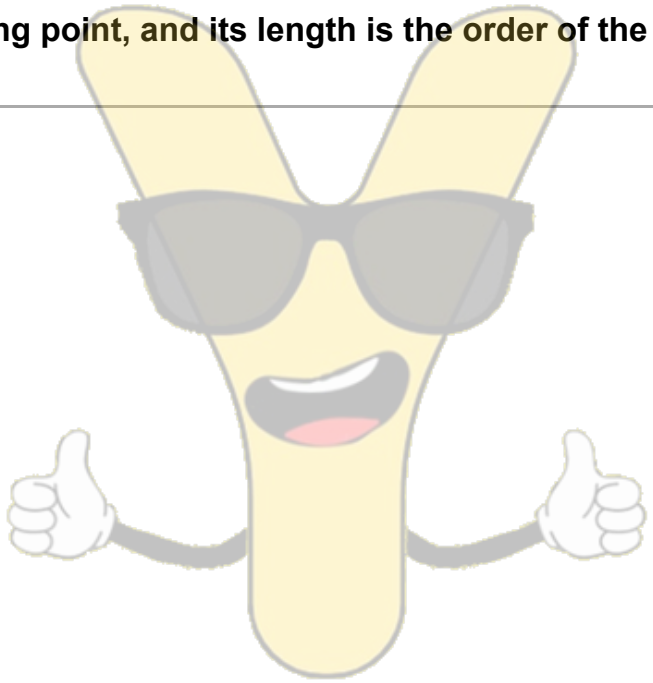
UNIT–4 : Feature Extraction (PYQ Solution)

AKTU · Image Analytics (BCDS061) · Solutions by **Chirag Jain**, Ycotes

SECTION A Answers (≈70 Words Each)

Q1. Define shape numbers. (Jun 2023)

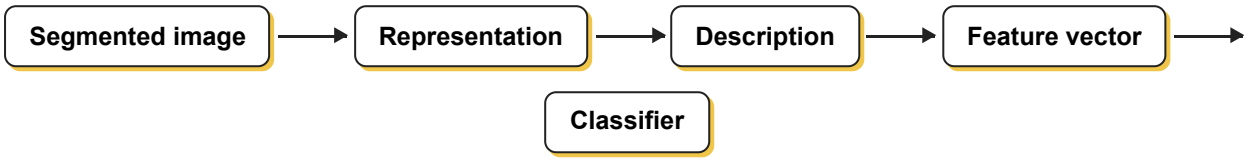
A shape number is a boundary descriptor derived from the chain code of a boundary. It is the first difference of the chain code (counting the number of direction changes, counter-clockwise) circularly rotated so that the resulting number has the minimum integer value. The shape number is invariant to rotation and starting point, and its length is the order of the shape.



SECTION B Answers (≈250 Words Each)

Q1. Explain feature extraction process in detail. (Jun 2023)

Feature extraction converts segmented image data into a compact set of numerical **features (descriptors)** that characterise objects and are used for classification. It reduces data while keeping discriminating information.



Feature extraction process

Steps

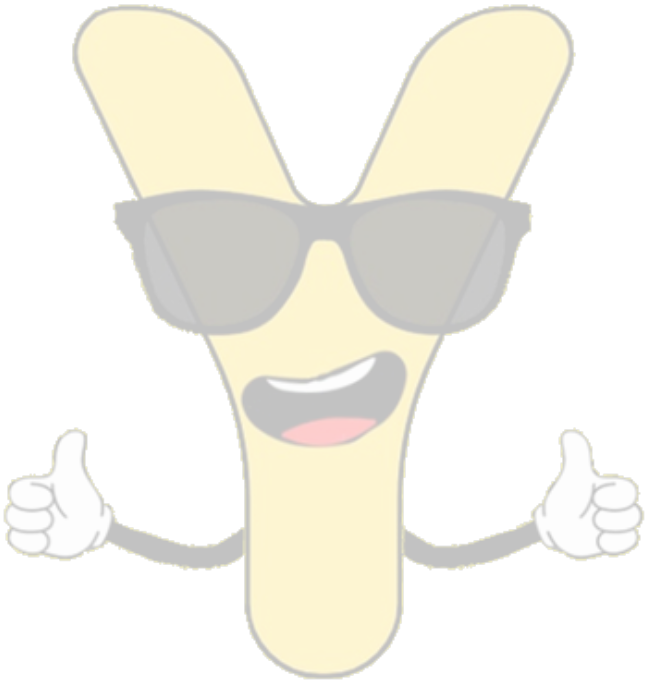
1. **Representation:** choose how to present the segmented object: as a **boundary (external)** when shape matters, or as a **region (internal)** when colour or texture matters. Boundary methods include chain codes, polygonal approximation and signatures.
2. **Preprocessing the boundary:** resample, smooth, make it closed.
3. **Description:** compute descriptors from the representation:
   - **Boundary descriptors:** length, diameter, curvature, shape numbers, Fourier descriptors.
   - **Regional descriptors:** area, perimeter, compactness (P^2/A), circularity, eccentricity, Euler number, topological descriptors.
   - **Texture:** statistical (mean, variance, entropy, GLCM), spectral.
   - **Moments:** invariant moments for scale, rotation, translation invariance.
4. **Normalise** the features to be invariant to size, position and orientation.
5. **Select and reduce** features (PCA, correlation) to remove redundant ones.
6. **Form feature vector** $x = (x_1, x_2, \ldots, x_n)$ and pass it to the classifier.

Good features are: discriminating, invariant, robust to noise, independent and few in number.

Example: to distinguish coins from screws, compactness $4\pi A/P^2$ is near 1 for coins and much smaller for screws.

Type	Examples
Shape	Chain code, Fourier descriptors
Region	Area, compactness
Texture	Entropy, GLCM
Colour	Histograms

In conclusion, feature extraction turns pixels into meaningful, invariant measurements that drive recognition.



SECTION C Answers (≈500 Words Each)

Q1. Explain topological and texture descriptors in detail. (Jun 2023)

Topological descriptors describe the structure of a region that stays unchanged under **rubber-sheet distortion** (stretching without tearing or joining); they ignore distance and size.

- **Number of holes (H)** and **number of connected components (C)**.
- **Euler number:** E = C − H. Example: the letter "A" has C = 1, H = 1, so E = 0; "B" has H = 2, so E = −1; "8" has E = −1; "0" has E = 0.
- **Polygonal networks:** for a region with V vertices, Q edges and F faces, E = V − Q + F = C − H.
- Regions can be classified by E, and the descriptors are useful for characters and objects of connected structure.

Texture descriptors quantify smoothness, coarseness and regularity of intensity patterns. There are three approaches.

1. **Statistical approach** using the histogram $p(z_i)$ with L gray levels and mean m:
   - **Moments** $\mu_n = \Sigma (z_i - m)^n p(z_i)$; μ_2 is variance.
   - **Smoothness** $R = 1 - 1/(1 + \sigma^2)$: 0 for constant regions, approaching 1 for rough ones.
   - **Uniformity** $U = \Sigma p^2(z_i)$; **entropy** $e = -\Sigma p(z_i) \log_2 p(z_i)$.
   - **Gray-level co-occurrence matrix (GLCM):** counts how often gray levels i and j occur at a given offset; features: contrast, energy, homogeneity, correlation.
2. **Structural approach:** texture is built from primitives (texels) arranged by placement rules (grammar), good for regular patterns like brick walls.
3. **Spectral approach:** uses the Fourier spectrum; peaks reveal periodicity, their positions give direction and spatial period. Features are taken in polar form S(r) and S(θ).

Descriptor	Captures	Example
Topological	Connectivity, holes	Euler number
Statistical texture	Smoothness, contrast	Entropy, GLCM
Structural	Repeating primitives	Grid pattern
Spectral	Periodicity	Fourier peaks

In conclusion, topological descriptors capture how an object is connected, and texture descriptors capture how its surface intensity is organised.

Q2. Write short notes on: (i) Boundary preprocessing, (ii) Fourier descriptors. (Jun 2023)

(i) Boundary preprocessing

A boundary must be put into a form suitable for description. Common steps:

- **Boundary following:** trace the boundary pixels in order (Moore boundary tracing, clockwise).
- **Chain codes:** represent the boundary as a sequence of direction numbers (4- or 8-directional). To make them useful, **resample** with a coarser grid to reduce noise, **normalise for starting point** by rotating the code to the minimum integer, and **normalise for rotation** by using the first difference.
- **Polygonal approximation:** approximate by a polygon using minimum-perimeter polygons, merging or splitting techniques.
- **Signatures:** a 1-D function (distance from centroid vs angle) describing the boundary.
- **Smoothing and size normalisation** make descriptors invariant.

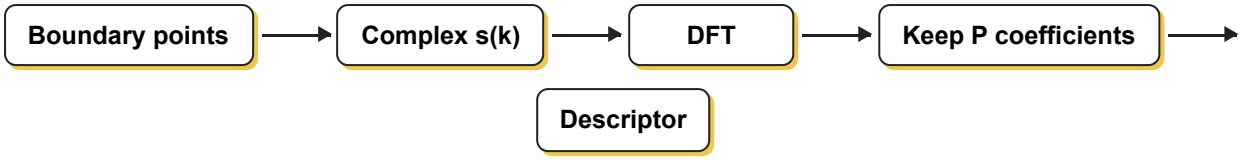
(ii) Fourier descriptors

The boundary of K points is treated as complex numbers $s(k) = x(k) + j\,y(k)$, $k = 0 \ldots K-1$. Its discrete Fourier transform is

$a(u) = \Sigma\, s(k)\, e^{(-j2\pi uk/K)}$, $u = 0 \ldots K-1$.

The coefficients a(u) are the **Fourier descriptors**.

- Low-order coefficients carry the **general shape**; high-order ones carry fine detail, so keeping only the first P coefficients gives a compact approximation $\hat{s}(k)$.
- **Invariance:** translation affects only a(0); scaling multiplies all a(u) by the same factor; rotation changes only the phase; starting-point change multiplies by a phase term. Using $|a(u)|/|a(1)|$ gives invariance to all.
- **Advantages:** compact, noise-reducing, easy to compare. **Limitation:** works for closed boundaries only.



Computing Fourier descriptors

