University of Kurdistan

Digital Image Processing (DIP)

Lecture 5: Morphological Image Processing

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Contents

• 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.

• This lecture will cover:

- 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…….

What is morphology?

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

• 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

• Structuring elements can be any size and make any shape.

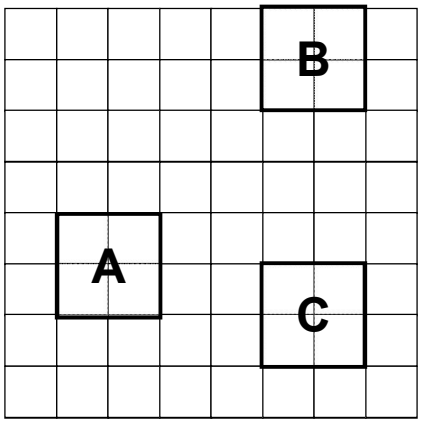
• However, for simplicity we will use rectangular structuring elements with their origin at the middle pixel.

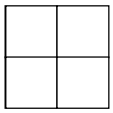
1	1	1
1	**1**	1
1	1	1

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





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.

Fitting & hitting (cont …)

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

• Fundamentally morphological image processing is very like spatial filtering.

• The structuring element is moved across every pixel in the original image to give a pixel in a new processed image.

• The value of this new pixel depends on the operation performed.

• There are two basic morphological operations: erosion and dilation.

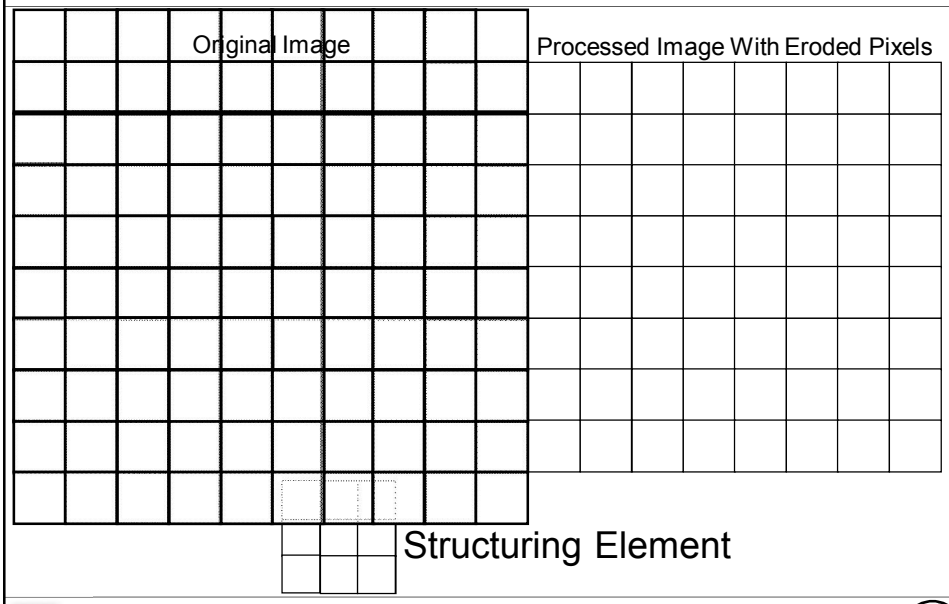
Erosion

• Erosion of image *f* by structuring element *s* is given by $f \ominus s$.

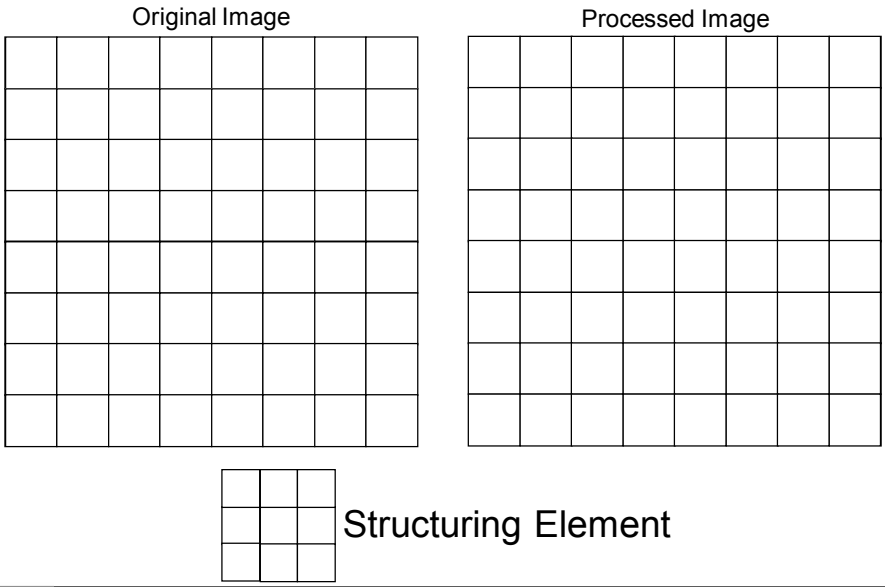
• The structuring element *s* is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

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

Erosion example



Erosion example



Erosion example 1

Original image

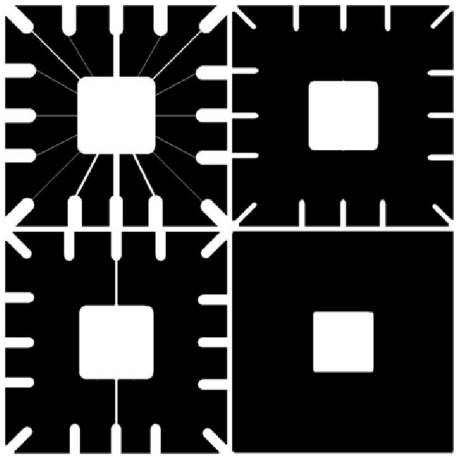
Erosion by 3*3 square structuring element

Erosion by 5*5 square structuring element

Watch out: In these examples a 1 refers to a black pixel!

Erosion example 2

Original image



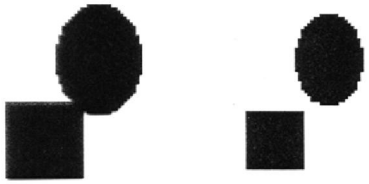
After erosion with a disc of radius 10

After erosion with a disc of radius 5

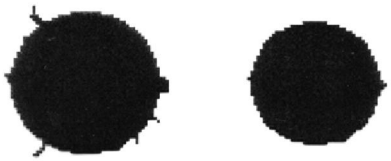
After erosion with a disc of radius 20

What is erosion for?

• Erosion can split apart joined objects.



• Erosion can strip away extrusions.



Watch out: Erosion shrinks objects.

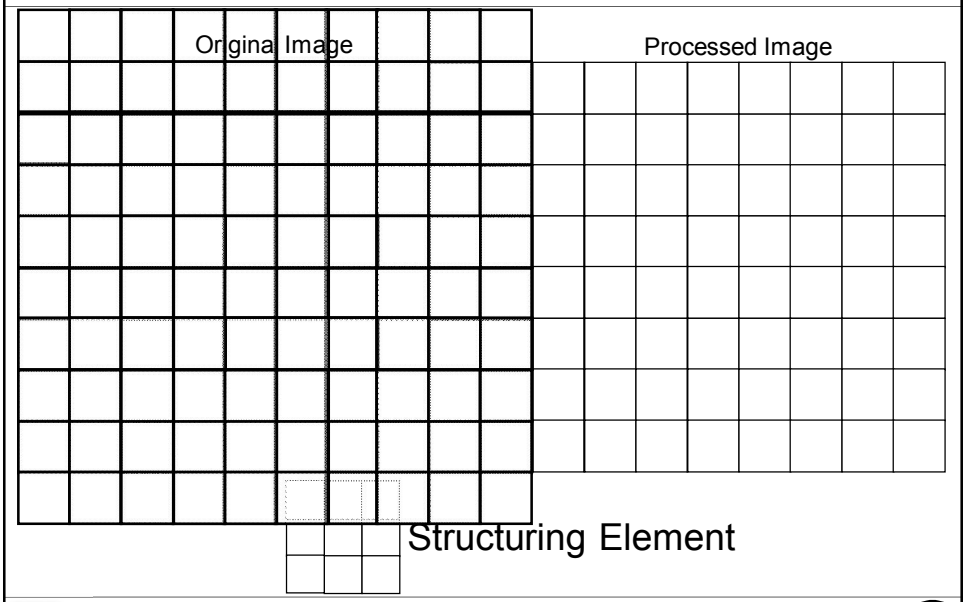
Dilation

• Dilation of image *f* by structuring element *s* is given by $f \oplus s$.

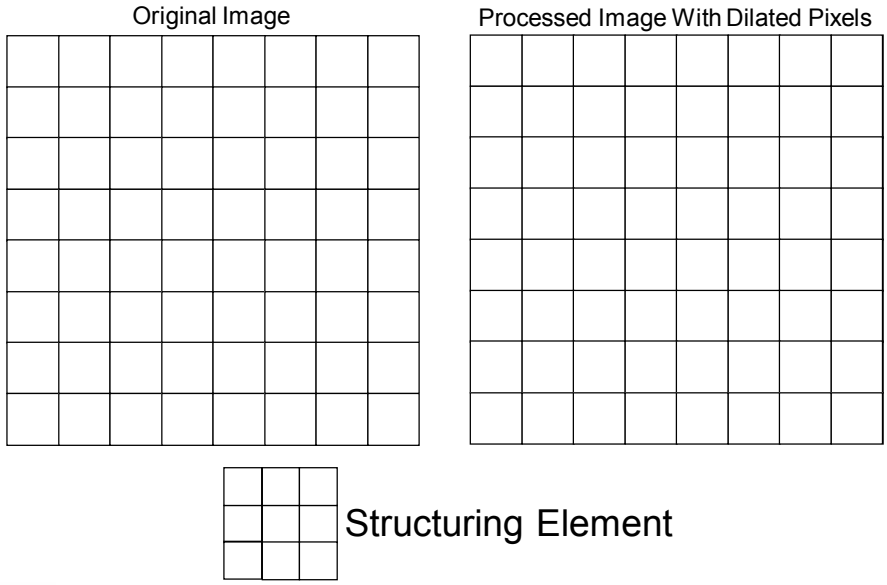
• The structuring element *s* is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

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

Dilation example



Dilation example



Dilation example 1

Original image

Dilation by 3*3 square structuring element

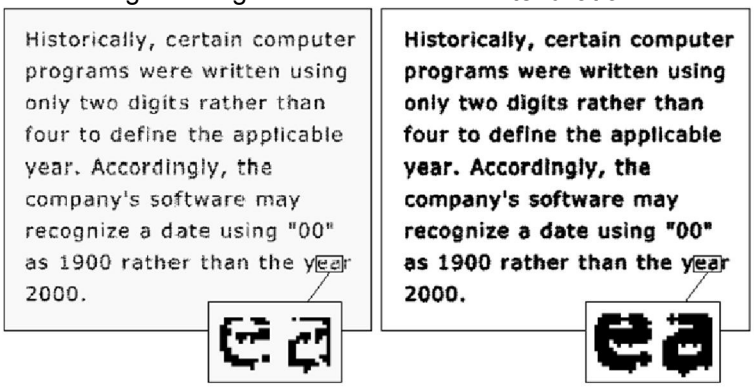
Dilation by 5*5 square structuring element

Watch out: 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 for?

• Dilation can repair breaks.

• Dilation can repair intrusions.

Watch out: Dilation enlarges 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

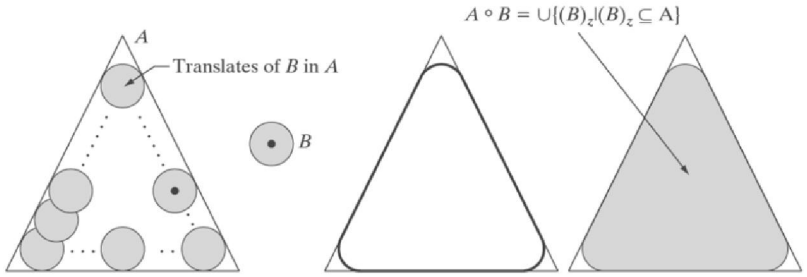
The opening of image f by structuring element s, denoted $f \bigcirc s$ is simply an erosion followed by a dilation:

$$f \bigcirc s = (f \ominus s) \oplus s$$

Original shape | After erosion | After dilation (opening)

Note a disc shaped structuring element is used.

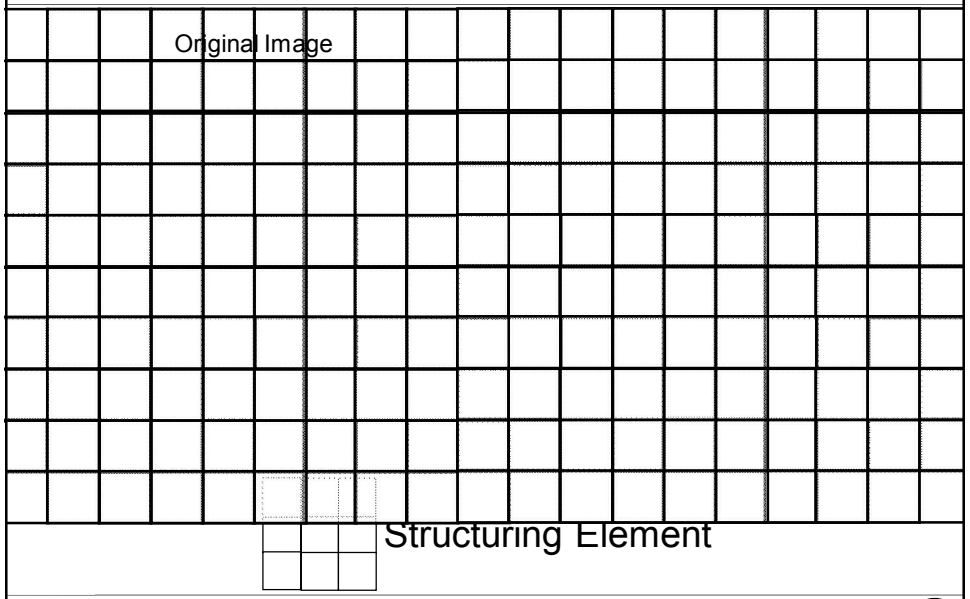
Opening (cont …)



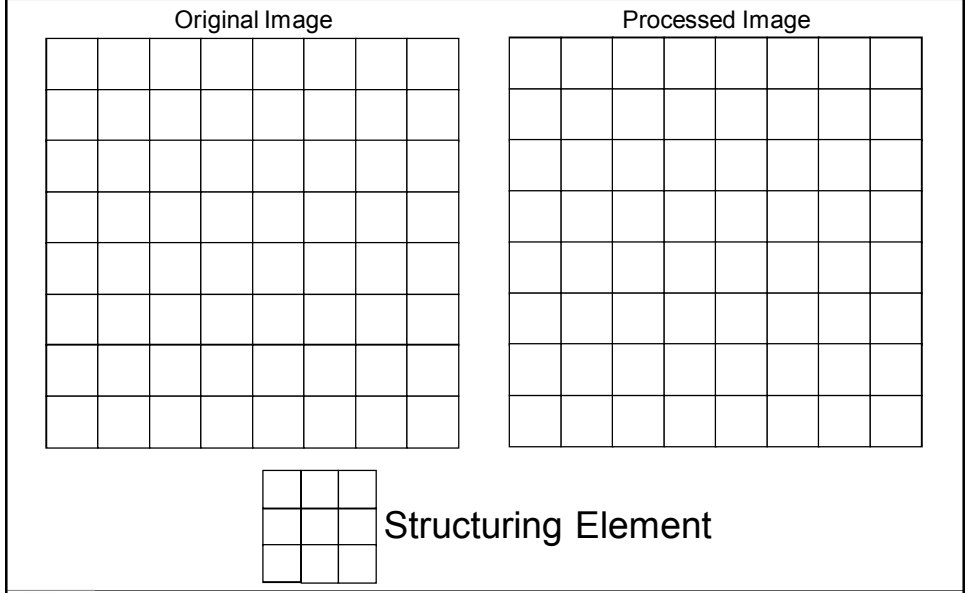
a b c d

FIGURE 9.8 (a) Structuring element B "rolling" along the inner boundary of A (the dot indicates the origin of B). (b) Structuring element. (c) The heavy line is the outer boundary of the opening. (d) Complete opening (shaded). We did not shade A in (a) for clarity.

Opening example



Opening example



Opening example

Original Image

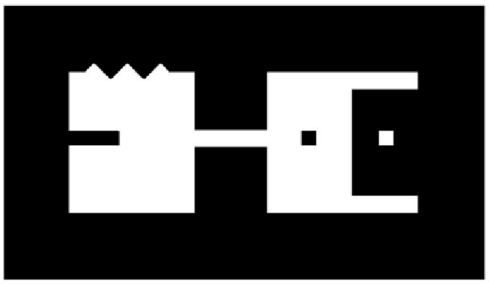
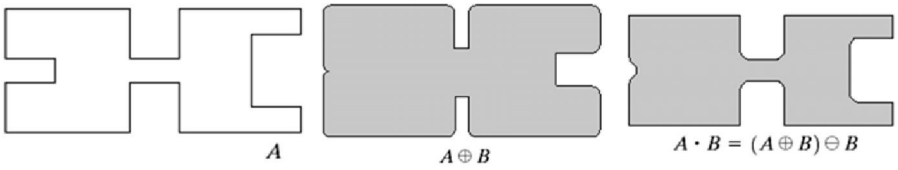


Image After Opening

Closing

The closing of image f by structuring element s, denoted $f \bullet s$ is simply a dilation followed by an erosion:

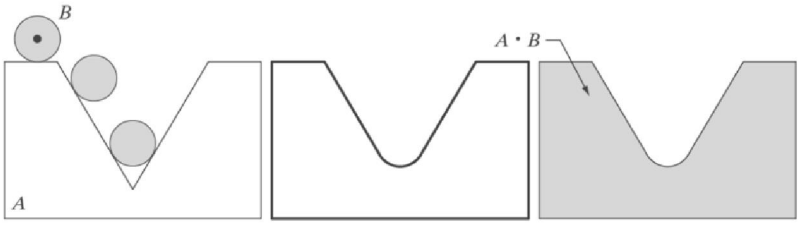
$$f \bullet s = (f \oplus s) \ominus s$$



Original shape | After dilation | After erosion (closing)

Note a disc shaped structuring element is used.

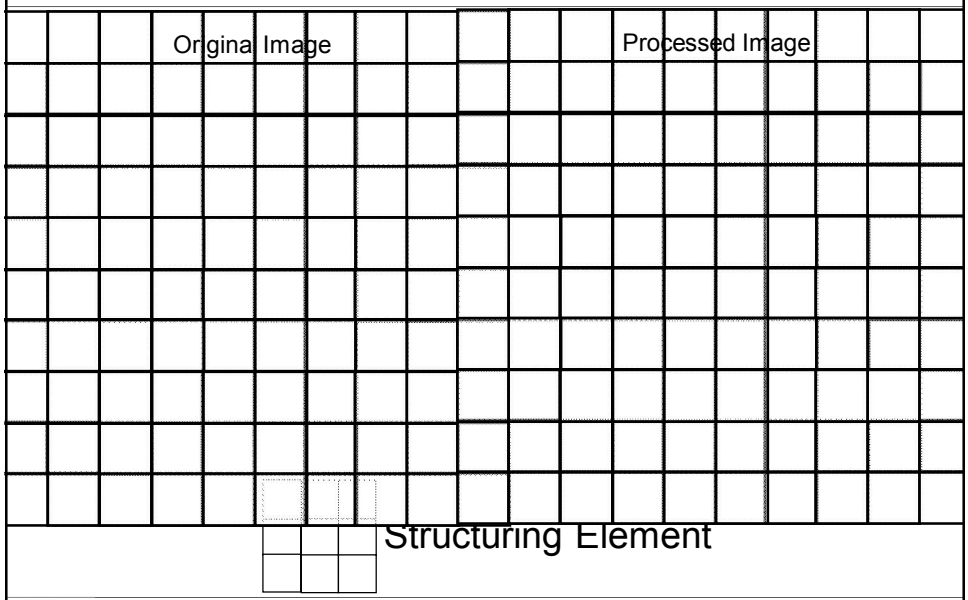
Closing (cont …)



a b c

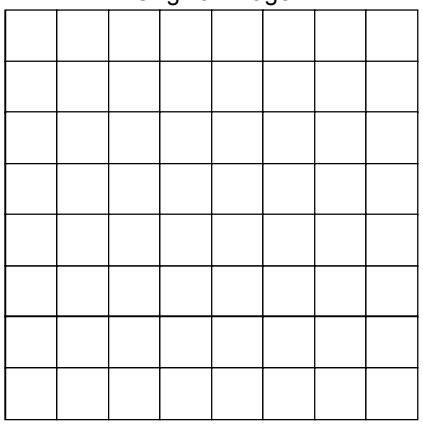
FIGURE 9.9 (a) Structuring element B "rolling" on the outer boundary of set A. (b) The heavy line is the outer boundary of the closing. (c) Complete closing (shaded). We did not shade A in (a) for clarity.

Closing example

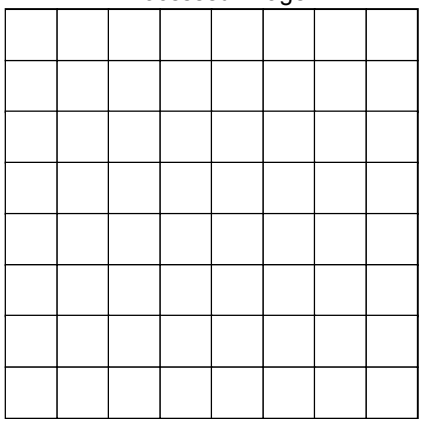


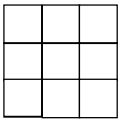
Closing example

Original Image



Processed Image





Structuring Element

Closing example

Original Image

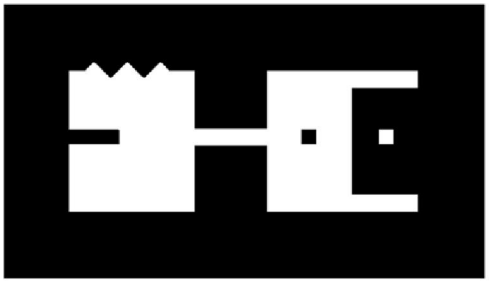


Image After Closing

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:

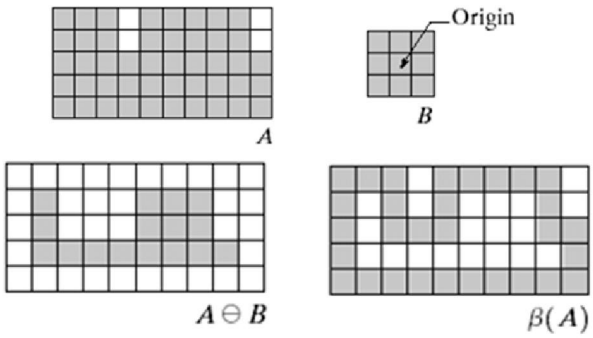
- Extraction of connected components
- Thinning/thickening
- Skeletonization

Boundary extraction

• Extracting the boundary (or outline) of an object is often extremely useful.

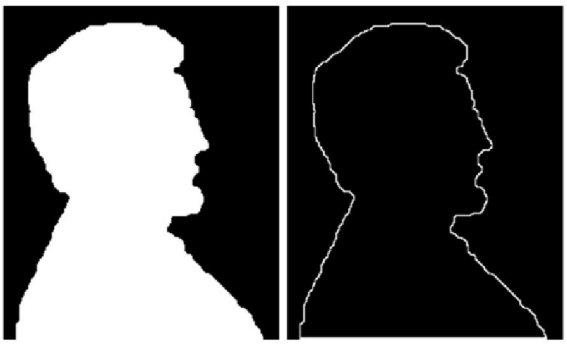
• The boundary can be given simply as:

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



Boundary extraction example

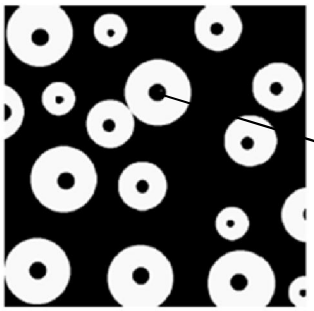
• A simple image and the result of performing boundary extraction using a square 3*3 structuring element.



Original Image Extracted Boundary

Region filling

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



Given a point inside here, can we fill the whole circle?

Region filling (cont…)

The key equation for region filling is:

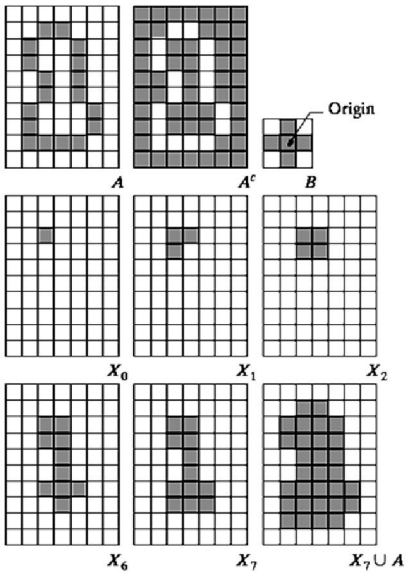
$$X_k = (X_{k-1} \oplus B) \cap A^c \qquad k = 1,2,3.....$$

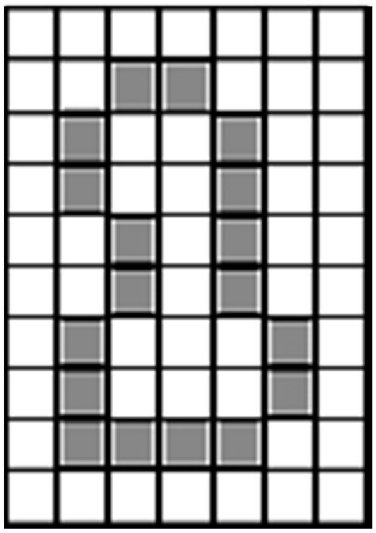
where X_0 is simply the starting point inside the boundary, B is a simple structuring element, and A^c is the complement of A.

This equation is applied repeatedly until X_k is equal to X_{k-1}.

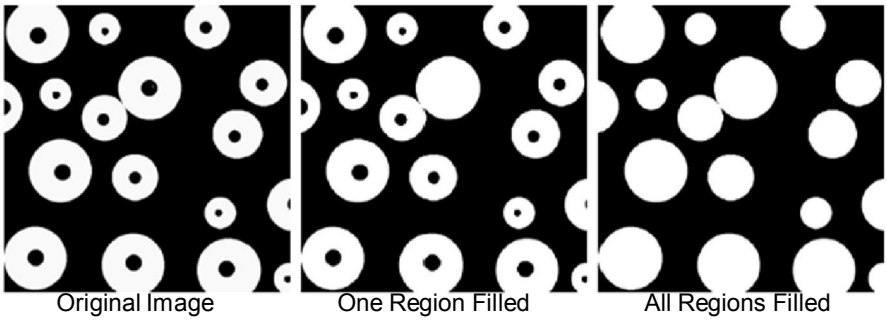
Finally the result is unioned with the original boundary.

Region filling step by step





Region filling 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.