Introduction to Morphological Image Processing

UNIT 5 | NCCS

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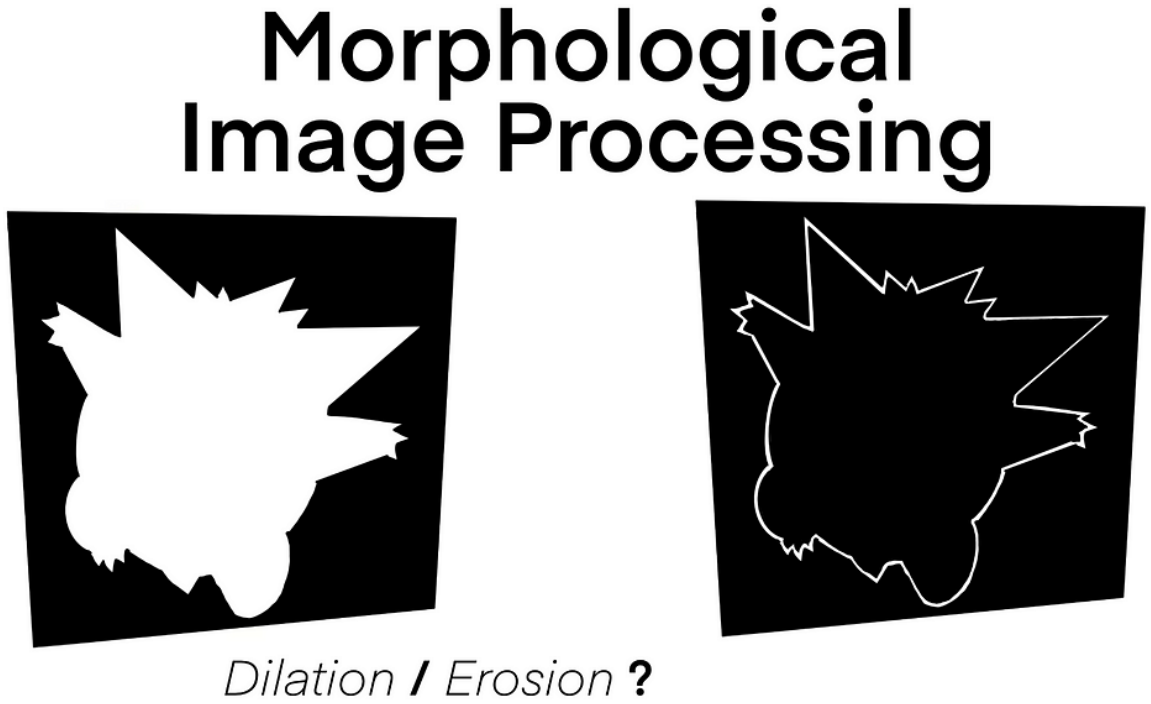
Image Processing | CSIT 5

Unit 5	**Introduction to Morphological Image Processing**	**Teaching Hours (2)**
Introduction	Logic Operations involving binary images, Introduction to Morphological Image Processing, Definition of Fit and Hit	1 hr
Morphological Operations	Dilation and Erosion, Opening and Closing	1 hr

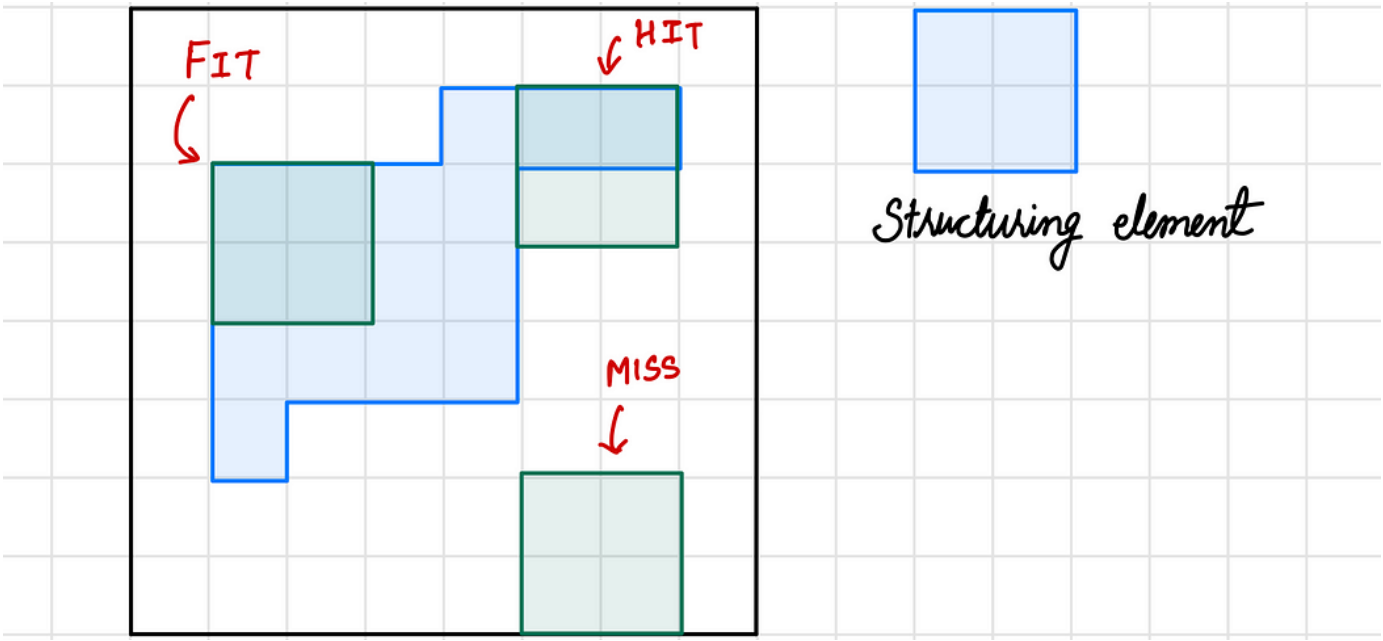
Introduction to Morphological Image Processing

- *Morphology* is a comprehensive set of image processing operations that process images based on shapes.
- Morphological operations apply a structuring element to an input image, creating an output image of the same size.
- These techniques are particularly useful for analyzing and processing geometrical structures and are widely used in tasks involving shape analysis, image segmentation, noise reduction, and image enhancement.
- The word *'Morphology'* generally represents a branch of biology that deals with the form and structure of animals and plants. However, we use the same term in *'mathematical morphology'* to extract image components useful in representing region shape, boundaries, etc.



Terminologies in Morphological Image Processing

- ***Structuring Element:*** It is a matrix or a small-sized template that is used to traverse an image. The structuring element is positioned at all possible locations in the image, and it is compared with the connected pixels. It can be of any shape.
- ***Fit:*** When all the pixels in the structuring element cover the pixels of the object, we call it Fit.
- ***Hit:*** When at least one of the pixels in the structuring element cover the pixels of the object, we call it Hit.
- ***Miss:*** When no pixel in the structuring element cover the pixels of the object, we call it miss.



Morphological Image Processing

Purpose:

- Morphological image processing is primarily concerned with the structure or shape of objects within an image. It is used to probe and manipulate these structures based on their geometrical features.

Techniques:

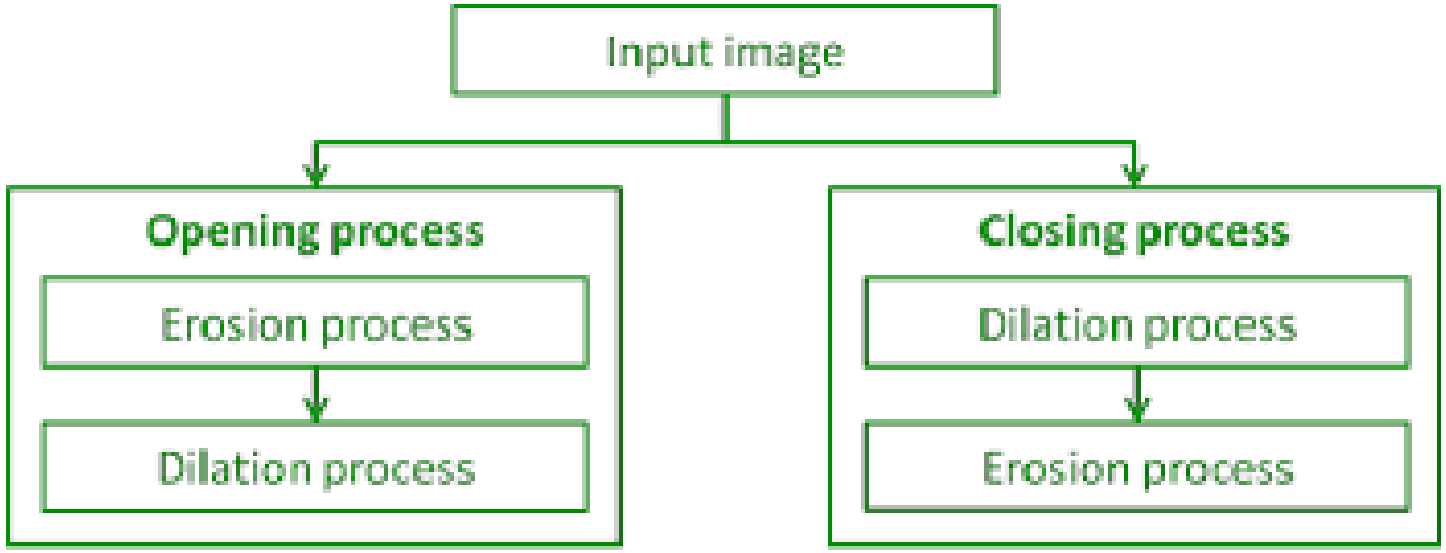
- **Dilation:** Expands the boundaries of objects.
- **Erosion:** Shrinks the boundaries of objects.
- **Opening:** Erosion followed by dilation, useful for removing small objects or noise.
- **Closing:** Dilation followed by erosion, useful for closing small holes and gaps in objects.
- **Morphological Gradient:** Difference between dilation and erosion, highlights the boundaries of objects.
- **Top-hat and Black-hat Transforms:** Highlight small elements or gaps.

Applications:

- Noise removal.
- Bridging small gaps and holes.
- Extracting and enhancing specific shapes and structures.
- Preparing images for further analysis or processing steps, such as segmentation.

Basis:

- Works on binary images and grayscale images.
- Utilizes structuring elements (kernels) to probe and transform the image based on spatial relationships.



Segmentation

Purpose:

- Segmentation is aimed at dividing an image into meaningful regions, typically corresponding to different objects or parts of objects. The goal is to simplify the image and make it more meaningful for analysis.

Techniques:

- **Thresholding:** Simple method based on intensity values; can be global or adaptive.
- **Edge Detection:** Identifies boundaries between regions based on gradients; techniques include the Canny, Sobel, and Laplacian operators.
- **Region-Based Methods:** Segments by finding regions that meet certain criteria; includes region growing and region splitting/merging.
- **Clustering:** Groups pixels based on feature similarity; includes k-means clustering and mean shift.
- **Watershed Algorithm:** Treats the grayscale image as a topographic surface and finds catchment basins and ridge lines.
- **Deep Learning-Based Methods:** Uses neural networks to segment images, typically producing more accurate and sophisticated results.

Applications:

- Object detection and recognition.
- Medical imaging (identifying tumors, organs, etc.).
- Scene understanding in autonomous vehicles.
- Image editing and enhancement.

Basis:

- Works on grayscale and color images.
- Often combines multiple features (color, texture, intensity) and may use prior knowledge or models to achieve accurate segmentation.

Key Differences

- **Objective:**
  - Morphological processing focuses on modifying the structure and shape of objects within an image.
  - Segmentation focuses on partitioning an image into meaningful regions for further analysis.
- **Approach:**
  - Morphological operations use structuring elements and geometric transformations.
  - Segmentation uses various algorithms to delineate regions based on pixel values, features, and spatial relationships.
- **Output:**
  - Morphological processing modifies the input image to highlight or suppress specific structures.
  - Segmentation produces labeled regions or masks that separate different objects or parts of objects.
- **Applications:**
  - Morphological processing is often a preprocessing or postprocessing step to clean up or enhance images.
  - Segmentation is a primary step for analyzing the content of the image, leading to tasks like object detection, classification, and recognition.

Erosion and Dilation in Image Processing

Dilation and erosion are fundamental operations in the field of image processing, specifically in the area known as mathematical morphology. They are used to process binary images and grayscale images, altering their shapes and structures in various ways. Let's break down each operation:

Dilation

- **It is a process of expanding image**
- **Increases the brightness of a image.**
- **Operation:** The structuring element is placed at all possible positions in the image. If at least one pixel under the structuring element is foreground (usually white), the pixel in the output image is set to the foreground.
- **Result:** The objects in the image become larger. Small holes and gaps may be filled, and the boundaries of objects become smoother and thicker.

Erosion

- **Opposite Process of Dilation**
- **Image Shrinking is obtained**
- **Operation:** The structuring element is placed at all possible positions in the image. If all pixels under the structuring element are foreground, the pixel in the output image is set to the foreground; otherwise, it is set to the background.
- **Result:** The objects in the image become smaller. Small noise and protrusions may be removed, and the boundaries of objects become thinner and more defined.

Applications

- **Noise Removal:** Erosion followed by dilation (a process called opening) can remove small objects or noise.
- **Bridging Gaps:** Dilation followed by erosion (a process called closing) can close small holes and gaps in the objects.
- **Shape Analysis:** Dilation and erosion can help in analyzing shapes and structures by highlighting or suppressing specific features.

0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	0	0	0	0

Segment A

Image segment

0	1	0
1	1	1
0	1	0

Segment B

Structuring element

⟹ Erosion (A ⊖ B)

0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0

⟹ Dilation (A ⊕ B)

0	1	1	1	0
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

Explain Opening and closing morphological operations in brief

- Morphological operations are fundamental image processing techniques used primarily in the field of computer vision and image analysis to process geometric structures in images.
- They are particularly useful for tasks like noise removal, shape extraction, and image enhancement. Two common morphological operations are **opening** and **closing**.
- Both are based on the basic operations of **erosion** and **dilation**.

- **Opening (Erosion followed by Dilation):** Removes small objects or noise while preserving the shape and size of larger objects.
- **Closing (Dilation followed by Erosion):** Fills small holes and gaps within objects, connecting disjoint parts of objects.
- These operations can be applied using libraries such as OpenCV in Python, which provides built-in functions for morphological transformations.

Opening :-

- Erosion is followed by dilation operation.

$$A \circ B = (A \ominus B) \oplus B$$

A → Original Image

B → Structural Image.

- Identify gaps in an Image
- Edges become sharp (or) Smooth
- Isolates objects which are touching one another.

Closing :

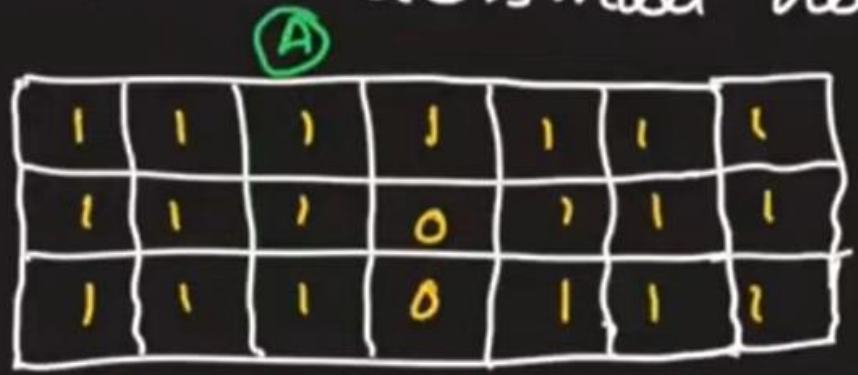
- Dilation is followed by Erosion

$$A \bullet B = (A \oplus B) \ominus B$$

Original Image ← A • B → Structural Image.

- used to fuse narrow breaks & eliminate small holes

Ex:-



Original Image

Structural Image

Eg-

Segment A

Segment B

Opening $(A \circ B)$

$A \circ B = (A \ominus B) \oplus B$

Closing $(A \bullet B)$

$A \bullet B = (A \oplus B) \ominus B$

2. Write short notes on dilation and erosion.

10. Explain opening and closing morphological operations in brief.