Lecture

Morphological Image Processing

Basics

- 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.

Basics

- In image processing, **morphology** refers to the study and manipulation of the structure or shape of objects within an image.

- It involves analyzing and processing an image based on the arrangement and form of its pixel groups, focusing on features like boundaries, skeletons, and overall shapes.

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Image after segmentation

Image after segmentation and morphological processing

Basics

- Morphological operations treat an image as a collection of shapes, often represented by sets of pixels, and apply transformations to enhance, extract, or modify these shapes.

- This step involves-

  - Removing noise (small, undesired shapes),
  - Separating objects that may be connected,
  - Extracting boundaries and other structural elements, and
  - Filling holes or gaps in objects.

Basics

- Morphological image processing is a technique used in computer vision and image analysis to process binary and grayscale images.
- It focuses on the structure or shape of objects within an image.
- Originates from mathematical morphology, a theory developed for analyzing geometrical structures in images.

Terminologies-

- All morphological processing operations are based on mentioned terms.

- **Structuring Element (SE)-**
  - 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.

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- **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.

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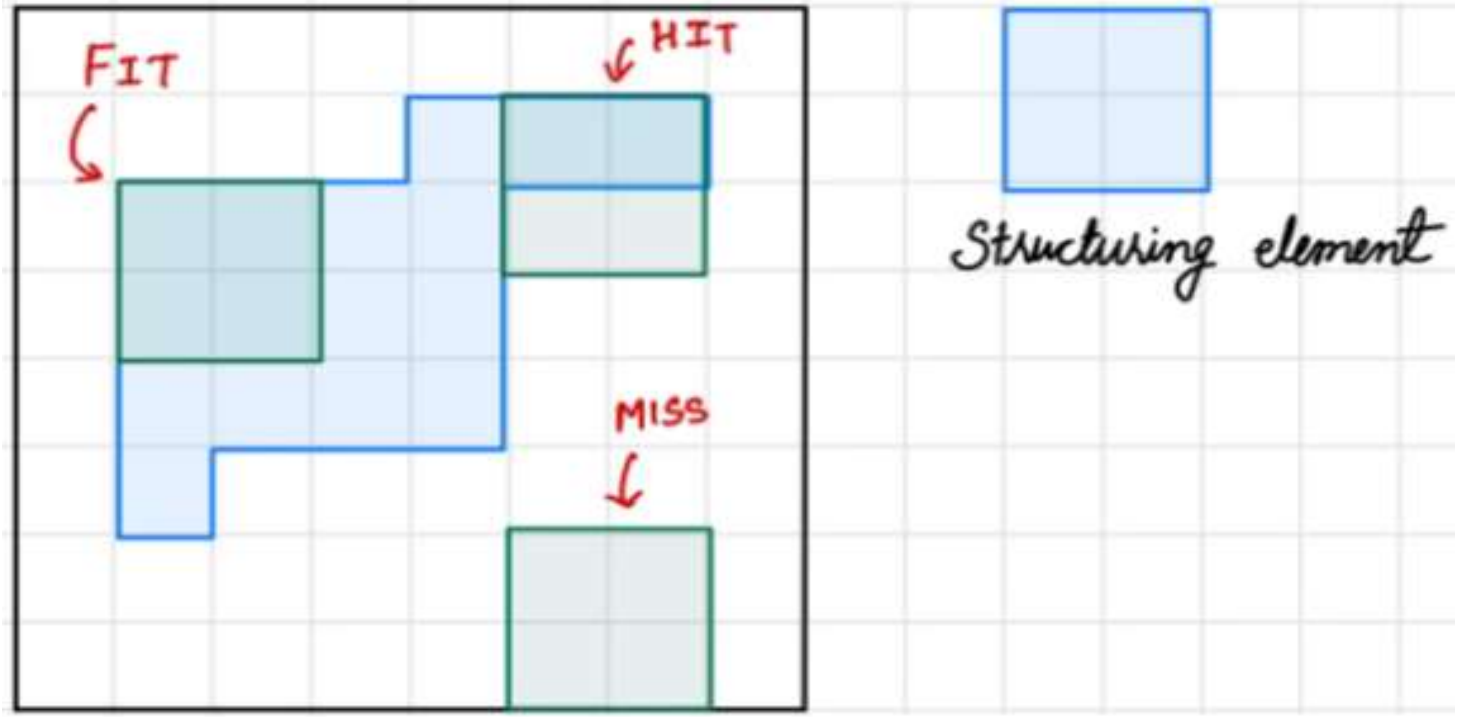

Morphological Operations

- Morphological operations rely on two key elements-

1. **The Input Image-**
   - Usually a binary image, where the objects of interest are represented by foreground pixels (typically white) and the background by background pixels (typically black).
   - Grayscale images can also be processed using morphological operations.

Morphological Operations

2. The Structuring Element-

   - A small matrix or kernel that defines the neighborhood of pixels over which the operation is performed.

   - The shape and size of the structuring element can greatly influence the outcome of the morphological operation.

Different Morphological Operations

1. Erosion

- Erosion is a fundamental morphological operation that reduces the size of objects in a binary image.
- It works by removing pixels from the boundaries of objects.
- **Purpose:** To remove small noise, detach connected objects, and erode boundaries.

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- Erosion shrinks the image pixels, or erosion removes pixels on object boundaries.
- First, we traverse the structuring element over the image object to perform an erosion operation.
- The output pixel values are calculated using the following equation.
  - Pixel (output) = 1 {if FIT}
  - Pixel (output) = 0 {otherwise}

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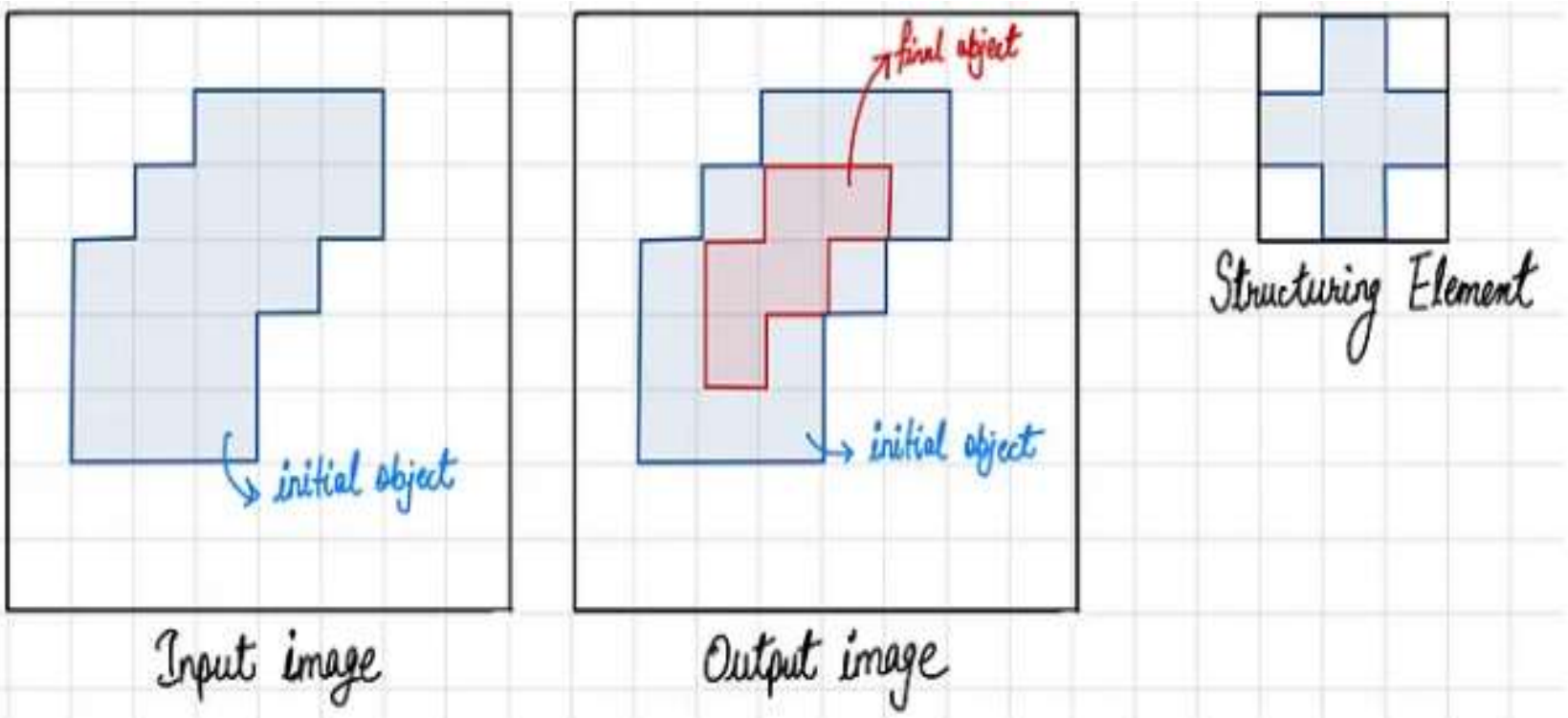
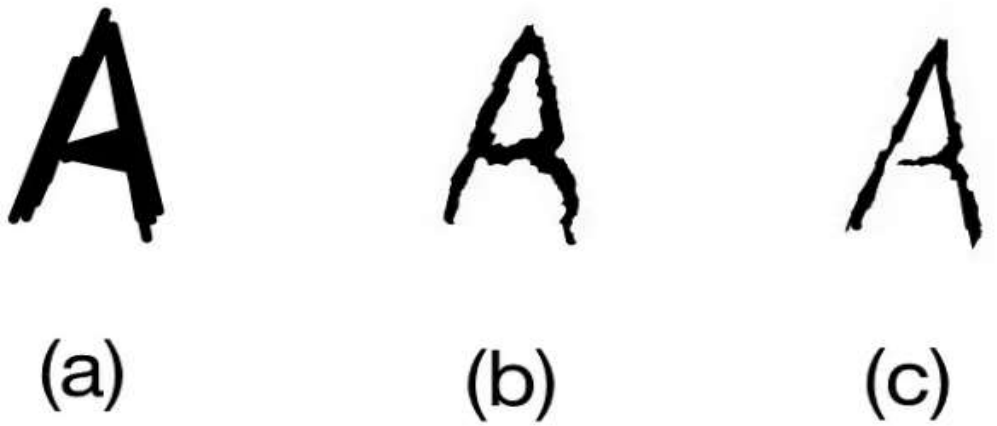

initial object
Input image
final object
initial object
Output image
Structuring Element

- An example of Erosion is shown in Figure. Figure (a) represents original image, (b) and (c) shows processed images after erosion using 3x3 and 5x5 structuring elements respectively.



(a) (b) (c)

Contd..

Properties-

- It can split apart joint objects.
- It can strip away extrusions.

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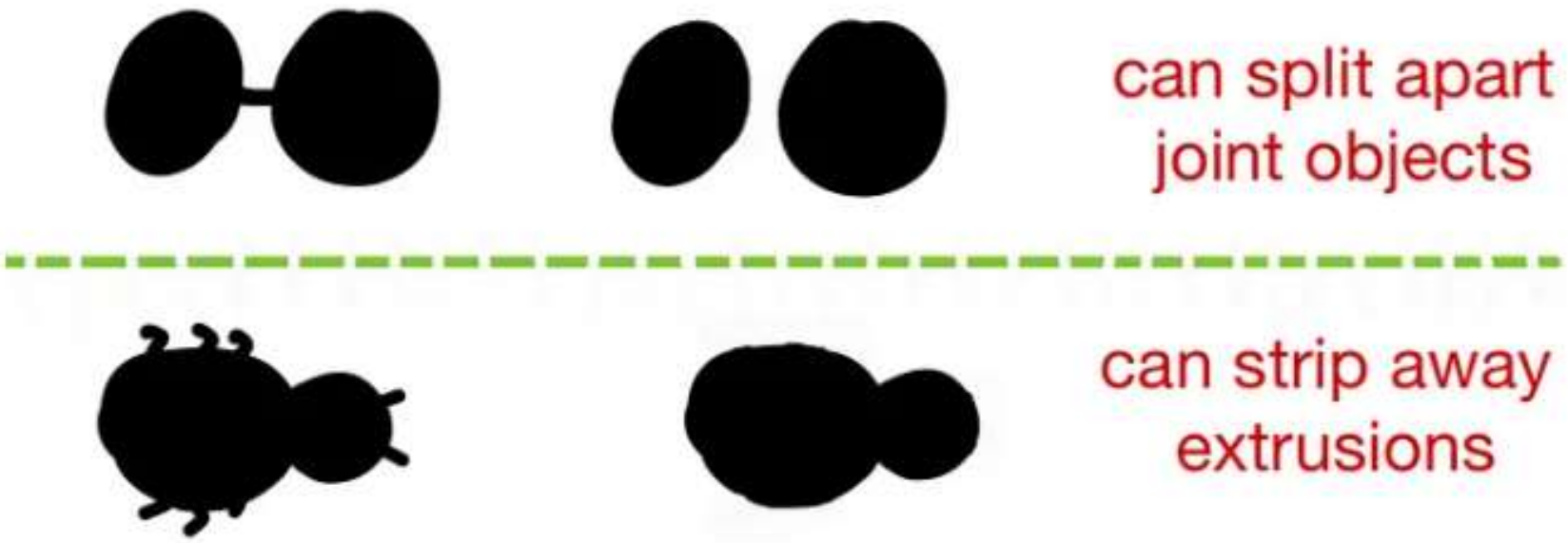
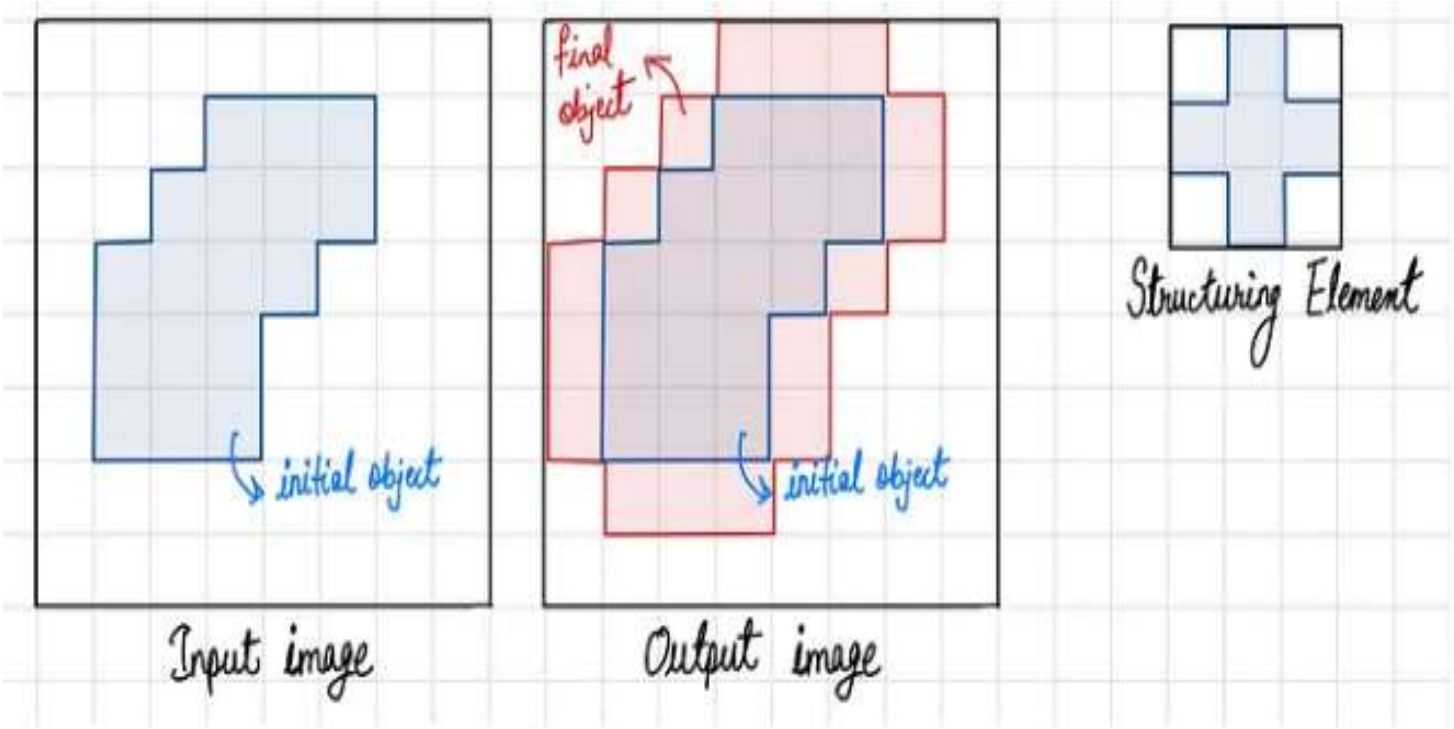


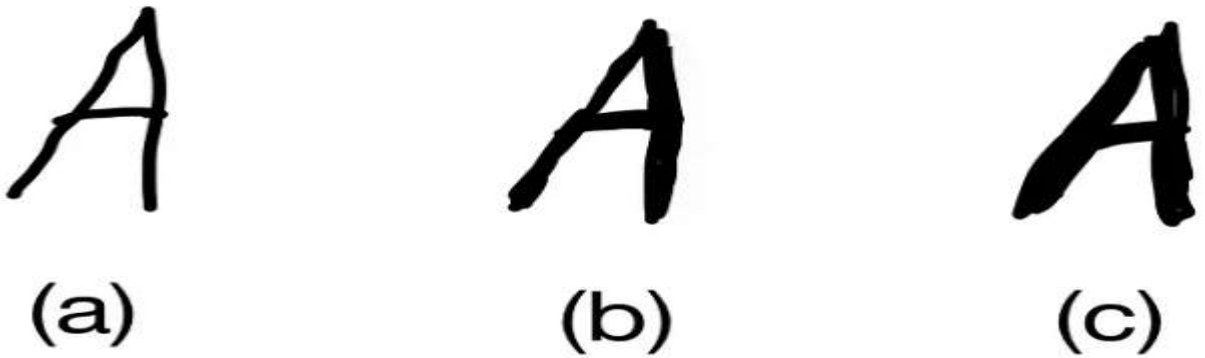
2. Dilation

- Dilation expands the image pixels, or it adds pixels on object boundaries.
- First, we traverse the structuring element over the image object to perform an dilation operation.
- The output pixel values are calculated using the following equation.
- Pixel (output) = 1 {if HIT}
- Pixel (output) = 0 {otherwise}

Contd..


initial object
Input image
final object
initial object
Output image
Structuring Element

- An example of Dilation is shown in Figure. Figure (a) represents original image, (b) and (c) shows processed images after dilation using 3x3 and 5x5 structuring elements respectively.

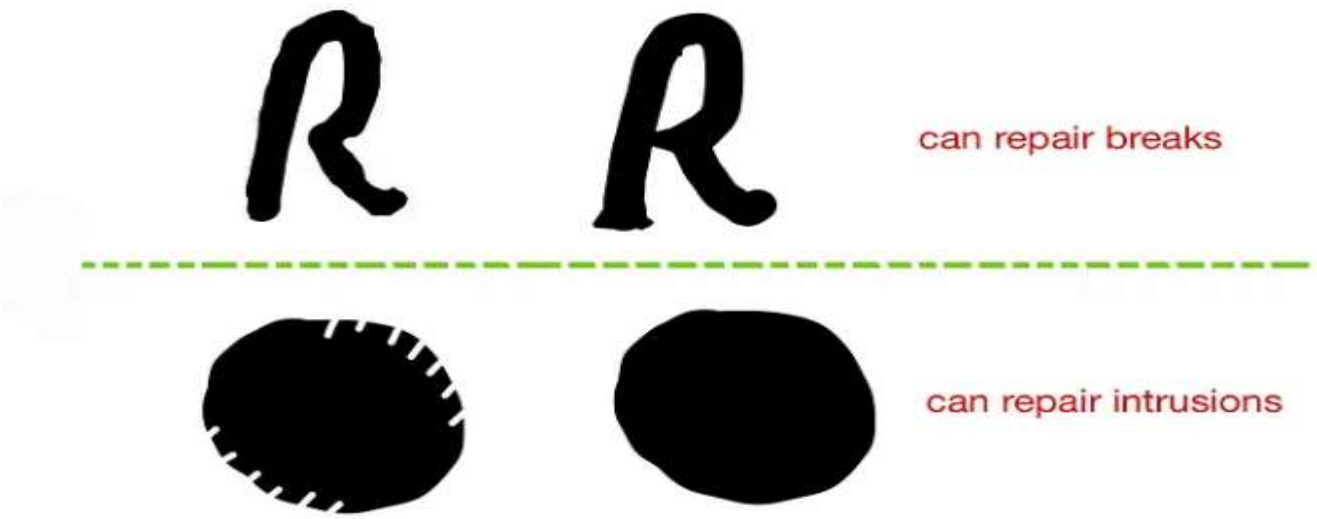


Contd..

Properties-

- It can repair breaks.
- It can repair intrusions.

Contd..



Compound Operations

- Most morphological operations are not performed using either dilation or erosion; instead, they are performed by using both.

- Two most widely used compound operations are-

  - Closing (by first performing dilation and then erosion), and

  - Opening (by first performing erosion and then dilation). Figure 10 shows both compound operations on a single object.

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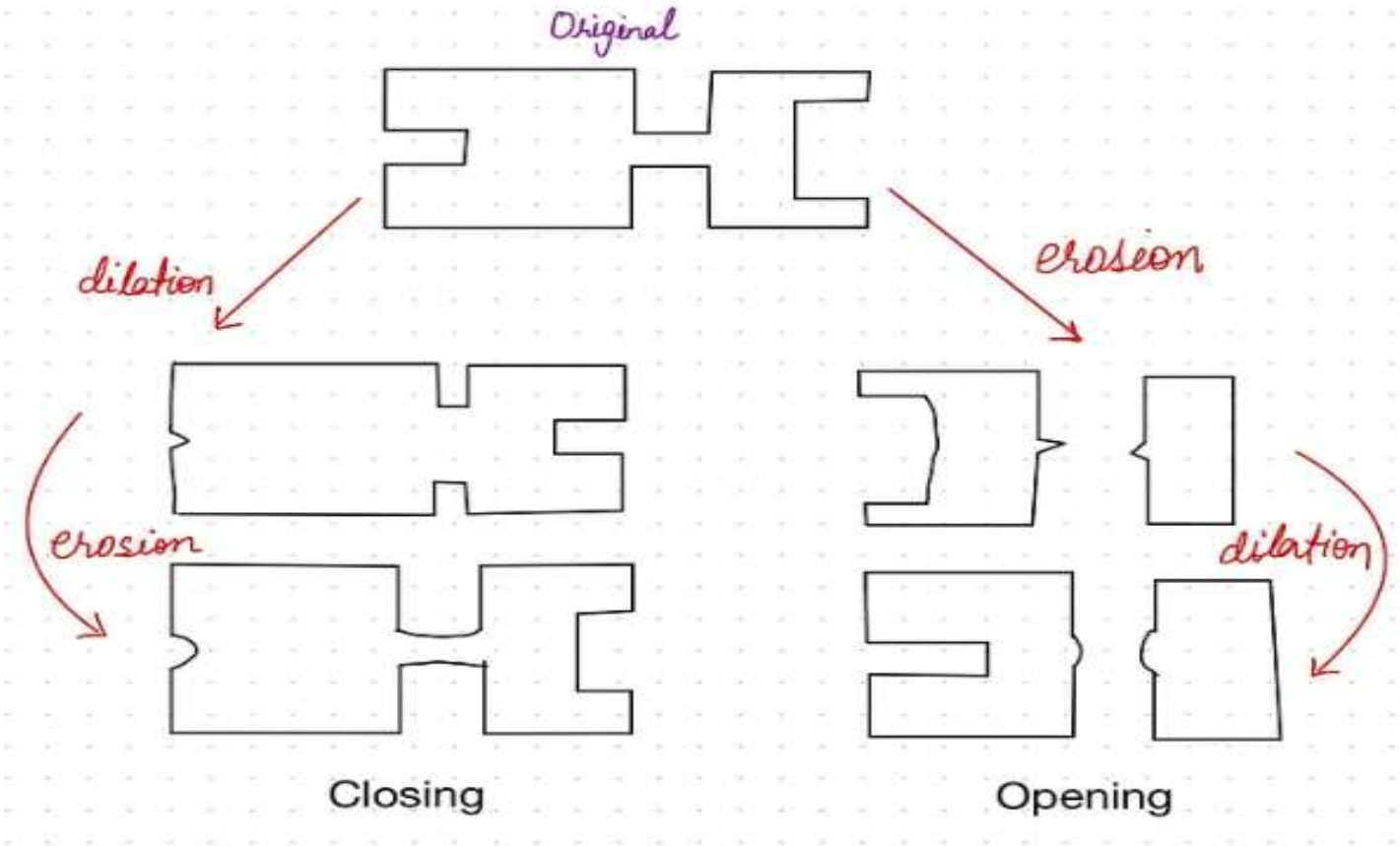
Original
dilation
erosion
erosion
dilation
Closing
Opening

Applications

- Noise Reduction: Opening and closing operations can remove noise in binary images.
- Image Segmentation: Helps to isolate individual objects in an image.
- Edge Detection: By using morphological gradients (dilation - erosion), one can detect object boundaries.
- Shape Analysis: Skeletonization and thinning help in analyzing object shapes for classification.

Advanced Morphological Operations

1. Hit-or-Miss Transformation:
2. Thinning and Skeletonization:
3. Top-Hat and Bottom-Hat Transformations:

Reference

- Books: "Digital Image Processing" by Rafael C. Gonzalez and Richard E. Woods.