unit – V

Image Segmentation → Edge based
→ Region based

Introduction

Segmentation algorithms Based 2 basic Properties → Discontinuity
→ Similarity

First category.

* Partition an image on abrupt changes in grey level.

* Principal approaches @ detection of isolated points and detection of lines and edges in an image.

Second category.

* It is based on thresholding, region growing and region splitting and Merging.

* Both is applicable to both static and dynamic.

Detection of Discontinuities :-

−1	−1	−1
−1	8	−1
−1	−1	−1

i) Detecting isolated points.

Point detection

Point is detected if

$|R| > T$

$T \rightarrow$ non negative threshold.

-1	-1	-1
2	2	2
-1	-1	-1

Horizontal

-1	-1	2
-1	2	-1
2	-1	-1

+45°

-1	2	-1
-1	2	-1
-1	2	-1

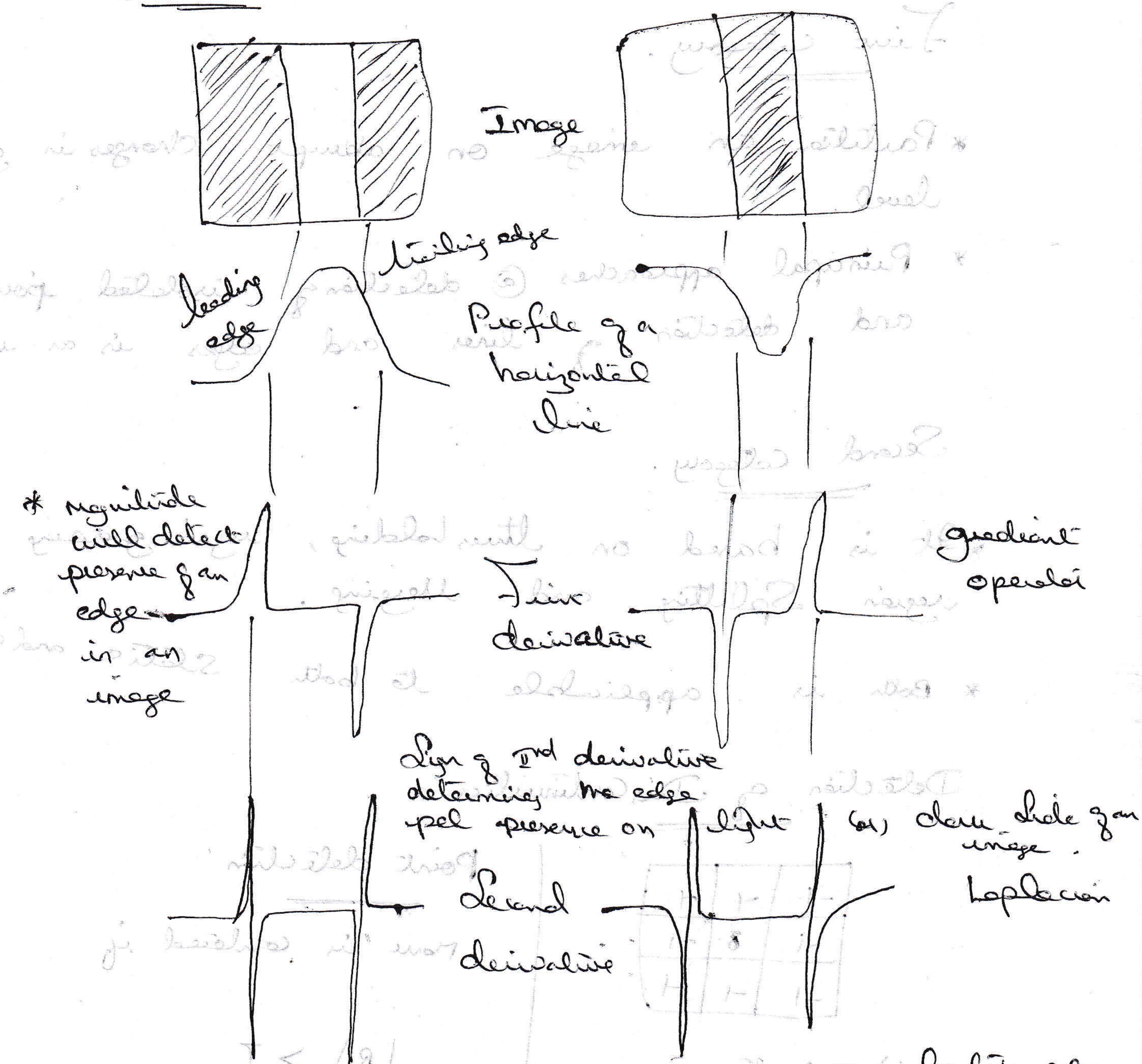
Vertical

2	-1	-1
-1	2	-1
-1	-1	2

-45°

ii) Line masks.

Edge detection



* Zero crossings → power approach for locating edges.

a) light Stripe on

b) Dark Stripe on light background

Gradient operator.

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{pmatrix} \partial f/\partial x \\ \partial f/\partial y \end{pmatrix}$$

$$\nabla f = \text{mag}(\nabla f) = \left[G_x^2 + G_y^2 \right]^{1/2}.$$

$$\nabla f \approx |G_x| + |G_y|.$$

Vector analysis $\Rightarrow \alpha(x,y) = \tan^{-1}\left(\frac{G_y}{G_x}\right).$

Sobel operator $\Rightarrow$ Differencing and Smoothing.

$$G_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)$$

$$G_y = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7).$$

Laplacian

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}.$$

$$\nabla^2 f = 4z_5 - (z_2 + z_4 + z_6 + z_8).$$

Laplacian $\Rightarrow$ Co-efficient $\rightarrow$ center pixel positive and co-efficients associated with outer pixels be -ve.

$\Rightarrow$ Sum of the co-efficients has to be zero.

* II order derivative $\Rightarrow$ Laplacian unacceptably sensitive to noise.

$\Rightarrow$ produces double edges and is unable to detect edge

* noise reduction lies in Zero crossing

0	-1	0
-1	4	-1
0	-1	0

Laplacian mask

Thresholding

Foundation

Role of illumination

Simple Global thresholding

optimal thresholding.

Threshold Selection based on Boundary characteristics.

Representation and Description

Representation Schemes

* Segmented pixels usually are represented $\boxed{\text{segmented}}$ and described in a form suitable for further Computer processing.

1) Represent in terms of external characteristics (its boundary). ⇒ Shape characteristics.
2) Represent in terms of its internal characteristics (pixels comprising the region) ⇒ reflectivity properties [such as color & texture].

Features selected as descriptors ⇒ insensitive i.e changes in size, translation & rotation.

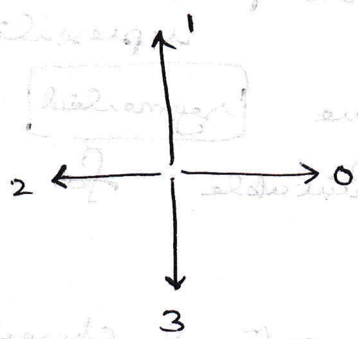
Chain codes

* It is used to represent a boundary by a Connected sequence of straight line segments of specified length & direction.

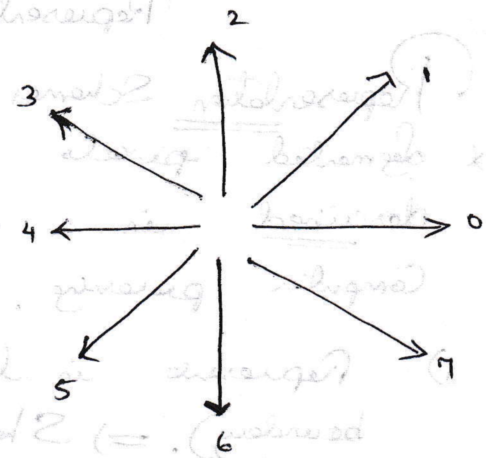
* Images ⇒ acquired and processed in a grid format ⇒ Equal spacing in x & y directions ⇒ chaincode could be generated following a boundary in Clockwise direction & assigning a direction to segments connecting every pair of pixels.

Reasons [Acceptable]

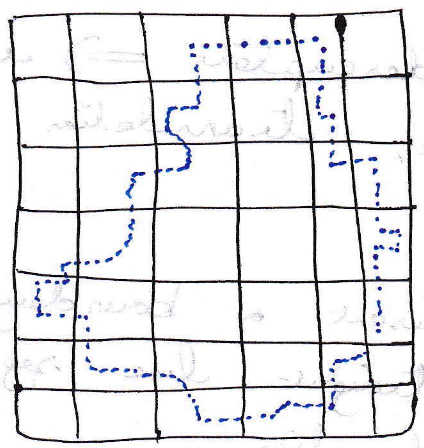
i) The resulting chain codes are usually quite long.
ii) Any small disturbances along the boundary owing to noise (or) imperfect segmentation cause changes in the code ⇒ May not necessarily be related to shape of



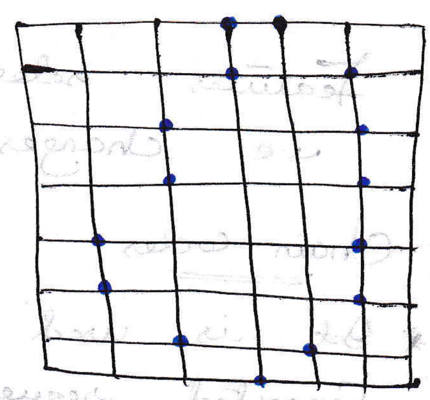
a) 4 directional Chain Code



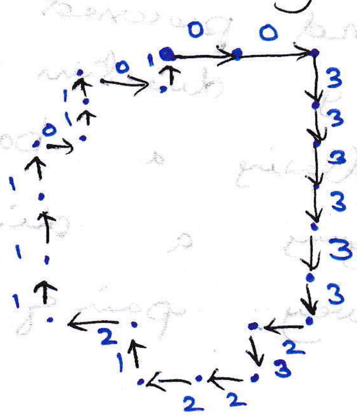
b) 8 Directional Chain Code.



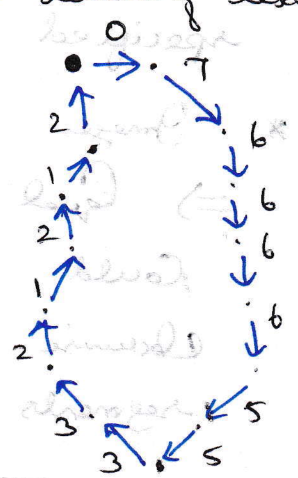
a) Digital boundary with resampling grid Superimposed



b) result of resampling.



c) 4 directional Chain Code



d) 8- directional Chain Code.

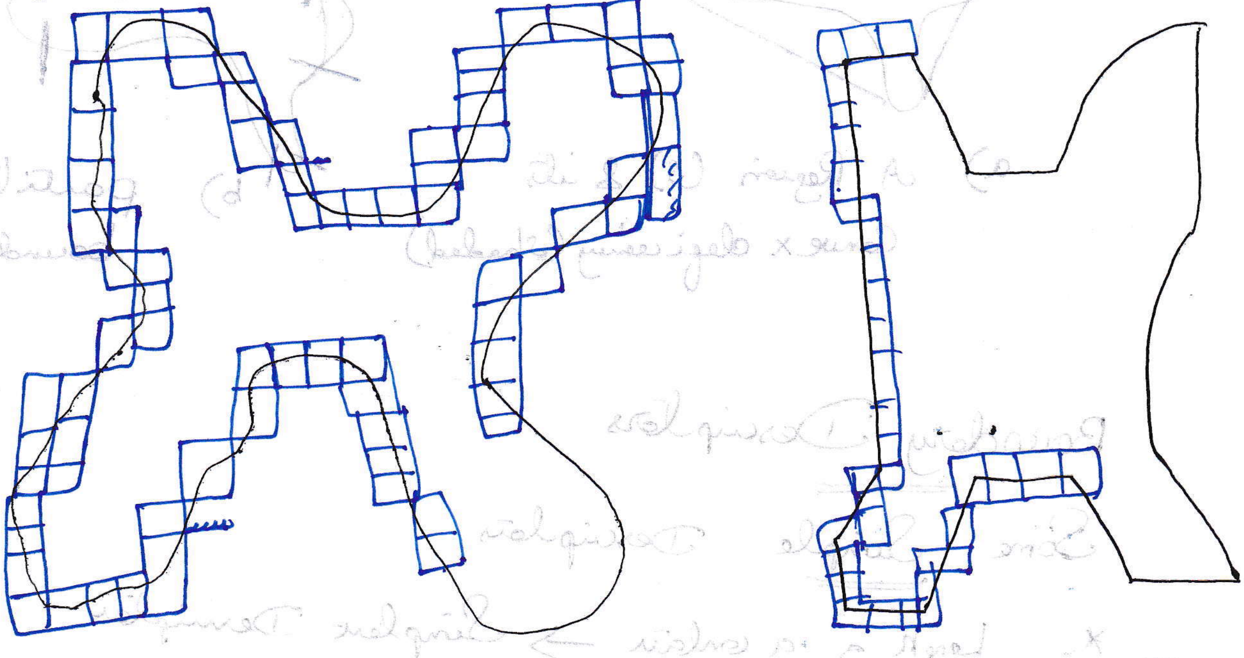
In c ⇒ chain code is 0033 ....

In d ⇒ Chain code is 076 ....

circular Sequence ... Scale change:

Polygonal Approximations

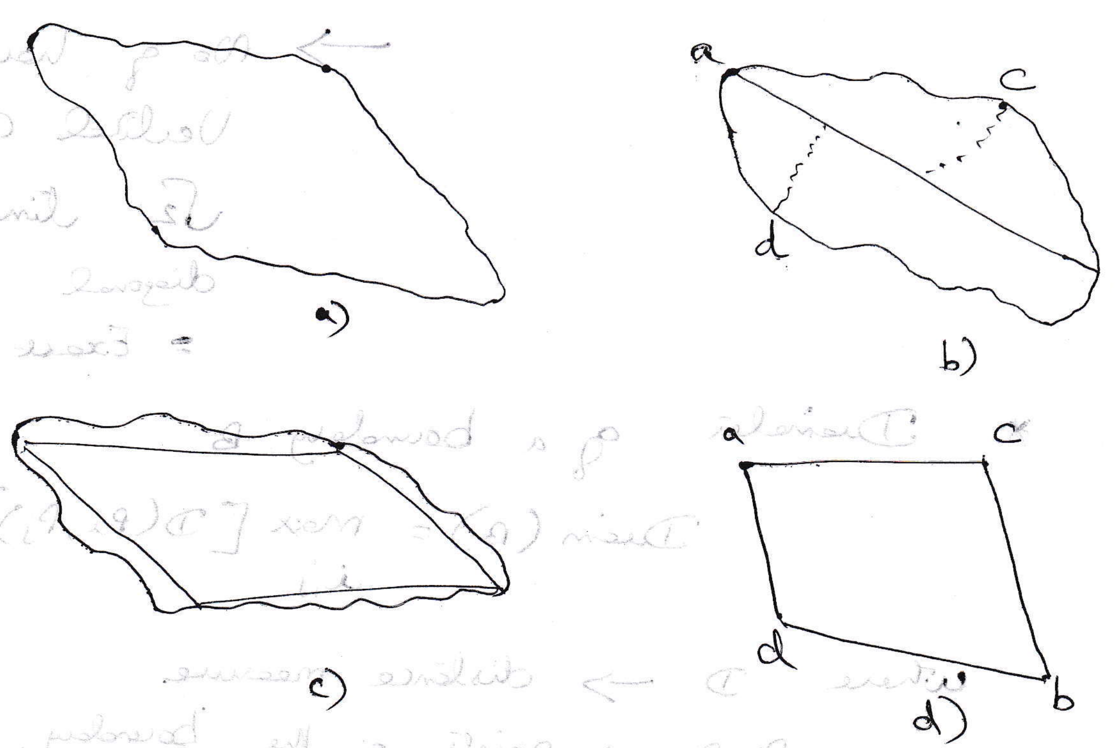
* A Digital boundary Can be approximated with arbitrary accuracy by a polygon.



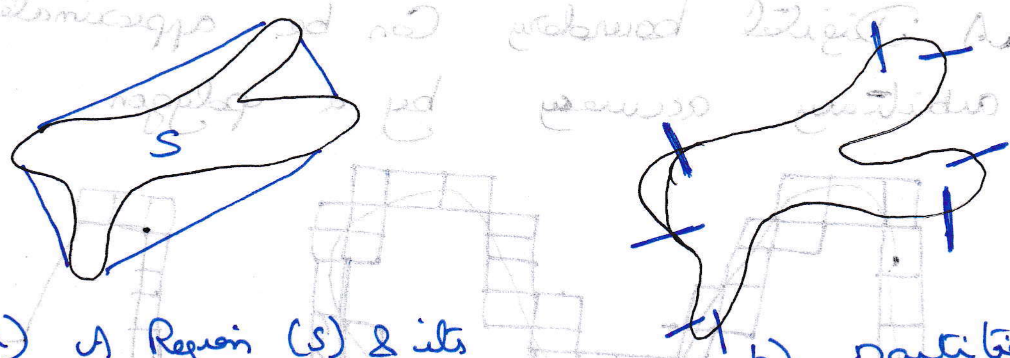
a) Object boundary enclosed by cells

b) Minimum Perimeter Polygon.

* Merging & Splitting



Boundary Segments.



a) A Region (S) & its Convex deficiency (Shaded)

b) partitioned boundary.

Boundary Descriptors

Some Simple Descriptors

* Length of a contour → Simplest Descriptor.

* Simply Counting No. of pixels along the Contour } → Rough approximation of length.

* Chain Code Curve → unit Spacing in both directions
  → No of horizontal & Vertical Components + $\sqrt{2}$ times No of diagonal Components = Exact length.

* Diameter of a boundary B

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

Where D → distance measure

p_i, p_j → points on the boundary.

* Value of diameter & orientation of line => Connecting 2 extreme points => descriptors of a boundary.

* Curvature -> Rate of change of slope.

-> Measurement is difficult

-> locally ragged.

=> previous figures are Curvature descriptors

* As the boundary is traversed in the clockwise direction => A vertex pt p is said to convex => Change in slope at p is nonnegative.

=> otherwise p is said to concave.

Shape Numbers

* Shape No. of a boundary based on 4 directional code.

* Order n of a shape number is defined as the no. of digits in its representation, n is even for a closed curve.

Fourier Descriptors

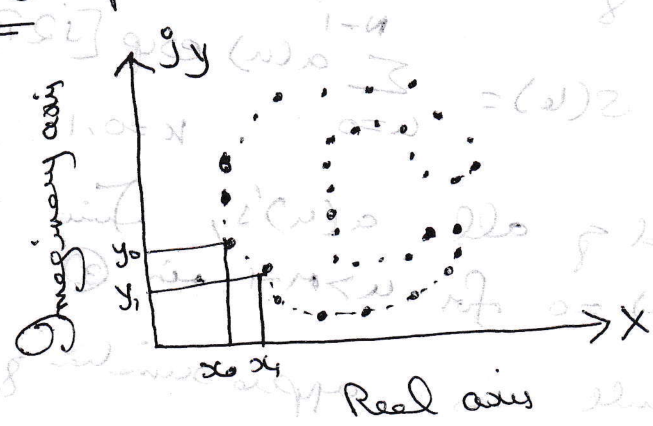


Fig (1) Digital boundary and its representation as a complex sequence. The points (x_0, y_0) and (x_1, y_1)

* Starting at an arbitrary point (x_0, y_0), Co-ordinate pairs (x_0, y_0), (x_1, y_1), $(x_2, y_2) \ldots$ (x_{N-1}, y_{N-1}) are encountered in traversing the boundary $\Rightarrow$ Counterclockwise.

$x(k) = x_k$, & $y(k) = y_k$.

* Boundary repres[entation]: Sequence of Co-ord. $s(k) = [x(k), y(k)]$, for $k = 0, 1, 2, \ldots N-1$

$s(k) = x(k) + j\,y(k)$ —— ①

$\hookrightarrow$ Co-ordinate pair can be represented as complex no

~~Sequence of Co-ordinates.~~ $s(k) = [x$

* x-axis $\Rightarrow$ real axis
  y-axis $\rightarrow$ Img axis.

* Advantage $\Rightarrow$ reduces a 2D to 1D problem.

* DFT of $s(k)$ is

$$a(u) = \frac{1}{N} \sum_{k=0}^{N-1} s(k) \exp\left[-j2\pi uk/N\right], \quad u = 0, 1, \ldots N-1 \quad \text{—— ②}$$

The Complex Co-efficients $a(u) \Rightarrow$ Fourier descriptors of boundary.

* IFT of $a(u)$ is

$$s(k) = \sum_{u=0}^{N-1} a(u) \exp\left[j2\pi uk/N\right] \quad \text{—— ③}$$

$k = 0, 1 \ldots N-1$

* Instead of all $a(u)$'s, First M Co-efficients
$\Rightarrow a(u) = 0$ for $u > M-1$ in ③
$\Rightarrow$ Result is approximation of $s(k)$

$$\hat{s}(k) = \sum_{u=0}^{M-1} a(u) \exp\left[j2\pi uk/N\right] \quad \text{—— ④}$$

* Same No. of points exists in app boundary but not as many terms are used in the reconstruction of each point.

* If Integer power of 2, so that an FFT algorithm be used to expedite computation of the descriptor.

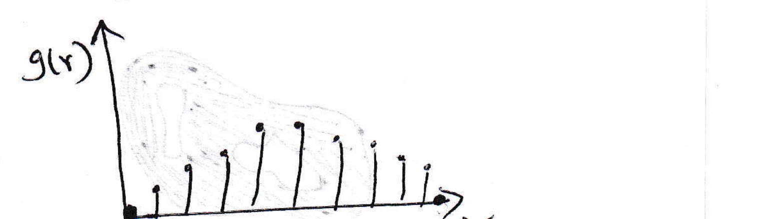
* High freq → Fine detail
  Low freq → global shape.
  Thus Smaller M ⇒ more detail is lost on the boundary.

Some Basic properties of Fourier Descriptor.

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	$S_p(k) = S(k-k_0)$	$a_p(u) = a(u)e^{-j2\pi k_0 u/N}$

Moments

Shape of boundary segments can be quantitatively described by using moments.



Regional Descriptors

* Area of a Region => No. of pixels contained within its boundary.

* Perimeter of a Region => Length of its boundary.

* Area & perimeter => Descriptors

* Compactness of region => (Perimeter)^2/area

  i) It is a dimensionless qty.

  ii) It is minimal for disc shaped region.

  iii) It is insensitive to orientation.

* Principal axes of a region => Eigenvectors of Covariance matrix obtained by using pixels.

* Spread & direction of region => Eigenvectors.

* Other measure => Mean & Median of grey levels.

  => Max & Min of " "

  => No. of pixels above & below the mean.

Topological Descriptors

* It is used for global descriptions of regions in image plane.

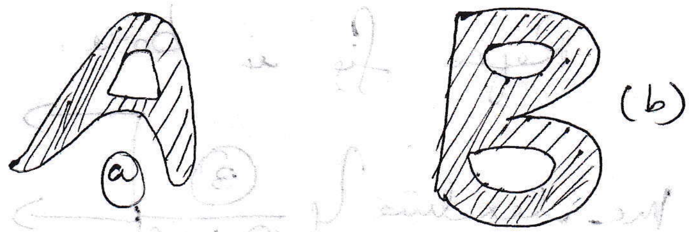
No. of holes = H

Connected Components = C.

Euler Number = E

$$\boxed{E = C - H} \quad \text{——— (1)}$$

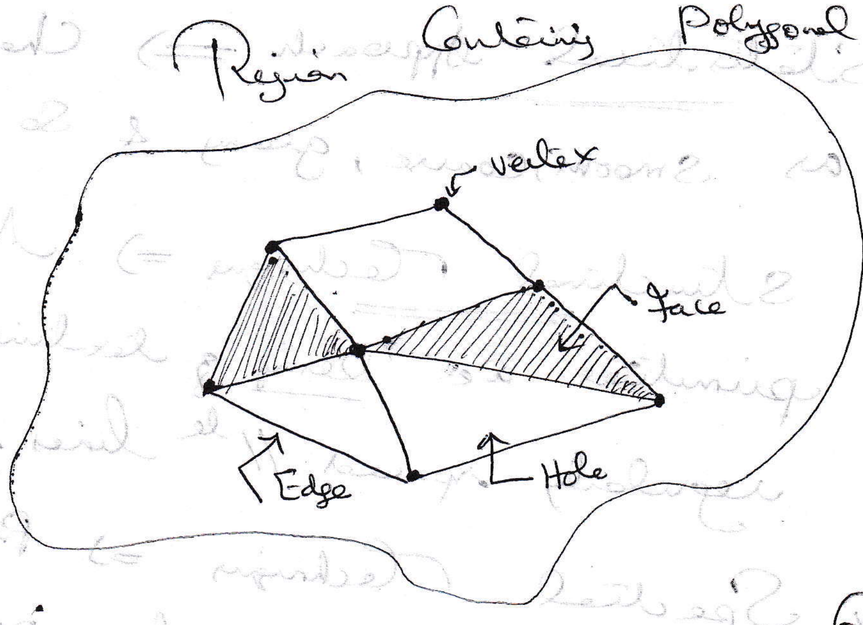
↓ Topological property.



Regions with Euler No. equal to 0 & −1 respectively.

Regions represented by st-line segments ⇒ Polygonal N/w's.

Region Containing Polygonal N/w.



$$W - Q + F = C - H = E \longrightarrow \text{Euler formula}$$

- W → No. of Vertices
- Q → No. of edges
- F → No. of Faces
- C → No. of Connected Components
- H → No. of Holes

$$7 - 11 + 2 = 1 - 3 = -2.$$

Texture.

* Important approach Region description } ⟹ Quantify its texture Content.

* Descriptor provides properties } ⟹ Smoothness, Coarseness & regularity.

* Examples Refer fig in book.

* Describe the texture of a region } ③ Principal approach → Statistical → Structural → Spectral.

* Statistical Approach ⟹ Characterization of texture as smooth, coarse, grainy & so on.

* Structural Techniques ⟹ Arrangement of image primitives i.e Desrip of texture based on regularly spaced //le lines.

* Spectral Techniques ⟹ Properties of Fourier Spectrum and are used primarily to detect global periodicity in an image by identifying high energy, narrow peaks in Spectrum.

Texture

Statistical approaches => chars of textures as smooth coarse, grainy & so on.

* Simplest approach.

* Moments of the grey level histogram of an image region.

* $z \rightarrow$ random variable denoting discrete image intensity

$p(z_i) \rightarrow i = 1, 2, \ldots L$ be the corresponding histogram

$L \rightarrow$ No of distinct intensity levels.

* n^{th} moment of z about the mean is

$$\mu_n(z) = \sum_{i=1}^{L} (z_i - m)^n \, p(z_i) \quad \text{——— (1)}$$

where m is the mean value of z (average Intensity)

$$m = \sum_{i=1}^{L} z_i \, p(z_i) \, . \quad \text{——— (2)}$$

* Note that in (1) $\mu_0 = 1$ & $\mu_1 = 0$.

* II nd moment [variance => $\sigma^2(z)$] is of Importance in texture description.

* It is a measure of grey-level contrast that can be used to establish descriptors of relative smoothness.

$$R = 1 - \frac{1}{1+\sigma^2(z)} \quad \text{——— (3)}$$

$\rightarrow \sigma^2(z) = \ldots$ for areas of constant intensity

* 3^{rd} moment → Measure of ~~smoothness~~ Skewness of the histogram.

* 4^{th} moment → Measure of relative flatness.

* 5^{th} & higher moments ⇒ not easily related to histogram shape but they do provide further quantitative discrimination of texture content.

* Pblm → Distribution of intensities but also the positions of pixels with equal (or) nearly equal intensity values.

* Position operator

one pixel to the right
one pixel to below ⇒ 3x3 matrix A:

$$A = \begin{bmatrix} 4 & 2 & 1 \\ 2 & 3 & 2 \\ 0 & 2 & 0 \end{bmatrix} \quad \text{—— (1)}$$

* Matrix C is called grey-level Concurrence matrix

C is formed by dividing every element of A by n, then C_{ij} is an estimate of joint probability that a pair of points satisfying P

* Soln ⇒ 1) maximum probability

Characterise the
2) element difference moment of order k.
3) Inverse element difference moment of order k,

Characterize ⇒ Content of C

* First property ⇒ Strongest response P.

Second descriptor ⇒ Low value ⇒ high values of C near the main diagonal.
∴ diff $(i-j)$ are smaller there.

Third descriptor ⇒ opposite effect

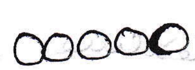
Fourth descriptor ⇒ Measure of randomness, achieving its high value when all elements of C are equal.

Structural approaches

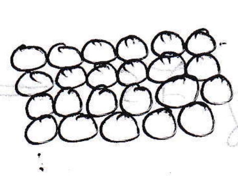
$S \rightarrow aS \overset{3}{\Rightarrow}$ applns of this rule $\Rightarrow aaaS$.

$a \rightarrow$ circle $\overset{1}{\Rightarrow}$ meaning of circles ⇒ to right is assigned to a string of the form aaa....., $S \rightarrow aS$ allows generating texture pattern as shown in 2.

a) Texture Primitive



b) pattern generated by the rule $S \rightarrow aS$.



* New rules $\Rightarrow S \to bA$,

$A \to cA$

$A \to c.$

$A \to bS.$

$S \to a.$

$b \to$ means circle down.

$c \to$ " circle left.

Generate aaabccbaa $\Rightarrow$  $\Rightarrow 3 \times 3$ matrix of circle.

* Larger texture pattern can be generated in the same way as (c).

* Basic idea $\Rightarrow$ texture primitive $\Rightarrow$ can be used to form more complex texture patterns by means of some rules $\Rightarrow$ limit no of possible arrangements of the primitive $\Rightarrow$ heart of relational description.

Spectral approaches.

* FS is $\Rightarrow$ Directionality of periodic or almost periodic 2D patterns.

* Global texture patterns $\Rightarrow$ easily distinguishable as concentrations of high energy bursts in the spectrum.

Three features of FS $\Rightarrow$ texture description

1) Prominent peaks in Spectrum } ⟶ Principal direction of the texture patterns.

2) Location of peaks in frequency plane } ⟶ Fundamental Spatial period of the patterns.

3) Eliminating any periodic Components } ⟶ Filtering leaves non periodic image elements.

⟶ Symmetric about the origin.

* Detection and interpretation of Spectrum features } ⟹ Spectrum in polar Co-ordinates to yield a func $S(r, \theta)$

* $S(r, \theta)$ ⟶ where S is Spectrum function.
r & θ are Variables in this Co-ordinate System.

* For each direction θ, $S(r, \theta)$ ⟶ may be considered as a 1D function $S_\theta(r)$.

For each frequency r, $S_r(\theta)$ ⟶ 1D function.

Global description ⟹ Integrating (Summing for discrete variables)

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

& $$S(\theta) = \sum_{r=1}^{R} S_r(\theta).$$

where R is the radius of a circle centered at the origin.

For N×N spectrum ⟹ R is $N/2$.