Computer Graphics and Image Processing Lecture 8

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Outline

Agenda

Today Discussion

- Once segmentation is complete, morphological operations can be used to remove imperfections in the segmented image and provide information on the form and structure of the image
- In this lecture we will consider
  - What is morphology?
  - Simple morphological operations
  - Compound operations
  - Morphological algorithms

1, 0, Black & White?

- Throughout all of the following slides whether 0 and 1 refer to white or black is a little interchangeable
- All of the discussion that follows assumes segmentation has already taken place and that images are made up of 0s for background pixels and 1s for object pixels
- After this it doesn't matter if 0 is black, white, yellow, green

Morphology - Definition

- Morphology: a branch of biology that deals with the form and structure of animals and plants
- Morphological image processing is used to extract image components for representation and description of region shape, such as boundaries, skeletons, and the convex hull

What Is Morphology?

Definition

- Morphological image processing (or morphology) describes a range of image processing techniques that deal with the shape (or morphology) of features in an image

Uses of Morphology

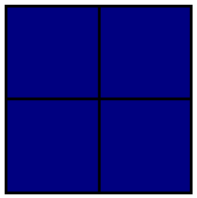
- Morphological operations are typically applied to remove imperfections introduced during segmentation, and so typically operate on bi-level images

Quick Example

Image after segmentation

Image after segmentation and morphological processing

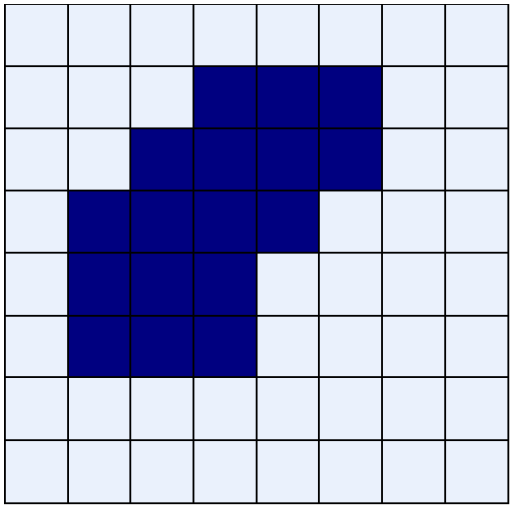
Structuring Elements, Hits & Fits



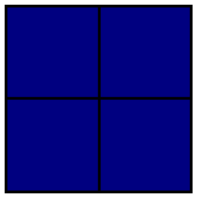
Structuring Element

- Fit: All on pixels in the structuring element cover on pixels in the image
- Hit: Any on pixel in the structuring element covers an on pixel in the image

All morphological processing operations are based on these simple ideas

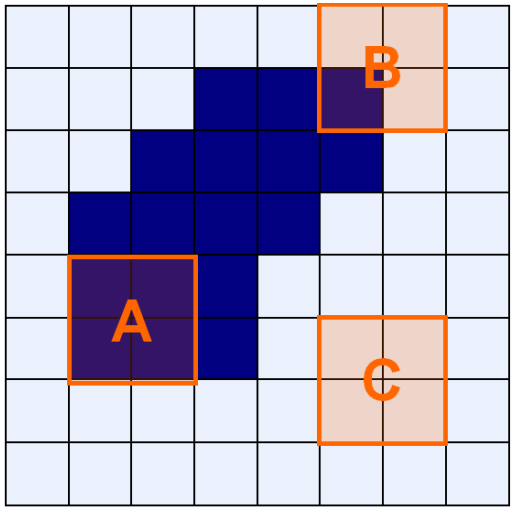


Structuring Elements, Hits & Fits



Structuring Element

- Fit: All on pixels in the structuring element cover on pixels in the image
- Hit: Any on pixel in the structuring element covers an on pixel in the image



Structuring Elements

- Structuring elements can be any size and make any shape
- However, for simplicity we will use rectangular structuring elements with their origin at the middle pixel

1	1	1
1	**1**	1
1	1	1

0	1	0
1	**1**	1
0	1	0

0	0	1	0	0
0	1	1	1	0
1	1	**1**	1	1
0	1	1	1	0
0	0	1	0	0

Fitting & Hitting

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

1	1	1
1	1	1
1	1	1

Structuring Element 1

0	1	0
1	1	1
0	1	0

Structuring Element 2

Fitting & Hitting

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0
0	0	1	B	1	1	1	0	C	0	0	0
0	1	1	1	1	1	1	1	0	0	0	0
0	1	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	0	0	0
0	0	1	1	1	1	1	A	1	1	1	0
0	0	0	0	0	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0

1	1	1
1	1	1
1	1	1

Structuring Element 1

0	1	0
1	1	1
0	1	0

Structuring Element 2

Fundamental Operations

1. Fundamentally morphological image processing is very like spatial filtering
2. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image
3. The value of this new pixel depends on the operation performed
4. There are two basic morphological operations: erosion and dilation

Erosion

- Erosion of image f by structuring element s is given by $f \ominus s$
- The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ fits } f \\ 0 \text{ otherwise} \end{cases}$$

Erosion Example 1

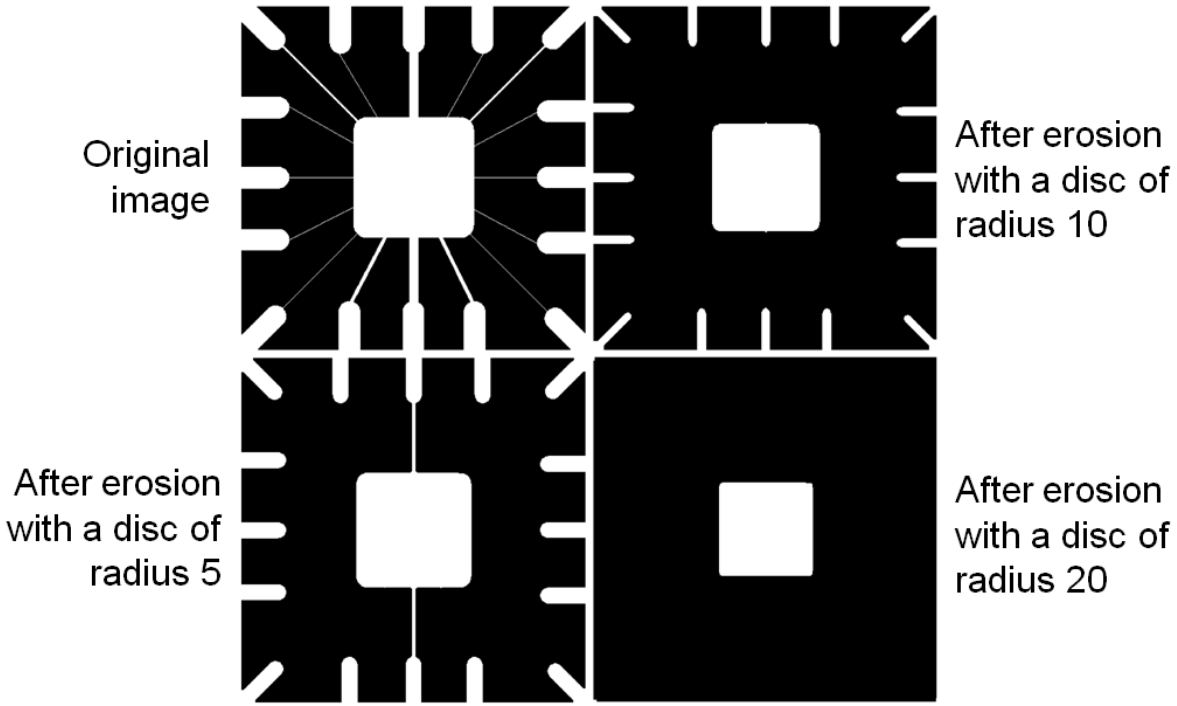
Original image

Erosion by 3*3 square structuring element

Erosion by 5*5 square structuring element

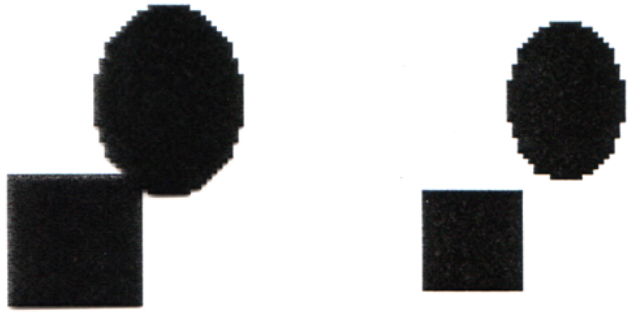
In these examples a 1 refers to a black pixel!

Erosion Example 2

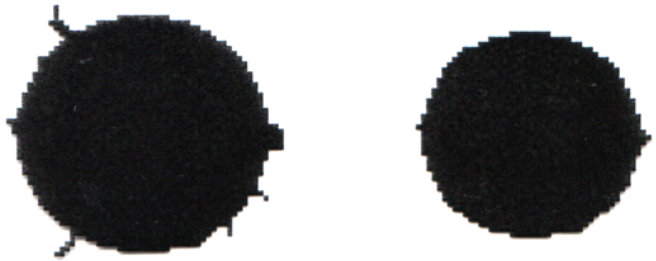


What Is Erosion For?

Erosion can split apart joined objects



Erosion can strip away extrusions



Erosion shrinks objects

Dilation

- Erosion of image f by structuring element s is given by $f \oplus s$
- The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ hits } f \\ 0 \text{ otherwise} \end{cases}$$

Dilation Example 1

Original image

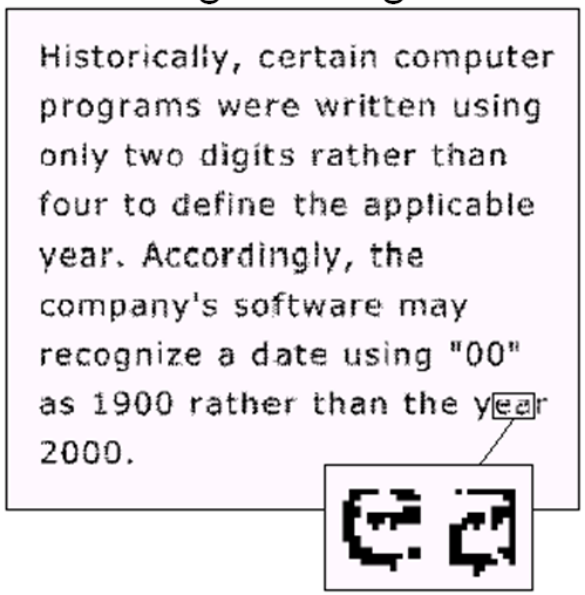
Dilation by 3*3 square structuring element

Dilation by 5*5 square structuring element

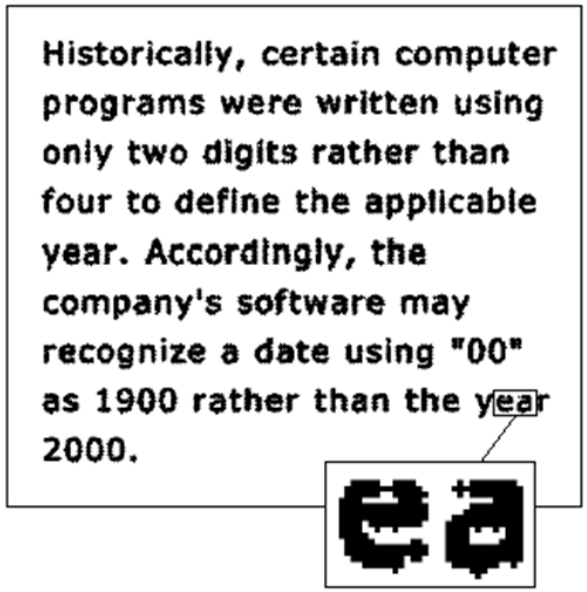
In these examples a 1 refers to a black pixel!

Dilation Example 2

Original image



After dilation



0	1	0
1	1	1
0	1	0

Structuring element

What Is Dilation Used For?

Dilation can repair breaks

Dilation can repair intrusions

Erosion enlarge objects

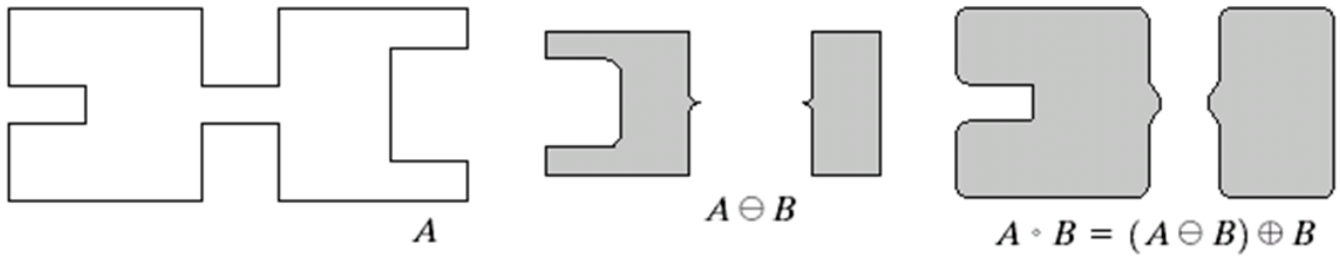
Compound Operations

- More interesting morphological operations can be performed by performing combinations of erosions and dilations
- The most widely used of these compound operations are:
  - Opening
  - Closing

Opening

- Opening of image f by structuring element s denoted by $f \circ s$ is simply an erosion followed by a dilation

$$f \circ s = (f \ominus s) \oplus s \tag{1}$$



Original shape | After erosion | After dilation (opening)

Note a disc shaped structuring element is used

Opening Example

Original Image

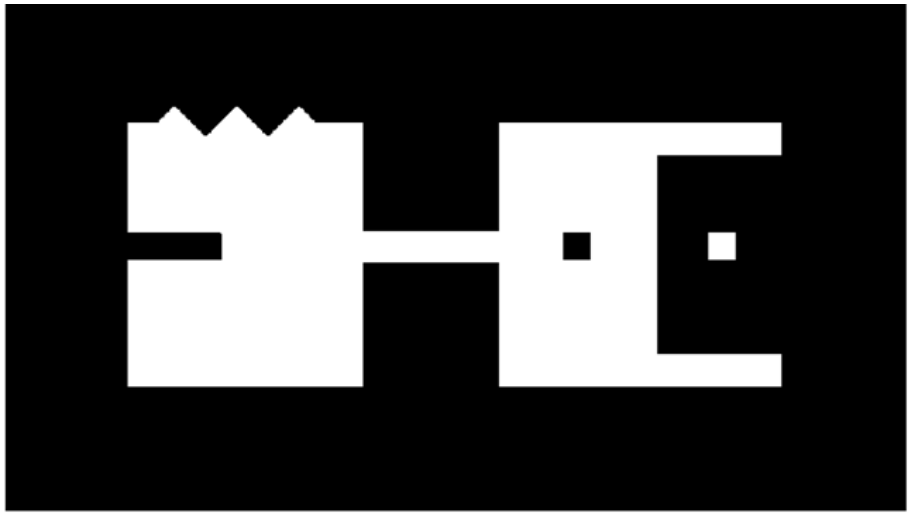
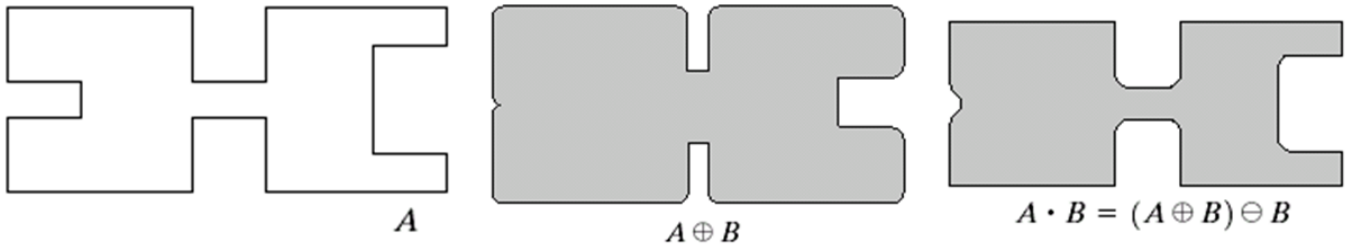


Image After Opening

Closing

- Closing of image f by structuring element s denoted by $f \cdot s$ is simply dilation followed by erosion

$$f \cdot s = (f \oplus s) \ominus s \tag{2}$$



Original shape | After dilation | After erosion (closing)

Note a disc shaped structuring element is used

Closing Example

Original Image

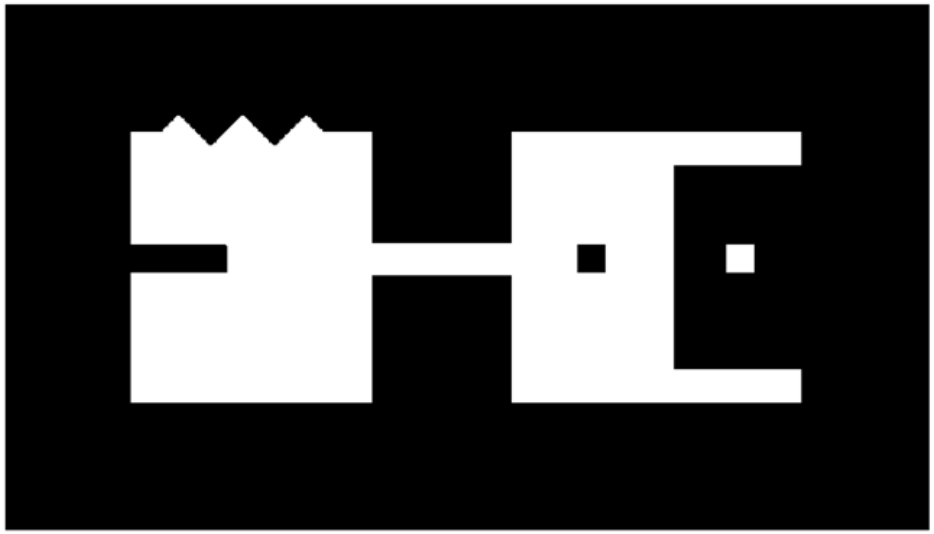
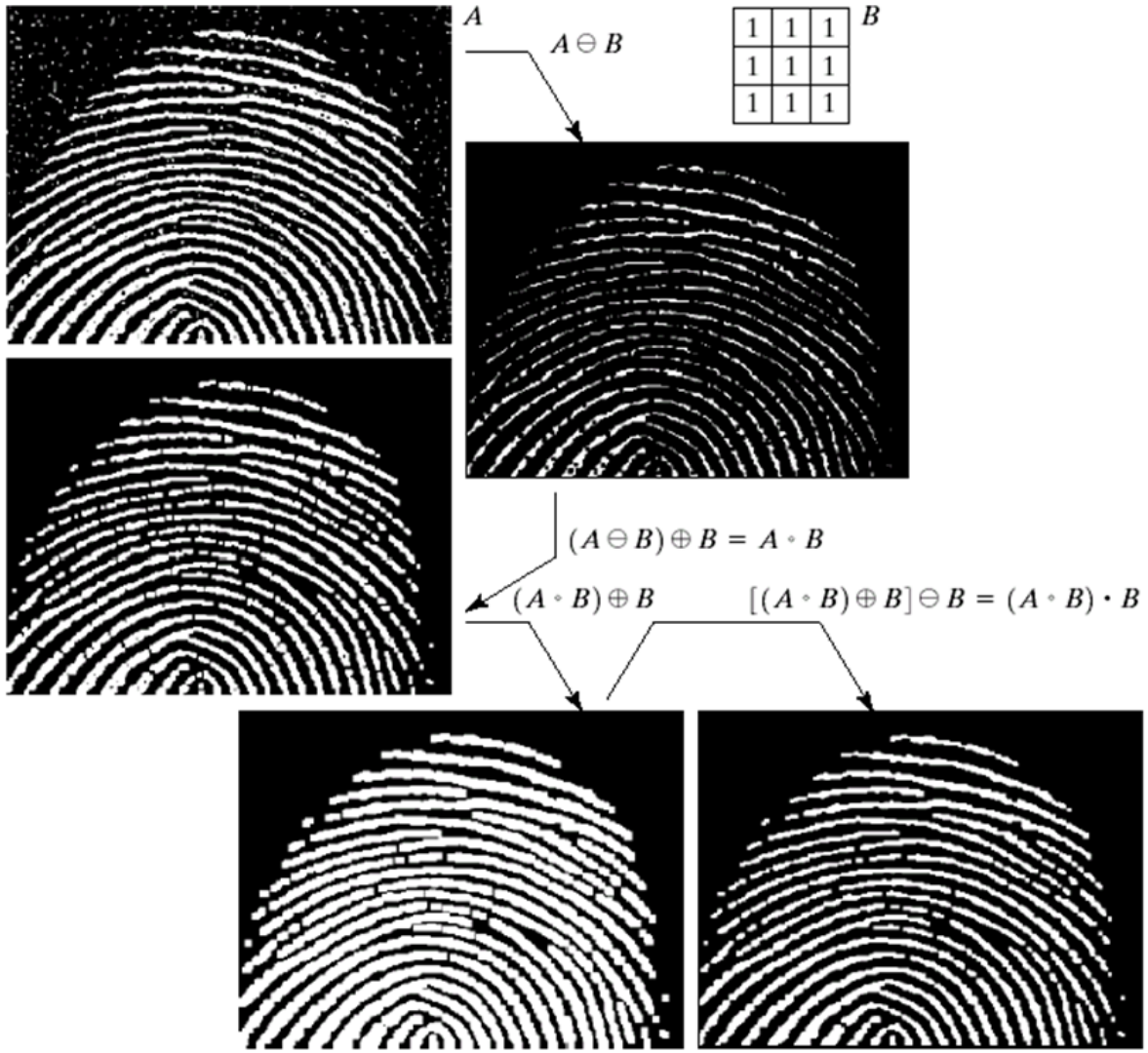


Image After Closing

Morphological Processing Example



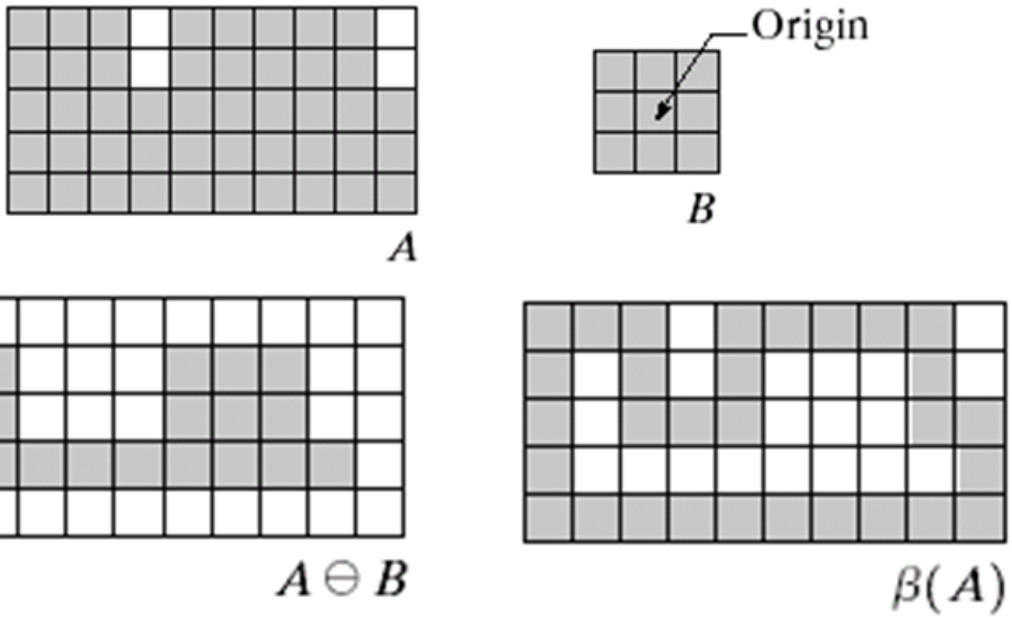
Morphological Algorithms

- Using the simple technique we have looked at so far we can begin to consider some more interesting morphological algorithms
- We will look at:
  - Boundary extraction
  - Region filling
- There are lots of others as well though:
  - Extraction of connected components
  - Thinning/thickening
  - Skeletonisation

Boundary Extraction

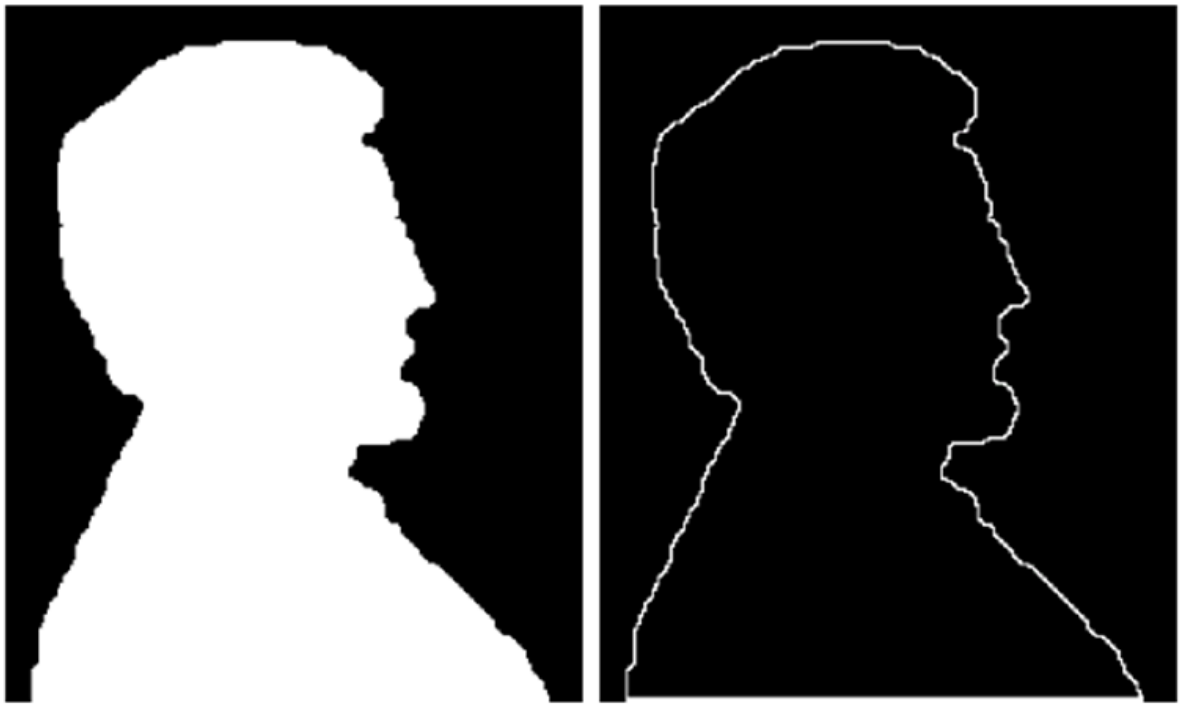
- Extracting the boundary (or outline) of an object is often extremely useful
- The boundary can be given simply as

$$\beta(A) = A - (A \ominus B)$$



Boundary Extraction Example

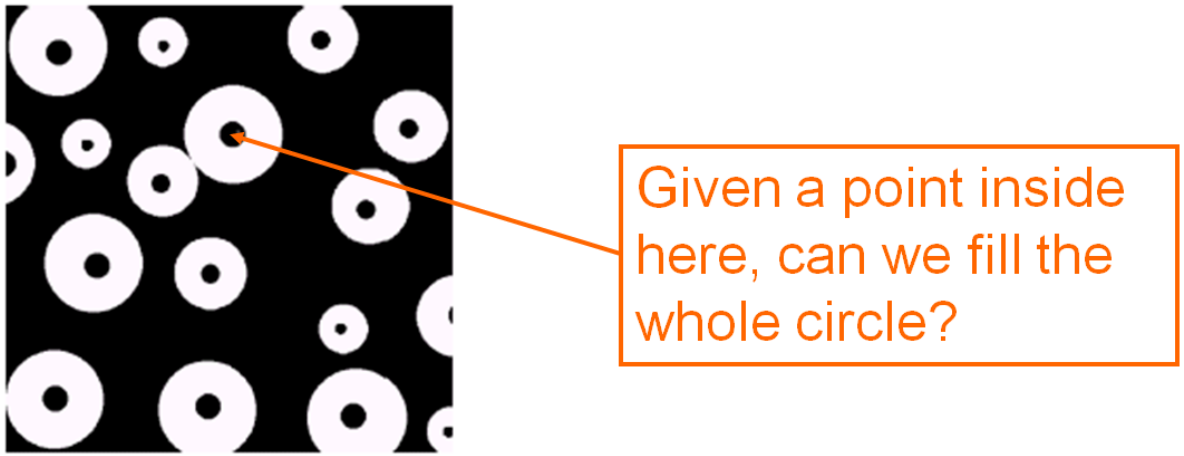
- A simple image and the result of performing boundary extraction using a square $3 * 3$ structuring element



Original Image Extracted Boundary

Region Filling

- Given a pixel inside a boundary, region filling attempts to fill that boundary with object pixels ($1s$)



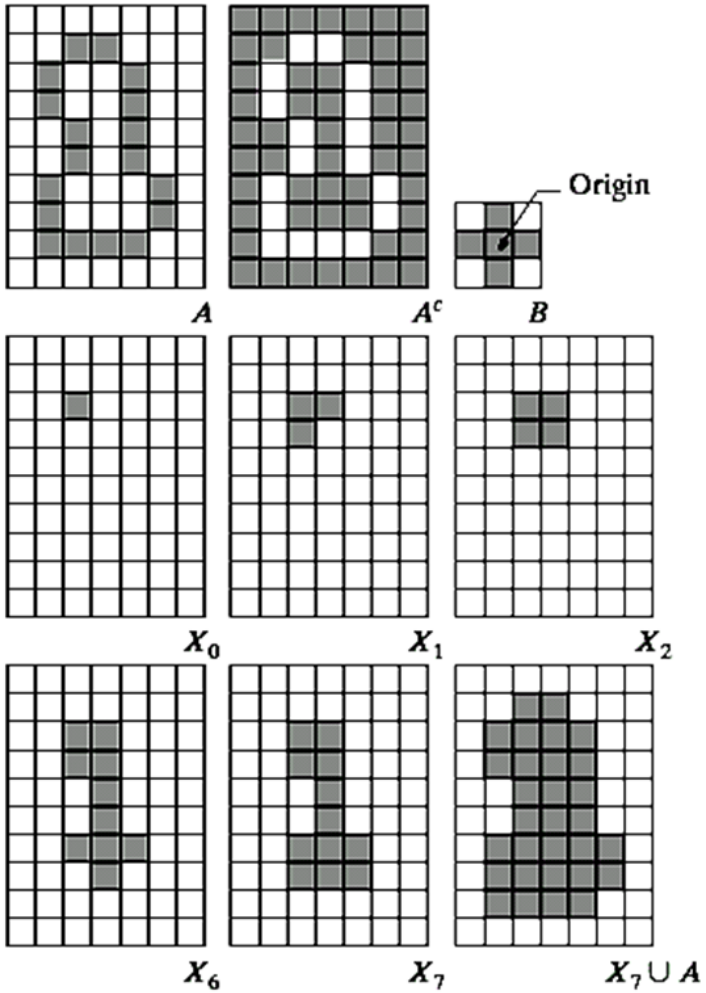
Region Filling Equation

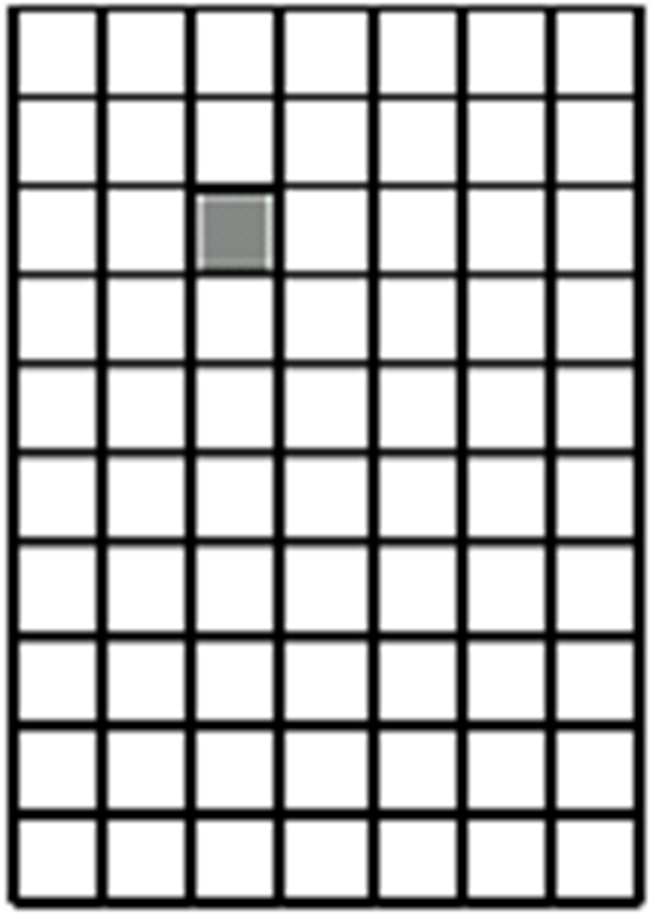
- The key equation for region filling is

$$X_k = (X_{k-1} \oplus B) \cap A^c \qquad k = 1,2,3.....$$

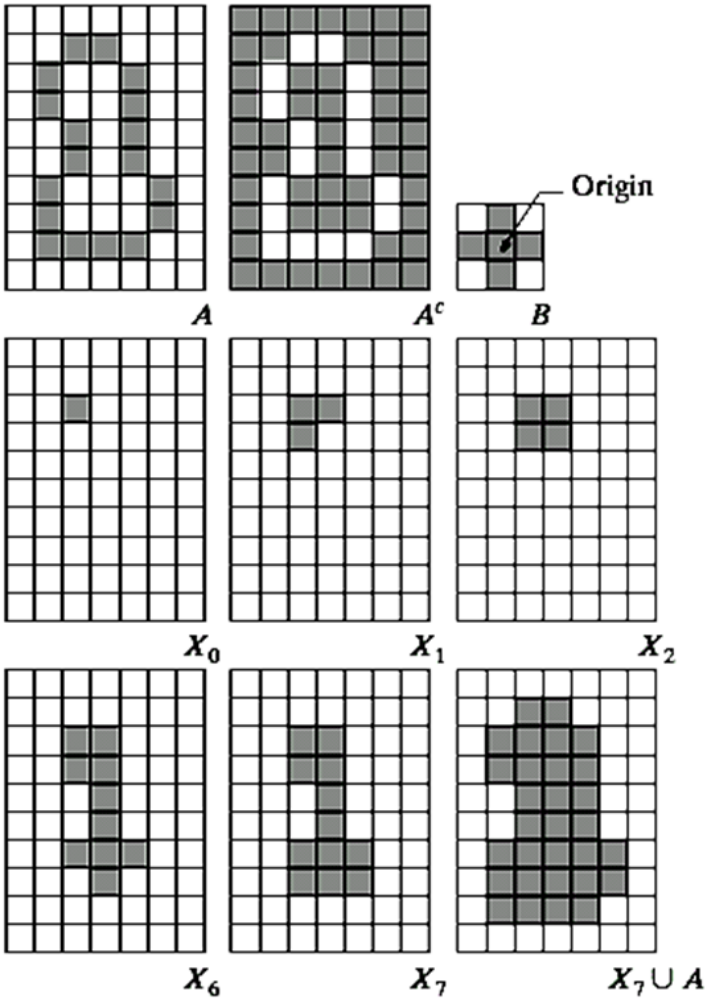
- Where X_0 is simply the starting point inside the boundary, B is a simple structuring and A^c is the complement of A
- This equation is applied repeatedly until X_K is equal to X_{K-1}
- Finally the result is unioned with the original boundary

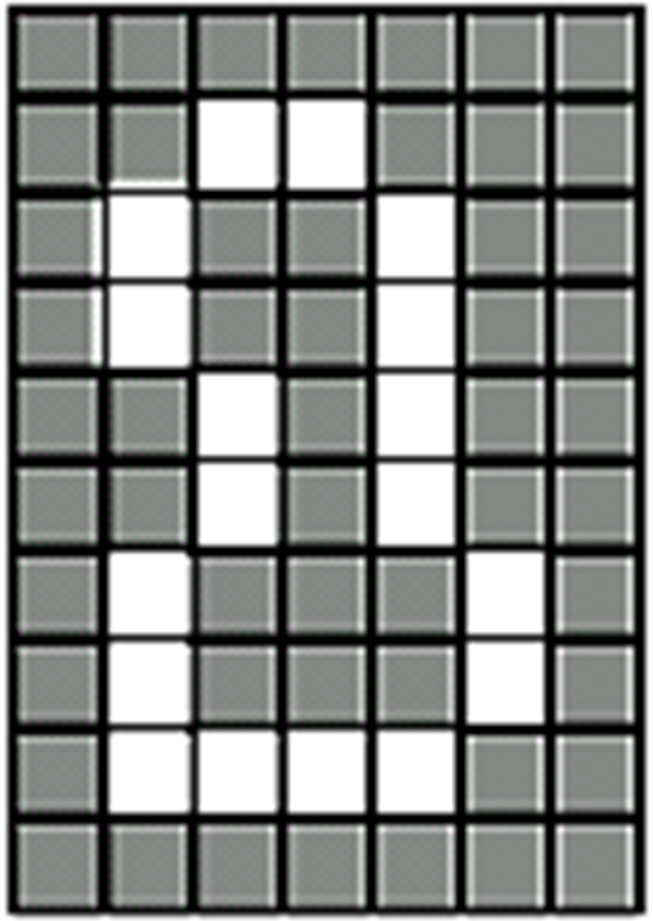
Region Filling Step By Step



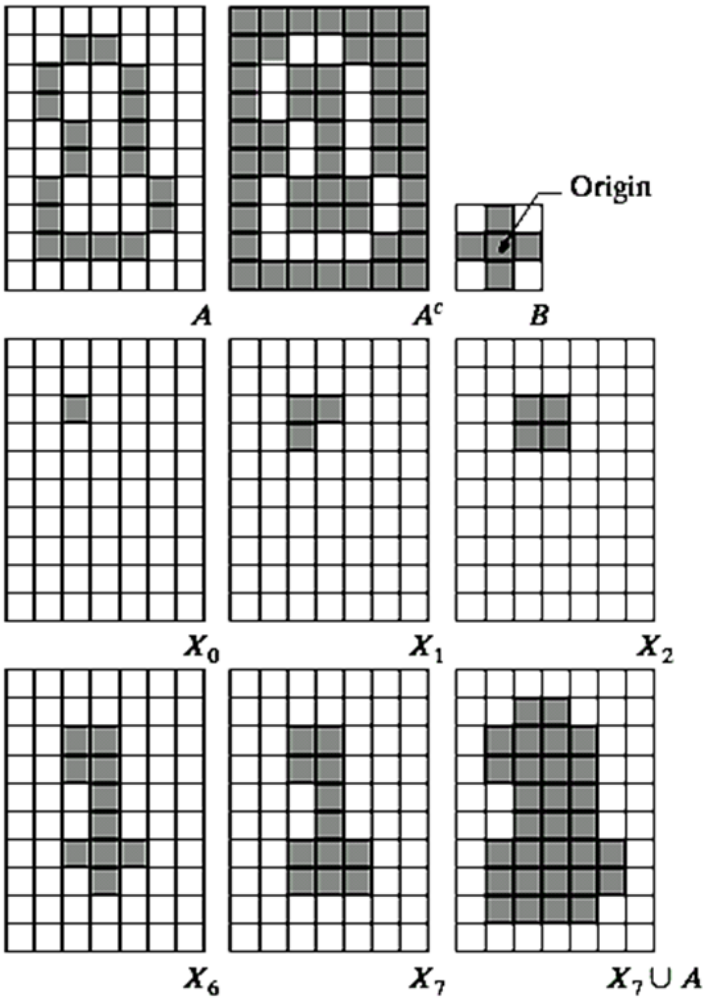


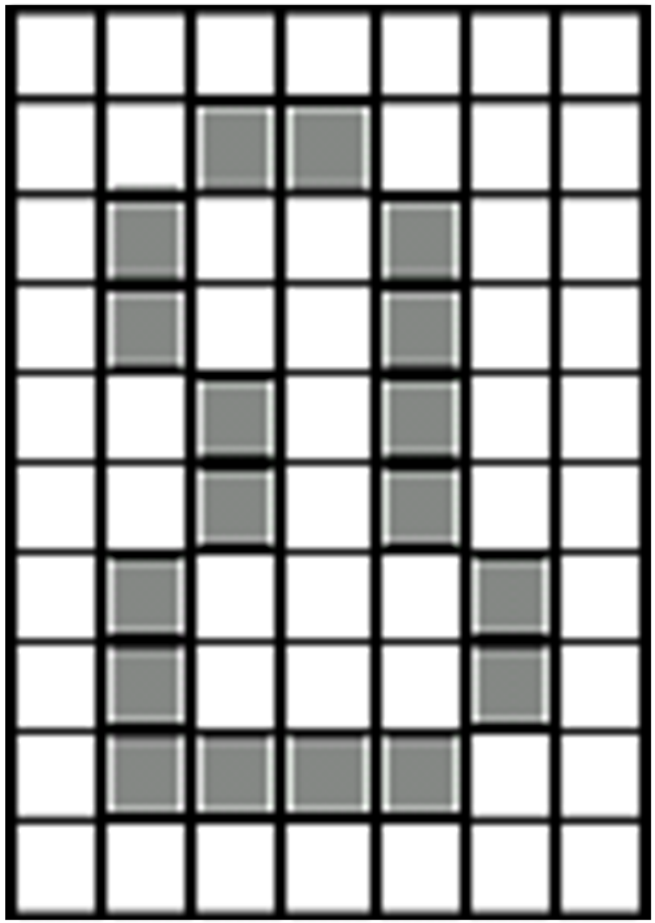
Region Filling Step By Step





Region Filling Step By Step





Region Filling Example

Original Image | One Region Filled | All Regions Filled

Summary

- The purpose of morphological processing is primarily to remove imperfections added during segmentation
- The basic operations are erosion and dilation
- Using the basic operations we can perform opening and closing
- More advanced morphological operation can then be implemented using combinations of all of these