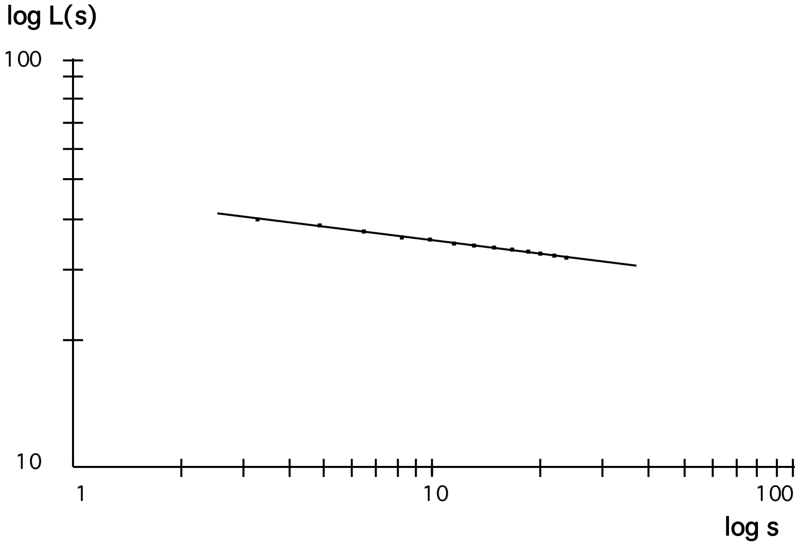
Take logarithm of both sides gives a line equation (log L(s) vs log s)

$$\log L(s) = \log \lambda + (1 - D) \log s$$

(1 - D) is the slope; D is the fractal dimension (can be a fractional number)

log λ is the intercept and is related to scale





Fractal dimension: 1.29

Topological properties

topological property - must be invariant under "rubber sheet" distortion

Examples

- region adjacency
  - Region Adjacency Graph (RAG)
  - nodes - regions
  - arcs - adjacency of the regions

- Euler number
  - no of holes

Tonal properties

Grey level statistics

- mean
- standard deviation
- minimum - maximum

Colour statistics

- colour spaces
  - RGB
  - HSV
  - CIE XYZ
- Ignoring illuminant

Textural properties

Texture Characterised by
- the tonal primitives
- the spatial inter-relations between them

Tone v/s texture
- Tonal properties depend only on grey levels and are independent of the spatial distribution of grey levels within the area.

- Textural properties relate to the way the pixels with various grey levels are spatially arranged within the area and depend both on grey level value and on the spatial distribution of grey levels.

- Distribution of grey levels can be regular or irregular.

Approaches

statistical, spectral, structural and syntactic.

Statistical approach

First order statistics tell nothing about spatial distribution.

Second order statistics describe various texture attributes, such as coarseness, homogeneity and contrast.

Co-occurrence (spatial dependency) matrix

A co-occurrence matrix is a two-dimensional matrix, indexed in each direction by grey-level values.

The position (i,j) in the matrix stores the number of times that a pixel with value **i** has as its neighbour a pixel with value **j** at a given distance and for a given angle.

Texture measures can then be derived from these matrices

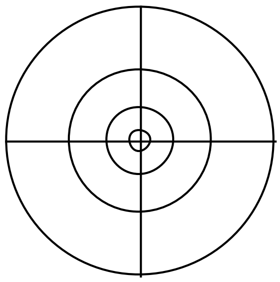
Spectral approach

Spectrum of a 2D Fourier transform of an image contains information about frequencies of grey level values in the image.

Power spectrum is divided into a sectors

The sum of values in each sector gives a measure of both 'granularity' and direction of texture

sectors near the origin will have high values for coarse texture and those further away - for fine texture.



Structural approach

Texture is defined by sub-patterns (texture primitives, **texels**) which occur repeatedly within the overall pattern

The observed texture is treated as a transformation (distortion) of the ideal texture defined by the rules.

Placement rules can be described by the tesselation list, the 'regular graph' or relative vectors.

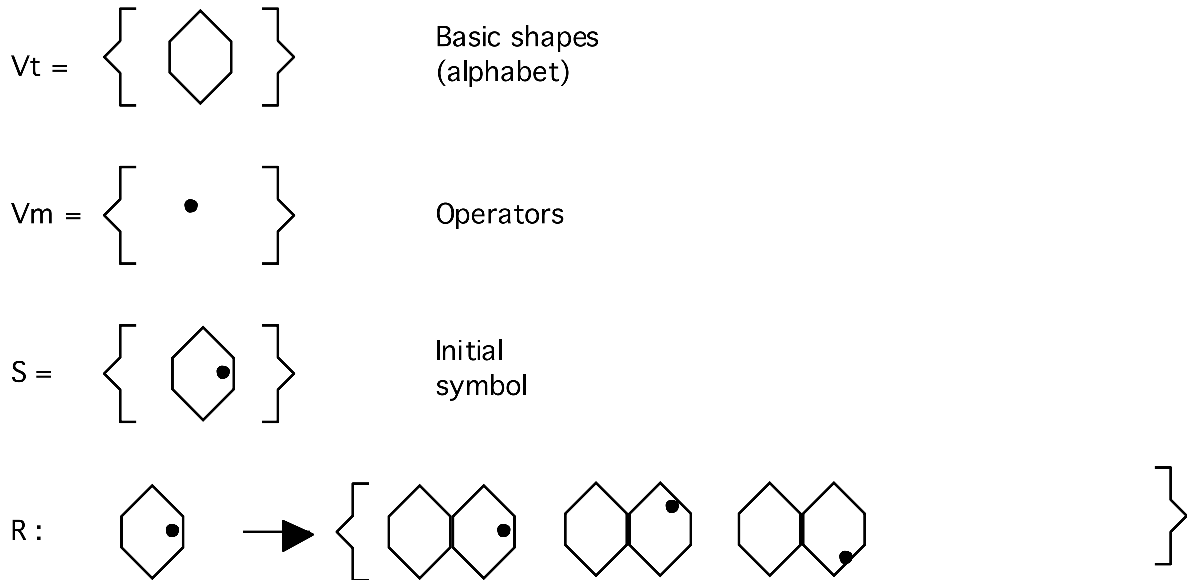
Thus approach is used for regularly arranged patterns.

Syntactic approach

The rules that govern the structure (placement of texels) are described by a grammar.

The grammar describes how to generate patterns by applying rewriting rules to a small number of symbols (texels).

Texture grammars are usually syntactically ambiguous (many choices for rules and symbols).


Vt =
Basic shapes
(alphabet)
Vm =
Operators
S =
Initial
symbol
R :

Texture can be used as a basis of segmentation.

In the analysis of 3D scenes it is possible to calculate a surface orientation from images of textured surfaces