Image Morphology

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.

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. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors.

There is a slight overlap between Morphology and Image Segmentation. Morphology consists of methods that can be used to pre-process the input data of Image Segmentation or to post-process the output of the Image Segmentation stage. In other words, once the segmentation is complete, morphological operations can be used to remove imperfections in the segmented image and deliver information on the shape and structure of the image.

Image after segmentation

Image after segmentation and morphological processing

Focus on Shapes: Unlike other image processing techniques that might focus on pixel intensity or color, morphological operations are concerned with the form, structure, and spatial relationships of objects in an image.

Structuring Element (Kernel): A crucial component of morphological operations is the "structuring element" (also called a kernel). This is a small matrix or template (like a brush or probe) with a defined shape and size. It's used to "probe" the input image and determine how pixels should be modified in the output image. The shape and size of this structuring element significantly influence the outcome of the operation.

Set Theory Principles: Morphological operations are grounded in mathematical morphology and rely on concepts from set theory, such as unions, intersections, and complements, when applied to binary images.

Typically on Binary Images: While some operations can be adapted for grayscale images, morphological operations are most commonly applied to binary images, where pixels are either foreground (object) or background.

Morphological operations are primarily used for:

- Removing noise
- Bridging gaps in objects
- Emphasizing structures (edges, outlines)
- Separating touching objects

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.

What It Does:

- Shrinks white regions.
- Removes white noise.
- Removes thin lines and small details.

Why & When:

- Use when removing small white noises or disconnecting two connected objects.
- Common in preprocessing for contour detection or segmentation.

Dilation

Dilation is the opposite of erosion and is used to increase the size of objects in an image.

What It Does:

- Expands white regions.
- Fills small holes or gaps.
- Can connect disjoint parts of an object.

Why & When:

- Use to connect broken lines or enhance features**.**
- Also helps after erosion to recover object size (see opening).

Opening

Opening is a compound operation that involves erosion followed by dilation.

What It Does:

- Removes small noise but preserves main objects**.**
- Useful when background is black and noise is white.

Why & When:

- Use to clean up the image by removing isolated white dots without breaking object shapes.
- Helps in foreground object isolation**.**

Closing

Closing is another compound operation that consists of dilation followed by erosion.

What It Does:

- Fills small black holes inside white objects.
- Closes small gaps or cracks in objects.

Why & When:

- Use when objects have holes or gaps (e.g., broken letters like “C” or “O”).
- Useful for smoothing contours.

Morphological Gradient

The difference between dilation and erosion of an image. Its Highlights the boundaries (edges) of objects.

Gradient = Dilation – Erosion

Why & When to Use:

- To detect edges or **object** outlines**.**
- Good for segmentation prep or feature detection.

Top-hat Transformation

The difference between the input image and its Opening. It extracts small bright elements on a dark background.

Top Hat = Original Image – Opening (Erosion , Dilation)

Why & When to Use:

- To extract fine white details like bright spots, scratches, text, hairs, etc.
- Used in illumination correction and enhancing contrast.

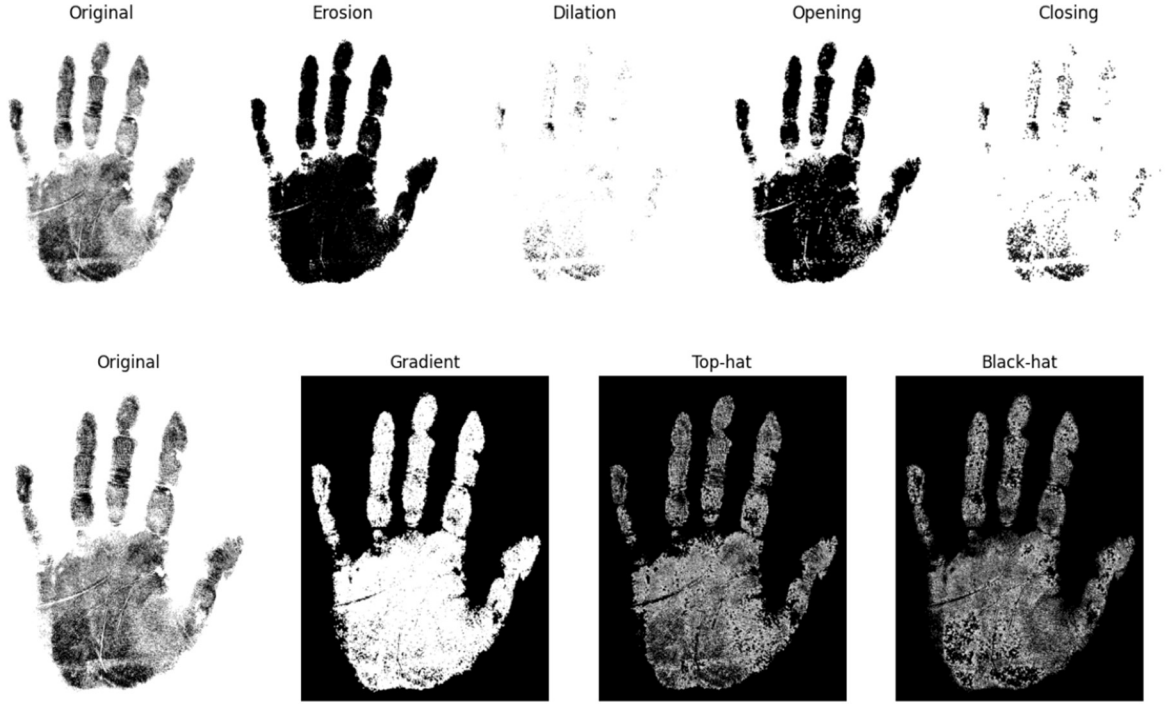
Black-hat Transformation

The difference between Closing and the original image. It extracts small dark elements on a bright background.

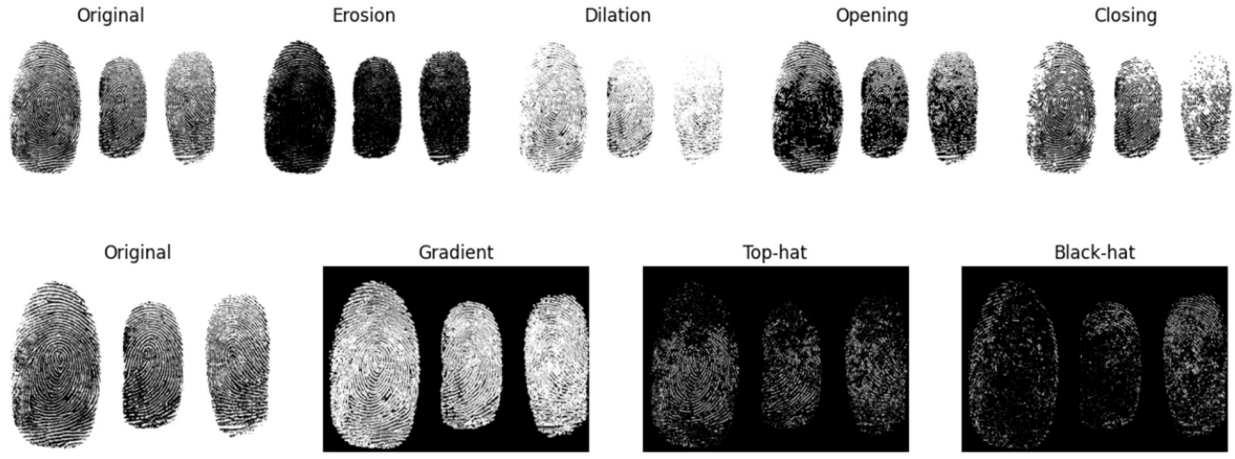
Why & When to Use:

- To highlight dark objects on a bright background.
- Common in document enhancement, medical imaging.

Handprint:



Fingerprint:



Graded Assignment 2

Thresholding and Image Segmentation for Forensic Analysis

1. Preprocess the Image

Convert image to grayscale and apply Gaussian blur to reduce noise.

2. Apply Thresholding Methods

Use global, adaptive (mean/gaussian), and Otsu's thresholding, and show results side by side.

3. Image Morphology

Apply erosion, dilation, opening, and closing to refine thresholded images.

4. Contour Detection

Detect and draw contours on processed images to highlight key patterns or edges.

5. Compare the Results

- **Evaluation Criteria**
  - Which method gives the best separation of the print/tool mark from the background?
  - How does morphology improve each thresholding result?
  - Where do the methods fail**?** (e.g., shadows, uneven lighting, smudges, low contrast regions)
- **Discussion Points**
  - Strengths and weaknesses of each thresholding method.
  - Visual effectiveness post-morphology.
  - Best-suited techniques for different types of forensic images (e.g., fingerprints vs shoeprints).

6. Report (Min 3 pages)

Include method summary, processed images, contour outputs, and analysis.