GNR607

COURSE INSTRUCTOR:BUDDHIRAJU K MOHAN

MORPHOLOGICAL OPERATIONS

MANUAL AND AUTOMATED APPROACHES

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WHAT ARE MORPHOLOGICAL OPERATIONS?

- Morphological operations are image processing techniques that process images based on their shapes.
- They apply a structuring element to an input image to probe and modify the geometric structure of objects in the image.

TYPES OF MORPHOLOGICAL OPERATIONS

- Dilation: Expands object boundaries (adds pixels to object edges).
- Erosion: Shrinks object boundaries (removes pixels from object edges).
- Opening: Removes small objects or noise (erosion followed by dilation).
- Closing: Fills small holes or gaps (dilation followed by erosion).

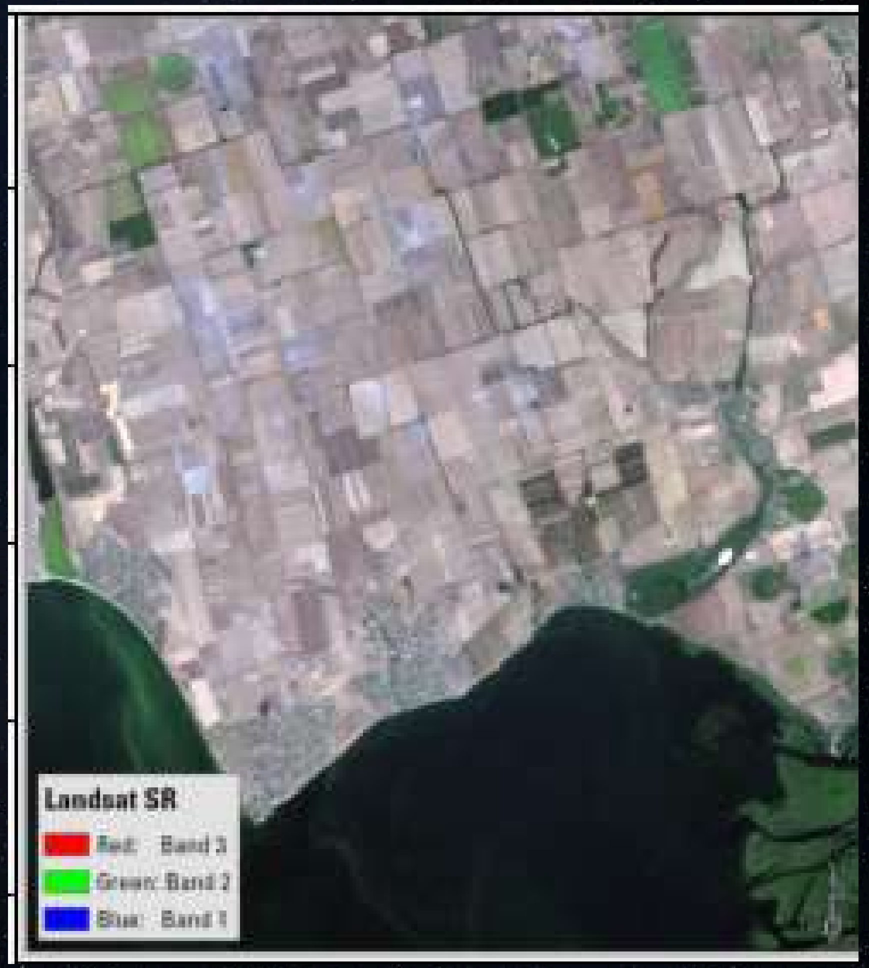
KEY APPLICATIONS

- Noise Removal: Eliminates small, unwanted regions in the image.
- Object Extraction: Helps in separating or isolating specific shapes in an image.
- Edge Detection: Highlights the boundaries of objects in an image.
- Shape Analysis: Identifies and measures the shape or structure of objects.
- Medical Imaging: Enhances features like veins, bones, or cells for analysis.
- Document Processing: Improves readability by filling gaps in text or removing noise.

BINARY IMAGE PROCESSING

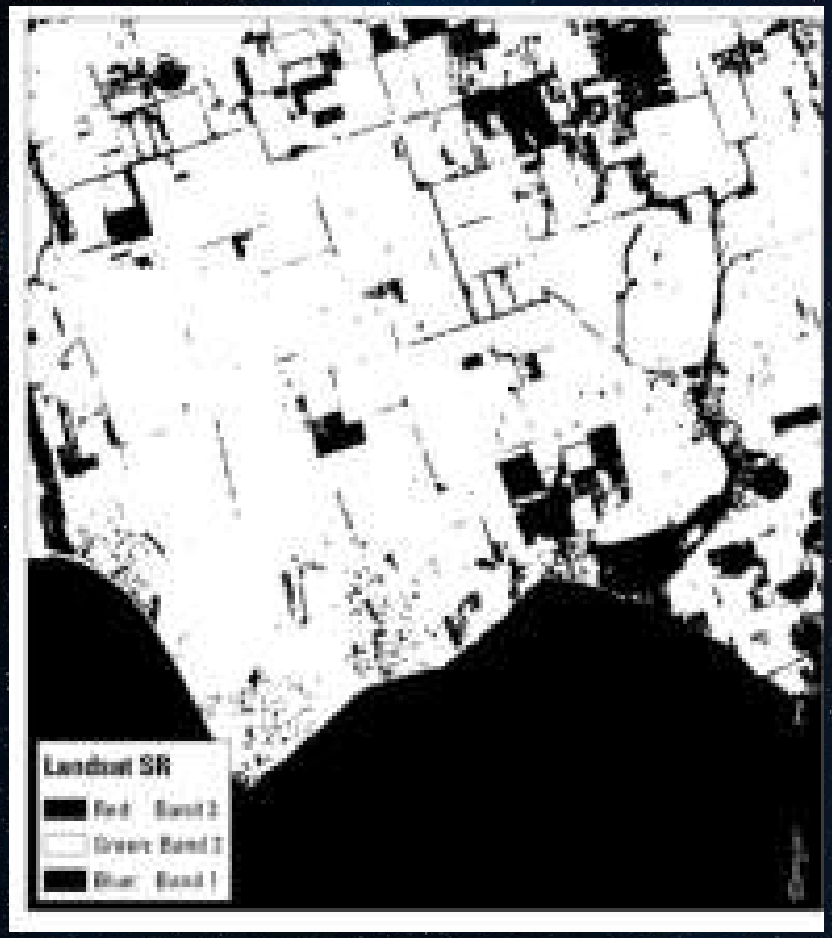
A binary image is a type of digital image where each pixel has one of two possible values:

- Black (0): Represents the background or absence of an object.
- White (1): Represents the foreground or presence of an object.



Original Image

→



Binary Image

Code:

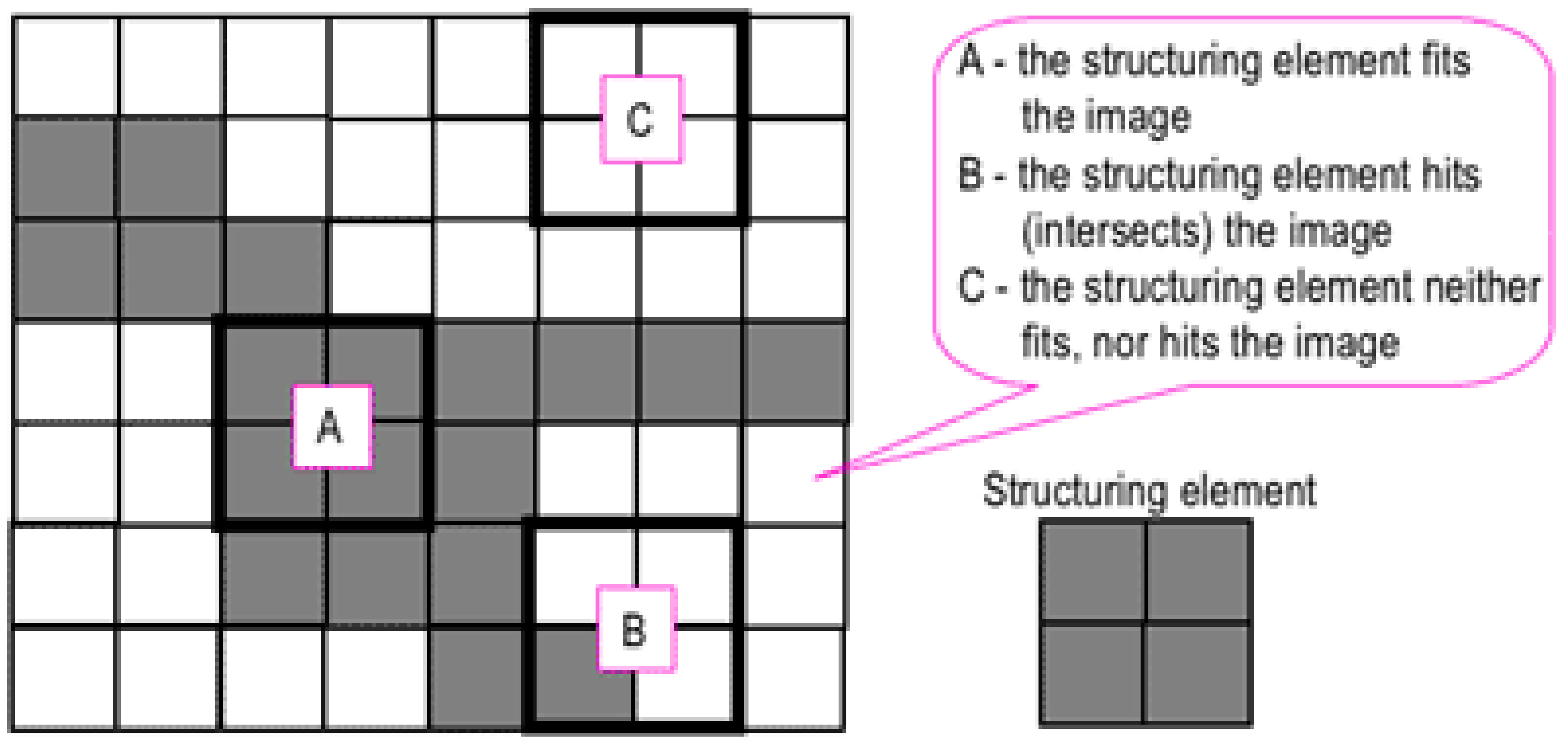
```
grayscale_image = img.convert("L")  # Convert to grayscale
binary_image = np.array(grayscale_image) > 128 e

# Display the binary image
plt.figure(figsize=(5, 5))
plt.imshow(binary_image, cmap="gray")
plt.title("Binary Image (Thresholded)")
plt.axis("off")
plt.show()
```

STRUCTURING ELEMENT IN MORPHOLOGICAL OPERATIONS

- A structuring element is a small, predefined matrix (or kernel) used in morphological operations to probe or interact with a binary image.
- It defines the shape and size of the neighborhood for operations like dilation, erosion, opening, and closing.

- The structuring element determines which pixels in the binary image will be affected during the operation.
- Common shapes:

1. Square (e.g., 3x3, 5x5).
2. Circle (for smooth, rounded effects).
3. Line (used for detecting or enhancing linear features).


C
A
B
A - the structuring element fits the image
B - the structuring element hits (intersects) the image
C - the structuring element neither fits, nor hits the image
Structuring element

OPERATIONS:

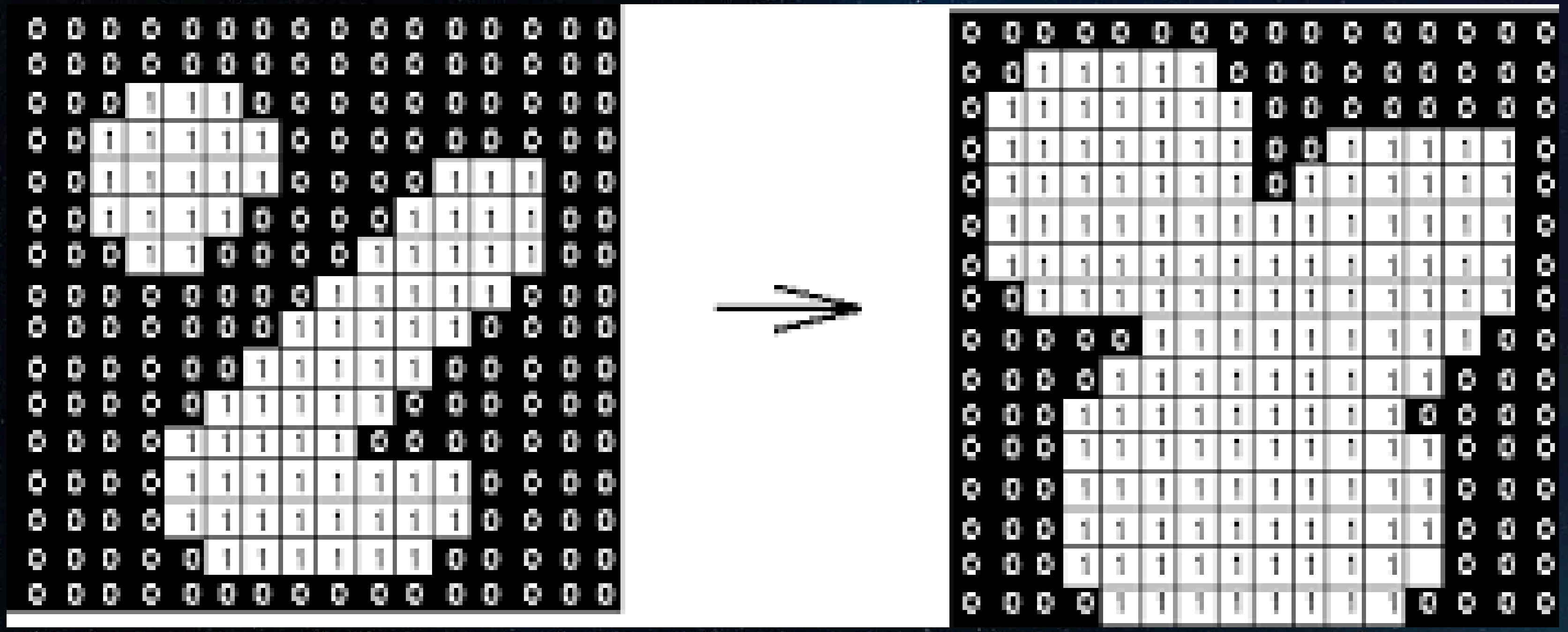
DILATION:

Definition: Expands the boundaries of white (foreground) regions in a binary image.

Purpose:

- Fills small gaps or holes.
- Enlarges objects for better visibility.

Formula: $A \oplus B=\{z \mid (Bz \cap A) \neq \varnothing\}A$



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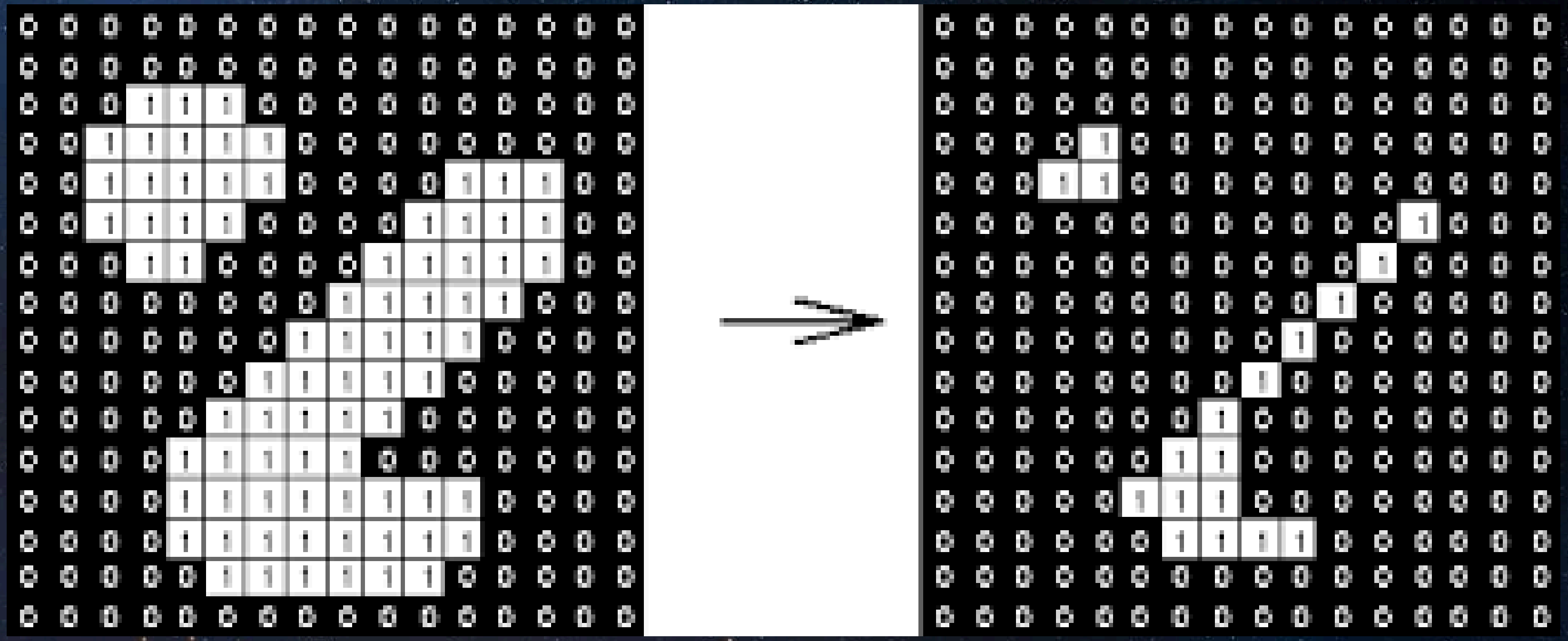
EROSION:



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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Definition: Shrinks the boundaries of white regions by eroding away pixels.

Purpose:

- Removes noise or small objects.
- Separates connected objects.

Formula: $A \ominus B=\{z \mid Bz \subseteq A\}$

OPERATIONS:

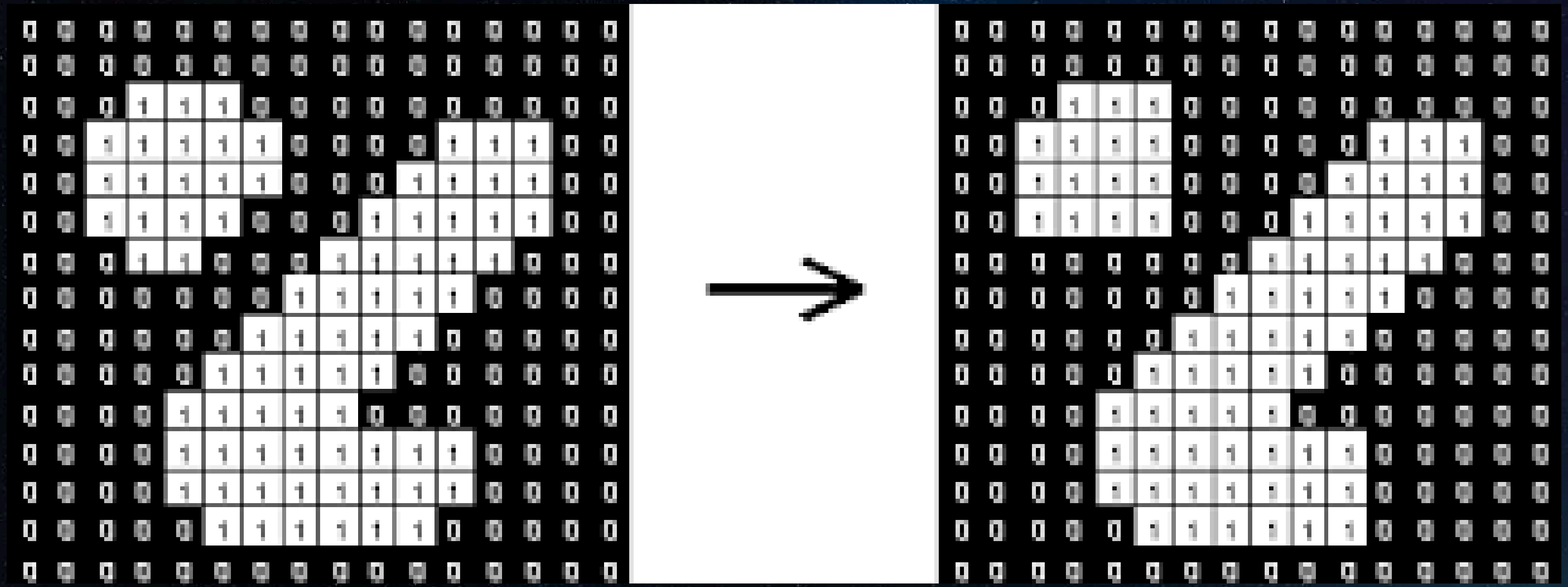
OPENING:

Definition: Smoothens object contours by removing noise and small protrusions (erosion followed by dilation).

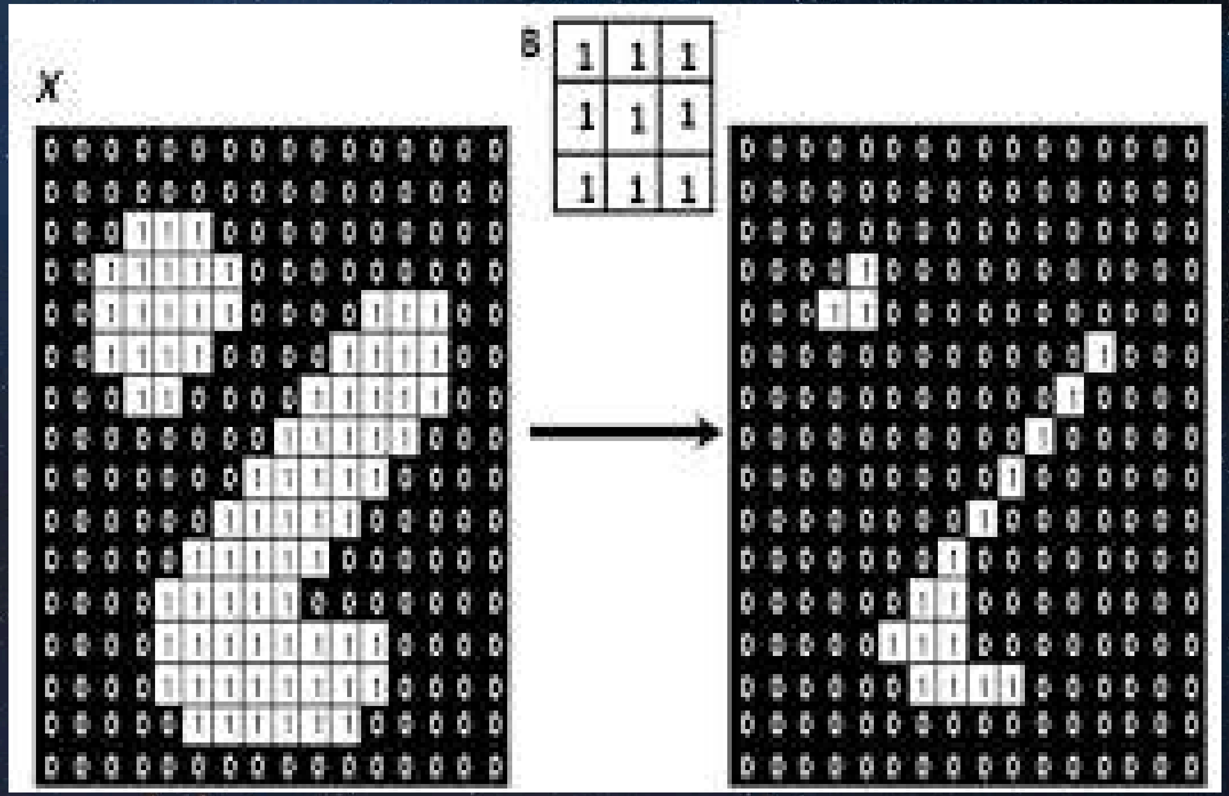
Purpose:

- Removes small objects or noise while preserving larger object shapes.

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



CLOSING:



Definition: Fills small holes and gaps within objects (dilation followed by erosion).

Purpose:

- Makes objects more complete by connecting small breaks.

Formula: $A \cdot B = (A \oplus B) \ominus B$

MANUAL IMPLEMENTATION OF DILATION

HOW MANUAL DILATION WORKS:

Padding the Image:

- Add a border (padding) around the binary image to ensure the structuring element can fully interact with edge pixels.

Iterating Over the Image:

- Traverse each pixel in the binary image (excluding the padded border).

Applying the Structuring Element:

- For each pixel, overlay the structuring element centered on the pixel.

Checking for Overlaps:

- If any part of the structuring element overlaps with a white pixel (1), set the current pixel in the output image to white (1).

CODE SNIPPET:

```
def manual_dilation(image, element):
  # Initialize an empty output image
  output = np.zeros_like(image, dtype=bool)

  # Calculate padding size
  pad_h, pad_w = element.shape[0] // 2, element.shape[1] // 2

  # Pad the binary image with zeros
     padded_image = np.pad(image, ((pad_h, pad_h), (pad_w, pad_w)),
mode='constant', constant_values=0)

  # Iterate over each pixel in the original image
  for i in range(image.shape[0]):
    for j in range(image.shape[1]):
      # Check for overlap with the structuring element
       if np.any(padded_image[i:i + element.shape[0], j:j + element.shape[1]] &
element):
        output[i, j] = 1  # Set the output pixel to white (1)

  return output
```

BUILT-IN METHODS FOR DILATION AND EROSION

WHY USE BUILT-IN FUNCTIONS?

Advantages

1. Speed:
   - Optimized algorithms for faster processing of large images.
   - Handles large-scale datasets efficiently.
2. Accuracy:
   - Eliminates manual coding errors.
   - Consistent and reliable results.
3. Ease of Use:
   - Simplifies implementation with just a few lines of code.
   - Built-in support for various structuring elements.
4. Versatility:
   - Can handle both binary and grayscale images.
   - Compatible with other image processing tools.

SciPy Functions

1. binary_dilation

- Function: Expands the boundaries of white (foreground) regions in a binary image.
- Usage:

```
from scipy.ndimage import binary_dilation
dilated_image = binary_dilation(input_image,
structure=structuring_element)
```

- Parameters:
  - input_image: Binary image to process.
  - structure: Structuring element to define the neighborhood.
- Output: A binary image with expanded white regions.

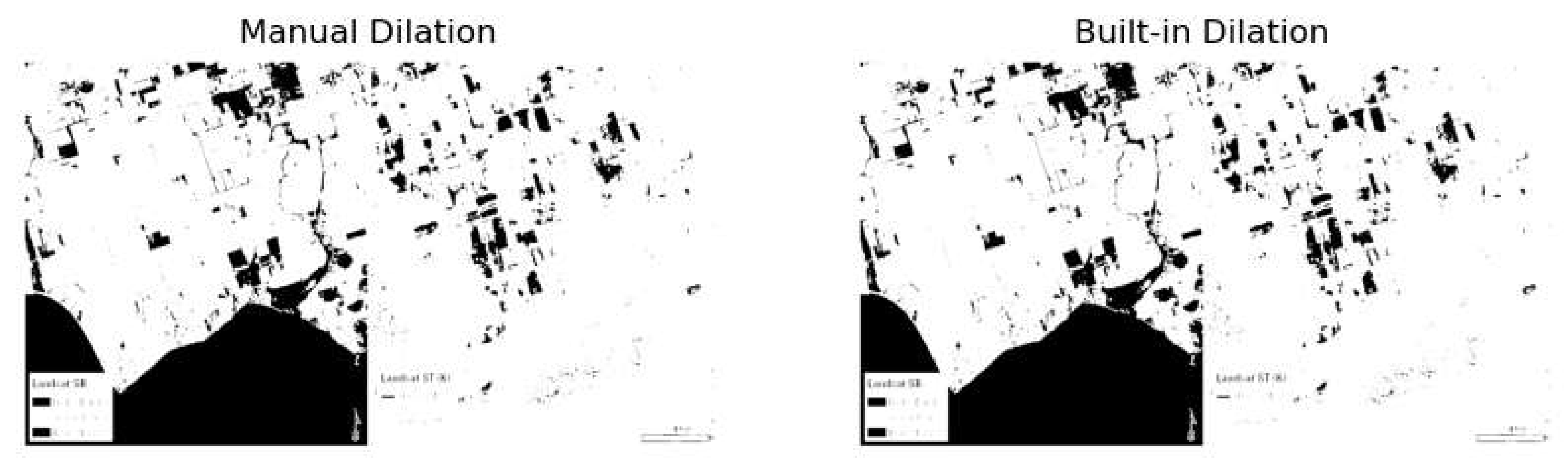
2. binary_erosion

- Function: Shrinks the boundaries of white regions by removing pixels at the edges.
- Usage:

```
from scipy.ndimage import binary_erosion
eroded_image = binary_erosion(input_image,
structure=structuring_element)
```

- Parameters:
  - input_image: Binary image to process.
  - structure: Structuring element defining the region for erosion.
- Output: A binary image with shrunken white regions.

COMPARISON: MANUAL VS. BUILT-IN DILATION



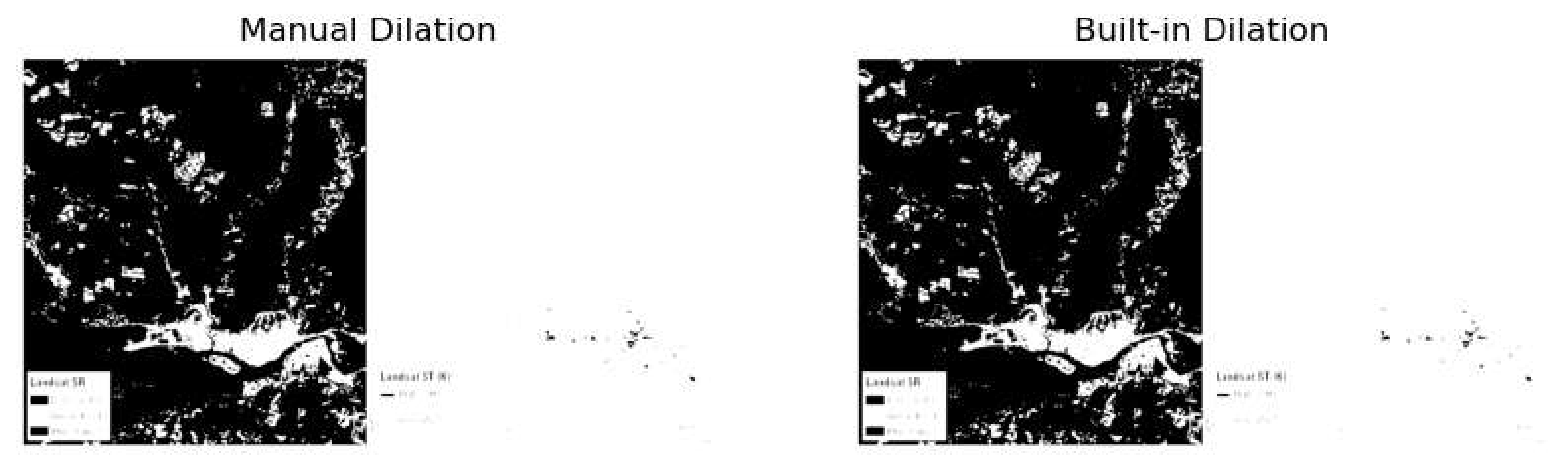
Manual Implementation:

- Computational Complexity:
  - Nested loops for every pixel and structuring element overlap.
  - Complexity: O(n×m×k×l)O(n \times m \times k \times l)O(n×m×k×l)
    - n,mn, mn,m: Image dimensions.
    - k,lk, lk,l: Structuring element dimensions.
- Performance:
  - Slower due to explicit iteration over pixels.
  - Best for small-scale images or educational purposes.

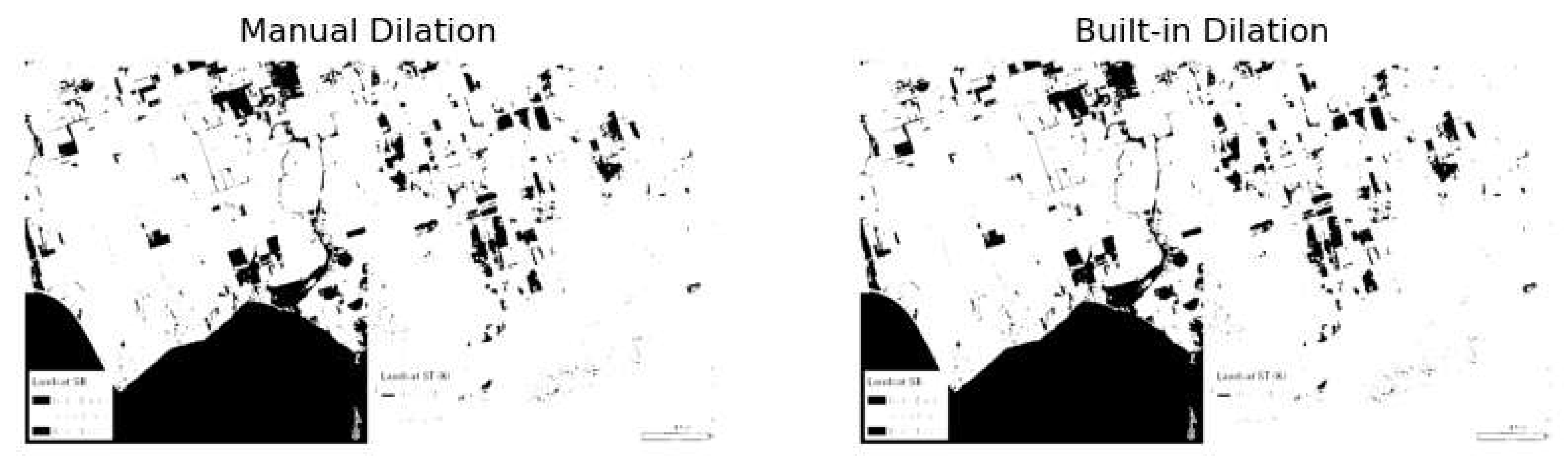
MANUAL METHOD TIME: 39.62264S
BUILT-IN METHOD TIME: 0.05638S

Built-in Implementation:

- Optimization:
  - Uses optimized libraries (e.g., C/C++) for faster processing.
  - Parallelized operations for large-scale datasets.
- Performance:
  - Significantly faster, especially for large images.
  - Ideal for real-world applications.



MANUAL METHOD TIME: 38.97058S
BUILT-IN METHOD TIME: 0.05382S



MANUAL METHOD TIME: 34.13963S
BUILT-IN METHOD TIME: 0.04249S

Similarities:

- Results are identical or nearly identical, demonstrating the accuracy of the manual method.
- Both use the same logic of structuring element overlap.

Differences:

- Built-in functions are faster and more efficient.
- Manual methods allow customization but are less practical for large images.

REFERENCES

Earth’s climate is shaped by the Sun, atmosphere, and oceans. Human activity is driving global warming and climate change.

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THANK

YOU