

Digital Image Processing

Morphological Image Processing

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

Throughout all of the following slides whether 0 and 1 refer to white or black is a little interchangeable

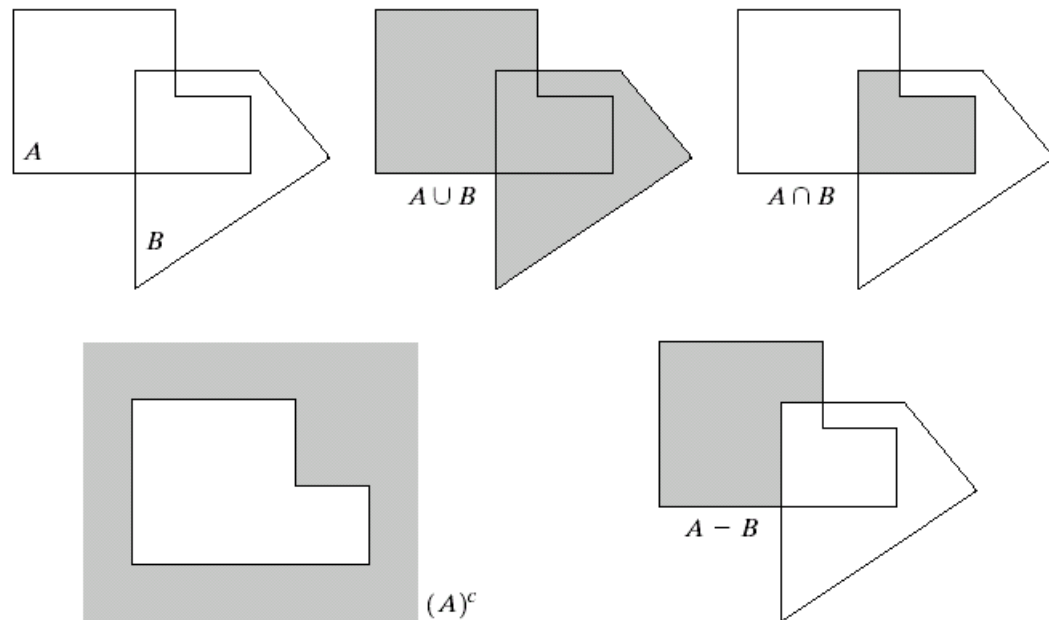
All of the discussion that follows assumes segmentation has already taken place and that images are made up of 0s for background pixels and 1s for object pixels

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



| | | |
|---|---|---|
| a | b | c |
| d | e | |

FIGURE 9.1

(a) Two sets A and B . (b) The union of A and B . (c) The intersection of A and B . (d) The complement of A . (e) The difference between A and B .

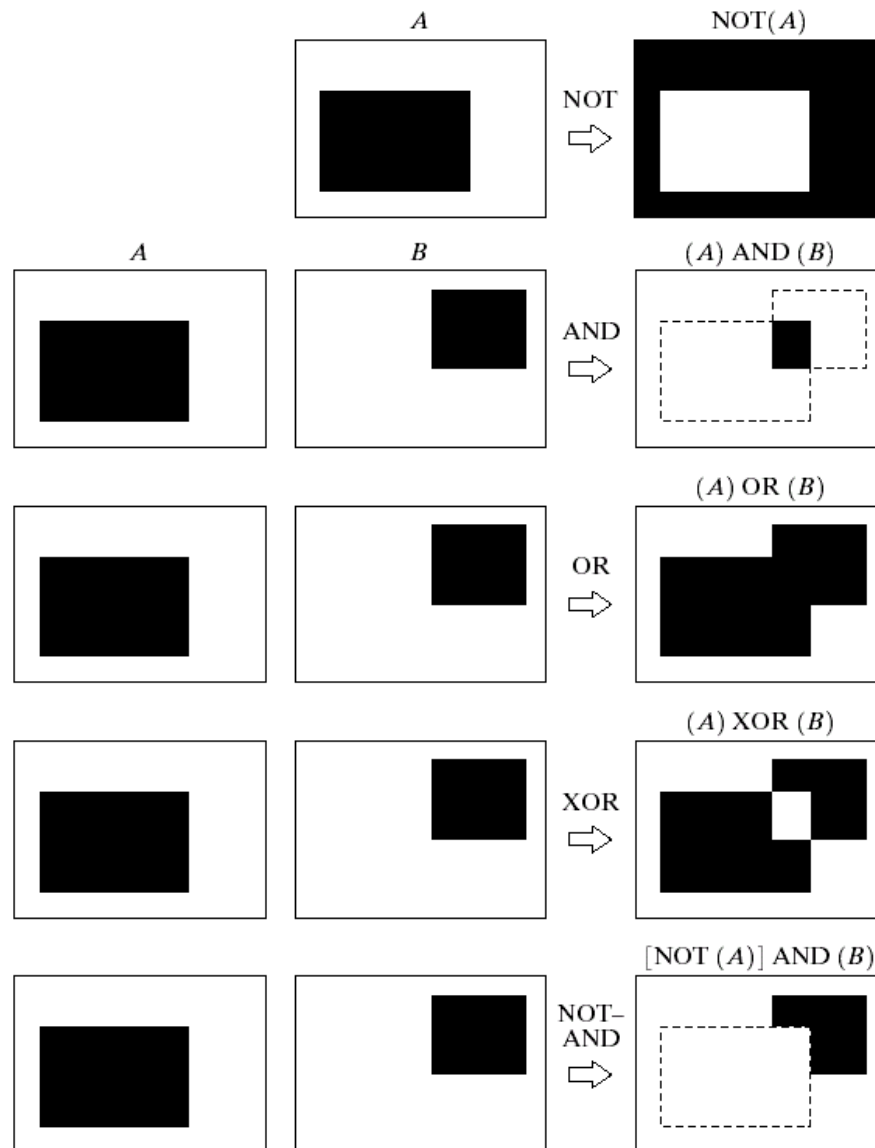


FIGURE 9.3 Some logic operations between binary images. Black represents binary 1s and white binary 0s in this example.

Quick Example

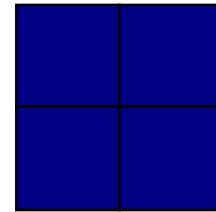
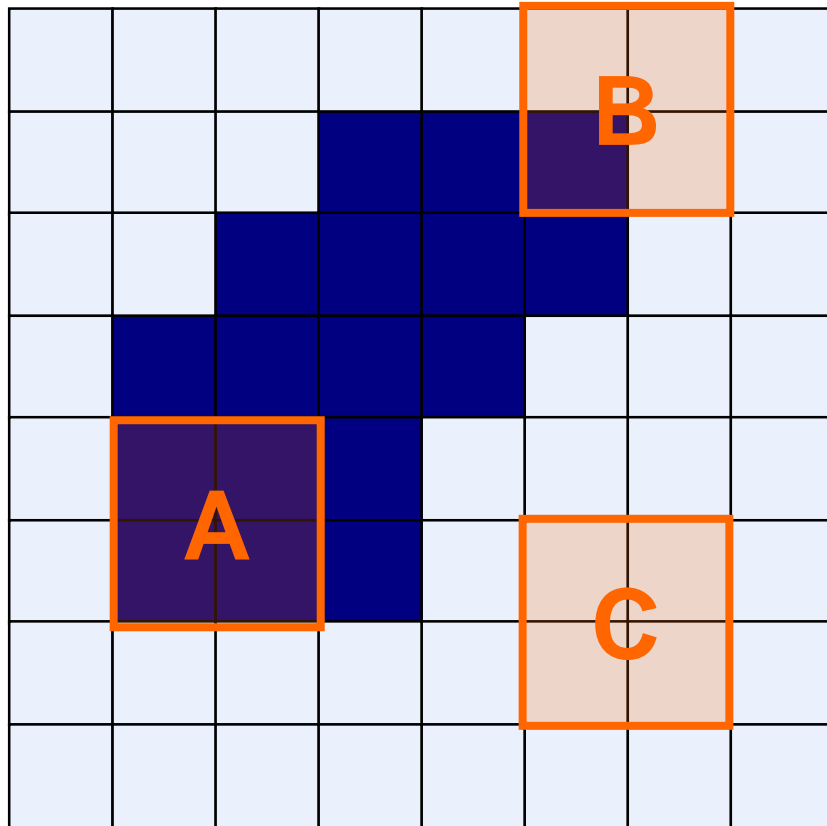


Image after segmentation



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

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 | 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 | 1 | 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

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

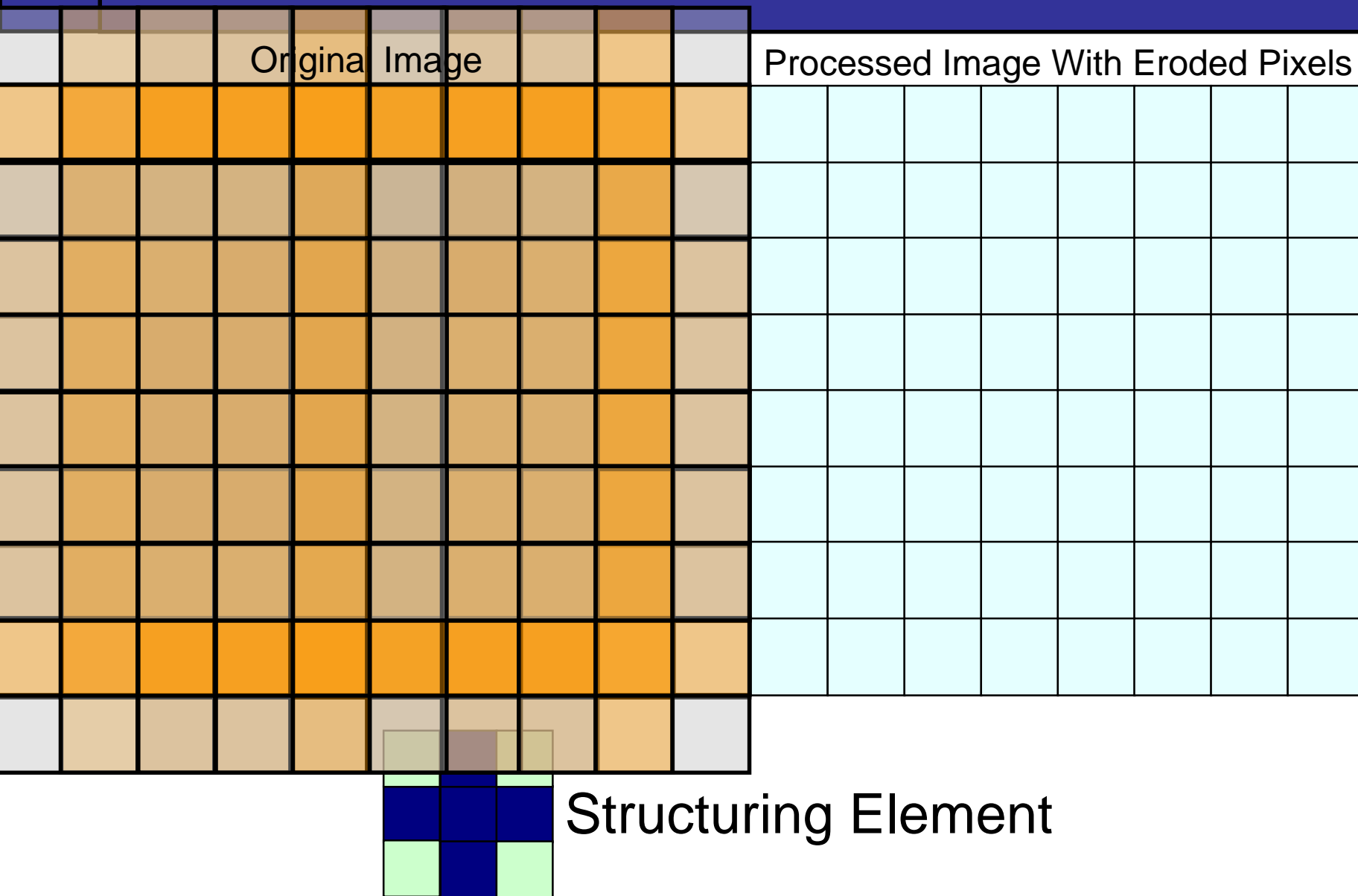
There are two basic morphological operations: **erosion** and **dilation**

Erosion 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:

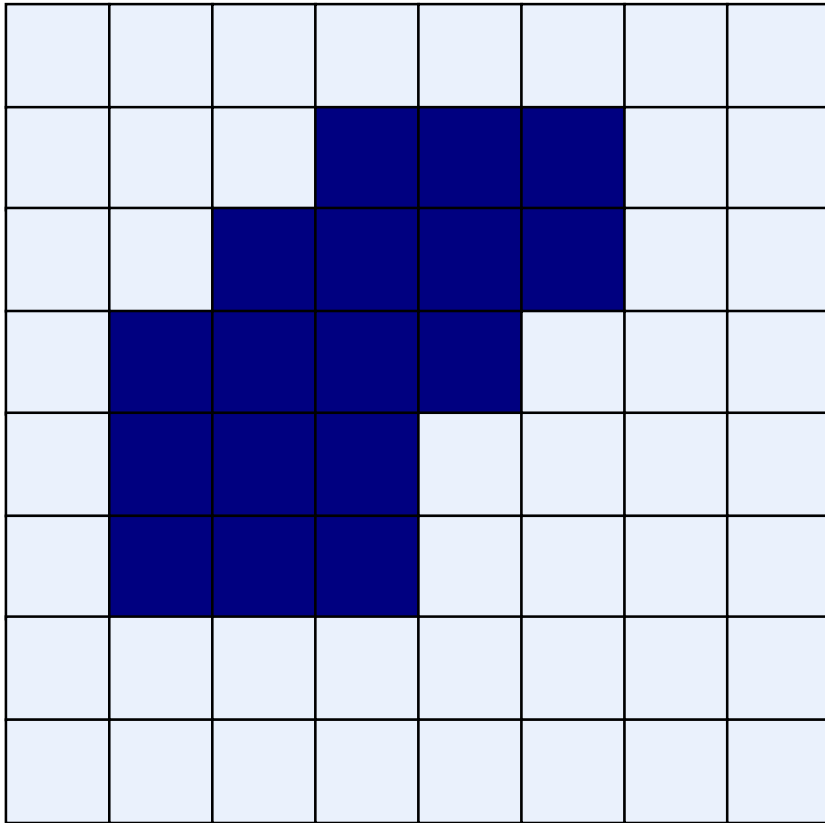
$$g(x, y) = \begin{cases} 1 & \text{if } s \text{ fits } f \\ 0 & \text{otherwise} \end{cases}$$

Erosion Example

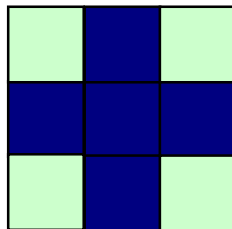
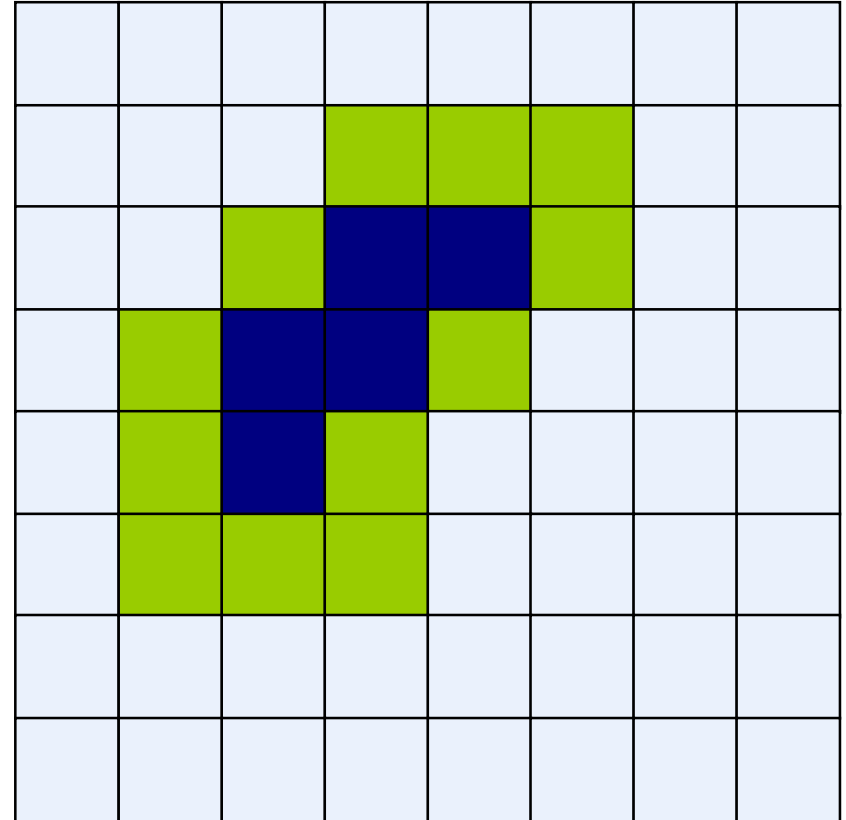


Erosion Example

Original Image



Processed Image

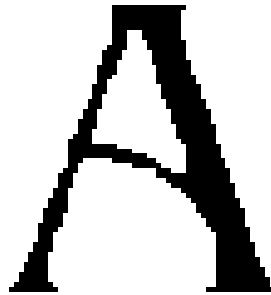


Structuring Element

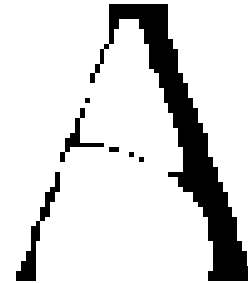
Erosion Example 1



Original image



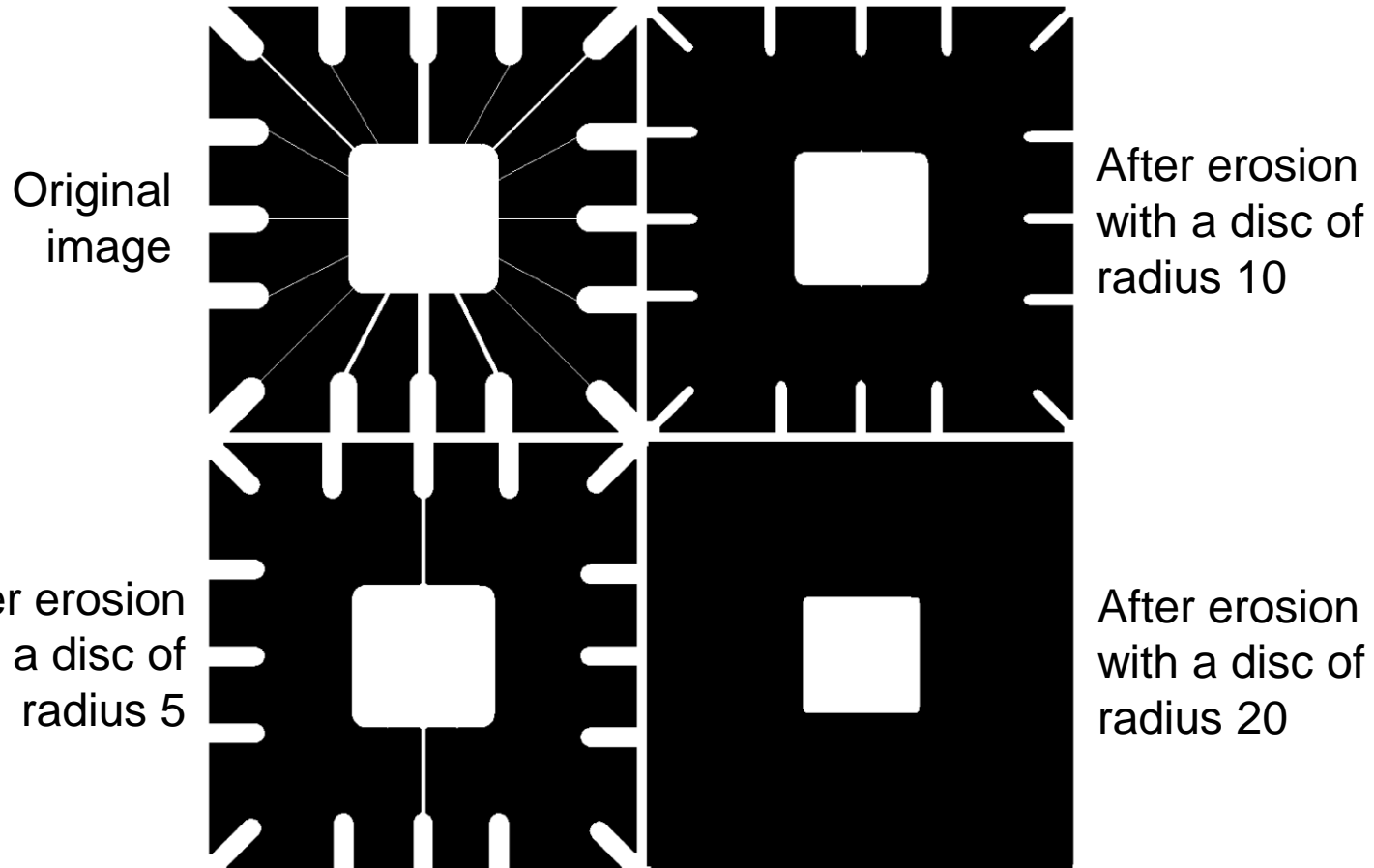
Erosion by 3*3
square structuring
element



Erosion by 5*5
square structuring
element

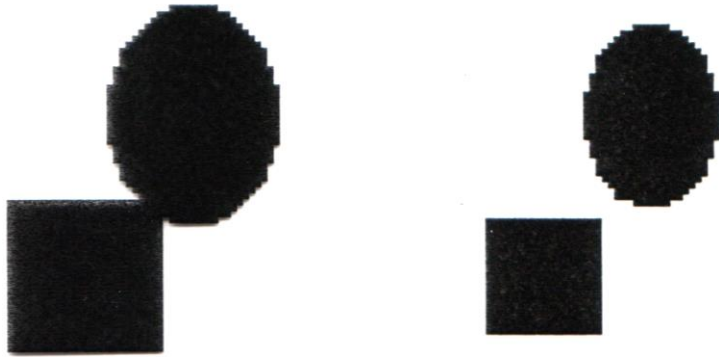
Watch out: In these examples a 1 refers to a black pixel!

Erosion Example 2

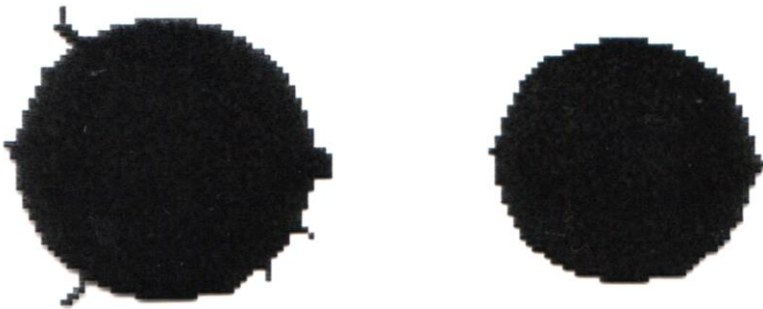


What Is Erosion For?

Erosion can split apart joined objects



Erosion can strip away extrusions



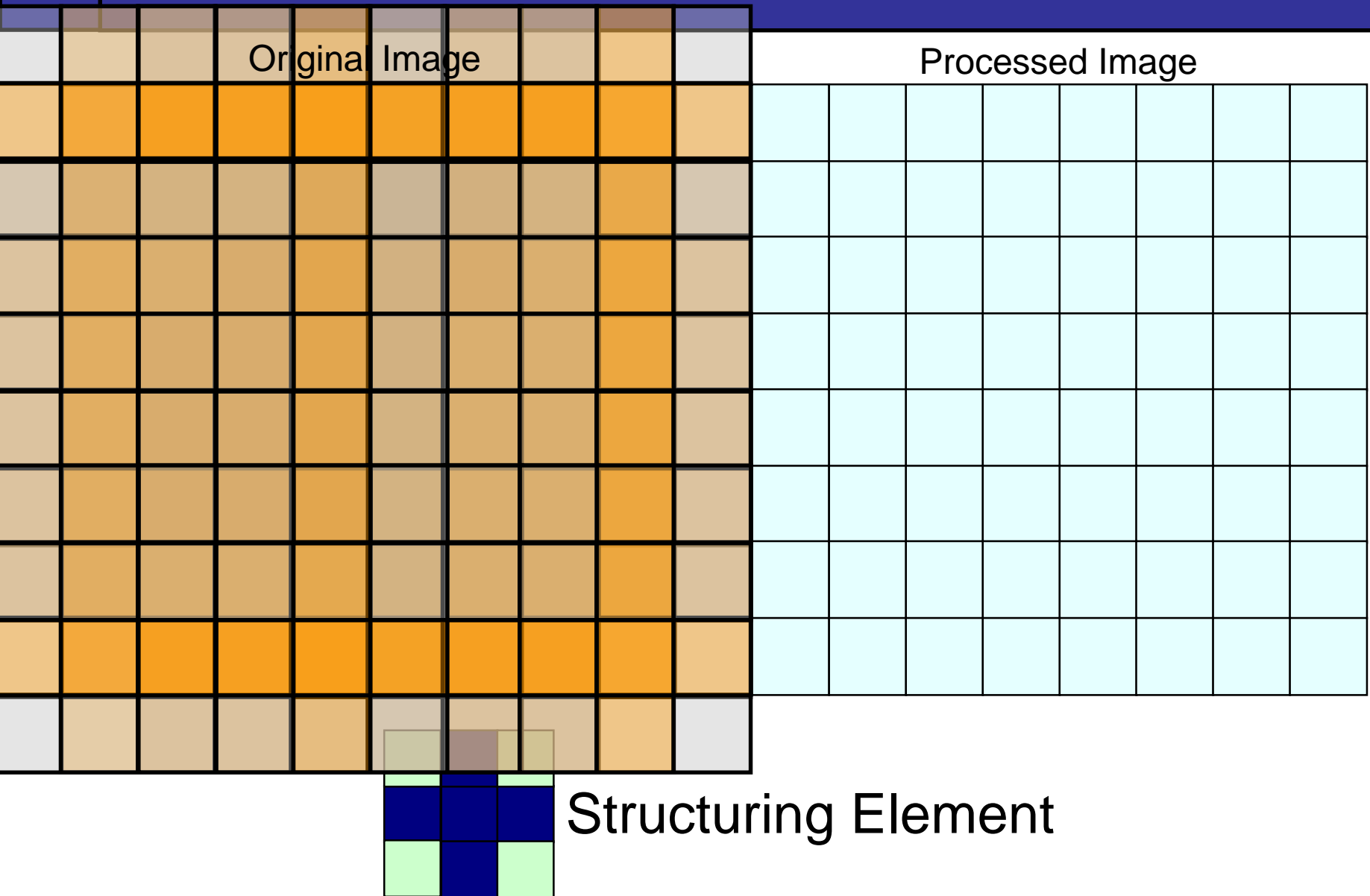
Watch out: Erosion shrinks objects

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:

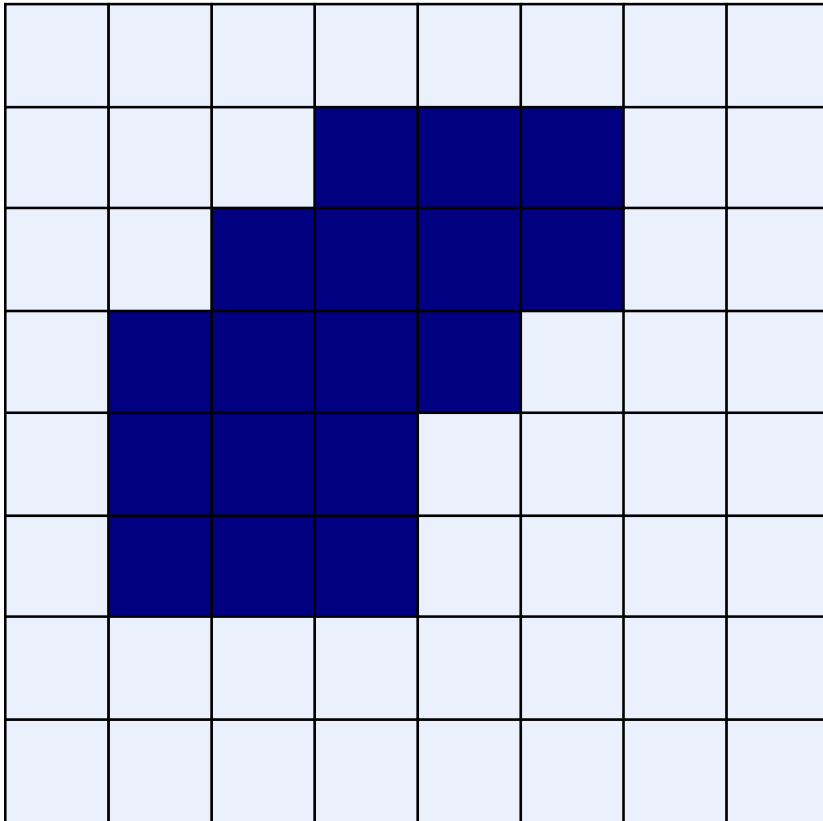
$$g(x, y) = \begin{cases} 1 & \text{if } s \text{ hits } f \\ 0 & \text{otherwise} \end{cases}$$

Dilation Example

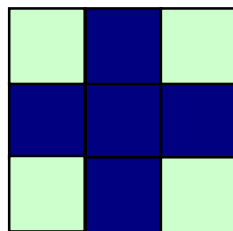
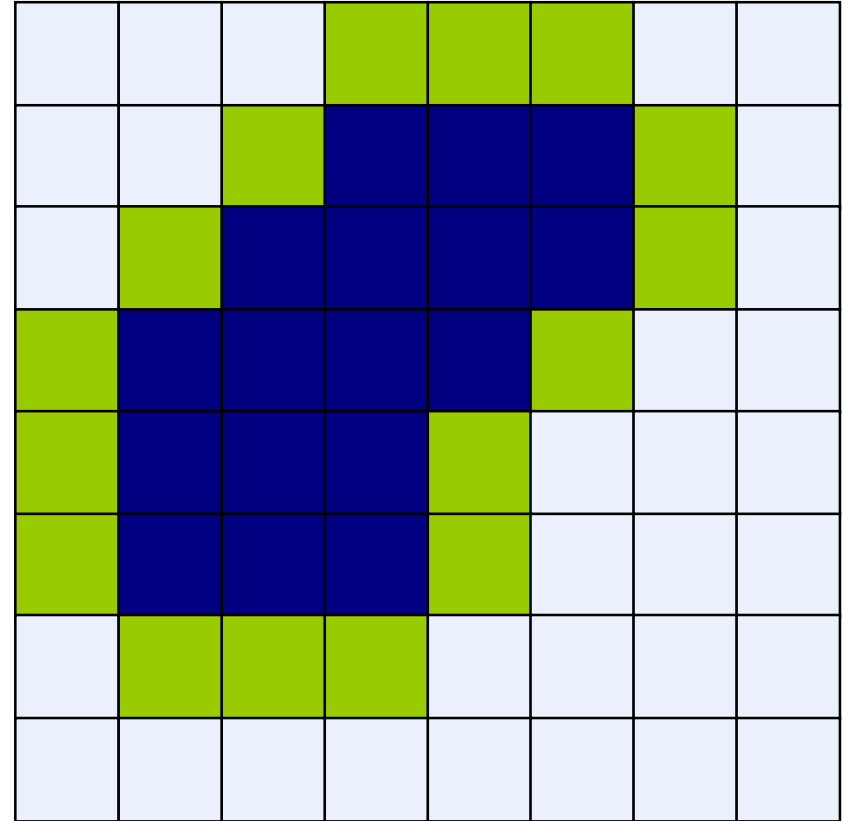


Dilation Example

Original Image



Processed Image With Dilated Pixels



Structuring Element

Dilation Example 1



Original image



Dilation by 3*3
square structuring
element



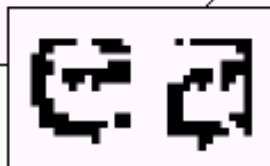
Dilation by 5*5
square structuring
element

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

Dilation Example 2

Original image

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.



After dilation

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.



| | | |
|---|---|---|
| 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

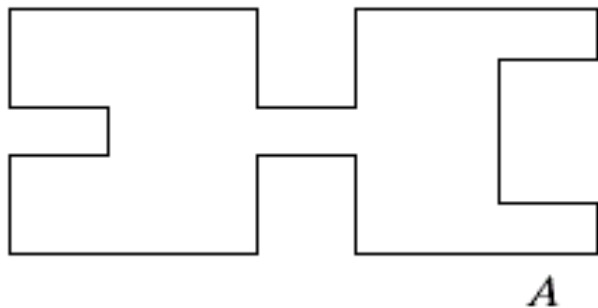
More interesting morphological operations can be performed by performing combinations of erosions and dilations

The most widely used of these *compound operations* are:

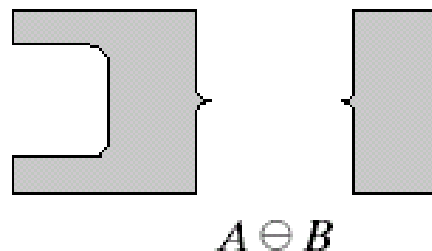
- Opening
- Closing

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

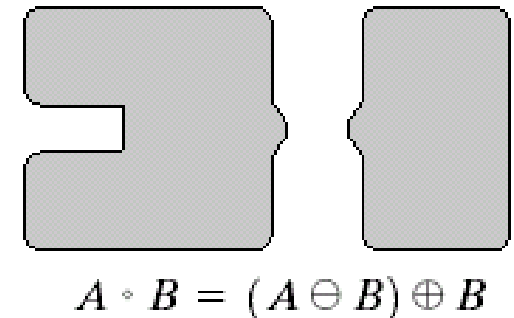
$$f \circ s = (f \ominus s) \oplus s$$



Original shape



After erosion

After dilation
(opening)

Note a disc shaped structuring element is used

Opening Example

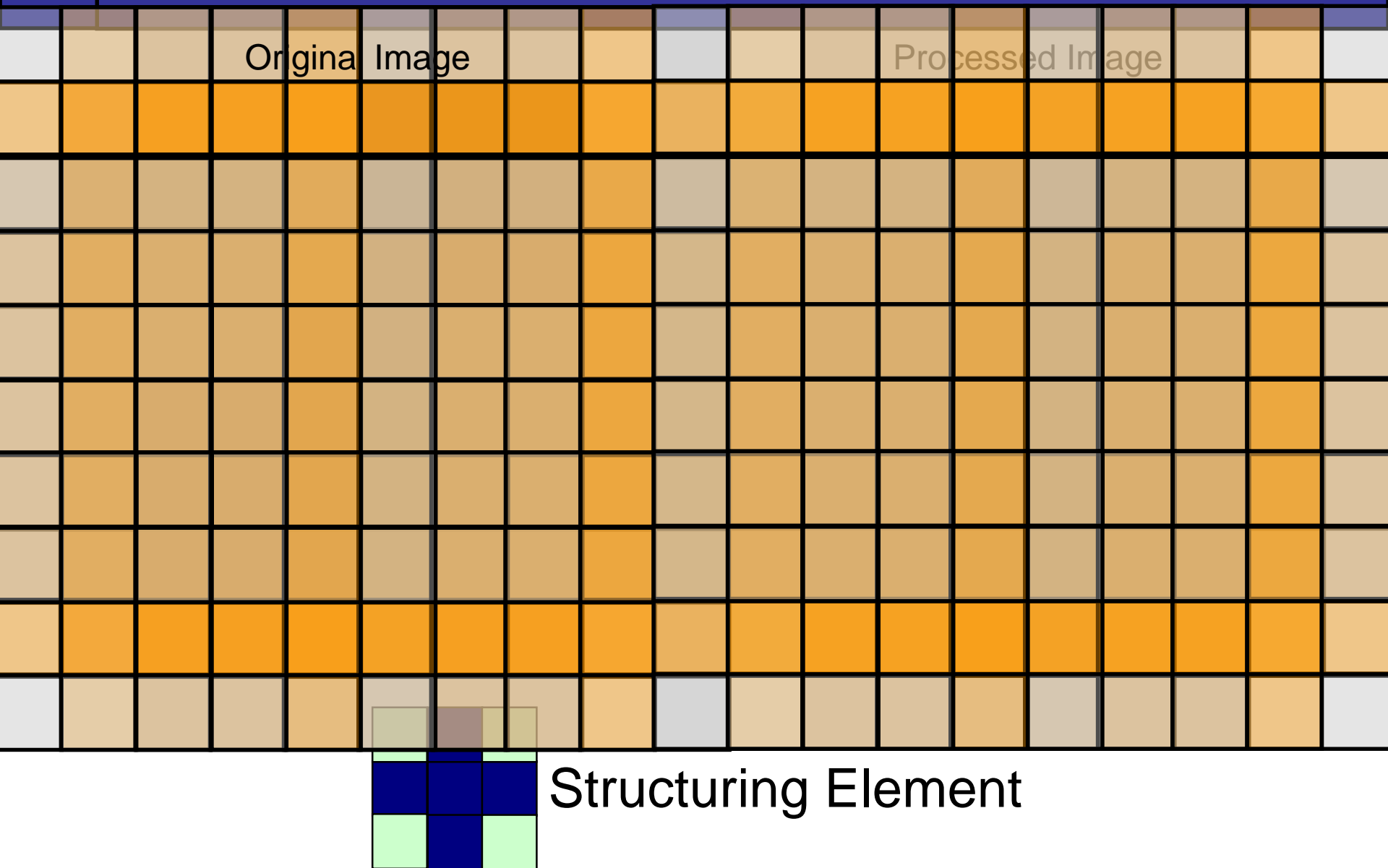
Original
Image



Image
After
Opening

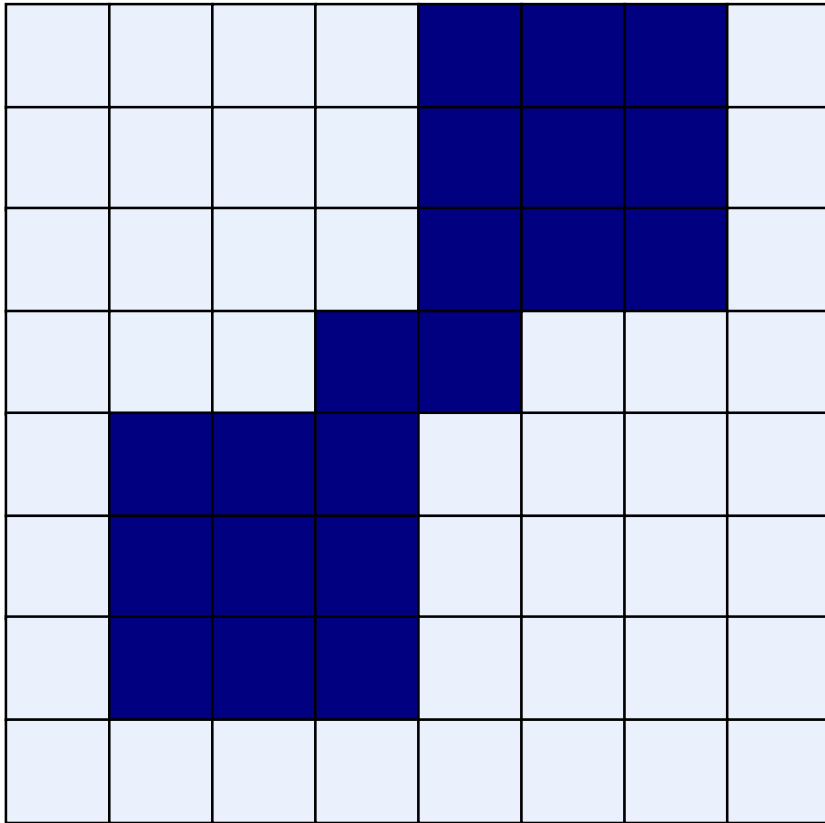


Opening Example

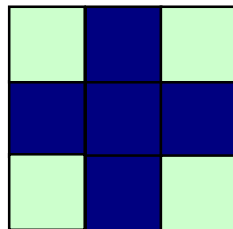
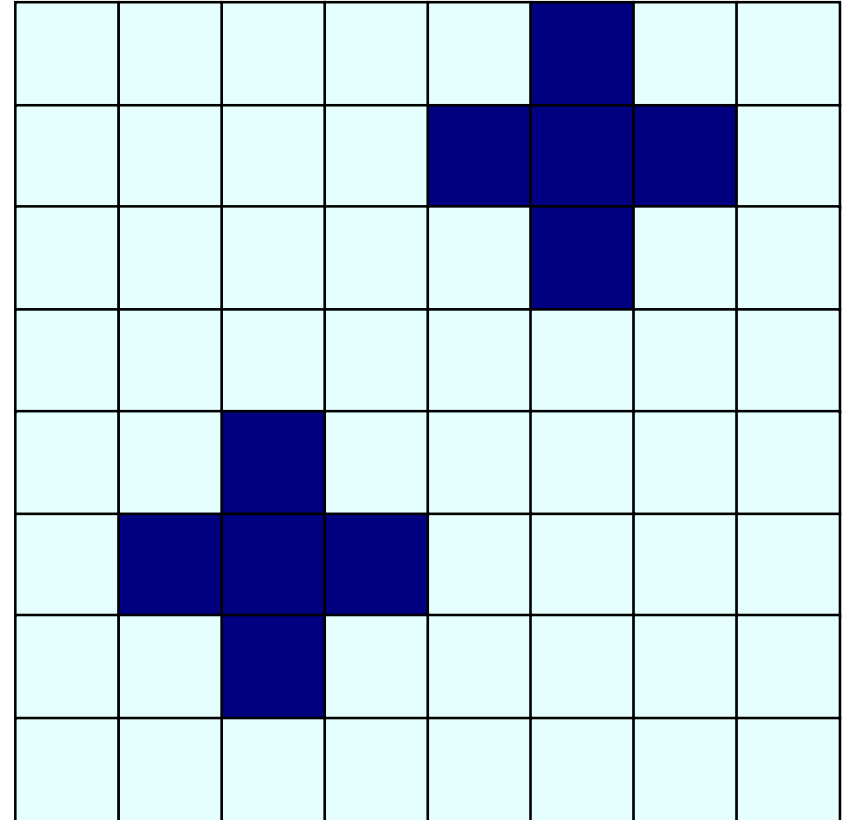


Opening Example

Original Image



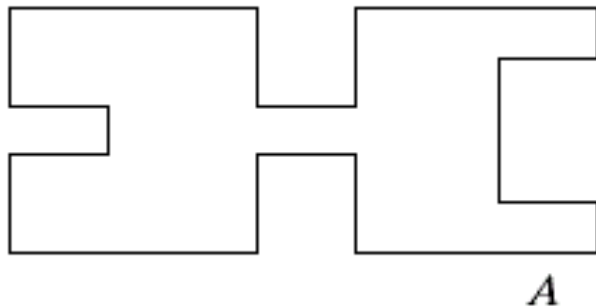
Processed Image



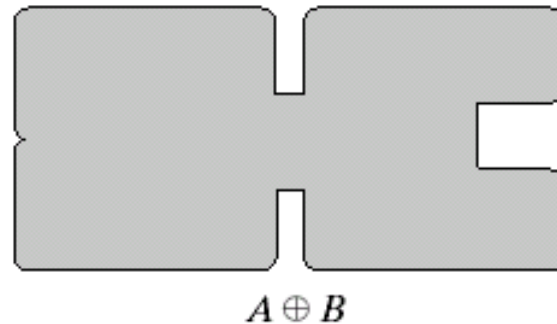
Structuring Element

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

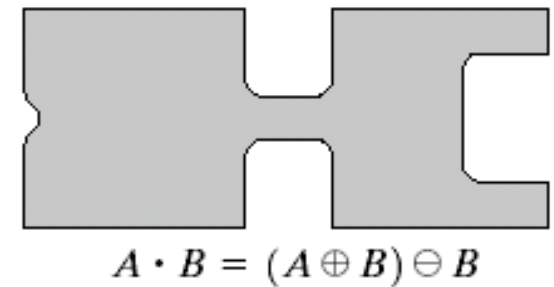
$$f \bullet s = (f \oplus s) \ominus s$$



Original shape



After dilation

After erosion
(closing)

Note a disc shaped structuring element is used

Closing Example

Original
Image

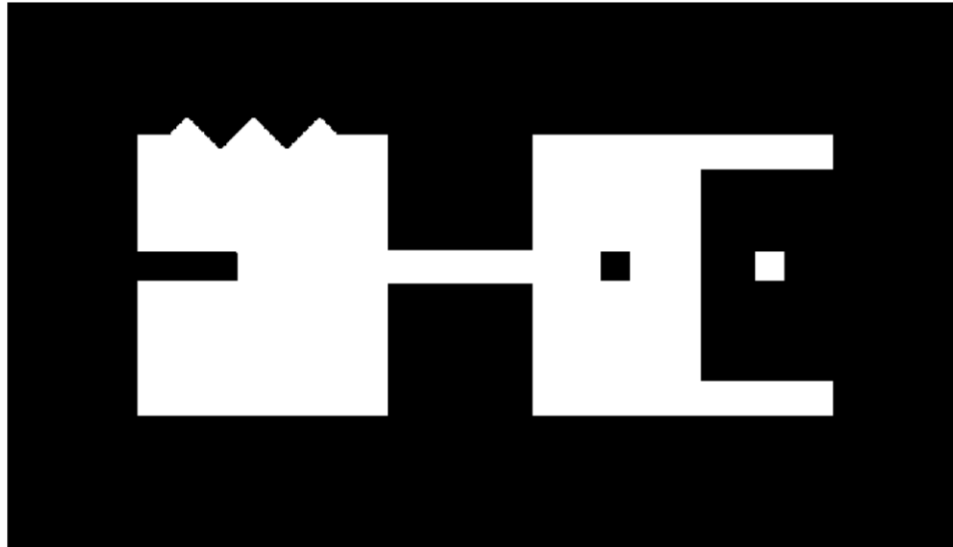
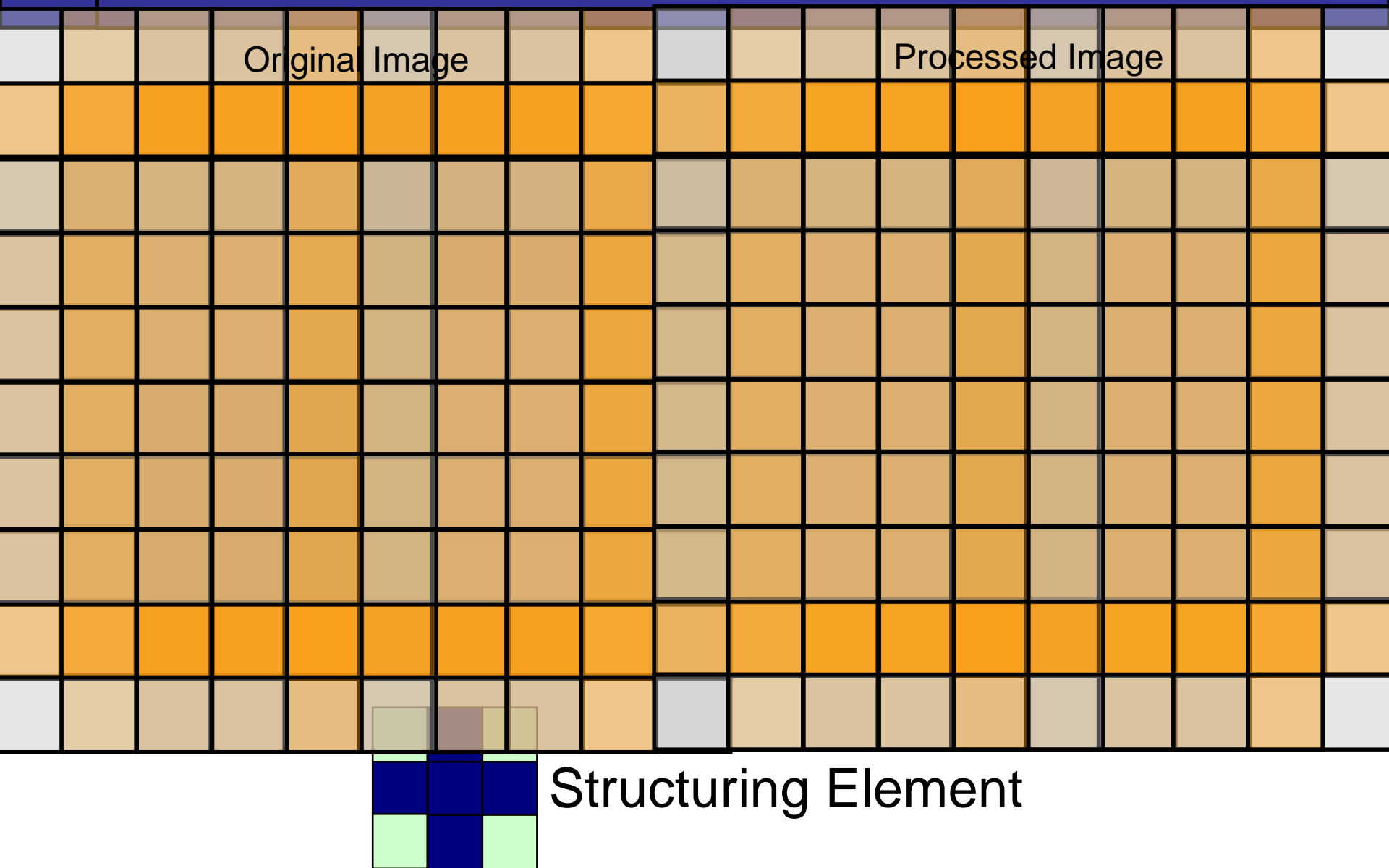


Image
After
Closing

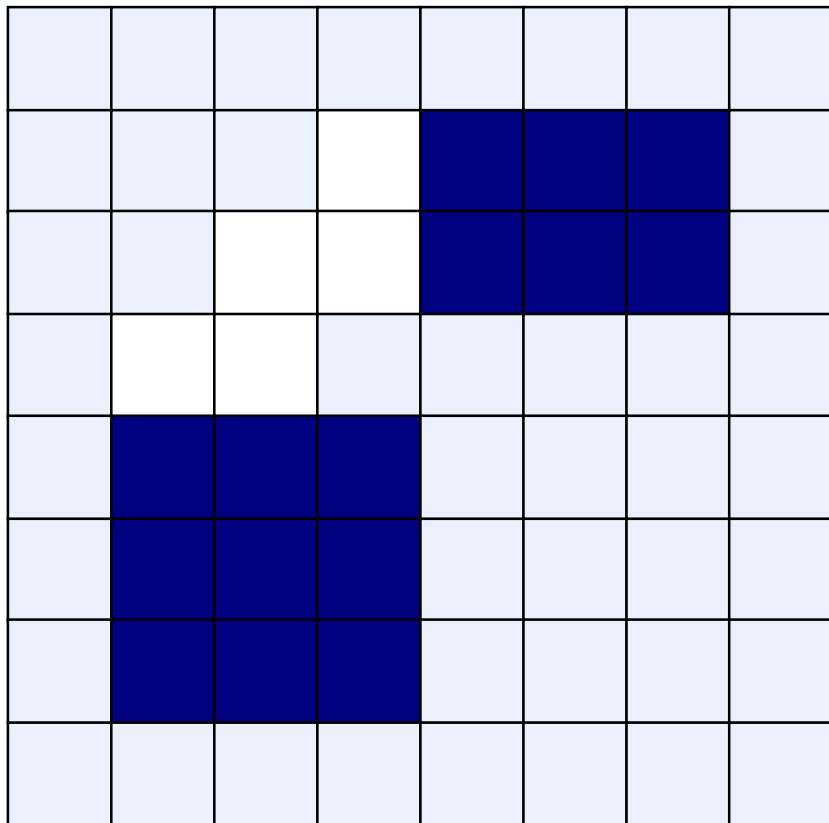


Closing Example

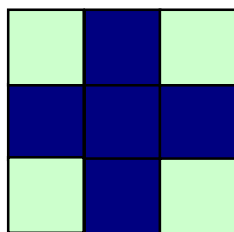
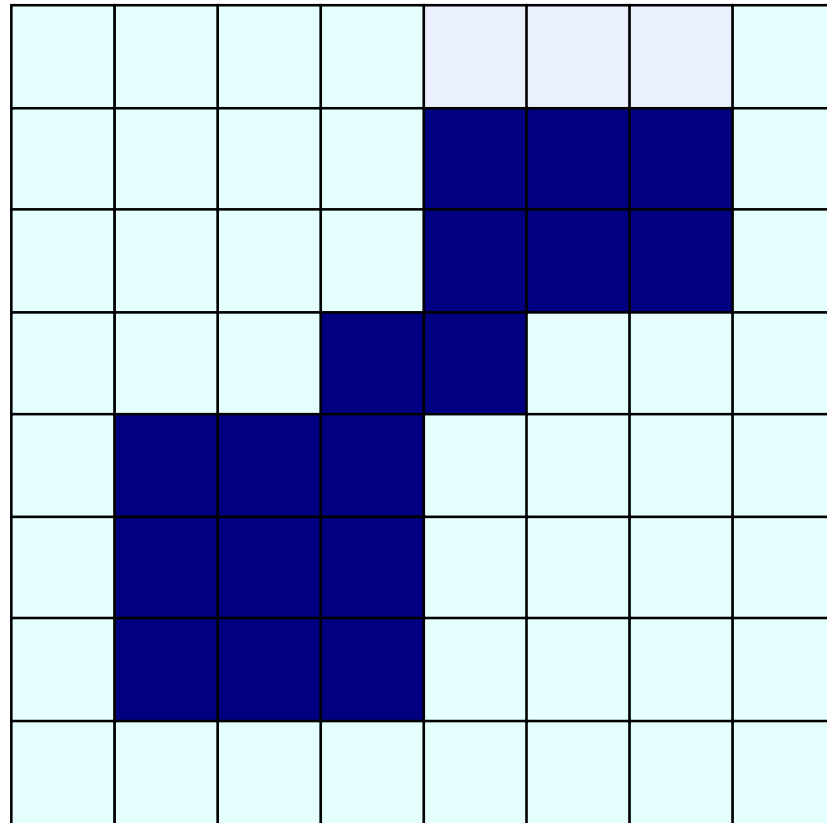


Closing Example

Original Image

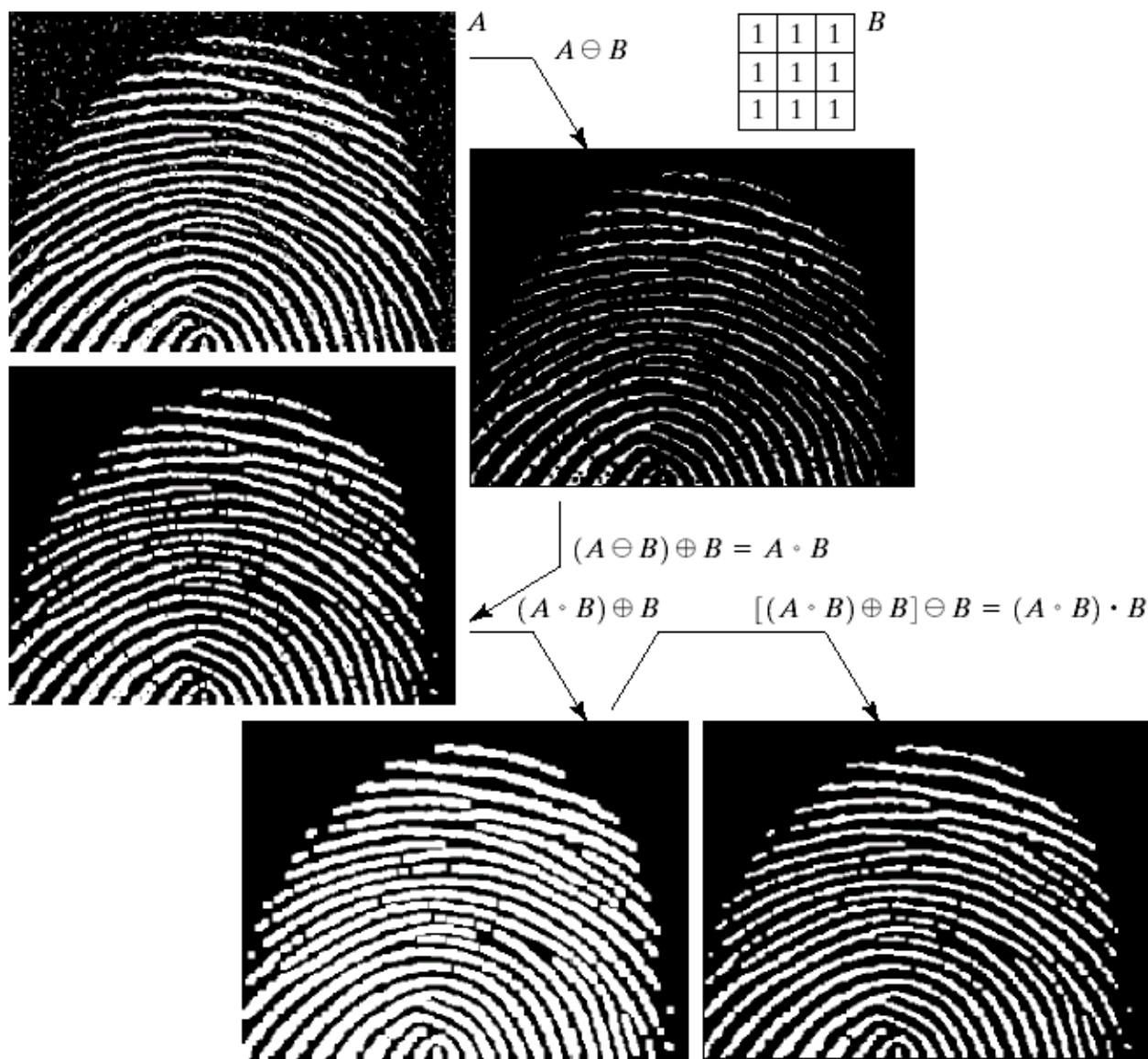


Processed Image



Structuring Element

Morphological Processing Example



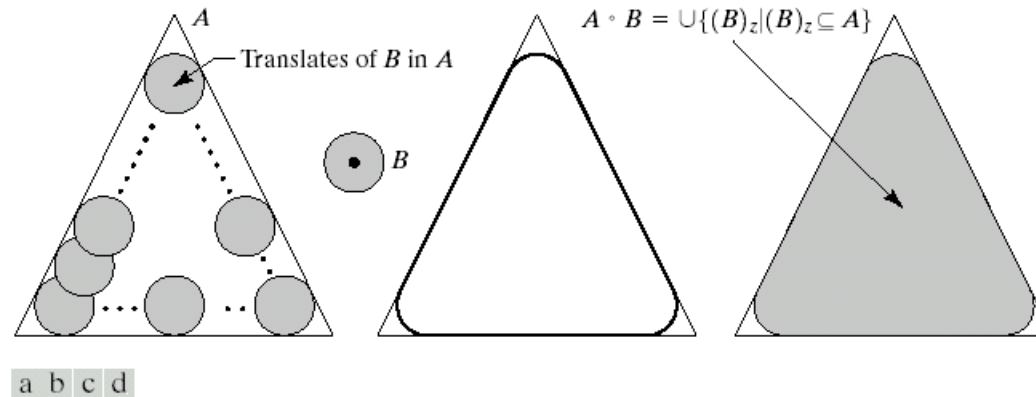


FIGURE 9.8 (a) Structuring element B "rolling" along the inner boundary of A (the dot indicates the origin of B). (c) The heavy line is the outer boundary of the opening. (d) Complete opening (shaded).

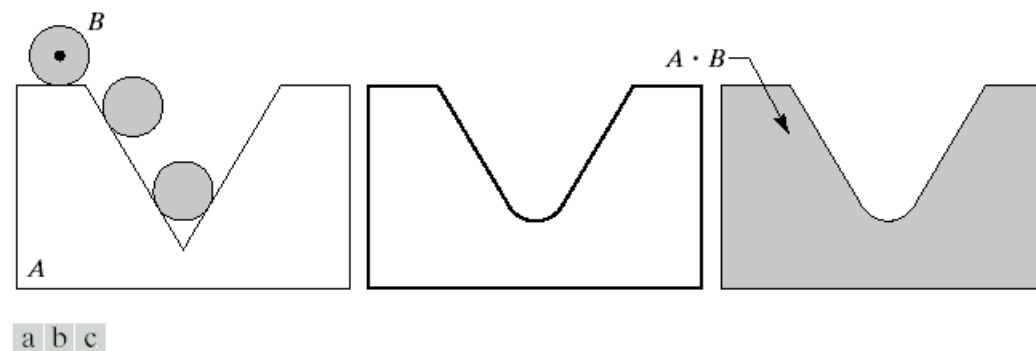
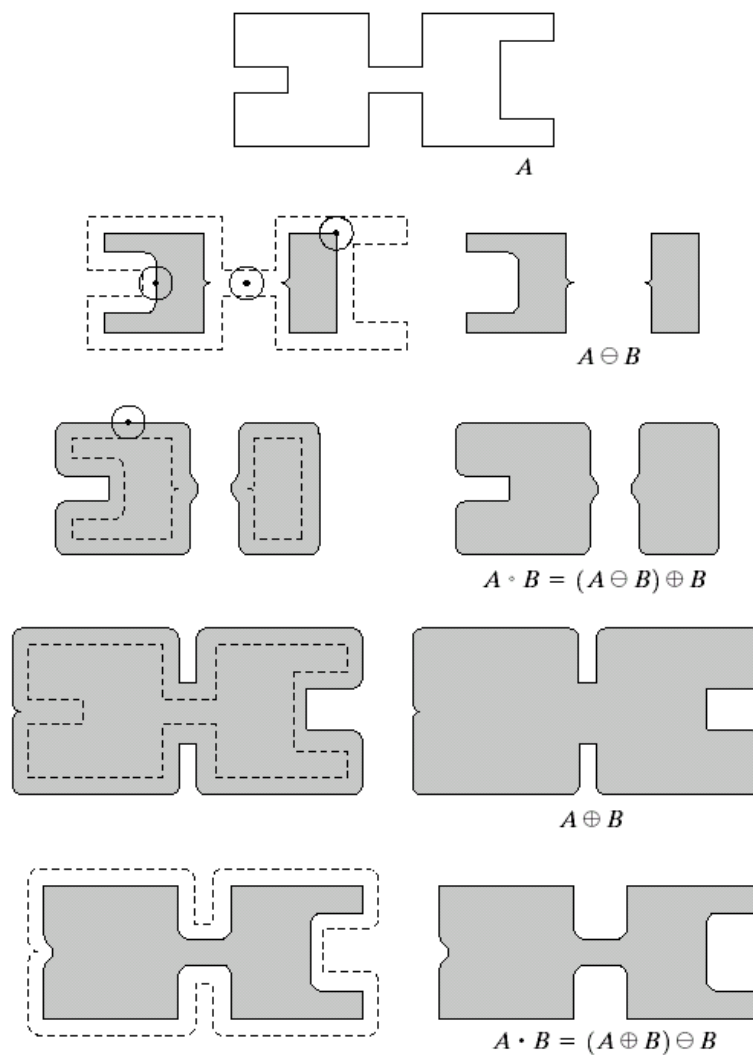


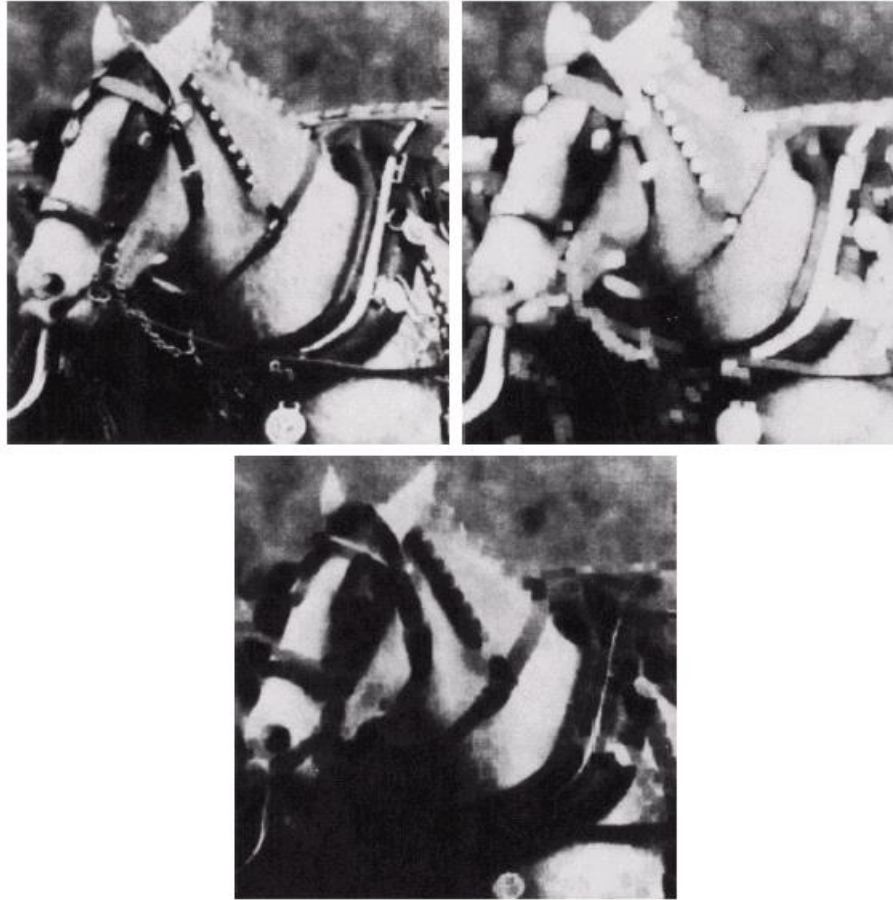
FIGURE 9.9 (a) Structuring element B "rolling" on the outer boundary of set A . (b) Heavy line is the outer boundary of the closing. (c) Complete closing (shaded).

| |
|-----|
| a |
| b c |
| d e |
| f g |
| h i |

FIGURE 9.10

Morphological opening and closing. The structuring element is the small circle shown in various positions in (b). The dark dot is the center of the structuring element.





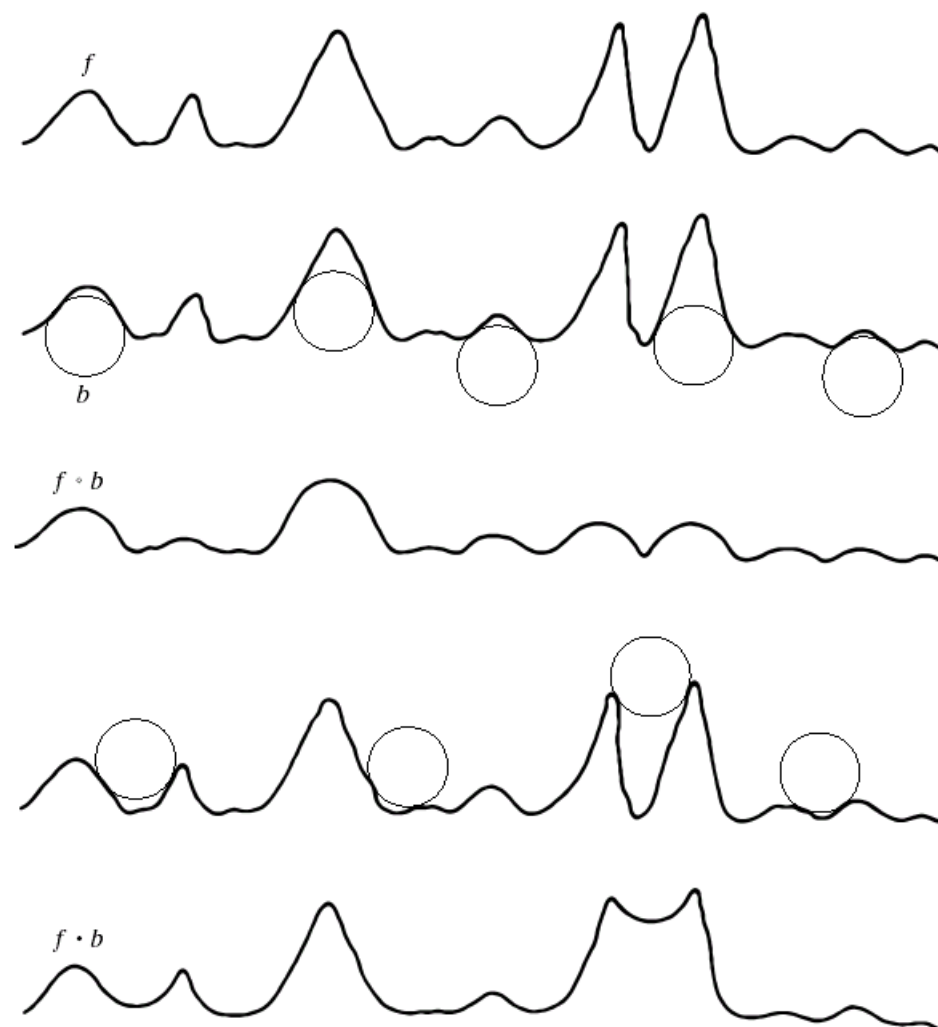
a b
c

FIGURE 9.29

(a) Original image. (b) Result of dilation.

(c) Result of erosion.

(Courtesy of Mr. A. Morris, Leica Cambridge, Ltd.)



a
b
c
d
e

FIGURE 9.30

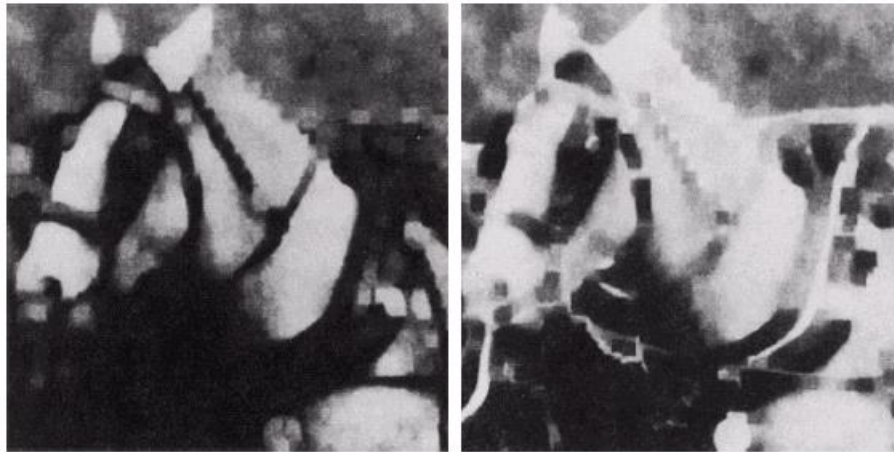
(a) A gray-scale scan line.

(b) Positions of rolling ball for opening.

(c) Result of opening.

(d) Positions of rolling ball for closing.

(e) Result of closing.



a b

FIGURE 9.31 (a) Opening and (b) closing of Fig. 9.29(a). (Courtesy of Mr. A. Morris, Leica Cambridge, Ltd.)

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

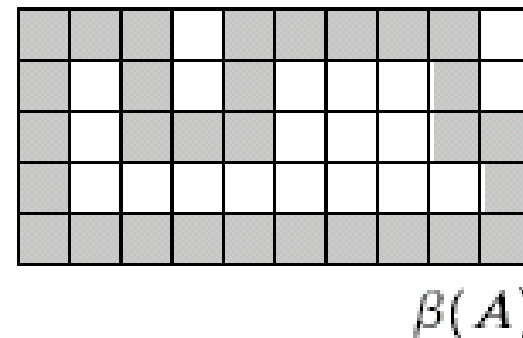
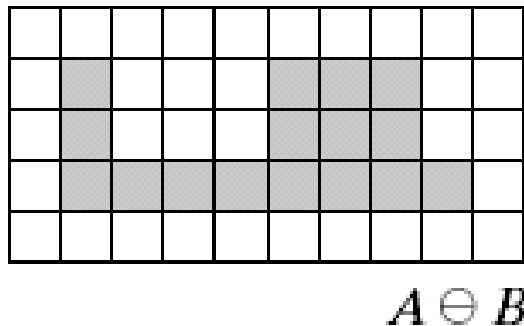
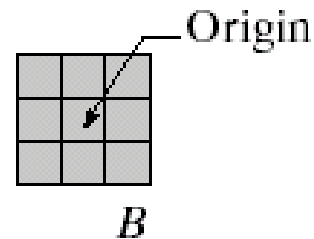
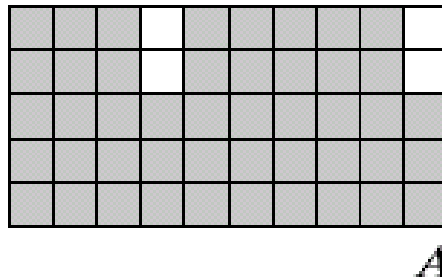
There are lots of others as well though:

- Extraction of connected components
- Thinning/thickening
- Skeletonisation

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

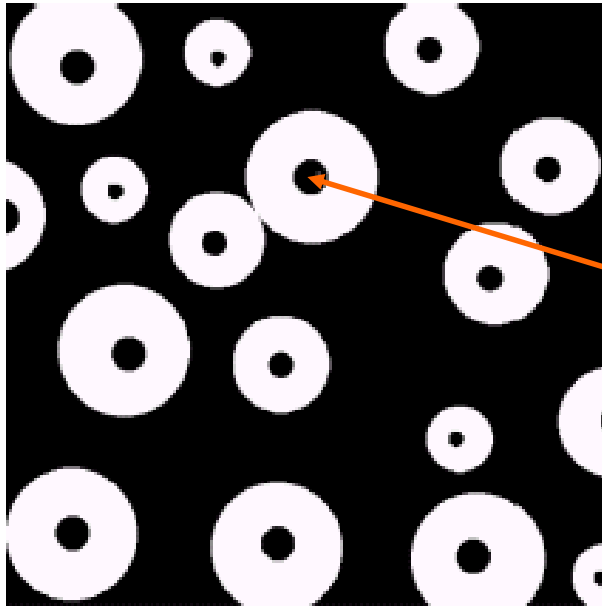
A simple image and the result of performing boundary extraction using a square 3×3 structuring element



Original Image

Extracted Boundary

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?

The key equation for region filling is

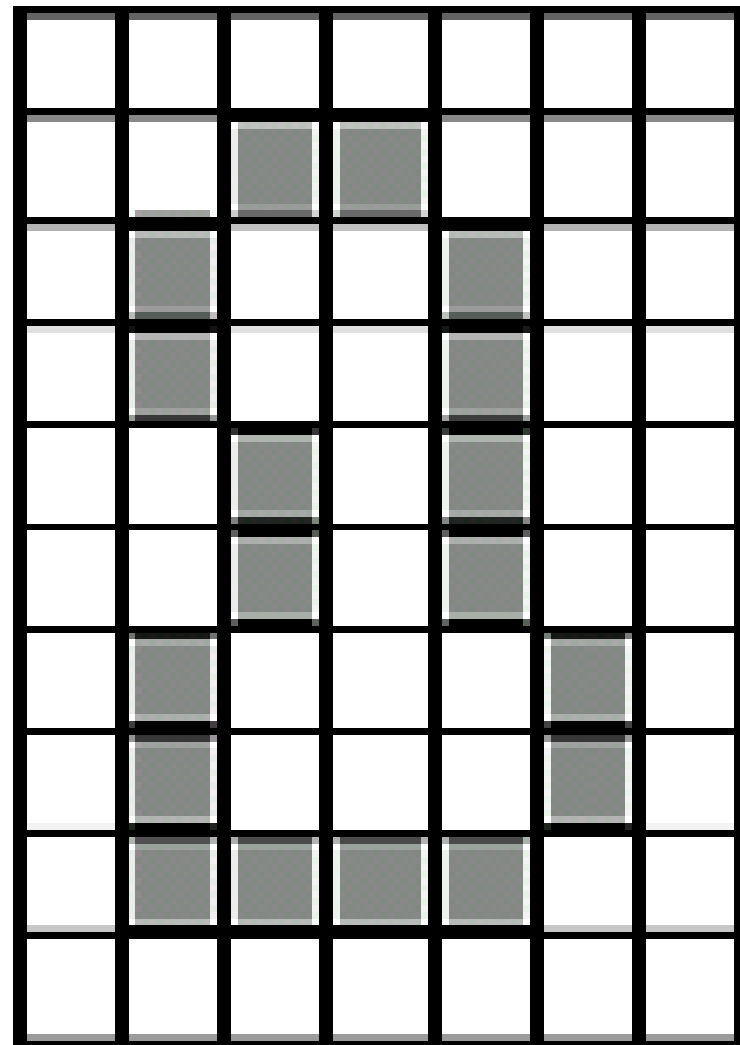
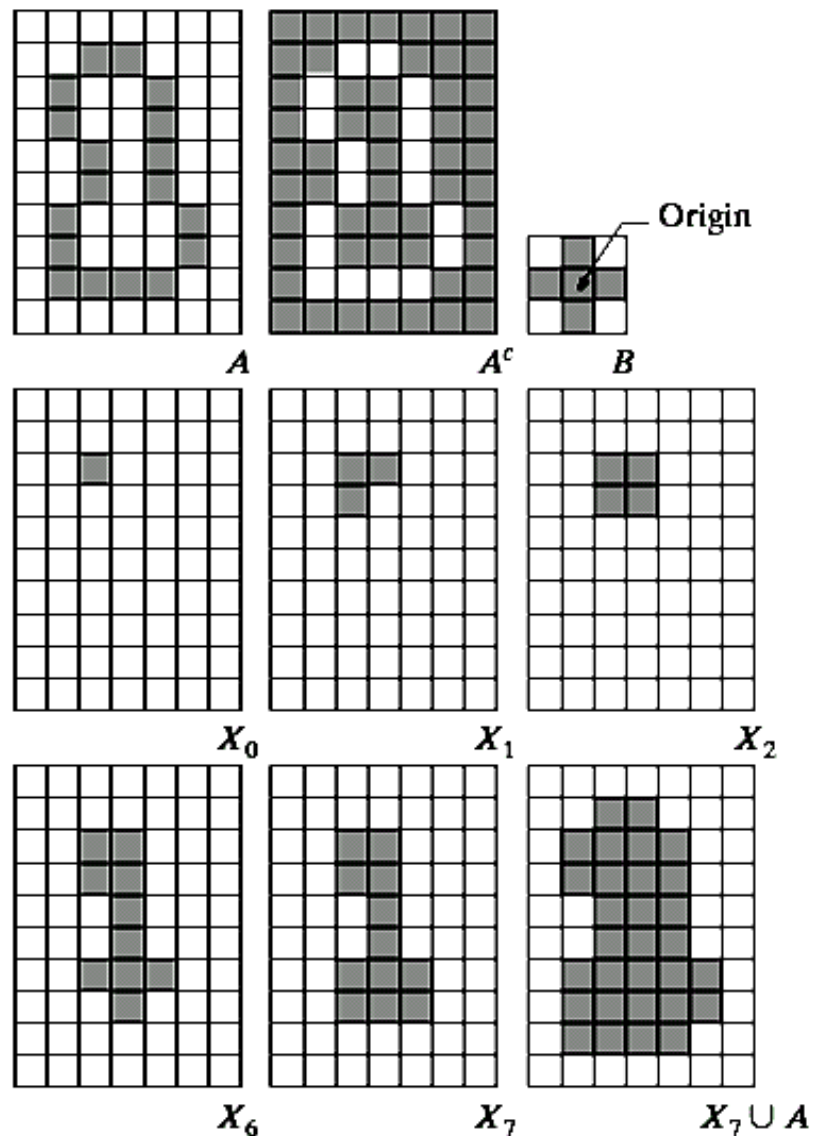
$$X_k = (X_{k-1} \oplus B) \cap A^c \quad k = 1, 2, 3, \dots$$

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

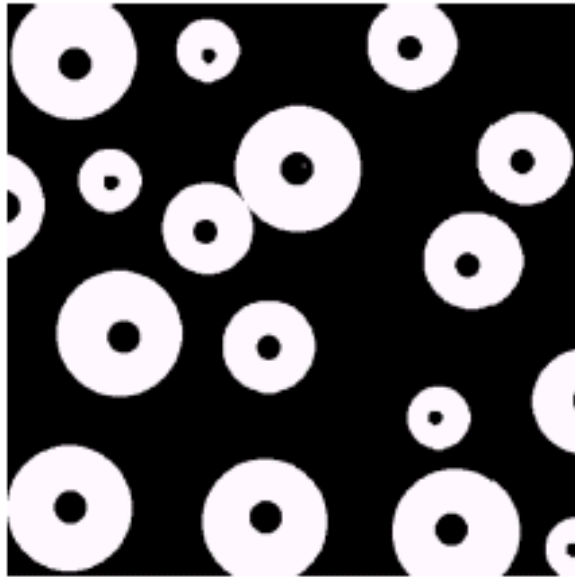
This equation is applied repeatedly until X_k is equal to X_{k-1}

Finally the result is unioned with the original boundary

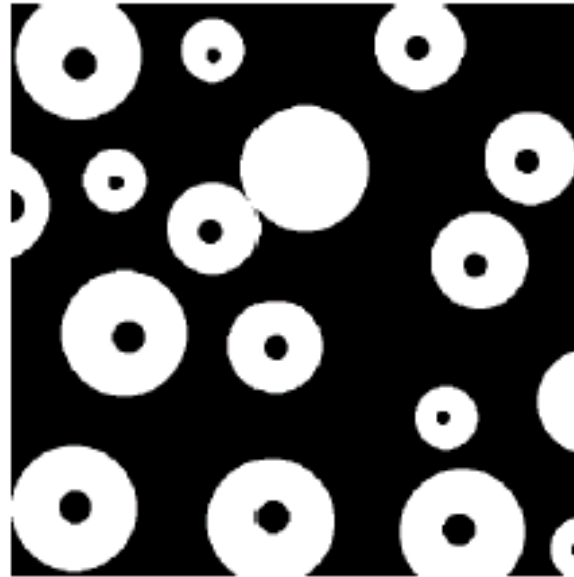
Region Filling Step By Step



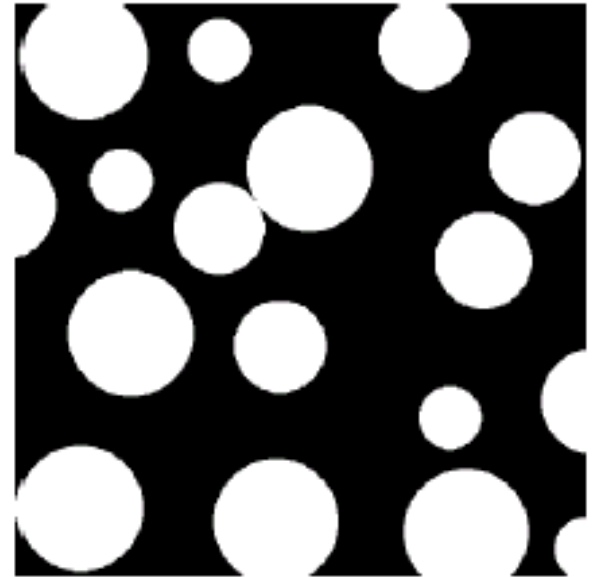
Region Filling Example



Original Image



One Region
Filled



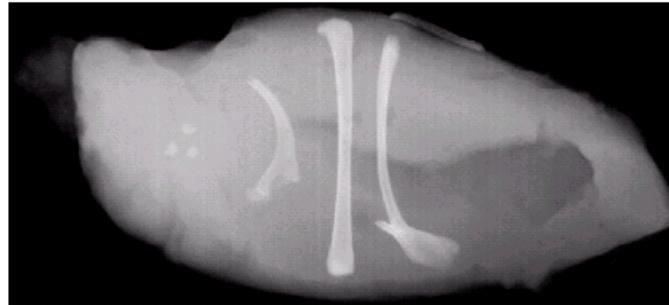
All Regions
Filled

a
b
c d**FIGURE 9.18**

(a) X-ray image of chicken filet with bone fragments.

(b) Thresholded image. (c) Image eroded with a 5×5 structuring element of 1's.

(d) Number of pixels in the connected components of (c). (Image courtesy of NTB Elektronische Geraete GmbH, Diepholz, Germany, www.ntbxbay.com.)



| Connected component | No. of pixels in connected comp |
|---------------------|---------------------------------|
| 01 | 11 |
| 02 | 9 |
| 03 | 9 |
| 04 | 39 |
| 05 | 133 |
| 06 | 1 |
| 07 | 1 |
| 08 | 743 |
| 09 | 7 |
| 10 | 11 |
| 11 | 11 |
| 12 | 9 |
| 13 | 9 |
| 14 | 674 |
| 15 | 85 |

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

Region Filling Step By Step

