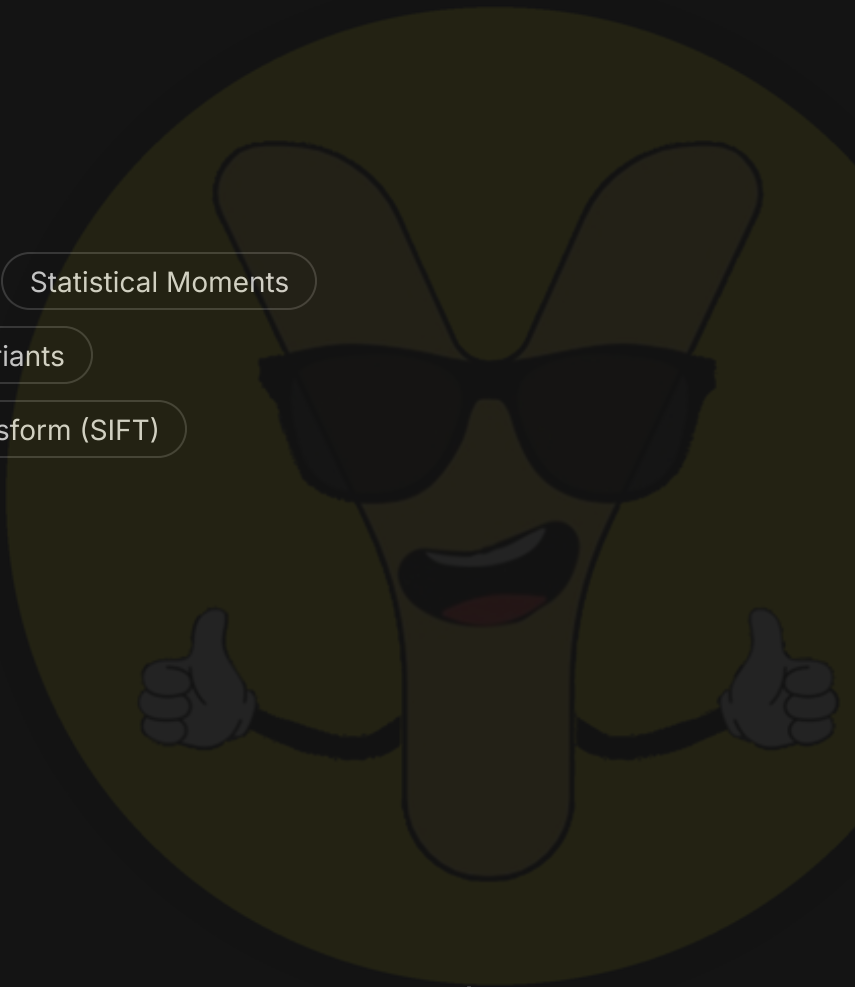
AKTU · 3RD YEAR · SEMESTER 6 · BCDS061

Image Analytics

Unit 4 — Feature Extraction

- Background (Feature Extraction)
- Representation
- Boundary Preprocessing
- Boundary Feature Descriptors: Some Basic Boundary Descriptors
- Shape Numbers
- Fourier Descriptors
- Statistical Moments
- Regional Feature Descriptors: Some Basic Descriptors
- Topological and Texture Descriptors
- Moment Invariants
- Principal Components as Feature Descriptors
- Whole-image Features Object
- Scale-Invariant Feature Transform (SIFT)



DECODED BY

Chirag Jain

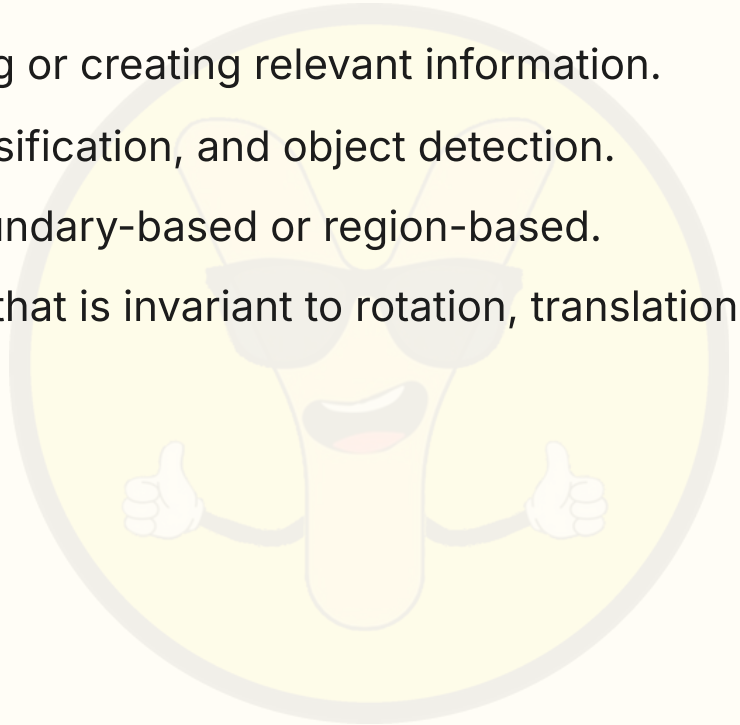
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Background: Feature Extraction

Feature extraction is the process of transforming raw image data into a set of measurable characteristics.

- Reduces dimensionality by selecting or creating relevant information.
- Crucial for pattern recognition, classification, and object detection.
- Features can be categorized as boundary-based or region-based.
- Goal: Represent an object in a way that is invariant to rotation, translation, and scaling.



Representation

IMAGE REPRESENTATION

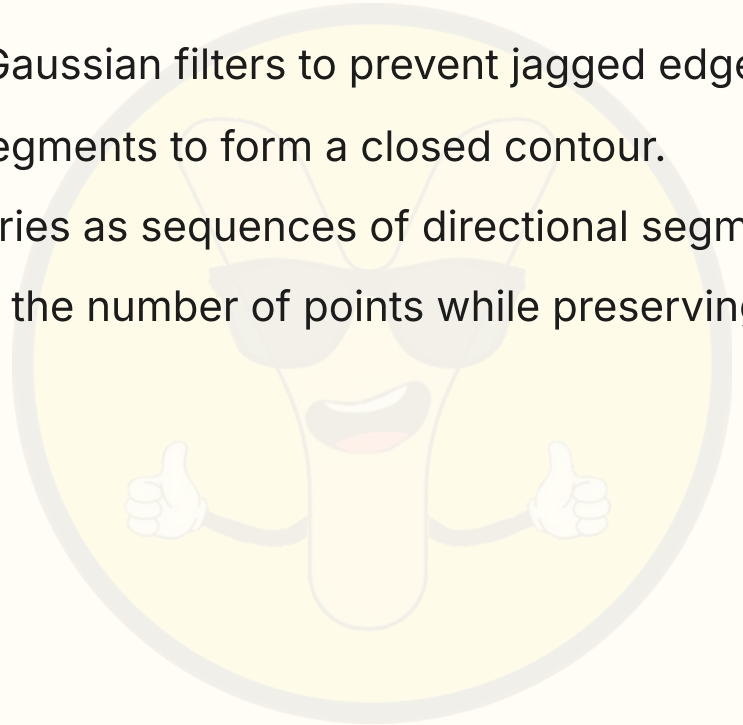
The method of describing an image or object in a format suitable for computer processing.

- External representation: Focuses on boundary characteristics.
- Internal representation: Focuses on regional properties like color, texture, or shape.
- Choice depends on the application requirements and computational constraints.

Boundary Preprocessing

Preprocessing ensures the boundary is clean before feature extraction.

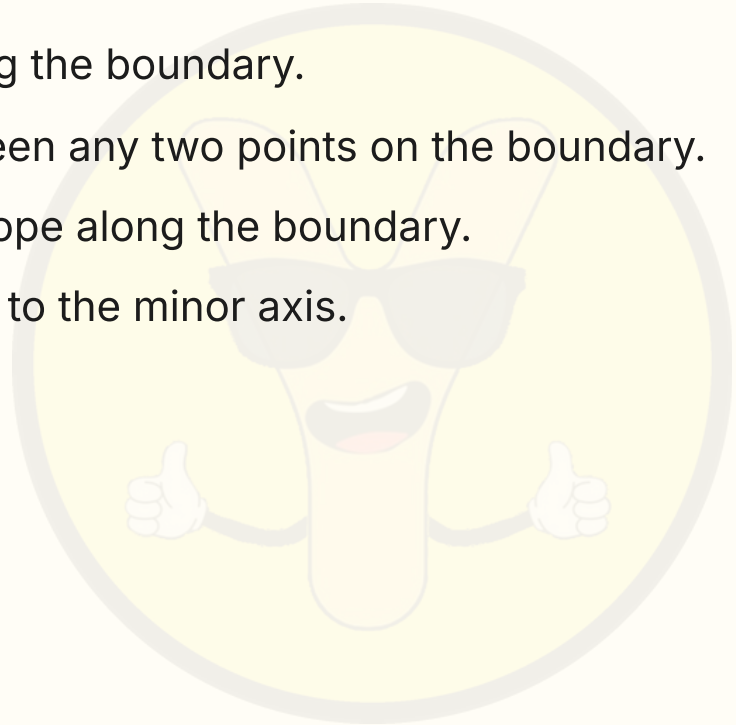
- Smoothing: Removing noise using Gaussian filters to prevent jagged edges.
- Linking: Connecting broken edge segments to form a closed contour.
- Chain Codes: Representing boundaries as sequences of directional segments.
- Polygonal Approximation: Reducing the number of points while preserving the shape.



Basic Boundary Descriptors

Simple geometric properties used to describe the shape of a boundary.

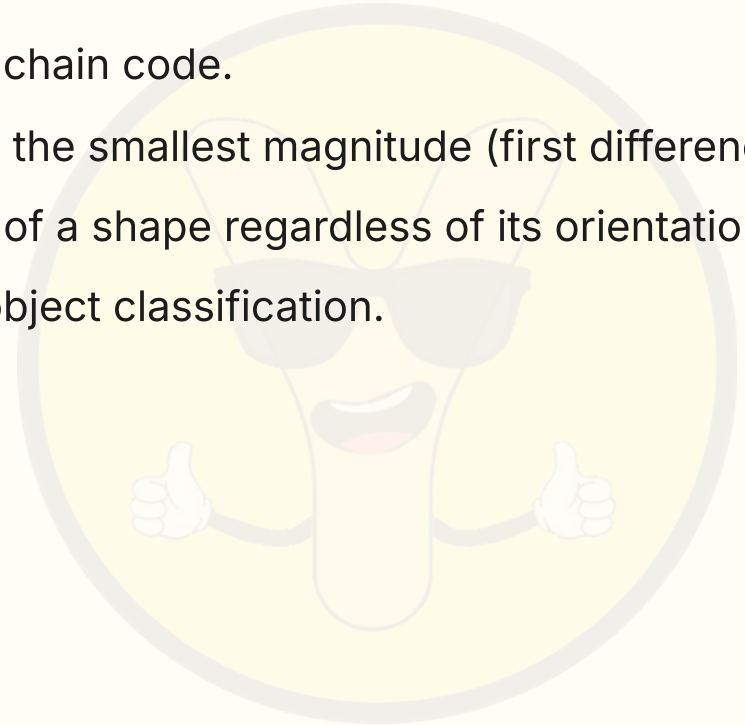
- Length: Total number of pixels along the boundary.
- Diameter: Maximum distance between any two points on the boundary.
- Curvature: Rate of change of the slope along the boundary.
- Eccentricity: Ratio of the major axis to the minor axis.



Shape Numbers

Shape numbers are derived from chain codes to provide rotation invariance.

- Based on the first difference of the chain code.
- The shape number is the n-tuple of the smallest magnitude (first difference).
- It provides a unique representation of a shape regardless of its orientation.
- Useful for simple, closed-contour object classification.



Fourier Descriptors

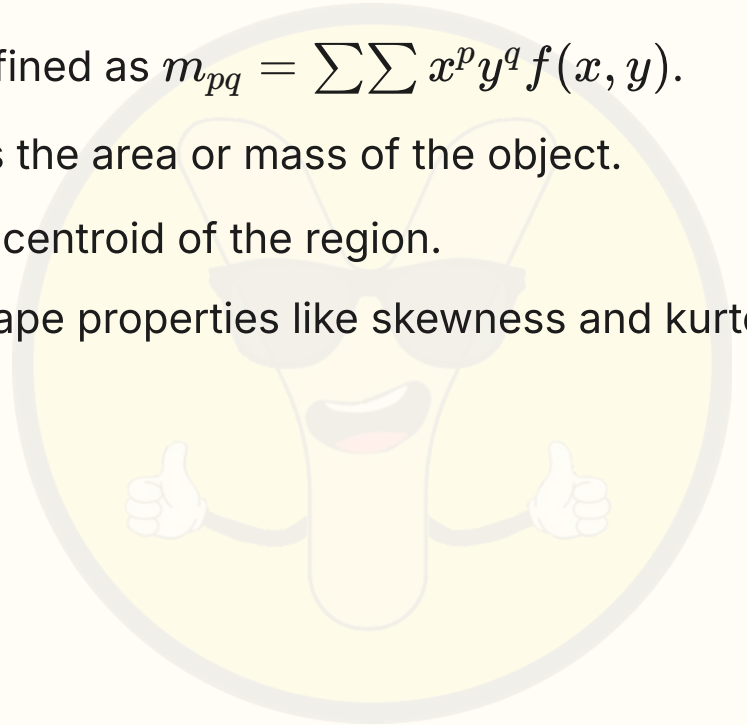
Representing a boundary in the frequency domain.

- A boundary is treated as a complex sequence $s(k) = x(k) + iy(k)$.
- Apply Discrete Fourier Transform (DFT) to the sequence.
- The resulting coefficients represent the shape at different frequency levels.
- Low-frequency coefficients capture the general shape, while high-frequency capture details.
- Truncating high-frequency coefficients provides a compressed representation.

Statistical Moments

Moments describe the distribution of pixels within a region.

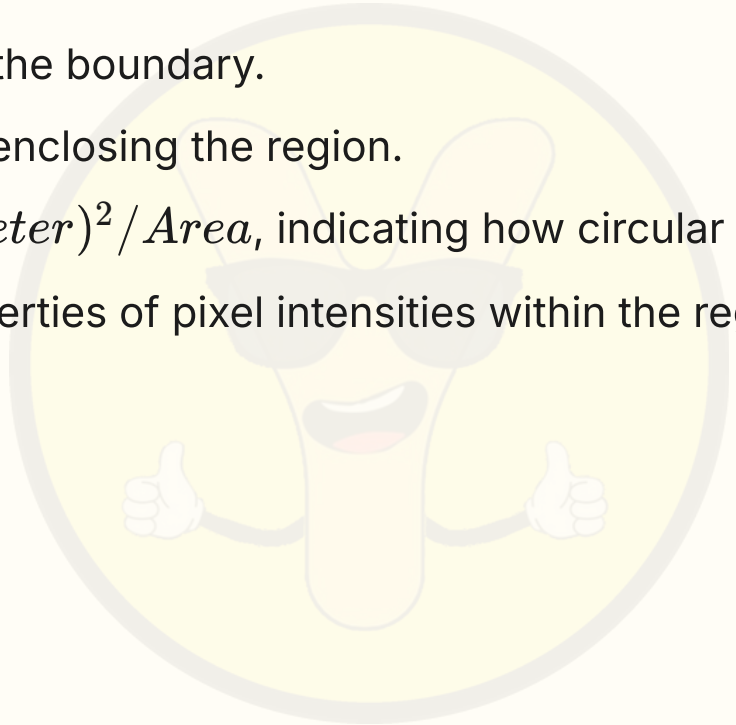
- The $(p+q)$-th order moment is defined as $m_{pq} = \sum\sum x^p y^q f(x,y)$.
- Zero-order moment m_{00} represents the area or mass of the object.
- First-order moments determine the centroid of the region.
- Higher-order moments describe shape properties like skewness and kurtosis.



Regional Feature Descriptors

Descriptors that analyze the entire area of an object.

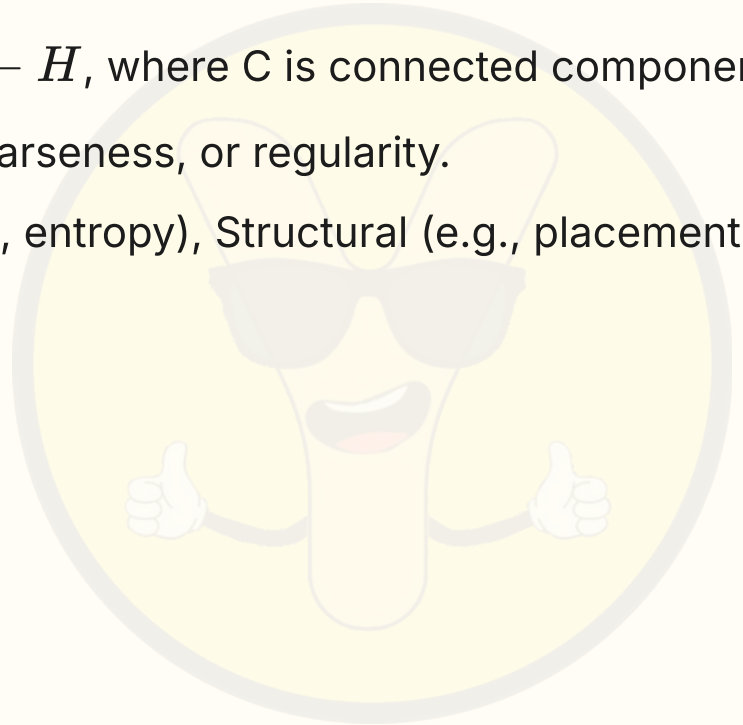
- Area: Total number of pixels inside the boundary.
- Perimeter: Length of the boundary enclosing the region.
- Compactness: Defined as $(Perimeter)^2/Area$, indicating how circular a shape is.
- Mean and Variance: Statistical properties of pixel intensities within the region.



Topological and Texture Descriptors

Topological features describe spatial relationships, while texture describes surface patterns.

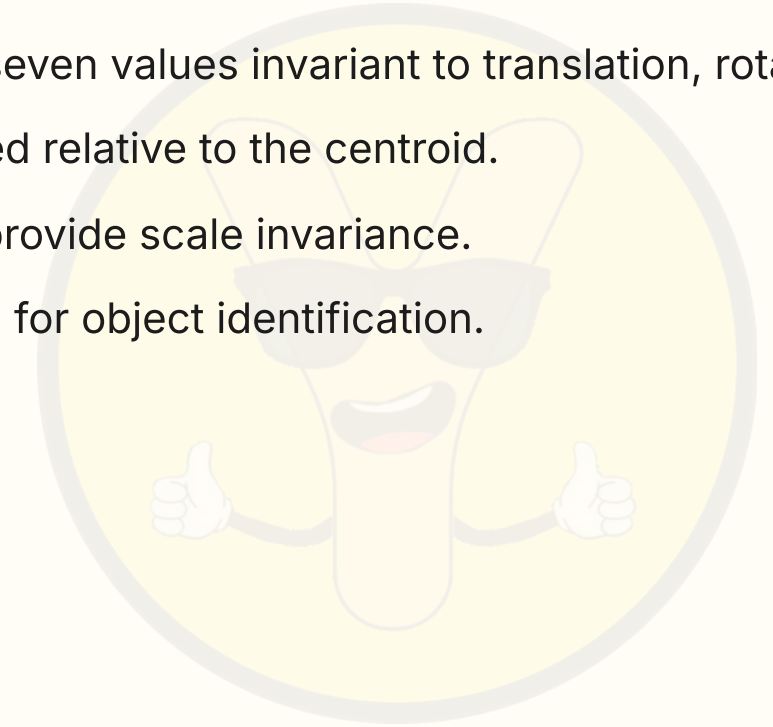
- Topological: Euler number $E = C - H$, where C is connected components and H is holes.
- Texture: Describes smoothness, coarseness, or regularity.
- Texture descriptors: Statistical (e.g., entropy), Structural (e.g., placement rules), and Spectral (e.g., Fourier power spectrum).



Moment Invariants

Moment invariants are functions of central moments that remain constant under transformations.

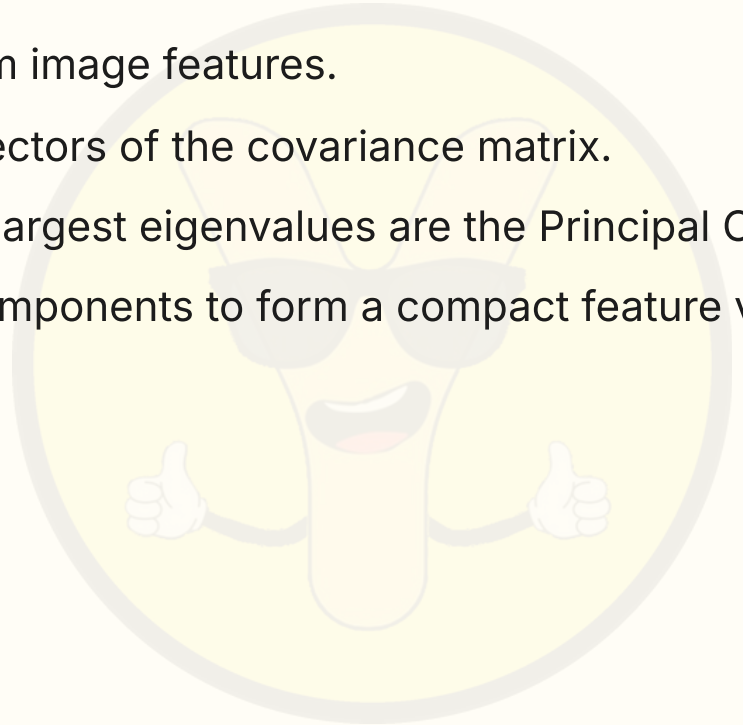
- Hu's Moment Invariants: A set of seven values invariant to translation, rotation, and scaling.
- Central moments μ_{pq} are calculated relative to the centroid.
- Normalized central moments η_{pq} provide scale invariance.
- Widely used in pattern recognition for object identification.



Principal Components Analysis (PCA)

PCA reduces data dimensionality by finding the directions of maximum variance.

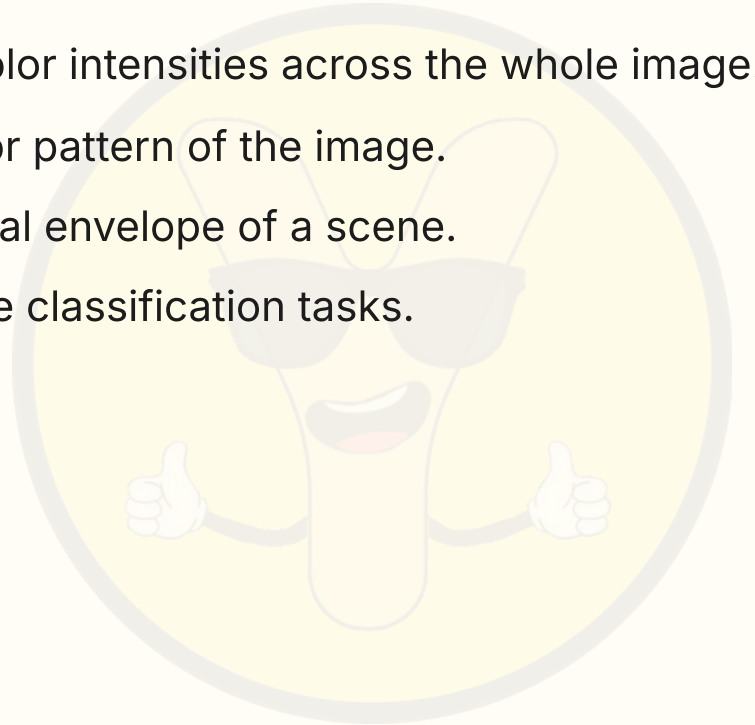
- Constructs a covariance matrix from image features.
- Calculates eigenvalues and eigenvectors of the covariance matrix.
- Eigenvectors corresponding to the largest eigenvalues are the Principal Components.
- Projects original data onto these components to form a compact feature vector.



Whole-image Features

Global features that describe the entire image content rather than specific objects.

- Color Histograms: Distribution of color intensities across the whole image.
- Global Texture: Overall roughness or pattern of the image.
- GIST Descriptor: Captures the spatial envelope of a scene.
- Useful for image retrieval and scene classification tasks.

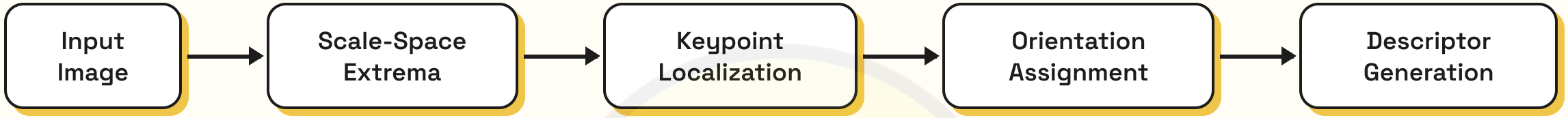


Scale-Invariant Feature Transform (SIFT)

SIFT extracts distinctive invariant features from images.

- Scale-space extrema detection: Identifying potential interest points using Difference of Gaussians.
- Keypoint localization: Refining locations and removing low-contrast points.
- Orientation assignment: Assigning a dominant orientation to each keypoint for rotation invariance.
- Keypoint descriptor: Creating a 128-dimensional vector based on local image gradients.

SIFT Pipeline



The sequential steps involved in the SIFT algorithm.

Comparison of Descriptors

Descriptor Type	Primary Use
Boundary	Shape identification
Regional	Object classification
Texture	Surface analysis
SIFT	Object matching

Exam corner

- **Q1** Explain the difference between boundary and regional descriptors with examples.
- **Q2** What are Fourier descriptors? How are they used for shape representation?
- **Q3** Define Hu's moment invariants and explain their significance in object recognition.
- **Q4** Describe the steps involved in the SIFT algorithm.
- **Q5** Explain the Euler number and its role in topological feature extraction.
- **Q6** How does PCA help in reducing dimensionality for image features?
- **Q7** What is the significance of chain codes in boundary preprocessing?

Unit 4 done. You are exam-ready.

Revise the Exam corner once more, then open Unit 5 on theycotes.com. Every AKTU subject, unit by unit, free. Notes by Chirag Jain, Ycotes.

